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Review Article

Maternal Malnutrition in Low-Income and Middle-Income Countries: A Closer Look at the Indian Scenario

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Abstract

Optimal nutrition in mothers is not only crucial for their own health but also for the health of future generations. Maternal undernutrition is a serious health issue which can lead to adverse pregnancy outcomes, stunting and wasting in children and childhood mortality. The association between maternal nutrition and birth outcome is influenced by many factors including socioeconomic, and demographic factors, which vary widely across the globe. India, which is one of the fastest-growing economies in the world, is facing the crisis of growing undernutrition in both mothers and children. The National Family Health Survey (NFHS)-4 reported that approximately one-fourth of women (23%) in India had a body mass index (BMI) below normal and more than half of women of reproductive age are anemic. The NFHS-4 also reported the existence of dual burden of malnutrition in women in India with nearly 20% of the women being overweight or obese. Apart from inadequate nutrient intake, poor maternal nutritional status in India can be attributed to early and multiple pregnancies, poverty, caste discrimination, gender inequality, etc. An optimal macro- and micronutrient intake by the mothers is essential to meet both maternal and fetal requirements and reduce adverse health consequences. Although several nutritional intervention programs have been introduced to improve maternal nutrition in India, the problem continues to persist. Efforts should be renewed to ensure a proper and widespread implementation of supplementation and fortification programs across India to uproot the problem of undernutrition.

Keywords: *Maternal Nutrition; Anemia; Nutritional Status in India; Undernutrition; Nutrition Interventions; Intrauterine Growth Restriction*

Introduction

Nutrition-related problems form the core of many current issues in women's health, and poor nutrition can have profound effects on reproductive outcomes. Maternal nutrition plays a critical role in fetal growth and development. Maternal nutrition refers to the nutritional needs of women during the antenatal and postnatal periods and also may refer to the pre-conceptual period. Poor maternal nutritional status is related to adverse birth outcomes; however, the association between maternal nutrition and birth outcome is complex and is influenced by many biologic, socioeconomic, and demographic factors, which vary widely in different populations. Maternal undernutrition plays a crucial role in influencing maternal, neonatal, and child health outcomes [1]. The hypothesis that early life diet *in utero* increases the vulnerability of the offspring to the development of poor outcomes and disease is now well accepted.

Malnutrition in India has been called "The Silent Emergency." The proportion of undernutrition among children and women in India is among the highest in the world. Despite economic growth, improvements in maternal and childhood nutritional status in India over the last decade have been slow. Suboptimal infant and young child feeding practices in particular continue to be a serious challenge in reducing malnutrition among children. High rates of maternal undernutrition measured by low body mass index (BMI) and anemia adversely affect the health and survival of mothers and newborns [2]. While under-nutrition continues to be a major problem in countries undergoing rapid economic growth, a progressive rise of overnutrition particularly among women during reproductive age both in urban and rural areas in India is a cause of concern [3].

Maternal malnutrition: Global and Indian trends

The spectrum of maternal malnutrition can range from undernutrition to excessive dietary intake before and during pregnancy leading to serious consequences [4]. Poor maternal nutritional status of woman before and during pregnancy such as short maternal stature due to mother's own childhood undernutrition, low BMI at conception, and inadequate gestational weight gain due to poor dietary intake has serious implications on birth outcome [5]. Maternal malnutrition leads to intrauterine growth restriction (IUGR) and low birth weight [6]. An important measure of malnutrition in women of reproductive age (20 - 49 years) is the BMI. A BMI of less than 18.5 kg/m^2 and more than 25 kg/m^2 (23 kg/m^2 for Asians) is defined as undernutrition (excessive thinness) and overweight, respectively [6]. The prevalence of low BMI (< 18.5 kg/m^2) in women of reproductive age has shown a decreasing trend since 1980 in Africa and Asia. However, it still remains more than 10% in these two regions. On the contrary, during the same period, there has been a rise in the prevalence of overweight (BMI ≥ 25 kg/m^2) and obesity (BMI ≥ 30 kg/m^2) in adult women. The figure reached more than 70% in America and the Caribbean and more than 40% in Africa in 2008. Figure 1 shows trends in thinness (BMI < 18.5 kg/m^2), overweight (BMI ≥ 25 kg/m^2), and obesity (BMI ≥ 30 kg/m^2) in women aged 20 - 49 years in Asia and globally, 1980 - 2008 [7].

