



THE IMPACT OF MATERNAL NUTRITION ON INFANT HEALTH: A REVIEW OF NUTRITIONAL INTERVENTIONS DURING PREGNANCY

Dr Suman Mohan*

*Assistant Professor, Department of Food & Nutrition and Food Technology, BNC, University of Delhi Email: reachdrsumanmohan@gmail.com

***Corresponding Author:** Dr Suman Mohan

*Assistant Professor, Department of Food & Nutrition and Food Technology, BNC, University of Delhi Email: reachdrsumanmohan@gmail.com

Abstract

Maternal nutrition is essential in determining both maternal and infant health outcomes. Adequate nutrition during pregnancy is essential for optimal fetal growth, organ development, and metabolic programming, while maternal undernutrition leads to complications such as intrauterine development restriction, poor birth weight, and ongoing medical hazards. This review critically examines the influence of maternal nutrition on short- and long-term infant health, focusing on key macronutrients and micronutrients like protein, iron, folic acid, iodine, calcium, and omega-3 fatty acids. The paper highlights the effectiveness of nutritional interventions, including supplementation, food fortification, and dietary changes, in enhancing the health of mothers and babies, especially in middle-income and low-income nations. Despite clear biological benefits, the success of these interventions is often constrained by socioeconomic disparities, cultural barriers, and limited healthcare access. The review underscores the importance of context-specific, equity-focused strategies to overcome these challenges. Additionally, it emphasises the significance of adopting a life-course perspective, recognising the long-term consequences of inadequate maternal nutrition on child development and the risk of chronic diseases in adulthood. In conclusion, the review calls for further research to optimise maternal nutrition interventions and improve global health outcomes.

Keywords: Maternal Nutrition, Fetal Development, Nutritional Interventions, Birth Weight, Public Health, Maternal Morbidity

1. Introduction

One of the most important factors influencing the health of mothers and infants is their diet. Personal nutrition is an essential aspect of prenatal care development, which determines the full development of the fetus and the well-being of the mother. Normal nutrition during pregnancy, especially in the initial stages of pregnancy, is essential to promoting good pregnancy outcomes (Apostolopoulou et al., 2024). Pregnancy is a period of high nutritional requirements due to the necessity to both meet the physical needs of the developing fetus and the changes of the body of a pregnant mother. Healthy eating at this stage will make sure the needs of both the mother and the foetus are balanced, so that the fetus will grow and develop well (Kinshella et al., 2025).

Besides aiding the development of the fetus, maternal nutrition has an influential part to play in the prevention of maternal morbidity as well as enhancing the overall health of the mother. Proper

micronutrient supplementation (that incorporates vitamins, iron, and calcium) also prevents such complications as neonatal diseases, intrauterine growth restriction (IUGR), and premature delivery, such as low birth weight. These interventions have been found to be effective in minimizing the risk of these adverse outcomes. As one example, micronutrient supplementation has been associated with a large decrease in the prevalence of IUGR and preterm birth among different populations (Keats et al., 2021). Consequently, maternal nutrition becomes the foundation of the pregnancy-related health issues for both the mother and the unborn kid, and this aspect makes it very vital in the context of the social interventions that governments must undertake in the quest of enhancing maternal and infant health.

Prenatal malnutrition is linked to numerous adverse consequences not only to the mother but also to the baby. Poor nutrition may lead to such complications as IUGR, premature birth, and increased infant mortality rates (González-Fernandez et al., 2024). The fact that the risks of certain nutrient deficiencies are dangerous is especially worrying. An example is that the deficiency of folic acid is greatly correlated with the high risk of neural tube defects against the infant. One of the most prevalent nutritional deficiencies among pregnant women that may cause anemia is the iron deficiency that has extensive effects on the health of both mothers and children (Bodnar et al., 2025). Pregnant women world-wide have an estimated prevalence of as high as 42 cases of anemia and this situation has resulted in low birth weights and preterm births. Moreover, the lack of iodine is also proven to be the contributor to the deterioration of cognitive development in the child, and it may lead to developmental difficulties throughout the whole life of the child (Lassi et al., 2021).

These effects of inadequate nutrition are not limited to the neonatal stage. The prolonged research has proved that maternal malnutrition is among the factors that contribute to chronic diseases in the babies. Such circumstances are likely to be maintained during the life cycle, which defines even better the importance of maternal nutrition in conditioning the future generations with regard to their health (Enujuba & Bassey, 2024). It has been observed that maternal malnutrition in pregnancy predisposes the occurrences of these conditions, which does not only impact on the direct well-being of the baby but also creates a risk to the child of developing metabolic disorders, high blood pressure, and heart illnesses.

Additionally, poor nutrition in the pregnancy period does not only impact the newborn health but can also lead to a cycle of poor health effects that will continue through the ages, not just in the respective of further pregnancies and the health of the generations to come. This is the case in this cycle where children born to malnourished mothers tend to become malnourished themselves and thus these children may end up becoming health problems in life. This highlights the need to focus more on nutritional interventions in order to interrupt this chain of malnutrition and the long-term dangers.

A variety of nutritional interventions have been designed to cope with the problems of maternal malnutrition, and the focus should be on the enhancement of the maternal and infant health. These interventions are usually in form of dietary modifications, micronutrient supplementation and community based health programs.

It was demonstrated that micronutrient supplementation (the administration of folic acid, iron, and calcium) can greatly decrease the risk of neural tube defects, anaemia, and bone health problems, respectively (Heidkamp et al., 2021). All pregnant women are recommended by the global recommendation to be supplemented with folic acid, to lower the occurrence of neural tube defects. The combination of these interventions with the current maternal healthcare services in low- and middle-income nations has resulted in significant changes in the diets of pregnant women and consequently, has caused the improvement in maternal and child health outcomes (Nnamani et al., 2025).

An example is the recent empowerment of the nutrition interventions in the antenatal care services in countries with high malnutrition rates, which leads to increased intake of the iron and folic acid supplement and improved breastfeeding behaviors (Kim et al., 2023). A study in Burkina Faso discovered that increased nutritional intervention that included encouraging the use of iron and folic acid supplements resulted in a significant change in practices related to early breastfeeding that directly related to improvements in the infant health outcome. These interventions when well

organized have been identified to enhance the health outcome since the mothers are well taken care of in terms of the nutrients they need to promote their health. Moreover, dietary diversity awareness, breastfeeding, and appropriate maternal supplementation have been effective in community health programs that have increased the nutritional status of pregnant women, especially in rural and underserved communities.

Although the advantages of maternal nutrition interventions have been established, several challenges have been encountered to the successful implementation of the programs. The main challenges of pregnant women are socioeconomic inequalities, inadequate healthcare, and inadequate nutrition education, particularly when it comes to rural and marginalised communities (Chanie et al., 2025). These obstacles lead to the poor health outcomes of motherhood and infantility, and, in most cases, the inability to get high-quality healthcare worsens the situation. Also, nutrition education is low in most regions and hence lacks awareness about the significance of maternal nutrition in pregnancy. The absence of specific nutrition education programs among pregnant women leads to the poor knowledge of mothers and the additional propagation of poor health outcomes. Focusing on such barriers necessitates a massive collaboration between governments, NGOs and health providers so that nutrition interventions can be effectively rendered to the most needy population.

