REVIEW

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THE INFLUENCE OF MATERNAL NUTRITION ON PREGNANCY OUTCOMES AND FETAL GROWTH

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ABSTRACT: Maternal nutrition plays a pivotal role in shaping pregnancy outcomes and the long-term health of both mother and child. This review explores the evolution of maternal nutrition research, highlighting historical shifts in dietary guidelines and the growing emphasis on personalized nutrition. It examines the physiological changes and varying nutritional demands across pregnancy trimesters, as well as the role of maternal diet in fetal epigenetic programming and future offspring health. The consequences of nutritional deficiencies, particularly in micronutrients like iron, folic acid, and calcium, are analyzed alongside the risks associated with overnutrition, including obesity and gestational diabetes. Additionally, the gut microbiome's influence on nutrient absorption and infant immunity is discussed. Psychosocial factors such as stress, mental health, and eating behaviors are also considered for their impact on maternal dietary choices. Finally, recent technological advancements, including the use of AI and digital tools, are reviewed for their potential to enhance maternal nutritional assessment and care. Together, these insights underscore the critical need for comprehensive, evidence-based strategies to optimize maternal nutrition and improve pregnancy-outcomes.

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INTRODUCTION

It has been observed that diet plays a critical role in pregnancy and has a significant impact on the health of the mother and her gestating baby. Low birthweight and premature delivery are more likely when a mother's intake is improper, insufficient, or unhealthy. On the downside, pregnant women who put on excessive weight run the danger of giving birth to kids that are too big and of experiencing weight retention after giving birth.

The first five key elements of the healthy eating index during pregnancy are the average daily servings of five food groups, making nutrition education a proven intervention to support long-term good eating habits.

In a population of expecting Japanese women, nutrition recognition was positively correlated with a lower intake of rice and greater consumption of fish, shellfish, vegetables, and potatoes. However, it was not correlated with the intake of bread, confections, noodles, fats, sugars, pulses, oils, meat, nuts, eggs, fruits, and dairy products. A meta-analysis of the study mentioned previously and related nutrition education experiments indicates that more research based on appropriate theories of behavior modification is required to restore trust in this area. (1).

Furthermore, nutrition is the basis of maternal fitness and prepares the mother for delivery and recovery postnatally. Some kinds of food are recognized to be associated with problems like gestational diabetes and pre-eclampsia, and therefore healthy nutritional intake will reduce the chances of these complications and their associated short- and long- term diseases (2).

The whole pregnancy period is a great deal that is mention to as a —learning momentǁ when women are inspired to make a positive behavioral alteration that is pertaining to their

health and welfare. This is especially important to considering the recent increase in research signifies that nutrition during early development can plan the long-term health of the infant.

Women's prenatal health and nutritional condition have a direct effect on the growth, their survival, wellness, and overall development of their unborn children through both fetal growth and development and reproductive survival and performance.

Women in developing nations consumed only roughly two-thirds of the recommended daily energy intake, according to a review of studies on the nutritional requirements of pregnant and lactating women. Additionally, their average height-to-weight ratio was typically significantly lower than the median of fifty percent for small-framed women in developed nations. Furthermore, although the dietary needs of pregnant and lactating women remained much higher than those of non-pregnant women, their nutrient and energy intakes seemed to be only slightly higher. A relatively small number of additional inquiries, such as the one conducted by Black et al., demonstrated that pregnant Mexican women seldom had micronutrient deficits, particularly those involving iron and vitamin B-12. Recurrent, sequential pregnancies that gradually deplete women's nutritional reserves to a certain level of nutritional depletion also referred to as the "maternal deprivation syndrome" are correlated with inadequate health and well-being.The main purpose of this systematic review is to understand how maternal nutrition affects fetal growth, maternal health, and pregnancy outcomes. Fetal growth, birth weight, and the general health of the mother are all significantly influenced by maternal nutrition. Also the complications that arise during pregnancy due to an unbalance diet include maternal anemia, poor birth weight, and early birth, gestational diabetes, and hypertensive diseases are linked to poor status of nutrition both before and throughout pregnancy. Inadequate maternal nutrition can also lead to long term effects in childern like retarted growth, delay in development and an higher risk of chronic illness in adulthood.

Maternal diet influence on cognitive development:

Prenatal and postnatal diet represent some of among the most significant environmental determinants throughout prenatal and newborn years because dietary habits, which is a result of all the environmental variables, is one of the most essential and quantifiable aspects of the environment-gene link.