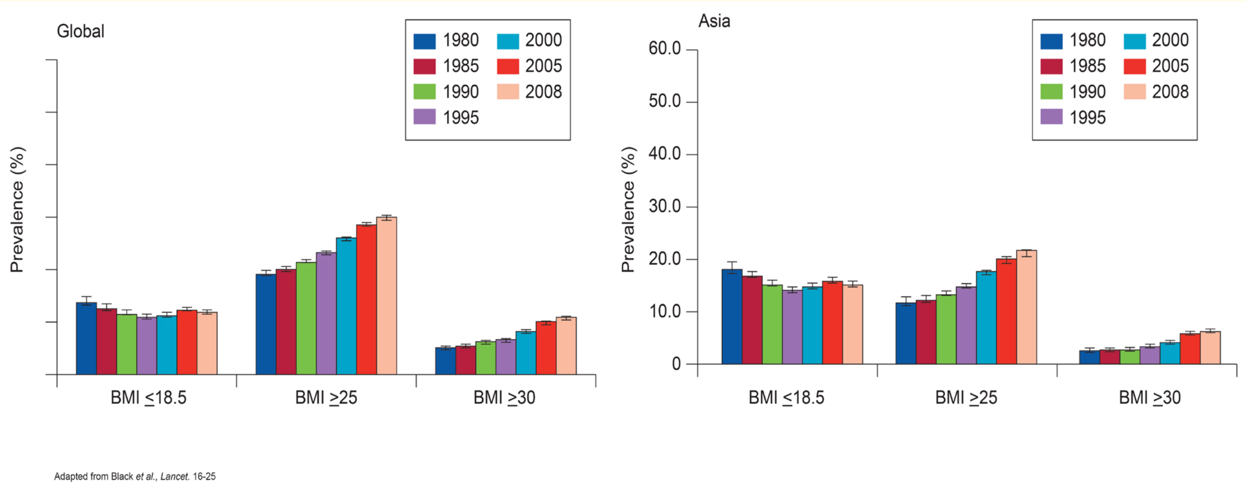

Figure 1: *Trends in thinness (BMI < 18.5 kg/m^2), overweight (BMI ≥ 25 kg/m^2), and obesity (BMI ≥ 30 kg/m^2) in women aged 20 - 49 years in Asia and globally, 1980-2008 (Black., et al. 2013).*

Remarkable changes post-independence has been witnessed in the nutritional scenario in India. In the recent National Family Health Survey (NFHS)-4 (2015 -2 016), the nutritional status of women was assessed based on BMI. A BMI less than 18.5 kg/m^2 was used to define thinness and a BMI of 25 kg/m^2 or above was used to define overweight or obesity. A total of 22.9% women (both from urban and rural areas) were observed to have a BMI below normal, which was considerably less compared with the NFHS-3 survey in which more than one-third of women (35.5%) had a below normal BMI (See Figure 2 for prevalence of undernutrition and overnutrition in women in India according to NFHS-3 and NFHS-4 reports). More women from rural areas (26.7%) reported a BMI less than 18 kg/m^2 compared with women from urban areas [8,9].

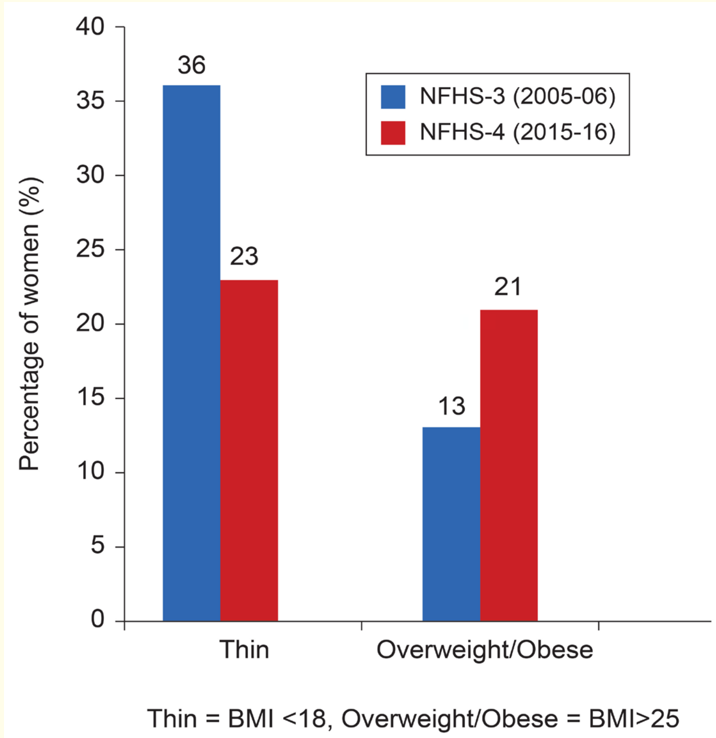

Figure 2: *Nutritional status of women (15 - 49 years) in India NFHS-3 versus NFHS-4 (NFHS-3, 2006) (NFHS-4, 2016).*

The NFHS-4 report also suggested that obesity is an emerging problem in India, particularly in women, with nearly 20% of the women being overweight or obese, a figure considerably higher than the NFHS-3 report (See Figure 2). The NFHS-4 shed light on the growing dual burden of malnutrition in women in India, where nearly 44% of women were either too thin or overweight [8,9].

Consequences of Maternal Malnutrition Before and During Pregnancy

Maternal mortality rate: Global and Indian Scenario

Poor maternal nutrition status is associated with poor maternal and fetal outcomes. Poor maternal outcomes also include an increased risk of maternal mortality [10]. Although globally the maternal mortality ratio (MMR) has declined by 44% from 385/100,000 live births in 1990 to 216/100,000 live births in 2015, it still falls short of the millennium development goal (MDG) target 5A, which called for MMR reduction of at least 75% [11]. In India, the MMR for year 2015 was 174/100,000 live births which is below the global average [11].