The absence of a coordinated way of addressing these barriers in most instances, leads to fragmented care, which impedes the total effect of nutritional programs. India State-Level Disease Burden Initiative, as an example, points to a profound disparity in the health outcomes of the states, with certain areas having a much higher rate of malnutrition and maternal morbidity. To resolve the implementation issues, there is need to take a holistic approach, not only in provision of nutritional interventions, but also enhancement of access to healthcare, education and social services. These measures will aid in making sure that nutritional interventions target most vulnerable groups and that it is possible to achieve the impact of nutritional interventions on maternal and infant health.

The major target of the analysis is to assess critically the impact of maternal nutrition on infant health status with a special view of determining the effectiveness of nutritional intervention during pregnancy. The current review follows an integrated life-course design, which connects maternal nutrition as a predictor of both the immediate neonatal outcomes and the health outcomes in the long term in the child (González-Fernández et al., 2024). It is also discussed in the review in the conceptual model of the fetal programming and placental functionality and it can provide a structure on how maternal nutrition may be able to influence fetal development and health outcomes. Through this model, the review will present a detailed study of the complicated interactions between maternal nutrition, infant health, and the future health of the child (Lassi et al., 2021). By so doing, the review will underscore the need to discuss maternal nutrition as a vital component that determines the health and well-being of infants.

To sum up, the issue of maternal nutrition is not only a condition that determines the immediate pregnancy outcomes, but it is also a driving force in the mother's and baby's ongoing medical outcomes. Malnutrition and its prevention can be a foundation of the public health activity because of its adverse outcomes and the potential to influence the health of the future generation, which can be addressed by means of specific interventions. Figure 1 summarises the theoretical mechanisms between maternal nutrition and infant health outcomes in the life course.

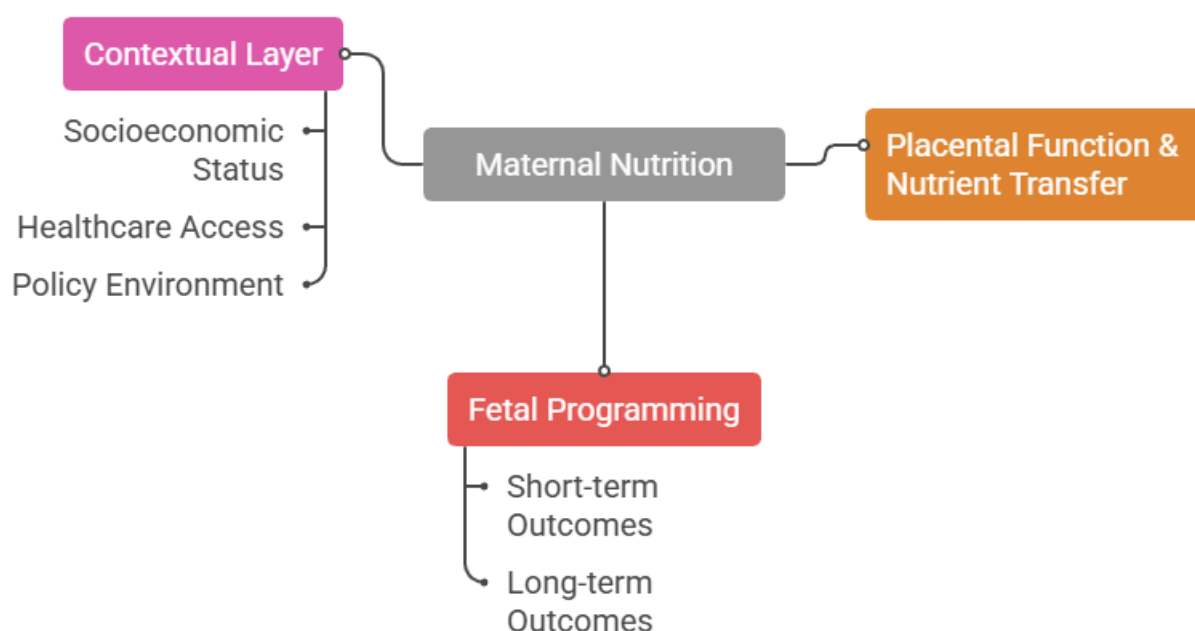


Figure 1. Conceptual framework showing how maternal nutrition shapes infant health outcomes across the life course

2. Maternal Nutritional Requirements and Key Nutrients

Nutritional requirements of the mother are raised tremendously during pregnancy, as it is a time when the body undergoes active physiological and metabolic transformations. The causes of these changes are the baby's, the embryos, and maternal tissues' higher requirements. Maternal health and foetal development are impossible without ensuring adequate nutrition, and the risks of pregnancy-related complications are also minimised (Brink et al., 2022; Kartchner et al., 2025). Maternal nutrition should be closely considered to fulfil the high index of both caloric and nutrient demands of pregnancy, as well as to aid the structural and functional growth of the fetus. The two broad classes of nutrients, which are macronutrients and micronutrients, have different but equally significant roles in pregnancy.

The physiological alterations of pregnancy including the volume of blood, low sensitivity of insulin and changes of nutrient absorption and metabolism influence the maternal nutrient requirements and fetal nutrient concentrations. Such changes reflect that sufficient intake is not sufficient, but there must be an appropriate timing and balance of nutrients in gestation.

2.1 Macronutrient Requirements during Pregnancy

Protein plays a critical function in the growth of the foetuses, development of the tissues, and the amniotic fluid. Pregnancy requires protein in about 25% more quantity since protein is required to form fetal cells and organs (Enujuba & Bassey, 2024). Protein is also involved in maternal tissue growth such as the uterus and mammary glands growth. Good sources of proteins: To address this increased need, it is essential to consume best sources of proteins (lean meat, fish, dairy, and legumes). Inadequate protein consumption in pregnancy has been linked to intrauterine growth restriction (IUGR) and low birth weight that may cause developmental problems in the infant in the long term (Brink et al., 2022).

On a mechanistic level, sufficient protein consumption aids placental development and the delivery of amino acids to the fetus which occurs especially in the early and mid-gestational stages as organogenesis and accelerated cellular growth take place. Some evidence indicates that protein adequacy is particularly significant in resource-restricted environments, in which maternal undernourishment in the baselines is more common; nevertheless, evidence obtained in high-income nations points to the fact that excessive protein consumption does not have any extra advantages and sometimes is linked to adverse effects. These observations emphasise the fact that there should be

specific recommendations and intake levels depending on the situation and not an increase in protein intake in general.

The growing embryo's main energy source is carbs. and they contribute significantly to maternal weight gain during pregnancy. The body's insulin sensitivity decreases during pregnancy to ensure a steady supply of glucose to the fetus, which necessitates increased carbohydrate intake (Bodnar et al., 2025). Additionally, fats, specifically omega-3 and omega-6 fatty acids, are vital for foetal brain development and the maturation of the central nervous system. Omega-3 fatty acids, found in fish, flaxseeds, and walnuts, have been shown to enhance cognitive and visual development in infants and decrease the risk of preterm birth. Thus, an appropriate balance of carbohydrates and fats is crucial for optimal fetal development.

The standard of consumption of macronutrients is also becoming as important as quantity. Low-glycemic index complex carbohydrates can be used to keep maternal glucose homeostasis and high consumption of refined carbohydrates has been linked to gestational diabetes and poor birth outcomes. On the same note, despite the biological plausibility of omega-3 fatty acids to enhance neurodevelopmental outcomes, the evidence is inconsistent in terms of optimal dosage, timing of supplementation, and long-term benefits with disparities being witnessed across populations and study designs.