In addition, the stage of pregnancy is incredibly adaptable and sensitive to the mother's environment and lifestyle. Nutrition becomes especially essential during this phase since it promotes DNA to become completely methylated. By describing the epigenetic pathways that occur through the metabolism of folic acid in the metabolic processes of starchy carbohydrates or in the transmethylation procedures that regulate the methylation of DNA, histones, or non-coding mRNAs, dietary elements such as micronutrients, vitamins and minerals, fatty acids, proteins, or carbohydrates can influence both the function and the expression of genes in the female reproductive system and during the initial stages of life.

The subject of epigenetic investigate studies whether the mother's nutrition program causes alterations in the genome that make the children more vulnerable to disorders which includes diabetes, overweight, and heart attack and stroke.

The last three months of pregnancy and the first two years of the life of the child are among numerous significant periods for the

brain's growth. These times are defined by significant brain development and maturation. Other carping stages, such as cell migration, growth of neurons, differentiating themselves, synaptic development, and maturation of neurotransmission pathways, are also recognized as early organizational procedures that take place during the initial month of gestation and are extremely significant.

Protein (which prevents intrauterine growth restriction, embryonic losses, and reduced postnatal growth), sufficient calorie intake, and expected minerals—like iron (essential for quick development and proliferation, playing an important part in brain development), zinc (which influences fetal growth), selenium (which diminishes the risk of infant infection and enhances psychomotor score), copper (necessary for rapidly developing cells and the differentiation of cells for both the mother and fetus), and iodine (which promotes thyroid and neurological development)—have all acquired notoriety for their distinctive roles in these processes.

In this context, specific vitamins and other nutrients, like long-chain fatty acids (which are vital as prostaglandin precursors and as the structural elements of cell membranes), choline (which determines stem proliferation of cells and the spinal cord and brain function and structure), the antioxidant vitamin A (which aids in both brain growth and cell advancement), and folate (which aids in the formation of the neural tube and cell proliferation), are also necessary for these processes. Therefore, a nutritious diet that fails to provide these essential nutrients in sufficient quantities at this crucial time might permanently change the brain and behavior of the child.

In this way, Coo et al. found a small physiological influence of mother obesity throughout pregnancy on progeny performance cognitive ability number, and modest connections involving mother's overweight and offspring the application cognitive ability ratio.(3)

It was proposed that the lack of awareness regarding the nutritional state of women, including mothers, is the reason why well-publicized programs like "child survival" and "safe motherhood" have not had the desired impact.(4)

Global Perspective On maternal Nutrition:

One of the primary health problems facing the world today is malnutrition in mothers. According to the United Nations International Children's Emergency Fund, the total number of pregnant and lactating mothers who are seriously malnourished in nations impacted by the current nutritional and food crisis is expected to rise by 25% within 2020 (5.5 million) and 2022 (6.9 million), with over 1 billion adolescent girls and women globally experiencing malnutrition. The United Nations General Assembly's 2015 Sustainable Development Goals, or SDGs, called for eliminating all types of malnutrition and recognizing the nutritional requirements of pregnant women and adolescent girls by 2030.Malnutrition rates continue to be high, particularly in low- and middle-income nations, and achievement in lowering them is still sluggish despite coordinated attempts.(5). While previous research has mainly focused on specific nutrients or dietary deficiencies, so there is a gap that remains in understanding the holistic function of nutrition that will ensure the optimal pregnancy outcomes. This research intends to cover this gap by analyzing the overall impact of balanced nutrition-related changes in maternal health and fetal growth and development which can contribute to a more broad perspective on maternal health.

Even though there have been many studies on maternal nutrition, there are still many significant issues that have not yet been resolved. For example, it is still unclear how exactly a balanced diet can prevent various pregnancy issues like gestational diabetes and hypertensive diseases like pre-eclampsia. While many studies focus on individual nutrients, few examine the overall impact of a well-balanced diet on the health of both the mother and the fetus. By closing this gap, more balanced and modified dietary recommendations will be made to improve the outcomes of healthy pregnancies.

Importance of nutrition in pregnancy:

Some nutrients are very important and should be given special consideration. First, pregnancy dramatically increases the rate of metabolism and ability to absorb several kinds of essential vitamins and minerals from the diet and the mother's reserves.Therefore, the suggested meals for numerous vitamins and minerals do not exceed those for non-pregnant women, even if the physical demands of pregnancy raise nutritional requirements.

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Pregnant women must be reminded, nevertheless, of how important it is to concentrate on following the guidelines. Women who start pregnancy with inadequate vitamin storage are more likely to have nutritional deficits due to the demands of pregnancy. Pregnancy- related nutrient deficits will affect the overall wellness of the fetus as well as the mother.