Impact of maternal nutrition on pregnancy outcomes and fetal health

Low birth weight and intrauterine growth retardation

Pre-pregnancy BMI has a major influence on obstetric outcomes and subsequent disease risk in the offspring and it has recently attracted attention due to the increasing prevalence of abnormal BMI values in women of child-bearing age [4]. Pre- pregnancy weight is considered as a strong predictor of low birth weight. The intergenerational cycle of growth failure (Figure 3) theory, first described in 1992, explains the impact of maternal size on child growth. According to this theory, small adult women are more likely to give birth to low-birth weight (LBW) infants [12]. The classic pattern in many developing countries is that female infants born with LBW continue to experience growth failure during childhood and adolescence and are more likely to have children at an early age. Pregnancy at an early age reduces their chances of reaching an optimal body size with adequate nutrient stores before conception, which increases the likelihood of LBW infants born to such mothers [13]. Studies suggest that gestational weight gain is positively associated with infant birth weight and reduced risk of preterm birth [14,15]. The World Health Organization (WHO) collaborative study that investigated the impact of maternal anthropometry on pregnancy outcomes in 111,000 women reported that mothers in the lowest quartile of pre-pregnancy weight were associated with an increased risk of intrauterine growth retardation (IUGR) and LBW in their offspring [16]. Poor maternal nutritional status of woman before and during pregnancy such as short maternal stature due to mother's own childhood undernutrition, low BMI at conception, and inadequate gestational weight gain due to poor dietary intake has serious implications on birth outcome [5].

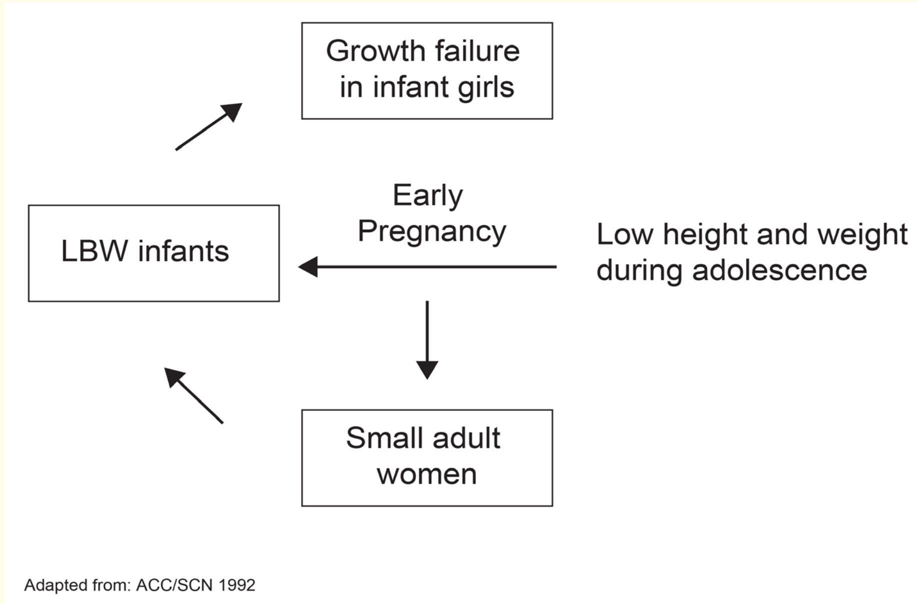

Figure 3: *The intergenerational cycle of growth failure (ACC/SCN 1992).*

Pregnancy outcomes

The impact of pre-pregnancy obesity and excess gestational weight gain on pregnancy outcomes was evaluated in a large population-based cohort of 6632 women. Women who were obese prior to pregnancy (BMI > 30 kg/m^2) and women who gained weight during pregnancy were found to be at a greater risk of pregnancy complications, caesarean sections, higher birth weight infants, greater placental weight, and longer length of hospital stay. Furthermore, mothers who were underweight before pregnancy and those who gained inadequate weight during pregnancy were at a greater risk of preterm births, LBW infant births, and lower placental weights [17]. In another study, higher pre-pregnancy BMI (≥ 25.0 kg/m^2) and gestational weight gain were associated with a higher incidence of postpartum hemorrhage, preterm delivery, premature rupture of membranes, gestational diabetes, and hypertension and preeclampsia [18].

Nutritional status of children

The data from NFHS-2 and NFHS-3 were analyzed to determine the impact of maternal nutrition on the nutritional status of under-three children in Empowered Action Group (EAG) states (Uttar Pradesh, Bihar, Rajasthan, Madhya Pradesh, Orissa, Jharkhand, Chhattisgarh, and Uttaranchal) and Assam in India. The analysis showed that percent distribution of wasted children from underweight mothers increased from 42.8 in 1998 - 1999 to 53 in 2005 - 2006 in Bihar. In Uttar Pradesh, Bihar, and Madhya Pradesh, the percent distribution of severe wasted children of underweight mothers increased from 42.8 in 1998 - 1999 to 53 in 2005 - 2006. The child nutrition was significantly associated with maternal nutrition in Uttar Pradesh, Bihar, Madhya Pradesh, and Rajasthan in 1998 - 1999 and in all selected states except Uttaranchal and Assam in 2005 - 2006 [19].

Between 2006 and 2016, there was a decline in stunting in under-5 children from 48% to 38.4% suggesting improved nutritional intake. A majority of districts across India, however, have a high stunting burden, with more than a third of children stunted in 439 districts [8].

Insights into Developmental Origins of Health and Disease

The role of early nutrition in long-term disease risk was first proposed by Barker., *et al*. who suggested that environmental factors, particularly nutrition, during early life can program the risk for cardiovascular (CV) disease in adult life (early or fetal origins of adult disease hypothesis) [20]. The fetal origins hypothesis has evolved into a new branch of scientific knowledge known as the developmental origins of health and disease (DOHaD) extending from the concept of oocyte to infant and beyond [21,22]. The DOHaD hypothesis states that environmental factors, particularly maternal undernutrition, can act during early life to program the risk for adverse health outcomes, such as CV disease, obesity, and metabolic syndrome in adult life (Figure 4) [20,21]. The fetal origins hypothesis traditionally focused on maternal undernutrition and micronutrient deficiencies. However, since the dual burden of under- and overnutrition is on the rise globally, it is increasingly being recognized that a higher incidence of disease can occur in both instances: those born small and those born large, thus forming a U-shaped curve [21].