2.2 Micronutrient Requirements during Pregnancy

Several vitamins play an essential role in the development of the foetus. Folic acid, a B-vitamin, is one of the most important, as it is essential for preventing neural tube defects such as spina bifida and anencephaly. Folic acid supplementation has been shown to significantly reduce the risk of these birth defects, particularly when taken in the early stages of pregnancy (Lassi et al., 2021). Additionally, vitamin D is vital for the proper development of fetal bones and immune function. Insufficient vitamin D levels during pregnancy can result in low birth weight, preterm birth, and an increased risk of childhood rickets (Cui et al., 2023).

At the folic acid level, it is found to facilitate DNA replication, DNA methylation, which is essential in the early embryonic growth, which explains the significance of periconceptional folic acid intake. Whereas Folic acid can aid in preventing neural tube abnormalities in the foetus, this applies less to other pregnancy outcomes, including preterm birth and fetal growth. On the same note, despite the occurrence of vitamin D deficiency in most parts of the world, especially in areas with minimal sunshine or cultural dressing, intervention studies have indicated mixed effects on non-skeletal outcomes, thus there is still no certainty on the best method of supplementation.

Two minerals that are of importance in pregnancy are iron and calcium. Iron is necessary to make hemoglobin which transports oxygen to the fetus. Pregnant mothers with maternal iron deficiency may have preterm birth and low birth weight due to anemia (Apostolopoulou et al., 2024). To avoid iron deficiency anemia, pregnant women are usually recommended to take iron supplements together with the intake of iron supplementing foods such as lean meats, legumes, and fortified cereals. Calcium is also vital, as it facilitates the growth of the skeleton of the fetus, as well as prevents bone loss in the mother. Lack of calcium in pregnancy may cause bone loss in the mother, and exposes her to the risk of developing hypertensive disorders of pregnancy, including preeclampsia (Bodnar et al., 2025).

The fact that the iron and calcium requirements are particularly acute in nations with low and medium incomes and the nutritional consumption may be low, and the maternal anemia and hypertensive states are frequent. However, the interpretation of effect of supplementation can be influenced by nutritional status during baseline, compliance as well as interaction with other nutrients. As an example, women with iron overload subjected to excess iron supplementation have been shown to develop gastrointestinal side effects and oxidative stress, meaning that in certain situations, particular actions are required not general ones.

Iodine is another key micronutrient, critical for thyroid function and the regulation of fetal brain development. Maternal iodine deficiency can lead to developmental delays and cognitive impairments

in the infant. As such, iodine supplementation during pregnancy is often recommended in regions where iodine deficiency is prevalent.

Although iodine fortification and supplementation initiatives have proved efficient in curbing severe deficiency, mild-to-moderate deficiency of iodine is still prevalent in most of the populations even in high-income nations. The impact of supplementation on the neurodevelopment of mildly deficient women is yet to be established and so is a significant area of investigation.

India-specific data indicates that major maternal micronutrient deficiencies are still very high and this supports the importance of ensuring that the nutrient intake of pregnancy is sufficient beyond the theoretical level. In India, iron deficiency affects approximately 50% of pregnant women, folic acid deficiency 25–30%, iodine deficiency 47%, vitamin D deficiency 45%, and vitamin A deficiency 18%. These gaps are associated with big baby threats, which include low birth weight, preterm birth, neural tube defects, cognitive delay, and weakened immune growth. Globally, the burden is also high, with iron deficiency affecting roughly 42% of pregnant women worldwide (WHO 2021), alongside substantial prevalence of folate, iodine, vitamin D, and vitamin A deficiencies in low-resource settings.

2.3 Impact on Fetal Growth and Development

All these macronutrients and micronutrients directly affect the development of the fetus. Proper protein consumption can help cellular development, but additionally, the growth of the brain and neurological system depends on the fatty acids. Vitamins and minerals, especially folic acid, iron, calcium, and iodine, have certain functions in the prevention of congenital defects, the correct functioning of the organs and in supporting the bone and neurological development. These nutrients are vital in their interaction to prevent such complications as preterm birth, low birth weight, and developmental delays (Enujuba & Bassey, 2024).

Moreover, maternal nutrition does not only influence the results of birth, but it may as well impact the health of the child in the future, including their predisposition to metabolic diseases, obesity, and cognitive losses (Marshall et al., 2022). The dietary needs in pregnancy are complex, and it includes both macro and micronutrients that are necessary in mother's health and the embryo's normal growth. The main priority is to make sure that a sufficient intake of these nutrients helps to prevent complications and provide a mother and a child with the most favourable results in terms of health (Khaled et al., 2024). Table 1 summarizes the maternal nutrient, biological functions, short-term and long-term infant health outcomes and the quality of available evidence.

Table 1. Key maternal nutrients, their biological roles, and associated short- and long-term infant health outcomes

Nutrient	Biological Role	Short-term Outcomes	Long-term Outcomes	Evidence Strength
Iron	Oxygen transport, placental function	Birth weight, anemia	Cognitive development	Strong
Folic acid	DNA synthesis, neural tube closure	NTD prevention	Neurodevelopment	Strong
Omega-3	Brain & retinal development	Neurodevelopment	Cognitive outcomes	Moderate

The current evidence of life-course and developmental origins of health and disease (DOHaD) research has suggested that improper nutrition during important developmental stages of fetal growth may lead to irreversible changes in the metabolism, immune regulation, and neurodevelopment. However, the extent to which the deficiencies or excesses of nutrients are the cause of such effects is the subject of current research with the stress on the need of more integrative and context-sensitive research.

3. Nutritional Interventions During Pregnancy

Adequate maternal nutrition in pregnancy is paramount in proving the best development in the foetus and minimizing occurrence of poor outcomes of pregnancy. The nutritional interventions, such as the supplements, fortified foods, and dietary advice are important in treating the deficiencies and enhancing the maternal and infant health (Hunter et al., 2023). In this section, the effectiveness of these interventions during pregnancy is discussed, and specific attention is paid to such supplements as folic acid and iron, dietary guidelines, and community-based health initiatives that are designed to enhance maternal nutrition.

Though, the biological rationale of nutritional interventions during pregnancy has been well comprehended, the extent of their effectiveness in the actual life conditions may vary significantly because of the nutritional status at the interventions time, compliance, time of intervention and health systems capacity to execute nutritional interventions (Kinshella et al., 2025). There is a need to then create a distinction between efficacy in controlled conditions and effectiveness in everyday practice in the evaluation of the effects of maternal nutrition interventions.

3.1 Supplements and Fortified Foods

A widely used approach to the identification of certain nutrient deficiencies in pregnant women is supplementation. One of the most well-known supplements is folic acid as it prevents neural tube defects that influence the way the embryonic nervous system and spinal cord grow. WHO advises all pregnant women to take folic acid supplements especially during the initial phases of the pregnancy when neural tube defects are mostly prevalent (Enujuba & Bassey, 2024). Several researchers have showed that folic acid supplementation has a profound effect on the occurrence of such conditions as spina bifida and anencephaly (Brink et al., 2022).

One of the best examples of nutrient-specific efficacy of maternal nutrition is the folic acid preventive effect on neural tube defects. Pregnancy outcome of folic acid supplementation at population level is however influenced by preconceptional use, unplanned pregnancies and disparity in accessing supplements. As a result, fortification measures have often been used as a supplementation program particularly where there is low attendance to early antenatal care.