Folic Acid (Prevents birth defects):

Folic acid-containing supplements used during pregnancy reduce both the incidence and recurrence of neural tube abnormalities. A large number of women who are at risk for negative pregnancy outcomes frequently eat diets that are deficient in vitamins, minerals, and folate.To lower the risk of additional unfavorable pregnancy outcomes, folate intake might need to be continued after the neural tube has completely closed. Because folate is essential for the production of nucleic acids, it plays a key role in general cell division, a crucial aspect of embryonic and fetal development.The fetus or placenta's cellular development and replication may be harmed by inadequate folate nutrition during pregnancy. Low dietary folate intake or an elevated metabolic need for folate due to a specific genetic fault or abnormalities can result in folate insufficiency.

Low levels of dietary food and circulatory folate during pregnancy are linked to increased risks of preterm delivery, fetal development retardation, and low birth weight in the baby. An increase in blood homocysteine is one metabolic consequence of a folate deficit.

Similarly, elevated maternal homocysteine levels have been linked to a higher risk of habitual spontaneous abortion as well as pregnancy complications (such as preeclampsia and placental abruption), which increase the likelihood of a poor pregnancy outcome, as well as a lower birth weight and gestational duration.(6)

Before administering high-dose supplements, it is important to consider the women's vitamin B12 status, particularly for those who are more prone to have B12 insufficiency, such as vegetarians or vegans, as large levels of folic acid supplements can conceal vitamin.

B12 deficiency.

It is advised that pregnant women take 200 µg of folate from meals daily, in addition to taking folic acid supplements. Citrus fruits, whole grain bread, legumes, leafy green vegetables, and certain fortified foods like morning cereals are good sources of folate, refers to the naturally occurring form of folic acid present in food. Because it is hard to get the recommended amounts from diet alone, folic acid supplements are necessary throughout the whole pregnancy

Iron (Prevents anemia):

In view of its functions in electron transport, enzyme activity, and oxygen delivery, iron is essential for the proper operation of every cell. High metabolic rate cells require more iron and are more likely to malfunction when iron levels are low. Iron needs rise rapidly throughout pregnancy as the fetus develops and grows and the mother's blood volume increases. Pregnancy is therefore a situation of future or current iron insufficiency, which can be challenging to identify due to differences in regularly used indicators like ferritin and hemoglobin levels. Increased maternal sickness, restriction on intrauterine growth low birthweight, and preterm are among the unfavorable pregnancy outcomes linked to iron deficiency. The rapidly growing fetal brain can be particularly vulnerable to iron shortage, which can be brought on by maternal iron insufficiency, hypertension from smoking, or glucose intolerance. Autism, aberrant brain development in the kids, and schizophrenia are all linked to low mother gestational iron consumption. Notwithstanding postnatal iron replacement, newborns with iron shortage suffer from recognition memory impairment, decreased processing speed, and wretched bonding. Preclinical evidence of prenatal iron deficit confirms that predicted iron-dependent activities, including gene expression, differentiation, neuronal development and myelination, monoamine neurotransmission, and neuronal differentiation, are all severely and permanently impaired throughout adulthood. The strategy for diagnosing and preventing iron deficiency during pregnancy is outlined in this paper. It outlines the effects of prenatal iron insufficiency on mental and neurocognitive health. It highlights the fact that prenatal iron is a crucial nutrient that affects the growth and functioning of the brain throughout life.

Given the high prevalence of the condition during pregnancy, the onset of pregnancy may be interpreted as an indication of an imminent iron deficit.

The rate approaches is 80% in low and middle-income countries In contrast, approximation rates in wealthy nations are close to 45% and depend on how sensitive the markers are.

During pregnancy the hepcidin concentration of serum, is extremely low which is regulated by maternal iron status. Since hepcidin is also a negative controller of intestinal iron absorption, a low level point out a high demand for iron.

There are three reasons that increases iron demands during pregnancy. During pregnancy, the mother's blood and plasma quantities are inflated. 3.46 mg of essential iron are needed for every additional gram of hemoglobin the mother produces. The fetus also needs iron to fill its relatively substantial endogenous iron reserves, which will be required throughout the first six months of postnatal life, as well as for its own internal metabolic and oxygen supply requirements.

The placenta is a extremely metabolically active organ with large iron requirements.