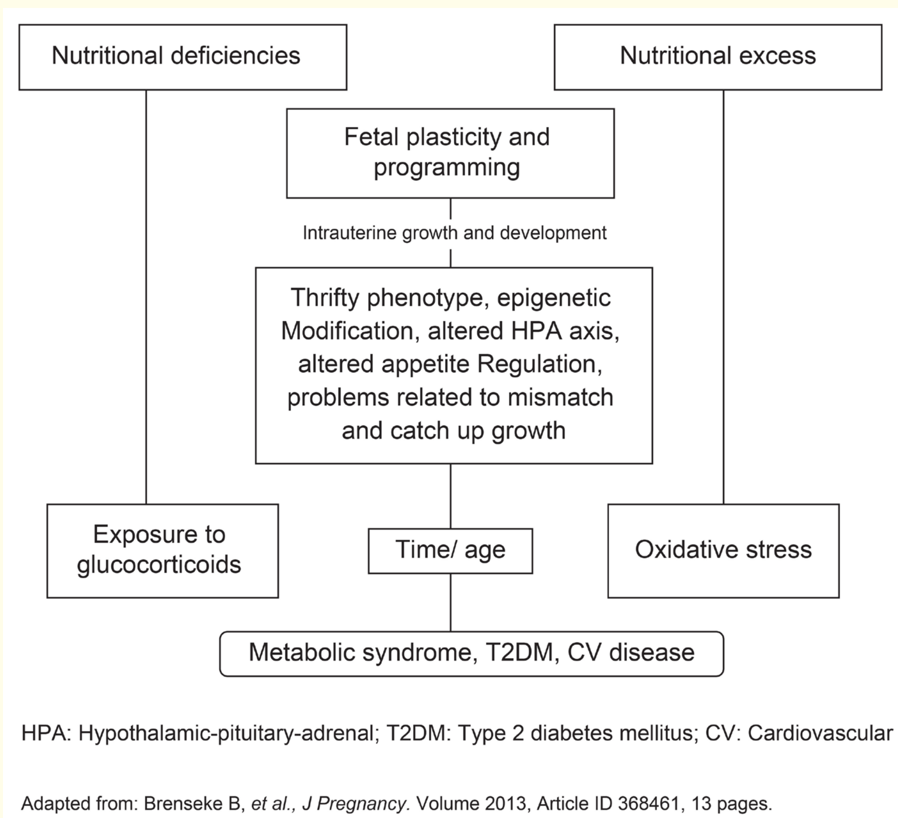

Figure 4: *Schematic representation of the concepts and mechanisms underlying the developmental origins of health and disease (DOHaD) (Brenseke., et al. 2013).*

Intrauterine factors contributing to long-term disease risk in India

The association between maternal nutrition and fetal growth pattern and subsequent risk of diabetes from an Indian context was best demonstrated in the Pune Maternal Nutrition Study (PMNS), a prospective, community-based study conducted in 6 villages near Pune. The PMNS showed that although Indian babies were small, short, and thin at birth, they had subscapular skin-fold thickness comparable to white babies born in the United Kingdom (thin-fat babies). The study suggested that body composition of an individual is established at birth and the description of "thin but fat" Indian adults actually starts *in utero* [23]. Indian babies also had higher concentrations of insulin and leptin and lower concentrations of adiponectin in cord blood when adjusted for birth weight, suggesting that the high-risk Indian phenotype is established *in utero* [24]. The PMNS also demonstrated that micronutrients are an important determinant of fetal growth in Indian population [25]. Maternal B_{12} and folate levels in pregnancy were found to be significantly related to the child's adiposity and insulin resistance. Higher maternal folate levels predicted higher adiposity, and mothers with low B_{12} concentrations but high folate concentrations gave birth to children who were insulin resistant. This study demonstrated the relationship between maternal nutrition in pregnancy and risk of diabetes in the offspring [26]. Based on these findings, Yagnik., *et al*. proposed that an undernourished mother produces a small but thin-fat insulin-resistant baby who will remain so if postnatal nutrition is not excessive. Such individuals may have low rates of non-communicable diseases (NCD) such as in rural India. However, if postnatal nutrition is excessive, it promotes obesity and hyperglycemia in the child. An obese and hyperglycemic mother produces a "macrosomic" baby who is at a future risk for diabetes, CV disease, and other disorders at a young age such as seen in urban India [27].

Macro- and Micronutrient Deficiencies in the Mother and its Impact

Maternal and fetal outcomes are highly dependent on the intake of nutrients to meet both maternal and fetal requirements. Malnutrition has been conventionally attributed to protein-energy malnutrition, especially during rapid growth phases of the life cycle. However, it is now recognized that in addition to protein and energy, several micronutrients are needed during rapid growth phases [28].

Energy and protein

Energy is one of the chief determinants of gestational weight gain. Additional energy is needed during pregnancy for the fetal growth and maintenance, as well as for the placenta and maternal tissues [28]. Caloric intake during pregnancy has been found to be significantly correlated to pregnancy weight gain, birth weight, and length [29]. Maternal protein intake during pregnancy is also highly essential for positive pregnancy outcomes, healthy fetal growth and development, and for accretion of maternal and fetal tissues. An optimal or balanced protein intake during pregnancy is important to prevent IUGR and infant low birth weight [30].