Besides folic acid, iron supplementation is also essential in the prevention of maternal anemia, which is a common condition in pregnancy and can cause fatigue, decreased oxygen delivery to the fetus, and preterm birth and low birth weight (Bodnar et al., 2025). Pregnant women are advised to take iron-containing supplements, which are often supplemented with folic acid, especially those who have low iron reserves or do not have sufficient iron intake in their diets (Lassi et al., 2021).

National evidence supports the continued prioritisation of iron and folic acid supplementation as a cornerstone pregnancy intervention in India. ICMR-linked data indicate that iron–folic acid supplementation is associated with a significant reduction in anaemia, and iron deficiency contributes substantially to maternal disease burden (reported as 15% in the provided table). These findings strengthen the rationale for maintaining high coverage of iron–folate supplementation, particularly in settings where baseline anemia is high and dietary iron intake is insufficient.

Despite the considerable evidence to lend credence to the benefits of iron supplementation in the prevention of maternal anemia, it has not had a consistent effect on maternal birth outcomes such as birth weight and preterm birth. The differences in the levels of baseline anemia, dosage, formulation and adherence result in discrepancies in outcomes of different studies. This together with the side effects of iron supplementation on the gastrointestinal tract has the potential to further reduce adherence, which restricts the utility of iron supplementation in practice despite ideal biological support.

Another intervention is fortified foods. Micronutrients including iron, iodine, and vitamins are commonly added into foods like flour, cereals, and dairy products to ensure pregnant women consume foods that meet their high nutritional requirements. Fortification programs have been specifically useful in enhancing maternal nutrition and lowering cases of nutrient deficiencies in regions with high levels of deficiencies, especially in low- and middle-income countries (Heidkamp et al., 2021). Examples of these include fortification with iodine, which is essential in the prevention of developmental delays and cognitive impairments among infants because iodine deficiency may result

in thyroid dysfunction and impaired brain development (Keats et al., 2021). The interventions are useful in those regions where there is a lack of access to a wide variety of foods or where the healthcare system fails to provide regular supplementation.

The advantage of fortification strategies is that they can target many people and are not limited to an individual. They, on the other hand, need frequent consumption of fortified staples, adequate doses of fortification and management. The increased pregnancy-specific requirements in some contexts cannot be met adequately by fortification, therefore the relevance of the complementary approaches in comparison to the application of a single intervention strategy.

3.2 Dietary Recommendations for Pregnant Women

Dietary recommendations are also important to achieve optimal maternal nutrition along with supplements and fortified foods. A healthy diet consisting of a wide range of foods rich in different nutrients is necessary to address the nutrition requirements of both the fetus and the mother. According to the 2015 Dietary Guidelines of Americans, it is better to take as many different fruits and vegetables, whole grains, lean proteins, and dairy products as possible to be sure of sufficient intake of all necessary nutrients during pregnancy (Marshall et al., 2022). Macronutrients such as carbohydrates, proteins, and fats are to be consumed in their right proportions with preference to healthy fats, especially omega-3 fatty acids, which facilitate the development of the fetal brain (Bodnar et al., 2025).

Although dietary guidelines provide an integrated guideline on the most appropriate nutrition to adopt, adherence to the dietary guidelines in the case of pregnant women who are often limited by socioeconomic factors, availability of food, cultural orientation and nutrition education is compromised. As a result, dietary interventions may manifest the existence of good potential benefits in theory, but poorer ones in practice, particularly in vulnerable populations.

Another major consideration in dietary recommendations is that of micronutrients. During pregnancy, women require more vitamins like vitamin D that aids in calcium absorption and bone formation in the fetus and vitamin A that is vital in immune functionality and cell differentiation (González-Fernández et al., 2024). The importance of calcium consumption is also paramount since it promotes the bone formation of the fetus and prevents bone loss in the mother. The suggested caloric amount of calcium per day to be taken in pregnancy is 1,000 mg, and extra calcium is required in the second and third trimesters to satisfy the needs of the fetus.

Contradictory evidence on the efficacy of dietary methods, without supplementation, still exists. Though the diversity of the diet has been associated with improvement in maternal micronutrient status and birth outcomes, it may be challenging to supplement adequate intake of specific nutrients with food intake during pregnancy, particularly in places with food insecurity or low dietary diversity. It is impossible to overestimate the role of dietary diversity. The dietary diversity of mothers has been linked to better birth outcomes such as increased birth weights and lower malnutrition rates (Kim et al., 2023). The risk associated with deficiency of nutrients can be resolved by encouraging pregnant women to take as many foods as possible, including high-protein, vitamin and minerals rich foods.

Dietary recommendations, in turn, are best suited to be combined with a wider nutrition education and support interventions, which help to overcome structural and behavioral barriers to healthy eating during pregnancy.

3.3 Public Health Programs and Interventions

The role of the public health programs is important to enhance maternal nutrition, especially in the resource constrained environment where the access to quality healthcare and nutrition might be poor (Gwacham-Anisiobi et al., 2024). It has been demonstrated that the addition of nutrition interventions to the maternal, neonatal, and child health programs will enhance the quality of maternal dietary intake, improve micronutrient status, and decrease pregnancy-related complications.

Multi-component interventions, i.e., those in which supplementation, dietary counselling, and behavior change communication have been used, should prove to be more effective, programmatically, when compared to single-component interventions (von Salmuth et al., 2021).

However, the discrepancies in the program design, coverage and the quality of implementation are what results in the heterogeneity of the results of various settings.

As an example, in Bangladesh, introducing nutrition interventions into the already existing maternal health programs resulted in the increased dietary diversity, as well as the improved intake of micronutrients among pregnant women (Kim et al., 2023). Nutrition education, supplementation and counselling are usually joined to encourage healthy eating habits and make sure that women get the nutrients required to have a healthy pregnancy.

Although these examples are promising regarding the potential of integrated public health approaches, scalability and sustainability will continue to be a persistent challenge, especially in low-resource contexts with limited health systems and capacity to employ the workforce.

Besides country-specific interventions, international programs, like the Global Strategy on Infant and Young Child Feeding by the WHO, promote breastfeeding and maternal nutrition and emphasise the need to continue through pregnancy and lactation. These and national policies that favour food fortification and supplementation can reduce the occurrence of maternal malnutrition and enhance the health status of mothers and infants. As demonstrated in the table summarising key nutritional interventions, various strategies have shown effectiveness in improving both maternal and infant health outcomes (Table 2).

Table 2. Pregnancy nutrition interventions: target nutrients and reported maternal–infant outcomes

Intervention	Target Group	ICMR Data on Effectiveness	Short-Term Impact on Infant	Long-Term Impact on Infant
Iron and Folic Acid Supplementation	Pregnant women	Significant reduction in anaemia, 15% of maternal disease burden due to iron deficiency (ICMR)	Reduces anaemia, prevents low birth weight	Improved cognitive development, lower risk of developmental delays
Sanitation and Safe Water Initiatives	Rural populations	Decrease in diarrheal diseases in EAG states (ICMR)	Prevents dehydration, reduces diarrheal diseases	Reduced risk of chronic gastrointestinal disorders, better long-term health
Mobile Stroke Units for NCDs (Hypertension/Diabetes)	Pregnant women with NCD risks	Reduction in hypertensive disorders (ICMR findings)	Reduces risk of stroke, preeclampsia	Long-term cardiovascular health, lower risk of obesity and diabetes

Nutritional Education and Counselling	Pregnant women in low-income settings	Improved dietary diversity in rural areas (ICMR)	Reduces risk of IUGR and preterm birth	Better nutritional habits, lower obesity rates later in life
Integrated Maternal Nutrition Programs	Pregnant women in rural areas	Improved birth outcomes in states with nutrition programs (ICMR)	Decreases infant mortality, reduces malnutrition rates	Long-term reduction in chronic diseases, improved quality of life

Beyond single-nutrient approaches, ICMR-linked program evidence highlights the role of integrated maternal nutrition programs and nutrition education/counselling in improving pregnancy and infant outcomes. Reported program effects include improved dietary diversity among pregnant women and improvements in birth outcomes in regions where structured maternal nutrition programs are implemented. In addition, nutrition-sensitive public health actions such as sanitation and safe water initiatives are described as contributing to reductions in diarrheal disease burden, supporting infant health indirectly through reduced infection and improved nutritional absorption (Indian Council of Medical Research, 2024).

Despite the existence of good policy frameworks in the world, loopholes exist in terms of policy recommendations and practical implementation. To address these gaps, the health, agriculture, and social protection sectors ought to collaborate to ensure that the nutritional intervention during pregnancy results in significant and parallel health outcomes.

4. Challenges in Implementing Nutritional Interventions

Although the advantages of maternal nutrition programs have been established, there are several obstacles to the successful delivery of such programs. Such obstacles are cultural, socioeconomic, and geographic barriers to access to sufficient nutrition, healthcare, and nutrition education among pregnant women. Addressing these problems is crucial to implement the interventions aimed at maternal nutrition effective in terms of better pregnancy outcomes and decreased maternal and infant morbidity and mortality.

4.1 Cultural Barriers

Cultural beliefs and practices tend to influence the dietary habits and the attitudes towards the nutritional interventions during pregnancy. In most societies, culture and food are not in line with the existing nutritional demands. Using the example, certain cultures can focus on foods that do not provide fundamental nutrients such as iron and folic acid, or certain cultures have specific food taboos that do not allow consuming the required amounts of nutrients during pregnancy (Zembe-Mkabile, 2023). Those are the sections of a nation, in which pregnant women might refuse to change and take supplements due to the false information about their safety or effectiveness (Chanie et al., 2025). In addition, some food taboos during pregnancy may cause deficiency in certain nutrients and this fact can lead to adverse impacts on the condition of the mother and the child. One such instance is that certain cultures think that this or that vegetable or meat should not be eaten during pregnancy, but it is very nutritious in terms of the content of the primary nutrients like iron, vitamin A and protein (Kinshella et al., 2025). The obstacles associated with the culture must be addressed through the assistance of the community-based interventions that are culturally aware and embrace the local traditions and promote the acquisition of the evidence-based nutrition practices. Possible methods of changing cultural attitudes towards maternal nutrition intervention include nutrition education

programs involving the local leaders, healthcare providers, and community members (Cui et al., 2023). The interventions should be cultural-specific to suit the local cultural patterns to be more effective to ensure that they are effective in the long run.

4.2 Socioeconomic Barriers

Socioeconomic factors such as poverty and the level of education are some of the greatest factors that make it impossible to access the right nutrition during pregnancy. Women with low incomes can hardly cover the cost of healthy diet or supplements, nor can they fulfill the high nutritional needs they have (Apostolopoulou et al., 2024). In most LMICs, fortified foods or supplements can be very costly, especially when the families are compelled to use up their funds to cover their basic needs such as shelter, power and medical services. In addition, the women in poverty are more susceptible to food insecurity and, therefore, unable to access a diverse array of essential nutrients (Keats et al., 2021). Low socioeconomic status has also been often associated with non-availability of healthcare and nutritional counselling besides affordability. Poor women would not have access to antenatal care (ANC) where the required nutrition education and supplementation are typically provided. This kind of denial of healthcare services further leads to the further deterioration of maternal malnutrition as well as to the likelihood of pregnancy complications in the form of anaemia and preterm birth. Such socioeconomic concerns require complex solutions that include subsidising prices of supplements, improving the food security mechanism, through involvement of community-based efforts, as well as provision of cheaper healthcare services.

4.3 Geographic Barriers

Other geographic issues, like rural or remote living conditions, are also a challenge to the efficient performance of the nutritional interventions. There are also a limited number of healthcare facilities or facilities that are inaccessible in most rural areas and women might not travel long distances to access antenatal care (Mehboob & Sanghi, 2023). Such restricted access to healthcare services leads to a decrease in maternal nutrition education and supplementation rates and to increased health disparities between urban and rural populations. Moreover, the women in remote places might not have access to fortified foods or nutrition supplements, since they might not be distributed or available in the local markets. There is also geographic isolation, which influences the spread of nutrition education. In less literate areas, especially among women, oral communication and face to face educative programs are necessary. Nevertheless, the shortage of healthcare workers in rural locations implies that the programs are not always easy to execute (Chanie et al., 2025). Although geographically remote areas need innovative solutions to expand the scope of maternal nutrition interventions, mobile health clinics, telemedicine, and community health workers can be used to provide nutritional education and supplementation services to pregnant women.

4.4 Access to Healthcare and Nutrition Education

Availability of health services and the education on proper diets is one of the most important determinants of the effectiveness of the interventions on maternal nutrition. In most of the environments, pregnant women are not getting the nutrition counselling and support that they require thus resulting in poor dietary habits and insufficient supplementation. Poor maternal and fetal outcomes are caused by low awareness of the significance of nutrition during pregnancy and the lack of knowledge of how to balance the diet (Brink et al., 2022). The lack of sufficient healthcare facilities, as well as the insufficiency of trained nutritionists or healthcare professionals, makes this issue even greater. To enhance maternal nutrition, it is important to increase access to healthcare and offer a full course of nutrition education during the antenatal visits. Interventions must be effective in providing healthcare providers with knowledge and resources to counsel pregnant women about proper diets, the need to take supplements, and the dangers of malnutrition (Enujuba & Bassey, 2024). The provision of nutrition education at the community level should also be targeted during public health campaigns where the limited access to formal healthcare services is considered, and community-based activities and outreaches are used to support the pregnant women in the communities.

5. Impact of Maternal Nutrition on Infant Health

Maternal nutrition is necessary to ascertain the status of infant health in the long and short term. The nutrition that a mother has during pregnancy can greatly determine the growth of the fetus, birth weight and the maturation of the organs and the systems of the baby. On top of short-term health consequences, maternal nutrition also has long term consequences on the child cognitive development, predisposition to chronic disease, and general health course during his or her lifetime. Figure 2 summarizes the biological mechanisms by which maternal nutrition affects the health outcomes of infants.