The effect of energy and protein supplementation during pregnancy to improve fetal outcomes has been studied extensively. In a prospective study in Guatemala, children born to women who received high-protein, moderate-energy supplements were taller than children whose mothers received low-energy supplements [31]. A recent meta-analysis demonstrated that balanced protein energy supplementation in pregnant women can lead to a reduction in the risk of small-for-gestational-age (SGA) infants, particularly in undernourished pregnant women [32].

Iron

Pregnant women are at the highest risk for iron deficiency anemia (IDA) due to an increased demand for fetal growth and development. Maternal IDA can have harmful effects on the child. Mothers with iron deficiency give birth to children who are more likely to have low iron stores, impaired physical and cognitive function, and suboptimal immune system [33].

According to the WHO estimates for 2011, 38% of pregnant women, 29% of nonpregnant women, and 29% of all women of reproductive age have anemia, corresponding to 496 million nonpregnant women and 32 million pregnant women globally. The proportion of all anemia amenable to iron was around 50% in women, and the proportion of severe anemia amenable to iron was over 60% in pregnant women. The highest number of women of reproductive age with anemia resided in the South-East Asian region (202 million) [34]. Anemia among women of reproductive age in India has remained stagnant over the last decade. According to the NFHS-4 report, nearly 53% of nonpregnant women of reproductive age are anemic, which shows a slight improvement (2%) compared with the NFHS-3 report. The prevalence of anemia was higher in women from rural areas than in those from urban areas (54.3% vs 53.1%). Furthermore, more than half of pregnant women aged 15 - 49 years had hemoglobin levels less than 11 mg/dL (the percentage was higher in rural areas), indicating a high prevalence of anemia during pregnancy. Several districts with extremely high prevalence of anemia were clustered across eastern areas [8,9]. A recent retrospective study in out-patient clinics of a rural hospital in India suggested that the prevalence of anemia was constantly over 50% in females after puberty and iron deficiency was the main cause [35].

Impact of maternal iron deficiency on pregnancy outcomes in India

The burden of anemia and iron deficiency and its association with pregnancy outcomes were evaluated in a study of 366 Indian pregnant women. Among these, 30% of women had anemia, 40% had iron deficiency, and 22% had IDA. Maternal anemia was associated with a 2.4 times greater risk of preterm birth and low birth weight, whereas maternal iron deficiency predicted a 2.5-fold higher risk of preterm birth. Iron deficiency anemia was associated with a 3-fold greater risk of preterm birth [36]. In a prospective study, the mean value of mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean serum iron in neonates born to anemic mothers were significantly lower than in neonates born to non-anemic mothers, suggesting adverse effects of maternal anemia on neonatal iron status [37]. Maternal anemia and iron-deficient status have also been reported to adversely affect cord blood hemoglobin levels, neonatal platelet indices, and neonatal anthropometric indices [38-40].

Iron supplementation programs for pregnant women in India and its status

The National Iron + Initiative 2013 by the Ministry of Health and Family Welfare Government of India proposed anemia supplementation program across the life cycle, in which the beneficiaries will receive iron and folic acid (IFA) supplementation irrespective of their iron or hemoglobin status. According to this initiative, the recommendations for IFA supplementation in pregnant and lactating women and women of reproductive age group are as follows:

- In pregnant and lactating women, 1 tablet daily containing 100 mg of elemental iron and 500 μg of folic acid should be given for 100 days, starting after the first trimester, at 14 - 16 weeks of gestation, and repeated for 100 days post-partum.
- In women of reproductive age group, weekly iron supplements containing 100 mg of elemental iron and 500 μg of folic acid should be given throughout the reproductive period.

Iron tablets for pregnant and lactating women were planned to be provided during the routine antenatal visits to the primary health centers, community health centers, and district hospitals. The Accredited Social Health Activist (ASHA) would ensure provision of IFA supplements and their compliance in pregnant women who are not able to come for regular antenatal checkups through home visits. In women of reproductive age group, IFA supplements were planned to be distributed during doorstep distribution of contraceptives [41].

One of the major issues with iron supplementation programs is the compliance with IFA tablets. In two studies that evaluated compliance with IFA tablets among pregnant women in tertiary health centers in Mangalore city in South India and Anganwadis of Surat Municipal Corporation area, the overall compliance rates were found to be 64.7% and 61.7%, respectively. Forgetfulness, side effects (both perceived and experienced), low palatability, and ignorance toward self-healthcare were some of the important factors for noncompliance [42,43]. The NFHS-4 reports that only 30% of pregnant women were consuming IFA supplements for 100 days during pregnancy (rural: 25.9%; urban: 40.8%) [8]; however, there is a 50% increase compared with the NFHS-3 survey, which reported only 15.2% of women using IFA supplements.

Vitamin A

Vitamin A deficiency (VAD) can hamper numerous vital functions and cause health consequences to which infants, young children, and pregnant women are at the highest risk. Night blindness is one of the complications of VAD that occurs as a result of pre-existing marginal maternal vitamin A status superimposed by increased nutritional demands during pregnancy [44]. Due to accelerated fetal development and increased blood volume, VAD is more common in the third trimester of pregnancy. Night blindness is also more common in the third trimester of pregnancy [45]. The deficiency of vitamin A in pregnant women is assessed by either history of night blindness or serum or plasma concentrations of retinol of less than 0.70 μmol/L (subclinical VAD) [7]. According to the WHO estimates for 2011, an estimated 9.8 million pregnant women were affected by night blindness and 19.1 million pregnant women (15.3%) had low serum retinol concentration < 0.70 μmol/L in 2011 globally. Highest proportion of pregnant women affected by night blindness were reported in Southeast Asia (9.9%) and Africa (9.8%) [44]. According to NFHS-3, nearly 9% of pregnant women in India were affected by night blindness and the proportion of pregnant women with night blindness was higher in rural areas (10.8%) than in urban areas (3.7%) [9]. Recent estimates of night blindness in pregnant women in India are not available.