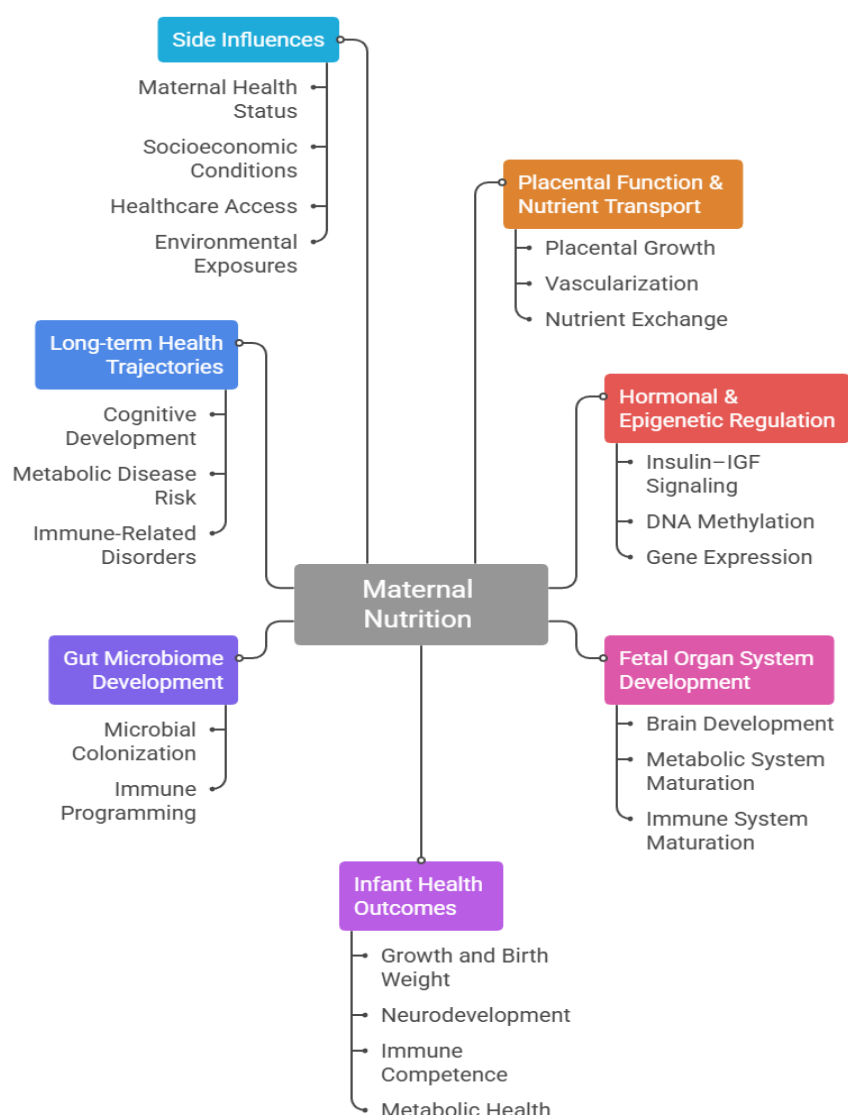


Figure 2. Biological pathways linking maternal nutrition to infant health outcomes, including placental function, fetal organ development, immune programming, and long-term health trajectories

The section is a review of the effects of maternal nutrition on short- and long-term infant health outcomes with particular focus on birth weight, developmental milestones and future chronic disease occurrence in later life. One of the most significant life-course early exposures that might control biological processes influencing health in infancy, childhood, and adulthood is maternal nutrition (Bust & Pedro, 2022). This perspective is related to the developmental origins of health and disease (DOHaD) model, which pays attention to future consequences of the nutritional conditions that fetuses experience during development.

5.1 Short-term Effects on Infant Health

Birth weight is one of the immediate and direct consequences of maternal nutrition on infant health. Good nutrition in pregnancy is necessary in fetus growth and development. One of the main causes of low birth weight (LBW) is maternal malnutrition, especially the lack of consuming such vital nutrients as protein, iron, and folic acid, which predisposes to the development of neonatal mortality, respiratory distress, and other disorders during the first days of postpartum. According to a study conducted by Mehboob & Sanghi, (2023), poor maternal nutrition, particularly a lack of proteins and calories, causes intrauterine growth restriction (IUGR) that causes the baby to be born with a birth weight of less than 2,500 grams. Low birth weight babies have a higher chance of developing problems in their early life, including difficulties with feeding, delayed motor growth and being susceptible to infections.

These early developmental growth retardations are caused by the underlying causes of placental functions, fetal delivery of nutrients, and metabolic adaptation of the fetus, the significance of proper nutrition during critical stages of gestation. The relationship between maternal undernutrition and poor birth outcomes is always supported by evidence; however, the level of effects may vary depending on the maternal baseline nutritional status, timing of exposure, and co-morbid health conditions.

Besides the birth weight, maternal nutrition is also a crucial factor in the developmental milestones of an infant. Omega-3 fatty acids, iron, and iodine are essential nutrients that are vital to the growth of the fetal nervous system and brain (Cui et al., 2023). The lack of these vital nutrients during pregnancy may result in the delay of motor skills, cognitive abilities, and social development (Fitriani & Yanti, 2023). As an example, inadequate consumption of omega-3 fatty acids, required to develop the neural system, has been linked to worse performance in infancy and childhood. Moreover, low maternal ironation may cause infants to develop anemia which causes developmental delay, especially in motor and language abilities. Even though the supporting evidence of short-term neurodevelopmental effects is large, it is hard to isolate the independent effect of individual nutrients, since there are a concomitancy of deficiencies and the effect of postnatal environmental factors, such as breastfeeding, caregiving, and early childhood nutrition. India-specific deficiency patterns help explain persistent risks of adverse neonatal outcomes. A low birth weight and premature delivery are associated with iron deficiency during pregnancy, while neural tube abnormalities (such as spina bifida) are associated with folic acid insufficiency, iodine deficiency to early cognitive delay and stunted growth, and vitamin D deficiency to impaired foetal growth and skeletal outcomes (e.g., rickets risk). These short-term outcomes are consistent with global patterns reported in the same tables, underscoring the importance of addressing micronutrient deficiencies early in pregnancy through supplementation and diet-based strategies (Indian Council of Medical Research, 2024). As shown in Table 3, maternal nutrient deficiencies, such as iron, folic acid, and iodine, contribute significantly to both short- and long-term health outcomes for infants.

Table 3: Maternal nutrient deficiencies, their prevalence in India and globally, associated disease burden, and short- and long-term health outcomes for infants

Maternal Nutrient Deficiency	ICMR Data on Prevalence in India	Associated Disease Burden	Global Data on Prevalence	Short-Term Impact on Infant Health	Long-Term Impact on Infant Health

Iron Deficiency	50% of pregnant women (ICMR)	Leading cause of maternal anemia, contributes to 15% of total disease burden (ICMR)	42% of pregnant women globally (WHO, 2021)	Low birth weight, preterm birth, poor cognitive development	Developmental delays, long-term cognitive impairments
Folic Acid Deficiency	25-30% of pregnant women (ICMR)	Neural tube defects, increased infant mortality (ICMR)	25% of pregnant women in developing countries (UNICEF, 2020)	Neural tube defects, spina bifida	Cognitive impairments, lower IQ
Iodine Deficiency	47% of pregnant women (ICMR)	Cognitive impairments, stunted growth (ICMR)	38% of pregnant women globally (UNICEF, 2019)	Cognitive delays, stunted growth	Lower IQ, neurodevelopmental disorders
Vitamin D Deficiency	45% of pregnant women (ICMR)	Bone deformities, poor fetal growth (ICMR)	40% of pregnant women globally (WHO, 2021)	Rickets, muscle weakness	Osteoporosis, autoimmune diseases
Vitamin A Deficiency	18% of pregnant women (ICMR)	Immune suppression, vision issues (ICMR)	19% of pregnant women in low-income countries (USAID, 2020)	Increased infection risk, delayed visual development	Chronic health issues, including respiratory conditions

5.2 Long-term Effects on Infant Health

Maternal nutrition is not limited to the immediate postnatal period only but can have long-term consequences on the health of the infants well into adulthood. Studies indicate that maternal malnutrition in pregnancy could predispose the child to develop chronic diseases in adulthood, such as obesity, diabetes, cardiovascular disease and hypertension. This is sometimes known as the fetal origins of adult disease, and it means that any form of nutritional deficiency during the critical periods of fetal development may change the metabolic programme of the fetus to a higher risk of developing chronic diseases later in life (Kinshella et al., 2025). According to the DOHaD hypothesis, long-term epigenetic effects, such as DNA methylation, histone modification, and altered hormonal signaling, of in utero nutritional exposures can be observed. The changes have the potential to influence metabolic regulation, insulin sensitivity, and cardiovascular performance and hence expose individuals to chronic diseases in the future.