Strategies for addressing maternal VAD

The recommended nutrient intake (RNI) of vitamin A is 800 μg retinol equivalents (RE)/day, which is difficult to achieve with diet alone. According to WHO guidelines on vitamin A supplementation (VAS) in pregnant women, VAS is not recommended as a part of antenatal care but is recommended for the prevention of night blindness in areas where there is a severe public health problem related to VAD. The suggested VAS scheme in pregnant women is up to 10000 IU vitamin A (daily dose) or up to 25000 IU vitamin A (weekly dose) for a minimum of 12 weeks during pregnancy until delivery. Other interventions such as dietary diversification and fortification can be used along with VAS to improve VAD. Rich dietary sources of vitamin A include carrot, pumpkin, papaya, red palm oil, dairy products, liver, and fish oil [43]. Fortification of cooking oils is one of the strategies used to combat VAD in developing countries [46].

Zinc

Maternal zinc deficiency can have adverse effects on progeny [47]. Based on zinc availability in National Food Supplies and the data on prevalence of stunting, globally 17.3% of the world's population was estimated to have inadequate zinc intake (2003 - 2007). South Asia and Sub-Saharan Africa were reported to have the highest prevalence (29.6% and 25.6%, respectively) [48]. In a study conducted on pregnant women in a rural block in Haryana, India, the prevalence of zinc deficiency was 64.6%. Low dietary intake was the prime cause for zinc deficiency in pregnant women since 86.2% of the women were consuming less than 50% of the recommended zinc intake (12 mg) [49]. A prospective study in a tertiary care hospital in Central India, which evaluated zinc levels in LBW (preterm and term IUGR) and term appropriate-for-gestational age (AGA) infants, showed that LBW neonates and their mothers had significant zinc deficiency. Low maternal zinc levels were significantly correlated to lower serum zinc in LBW neonates [50]. In another study, it was observed that pregnant women with zinc concentrations in the lowest quartile were associated with significantly higher occurrence of low birth weight babies compared to pregnant women with zinc concentrations in the upper three quartiles. The study also suggested the possibility of a threshold for maternal serum zinc levels below which the prevalence of low birth weight increases significantly [51]. A population-based cohort study involving 3187 pregnant women showed that maternal zinc deficiency during pregnancy elevates the risks of LBW and SGA infants. Furthermore, an association was demonstrated between maternal serum zinc level, placental inflammation, and incidence of SGA infants [52].

Strategies for combating zinc deficiency

Supplementation, fortification, and dietary diversification are some of the strategies to help improve maternal zinc status. Currently, there are no national-level zinc supplementation programs in any of the South Asian countries [53]. Furthermore, a recent meta-analysis of randomized controlled trials showed that zinc supplementation ranging from 5 to 50 mg/day given for at least one trimester of pregnancy did not affect any parameter of fetal growth such as risk of low birth weight, birth weight, length at birth, or head circumference at birth. The authors also suggested that the effect of zinc supplementation on preterm birth, if any, was due to reduction in maternal infection, which is a primary cause of prematurity [54].

Iodine

Maternal iodine deficiency is of significance due to its adverse effects on fetal development. Recent global estimates of iodine deficiency suggest that 29.8% (241 million) have insufficient iodine intake [55]. In a study that evaluated iodine deficiency in pregnant women (n = 237), lactating mothers (n = 73), and healthy nonpregnant female control subjects (n = 59), iodine deficiency was demonstrated in 37% of pregnant women, 33% of lactating women, and 3% of healthy control subjects [56]. The iodine status in pregnant women and neonatal and infant outcomes was evaluated in two centers in India. The urinary iodine concentrations (UICs) at 17 and 32 weeks were used and extreme UIC quartiles were compared for predictors and outcomes. Developmental outcomes such as abdominal circumference at 24 months, and subscapular and triceps skin folds at 12 and 24 months in offspring differed between the lowest and highest UIC quartiles [57]. A meta-analysis also demonstrated deficit of intelligence quotient (IQ) points in children whose mothers had iodine deficiency during pregnancy [58].

Strategies for addressing iodine deficiency

Universal salt iodization (USI) is a global strategy to control iodine deficiency and is implemented in nearly all countries worldwide. However, in some countries, implementation of USI is not feasible, resulting in lack of access to adequately iodized salt in some areas [59]. The NFHS-4 data revealed that percentage of households using iodized salt in the Indian population is currently 93%, showing a significant improvement over the past decade. The consumption of iodized salt was 76% in the NFHS-3 report [8,9]. The WHO recommends that countries should assess and categorize the level of implementation of salt iodization programs and should take additional steps to curb iodine deficiency. Iodine supplementation can be provided by two approaches in pregnant and lactating women: a dose of 250 μg/day or a single annual dose of iodized oil supplement of 400 mg [60]. However, this approach is not followed in India due to the risk of iodine-induced hypothyroidism, also known as Wolff-Chaikoff effect.