To demonstrate, the case of maternal undernourishment has been associated with a higher likelihood of obesity in the offspring, which is assumed to be caused by changes in the endocrine system of the fetus and challenges in controlling appetite and adipose tissue (Marshall et al., 2022). Besides metabolic diseases, maternal nutrition also influences the cognitive development and school performance. Pregnant women consuming the necessary amounts of essential nutrients such as iron, iodine, and folic acid have been linked to better cognitive functioning and academic achievement in children (Mateu-Fabregat et al., 2025). A well-known risk factor of the poor intellectual development and low IQ scores in children is maternal iodine deficiency. Moreover, the pregnancy loss of iron in mothers may result in cognitive impairments in children in the long term such as learning, memory, and attention (Cui et al., 2023).

Despite the obvious evidence, which is observed, of maternal nutrition, which has a long-term health outcome, the capability to produce causal inference is limited by the ethical constraint of experimental control of maternal diets in pregnancy. As a result, much of the evidence is grounded on cohort studies and natural experiments, which, despite being informative, are susceptible to residual confounding and contextual variability.

One of the major studies by Mehboob & Sanghi, (2003) indicates that maternal nutrition during pregnancy is a determinant of the long term child health outcomes and there is evidence that proper nutrition can help to minimize the risk of chronic diseases like asthma and allergies in children. Maternal nutrition is particularly important in the development of immune activity during the first 1000 days of life since this is the time when the immune system is formed. It has also been demonstrated that maternal nutrient consumption, specifically consumption of vitamins A, D and E, has effects of regulating immune responses in infants, thus lowering the chances of immune related disorders in the future (Zembe-Mkabile, 2023).

Recent research also suggests that the immune development is affected by maternal nutrition through the interactions with the infant gut microbiota. The patterns of microbial colonization may be affected by nutritional exposures at the prenatal stage, which affects immune development and predisposition to life course diseases.

Furthermore, the maternal nutrition also has the capacity to shape the fetal environment and the formation of the gut microbiota of the infant, which is essential to the immune system and overall health. As a recent review by Zaidi et al. (2021) highlights, the composition of the gut microbiota of the infant can be positively influenced by maternal supplementation during pregnancy, especially prebiotics and probiotics, thus lowering the chances of infections and allergic diseases during the early childhood. A life-course framing is supported by national burden evidence showing that early-life nutritional risks are major contributors to population health loss. Since child and maternal malnutrition represents the leading risk factor for disease burden nationally, addressing maternal nutrition is likely to generate long-term benefits beyond neonatal survival, including improved developmental potential and reduced downstream vulnerability to chronic disease through early-life programming pathways (Indian Council of Medical Research, 2017).

Although these findings are encouraging, the long-term clinical significance of microbiota-mediated effects remains in progress, and this is why it is an important area of possible future studies within the context of the life-course paradigm of maternal and infant nutrition.

6. Conclusion

Prenatal nutrition is extremely important about both the long-term and short-term health of the child. The facts that have been analysed in this paper show that good nutrition during pregnancy is essential to optimized growth of the foetus, maturation of organs and elimination of pregnancy complications. Essential nutrients, e.g. protein, iron, omega-3 fatty acids, folic acid, iodine and essential vitamins, have a significant influence on foetal brain, immune and metabolic growth. Deficiency of these nutrients is associated with negative outcomes of low birth weight, intrauterine growth retardation, developmental delays and a high chance of developing chronic diseases in future. In addition to immediate birth outcomes, the present review establishes maternal nutrition as a key determinant of the health life path, which aligns with the developmental origins of health and disease (DOHaD)

model. The long-term biological outcomes of nutritional exposures during the sensitive stages of foetal development could include effects on metabolism, immune responses, and neurodevelopment throughout the lifespan. Specifically, the nutritional interventions, such as supplementation, food fortification and evidence-based diet, are effective in enhancing the pregnancy and infant health outcomes especially when other interventions such as the maternal and child health programs are implemented. The interventions primarily apply to the low and middle-income nations where the nutritional deficiencies still exist. However, the embedded barriers like cultural beliefs and ideologies, socio-economic inequalities, geographical limitations and access to healthcare and nutritional education, continue to limit their population impact. It is important to note that biological efficacy alone is not enough to bring nutritional evidence to long-term health benefits. The implementation involves the capacity of the health system, favourable policies, the program design that is equity-focused and the long-term behaviour change. These areas need to be addressed and inequalities in maternal and infant health and the maximisation of the use of nutritional interventions.

7. Future Directions

Although the role of maternal nutrition in infant health has had tremendous improvements, gaps in knowledge should not be ignored. Future research ought to consider long-term and longitudinal studies as a way of enhancing the comprehension of long-term consequences of maternal nutrition on cognitive, metabolic and immune development of childhood and adulthood. This evidence plays a crucial role in developing better life-course nutritional programming models and enhancing the causal inference. Further studies are needed to ascertain the impacts of nutrients, specifically, the most appropriate doses and the critical periods of exposure during pregnancy. Studies on the interaction of different nutrients and the integrative effect of diet quality, supplementation and fortification intervention measures in any population group should be encouraged. One of the potential fields of research is the significance of maternal nutrition in the formation of the infant gut microbiome and immune. A greater understanding of the consequences of prenatal nutritional exposures to microbial colonisation and immune development can be applied to inform interventions to reduce the threat of infections, allergies, and immunogenic disorders in early development. At the policy level, the future must promote the improvement of nutrition services as an aspect of routine antenatal care, improvement in coverage rates and adherence to supplementation programs and augment food fortification programs in low dietary diversity regions. Finally, individualised nutrition plans and structural inequalities countered by multisectoral policies will play a critical role in maximising maternal and infant health in the world.

References:

1. Apostolopoulou, A., Tranidou, A., Tsakiridis, I., Magriplis, E., Dagklis, T., & Chourdakis, M. (2024). Effects of nutrition on maternal health, fetal development, and perinatal outcomes. *Nutrients*, 16(3), 375.
2. Bodnar, L. M., Kirkpatrick, S. I., Yu, Y. H., Kennedy, E., Parisi, S. M., & Naimi, A. I. (2025). Heterogeneity in the association between a dietary pattern high in fat, sugar, and sodium and adverse pregnancy outcomes by maternal characteristics: a US pregnancy cohort study. *The American Journal of Clinical Nutrition*.
3. Brink, L. R., Bender, T. M., Davies, R., Luo, H., Miketinas, D., Shah, N., ... & Fawkes, N. (2022). Optimizing maternal nutrition: the importance of a tailored approach. *Current developments in nutrition*, 6(9), 118.
4. Bust, E., & Pedro, A. (2022). 'Your baby's life depends on those first 1000 days': community health workers' perspectives of the first 1000 days of life. *Early child development and care*, 192(6), 904-913.
5. Chanie, S. D., Tilahun, W. M., Menber, Y., Wasihun, Y., Gebreegziabher, Z. A., Andualem, Z., ... & Simegn, M. B. (2025). The effect of nutrition education and counseling on the nutritional status of pregnant women in Ethiopia, 2025: a systematic review and meta-analysis. *Journal of Health, Population and Nutrition*, 44(1), 334.