Folate and Vitamin B12

Vitamin B_{12} and folate are essential micronutrients for embryogenesis. Results from a recent meta-analysis showed that vitamin B_{12} insufficiency is prevalent in 21%, 19%, and 29% of pregnant women in the first, second, and third trimesters, respectively, and high rates were reported in the Indian subcontinent [61]. Low maternal folate concentrations have been associated with low birth weight, low placental weight, neural tube defects, increased risk of SGA, and prematurity [62,63]. An association between maternal folate and homocysteine concentrations and insulin resistance in the offspring was also demonstrated in an Indian study [64]. Low maternal vitamin B_{12} levels are also associated with fetal neural tube defects, IUGR, and low birth weight in infants [65-67].

To combat adverse outcomes associated with folate deficiency in pregnant women, the WHO recommends daily folic acid supplementation as a part of antenatal care. A dose of 400 μg of folic acid daily throughout pregnancy is recommended [59]. A Cochrane review has shown that folate supplementation in pregnancy is associated with reduction in the risk of neural tube defects [68]. Dietary vitamin B_{12} is usually stored in the liver because of which vitamin B_{12} deficiency occurs only after long periods of inadequate intake or malabsorption disorders. Because vitamin B_{12} is found only in animal foods, women who follow strict vegetarian diets are at a risk of vitamin B_{12} deficiency. In such women, preconceptional supplementation of at least 2.4 μg per day of vitamin B_{12} is recommended [3].

Omega-3 fatty acids

Several studies have established that quantity and quality of dietary fats consumed during pregnancy have profound health implications during and after pregnancy. Omega-3 fatty acids are essential fatty acids and can only be obtained from the diet. Marine sources, fish oil supplements, canola, soybean, and selected vegetable oils such as flaxseed are some rich sources of omega-3 fatty acids [69]. Omega-3 fatty acids play critical roles during fetal growth and development, and higher intakes of omega-3 fatty acids during pregnancy have been associated with decreased maternal depression, reduced rates of IUGR, preterm birth, reduced allergies and asthma in children, and improved neurocognitive outcomes in the offspring [70]. Omega-3 fatty acid intake in pregnant women and women of childbearing age has not been reported in the Indian diets. Prospective studies in pregnant women who consumed the recommended fish intake or received supplements of fish oil generally demonstrate a beneficial effect on neurodevelopmental outcomes of offspring [71]. There are limited studies that report the association between maternal omega fatty acid intake and birth outcome among Indian women. However, cross-sectional human studies have demonstrated lower LCPUFA levels in pregnancy complications such as preeclampsia [72,73]. A prospective study reported the possible role of the maternal omega-3 and omega-6 fatty acids in the etiology of LBW babies right from early pregnancy [74], suggesting supplementation of DHA may be useful in improving pregnancy outcome. In view of the importance of the fatty acids in maternal-fetal health, the impact of socio-economic factors on intake of omega-3-fatty acids among women of child bearing age in India needs to be examined.

Vitamin D and Calcium

Vitamin D plays a vital role in maintaining bone integrity through the regulation of calcium. In addition, vitamin D influences extra-skeletal processes such as immune function and blood glucose homeostasis. Vitamin D requirements increase in pregnancy because the fetus is entirely dependent on maternal vitamin D stores for growth and development [3]. A high prevalence of hypovitaminosis D (25-hydroxyvitamin D [25{OH}D] < 50 mmol/L) during pregnancy has been reported in a few studies from India. The prevalence rate of hypovitaminosis D in pregnant women was 96.3% and 84% in two studies, respectively [75-76]. Poor maternal vitamin status is associated with preeclampsia, higher prevalence of gestational diabetes, risk of low birth weight, and SGA infants [77-79]. Although there is some evidence that vitamin D supplementation during pregnancy may lower the risk of preeclampsia in pregnant women, WHO currently does not recommend vitamin D supplementation during pregnancy to prevent the development of preeclampsia and its complications. In addition, due to limited evidence on the benefits of vitamin D supplementation, WHO does not recommend vitamin D supplementation during pregnancy as part of routine antenatal care [80].

Calcium is an essential nutrient for women's preconception health for maintenance of vascular function, muscle contraction, nerve transmission, and glandular secretion of hormones. During pregnancy, calcium is mobilized from maternal skeleton for fetal growth and development [3]. Global estimates suggest that nearly 3.5 billion people in 2011 were at risk for calcium deficiency. There was a reduction in the risk of calcium deficiency from 76% in 1992 to 51% in 2011 [81]. Studies suggest an inverse relationship between calcium intake during pregnancy and preeclampsia and gestational hypertension [82,83]. Calcium supplementation during pregnancy has been found to be associated with a reduction in gestational hypertension, preeclampsia, and neonatal mortality in a meta-analysis of studies from developing countries [84]. WHO guidelines on calcium supplementation in pregnant women 2013 recommend calcium supplementation as part of the antenatal care in populations where calcium intake is low and particularly in those women who are at a higher risk of developing hypertension. Suggested dosage of calcium is 1.5 - 2.0g of elemental calcium/day, with the total daily dosage divided into three doses from 20 weeks of gestation until the end of pregnancy [85].

Barriers and Opportunities for Improving Maternal Nutrition in India

Despite several nutrition policies and interventions, maternal and child undernutrition still persists as a severe public health problem. Inadequate nutrient intake, early and multiple pregnancies, poverty, caste discrimination, gender inequality, etc., contribute to poor maternal malnutrition in India. Furthermore, the coverage of maternal nutrition programs in India is not widespread. In addition, lack of proper communication with the beneficiaries can lead to lack of compliance with such programs. A study assessed the implementation of maternal nutrition programs in three states in India (Tamil Nadu, Uttar Pradesh, and Bihar) and identified several barriers for the effective utilization of the nutrition programs. One of the main problems is that women are not empowered to take necessary steps to improve their nutritional status. Lack of literacy, awareness, decision-making power, and freedom of movement acted as a barrier to care. Food intake during pregnancy was guided by poor nutrition advice by family members, food taboos, lack of adequate household income, customs of gender- and age-based eating order, etc. Several barriers were also noted in the utilization of services such as IFA supplements and food fortification programs. Side effects, concerns about IFA-associated miscarriages, and other misconceptions about IFA tablets were cited as the reasons for noncompliance with IFA tablets. Lack of availability and lack of quality were reported as barriers for effective utilization of food fortification programs [86].

Recommended actions to improve women's nutrition in India

The following recommendations can be implemented at various levels with the help of Anganwadi workers, ASHA, and healthcare personnel (auxiliary nurse midwives and district medical officers) to strengthen the existing interventions in India:

- Improve IFA programs through the development of an evidence-based national policy on dosage
- Propagate targeted media campaigns to reinforce compliance and strong supply chain
- Strengthen all components of ANC services, which are currently suboptimal
- Standardize food fortification programs on a national level, improve quality control measures, and increase the availability of quality fortified foods
- Micronutrient fortification of staples, oil, milk, supplementary foods, etc.
- Universal treatment of all pregnant women for helminthic infections
- Promote weight gain during pregnancy and introduce interventions to improve diet quality and food intake [86].

WHO Global Targets 2025: Improving Maternal, Infant, and Young Child Nutrition

To tackle the double burden of malnutrition, the 2012 World Health Assembly (WHA) agreed unanimously to a set of six global nutrition targets to be achieved by 2025. The targets are as follows:

- 40% reduction in the number of children under-5 who are stunted
- 50% reduction of anemia in women of reproductive age
- 30% reduction in low birth weight
- No increase in childhood overweight
- Increase the rate of exclusive breastfeeding in the first 6 months up to at least 50%
- Reduce and maintain childhood wasting to less than 5% [87].

Conclusion

Poor nutrition *in utero* and during early childhood in girls constraints future capacity to support healthy fetal and infant growth, and this capacity is further diminished by continued poor nutrition throughout lifecycle. Maternal malnutrition not only increases the risk of acute and chronic diseases both in the mother and the child but also affects the economical productivity of individuals and places additional financial burden on the health system. In India, more than one-third of women of reproductive age are below the standard BMI of 18.5 kg/m2 and the percentage of overweight or obesity is also on the rise. Maternal nutrition can have a huge influence on fetal growth. Nutritional deficiencies before and during pregnancy increase the risk of adverse obstetric outcomes, low birth weight, and IUGR in the offspring. The effect of maternal nutrition on the offspring starts early and nutritional insults during early life can program the risk for adverse health outcomes later in life. Optimal intake of macro- and micro-nutrients is essential to meet both maternal and fetal requirements and reduce adverse health consequences. Several barriers exist for the implementation of maternal nutrition programs directed at improving maternal nutrition in India. These barriers can be addressed by promoting integration of services, ensuring effective supplementation and fortification programs, and strengthening the monitoring and evaluation of nutrition-specific programs.

Key Messages

- Despite rapid economic growth, improvement in maternal and child nutritional status in India has been slow over the last decade. About 23% women (both from urban and rural areas) in India have a BMI below normal according to the NFHS-4 report and this figure is higher in rural areas. Furthermore, more than half of pregnant women have hemoglobin levels less than 11 mg/dL indicating a high prevalence of anemia during pregnancy. Poor maternal nutritional status of woman before and during pregnancy increases the risk of IUGR and LBW in infants and stunting and wasting in children.
- The NFHS-4 report also suggested that obesity is an emerging problem in India, particularly in women, with nearly 20% of the women being overweight or obese, a figure considerably higher than the NFHS-3 report. This suggests the existence of dual burden of under- and overnutrition in women in India where nearly 44% of women are either too thin or overweight. Pre-pregnancy obesity and excess gestational weight gain may increase the risk of gestational diabetes, pregnancy complications, caesarean sections, higher birth weight infants, preterm births etc. and can also have serious long-term consequences
- Maternal and fetal outcomes are highly dependent on the intake of nutrients to meet both maternal and fetal requirements. Despite several initiatives by the Government to improve maternal nutritional status, maternal undernutrition remains prevalent. Inadequate nutrient intake, early and multiple pregnancies, poverty, caste discrimination, gender inequality, etc., contribute to poor maternal nutritional status. Furthermore, the coverage of maternal nutrition programs is not widespread; and lack of proper communication with the beneficiaries can lead to lack of compliance resulting in underutilization of such programs.
- There is a need for strengthening of existing nutritional interventional programs to tackle the problem of undernutrition in India. Strengthening of antenatal care services, broadcasting of targeted media campaigns to emphasize compliance to iron and folic acid and other supplements, standardization of food fortification programs, improving quality control measures, increasing the availability of quality fortified foods, promoting weight gain during pregnancy, micronutrient fortification of staples, oil, milk, supplementary foods, etc. are some of the measures to improve nutritional status of women in India.

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Conflict of Interest

None.

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