6. Cui, Y., Liao, M., Xu, A., Chen, G., Liu, J., Yu, X., ... & Zeng, F. (2023). Association of maternal pre-pregnancy dietary intake with adverse maternal and neonatal outcomes: a systematic review and meta-analysis of prospective studies. *Critical reviews in food science and nutrition*, 63(19), 3430-3451.
7. Enujuba, U. L., & Bassey, I. E. (2024). Impact of maternal nutrition on child health outcomes: A scoping Review. *Direct Research Journal of Health and Pharmacology*, 11(2).
8. Fitriani, L., & Yanti, D. (2023). Efficacy of macro and micronutrient interventions in adolescent nutritional status: a systematic review. *INFLUENCE: INTERNATIONAL JOURNAL OF SCIENCE REVIEW*, 5(2), 176-183.
9. González-Fernández, D., Muralidharan, O., Neves, P. A., & Bhutta, Z. A. (2024). Associations of maternal nutritional status and supplementation with fetal, newborn, and infant outcomes in low-income and middle-income settings: An overview of reviews. *Nutrients*, 16(21), 3725.
10. Gwacham-Anisiobi, U., Boo, Y. Y., Oladimeji, A., Kurinczuk, J. J., Roberts, N., Opondo, C., & Nair, M. (2024). Effects of community-based interventions for stillbirths in sub-Saharan Africa: a systematic review and meta-analysis. *EClinicalMedicine*, 67.
11. Heidkamp, R. A., Piwoz, E., Gillespie, S., Keats, E. C., D'Alimonte, M. R., Menon, P., ... & Bhutta, Z. A. (2021). Mobilising evidence, data, and resources to achieve global maternal and child undernutrition targets and the Sustainable Development Goals: an agenda for action. *The Lancet*, 397(10282), 1400-1418.
12. Hunter, P. J., Muthiani, Y., Näsänen-Gilmore, P. K., Koivu, A. M., Pörtlors, P., Bastola, K., ... & Ashorn, P. (2023). A modular systematic review of antenatal interventions to address undernutrition during pregnancy in the prevention of low birth weight. *The American journal of clinical nutrition*, 117, S134-S147.
13. Indian Council of Medical Research, Public Health Foundation of India, & Institute for Health Metrics and Evaluation. (2017). *India: Health of the nation's states: The India state-level disease burden initiative* (Report). Indian Council of Medical Research.
14. Indian Council of Medical Research. (2024). *Annual report: Antimicrobial resistance research and surveillance network (AMRSN), January 2024–December 2024* (Annual report). Division of Descriptive Research, Indian Council of Medical Research.
15. Indian Council of Medical Research. (2024). *ICMR annual report 2023–2024* (Annual report). Indian Council of Medical Research.
16. Kartchner, L. C., Dunn, A., Taylor, K. H., Ali, M. M., Manning, N. A., Dajani, N. K., & Magann, E. F. (2025). Lifestyle modifications prior to pregnancy and their impact on maternal and perinatal outcomes: a review. *Journal of Clinical Medicine*, 14(18), 6582.
17. Keats, E. C., Das, J. K., Salam, R. A., Lassi, Z. S., Imdad, A., Black, R. E., & Bhutta, Z. A. (2021). Effective interventions to address maternal and child malnutrition: an update of the evidence. *The Lancet Child & Adolescent Health*, 5(5), 367-384.
18. Khaled, N., Kalbarczyk, A., Zavala, E., Rahman, A., de Boer, M., Chakraborty, B., ... & Thorne-Lyman, A. L. (2024). A formative study of the sociocultural influences on dietary behaviours during pregnancy in rural Bangladesh. *Maternal & child nutrition*, 20, e13713.
19. Kim, S. S., Zagr , R. R., Ou draogo, C. T., Sununtnasuk, C., Ganaba, R., Zafimanjaka, M. G., ... & Menon, P. (2023). Intensified nutrition interventions in antenatal care services increased consumption of iron and folic acid supplements and early breastfeeding practices in Burkina Faso: results of a cluster-randomized program evaluation. *The Journal of Nutrition*, 153(10), 3058-3067.
20. Kinshella, M. L. W., Moore, S. E., & Elango, R. (2025). Current evidence around key underrepresented women's health topics in pregnancy and postpartum nutrition: a narrative review. *Applied Physiology, Nutrition, and Metabolism*, 50, 1-16.
21. Lassi, Z. S., Padhani, Z. A., Rabbani, A., Rind, F., Salam, R. A., & Bhutta, Z. A. (2021). Effects of nutritional interventions during pregnancy on birth, child health and development outcomes: A systematic review of evidence from low-and middle-income countries. *Campbell Systematic Reviews*, 17(2), e1150.

22. Marshall, N. E., Abrams, B., Barbour, L. A., Catalano, P., Christian, P., Friedman, J. E., ... & Thornburg, K. L. (2022). The importance of nutrition in pregnancy and lactation: lifelong consequences. *American journal of obstetrics and gynecology*, 226(5), 607-632.
23. Mateu-Fabregat, J., Canals, J., Jardí, C., Hernández-Martínez, C., Voltas, N., Bulló, M., & Arija, V. (2025). Associations of maternal dietary carbohydrate intake, glycemic index, and glycemic load during pregnancy with offspring neurodevelopment. *European Journal of Pediatrics*, 184(11), 1-13.
24. Mehboob, A., & Sanghi, D. (2023). Influence of nutrition knowledge on the association between maternal nutrition and birth outcomes. *International Journal of Child Health and Nutrition*, 12(2), 58-66.
25. Nnamani, J. E., Agu, U. F., Okafor, B. C., Aransiola, M. M., Ezeamii, J. C., Benson, O. C., ... & Nwokedi, V. U. (2025). A Review on Micronutrient Malnutrition in Pregnant Women and Children Under Five Years. *Journal of Pharma Insights and Research*, 3(3), 304-316.
26. von Salmuth, V., Brennan, E., Kerac, M., McGrath, M., Frison, S., & Lelijveld, N. (2021). Maternal-focused interventions to improve infant growth and nutritional status in low-middle income countries: A systematic review of reviews. *PloS one*, 16(8), e0256188.
27. Zaidi, A. Z., Moore, S. E., & Okala, S. G. (2021). Impact of maternal nutritional supplementation during pregnancy and lactation on the infant gut or breastmilk microbiota: a systematic review. *Nutrients*, 13(4), 1137.
28. Zembe-Mkabile, W. (2023). Social protection as a nutrition-sensitive instrument to address malnutrition in sub-Saharan Africa: Examining the utility of the UNICEF conceptual model of care for maternal and child nutrition. *Journal of International and Comparative Social Policy*, 39(3), 295-305.