It can act as a buffer against times when the mother's iron supply is low by storing iron in the reticuloendothelial cells. An extra gram of iron is needed during pregnancy and should

be split fairly both the pregnant woman and the fetus. (7)

Heme and non-heme iron are found in two forms in food. About 20–30% of the heme iron contained in meats, poultry, fish, and seafood is absorbed. These foods also contain non-heme iron, which is also present in nuts, seeds, legumes, fortified meals (also in breakfast cereals), and vegetables green. Only about 4.9% of this iron become absorbable. Iron levels should be checked during pregnancy for women who eat a vegetarian diet before becoming pregnant or during pregnancy since they are especially susceptible to iron insufficiency.

Iodine (Supports brain development):

Iodine deficiency during pregnancy has been identified as the leading avoidable cause of brain injury and is associated with abnormal brain development. These effects are triggered by the fact that iodine plays a part in the synthesis of thyroid hormones such as thyroxin (T4) and the hormone that stimulates the thyroid, and that thyroid hormone subsequently plays a part in neurological development.

Thyroid-stimulating hormone (TSH) controls the production of thyroid hormones by consuming circulatory iodide into the thyroid, oxidizing it (with the help of thyroid peroxidase) and adding it to the tyrosyl residue on the thyroid-specific protein's thyroglobulin.Thyroid peroxidase then combines the mono- and diiodotyrosine to create tri-iodothyronine or T4, which may subsequently be released into the bloodstream.(Bath, 2019).A mineral called iodine is necessary for the thyroid to produce hormones healthily.Iodine deficiency can cause problems with the fetus's and mother's thyroid hormone production, which can affect the developing baby's growth and development along with the mental health of the newborn.

In the UK, pregnant women should consume 140 µg of iodine daily, which is the same amount as is advised for women who are not pregnant. Iodized salt, eggs, are some of the foods that contain iodine. Although seaweed and kelp pills are high in iodine, they should not be used while pregnant since they can contain hazardous amounts of the mineral (8).

Vitamin D (Helps bone formation):

The life stages of infancy and pregnancy are those for which there are many indicators of poor vitamin D status, but there is no evidence to support stage-specific dietary needs for vitamin D. In order to lower the risk of metabolic rickets in children and adolescents as well as osteomalacia in adulthood, which can have serious and permanent effects on bone formation and skeletal integrity, low vitamin D status must be prevented.. The landscape has changed significantly with the recent discovery of vitamin D's non-skeletal functions, and mechanistic research has clarified the molecular involvement of vitamin D in several systems, such as bodily immunity.Preeclampsia, frequent pregnancy loss, and spontaneous preterm delivery are among the negative perinatal outcomes linked to vitamin D's transition of the intrauterine immunological milieu. There are indications that the window of opportunity to prevent these adverse outcomes may be early in pregnancy. (9)

Calcium (Builds fetal bones):

Calcium plays a significant role in the maintenance and development of strong bones and teeth. Calcium is crucial for maintaining healthy bones and may guard against hypertensive conditions during pregnancy, such as pre-eclampsia. 700 mg per day is the recommended daily dose during pregnancy.World Health Organization,(10). Even though The calcium

guidelines for expectant mothers must strive to meet these guidelines to ensure that their calcium stores, particularly bone mass, are not depleted to
meet the needs of the fetus. Green leafy vegetables, tinned fish with bones, milk, cheese, yogurt, and nuts are foods high in calcium. When choosing dairy alternatives during pregnancy, such as nut milk or soy milk, expectant mothers would select calcium-fortified options.

Vitamin B12 (Aids nerve development):

The formation of healthy red blood cells and the growth and maturation of your baby's brain and spinal cord depend on vitamin B12. The genetic material found in all of your baby's cells, DNA, is also made with the aid of vitamin B12.

Some recent studies also suggest that babies which are born to women who suffer low levels of vitamin B12 during her pregnancy may have high risk of neural tube defects.(11)

Healthy blood and neurological function depend on vitamin B12. There is no difference between 1.5(microgram) the daily suggested consumption for the women who are not pregnant and the prescribed dosage for expected women. However, because the supply of fetus is totally influenced what the food intake—which is favorably transferred through the placenta, regardless the store of maternal vitamin B12 intake during pregnancy is particularly crucial. Since vitamin B12 is produced by the bacteria that are only present in products of animals, including meat,fish, poultry, eggs, seafood, and dairy products, all sources that are dietary of vitamin B12 are derived from animals. Women that are pregnant and also who adopt a vegetarian and vegan diet frequently have reduced vitamin B12 consumption. In order to fulfill the daily needs for vitamin B12, Women who are vegetarian should make sure that they get enough milk and all the milk based food. Vitamin B12 supplementation should taken into consideration by vegan women or who decide to cut out all the products that are animal derived and from their food, such as dairy products eggs and milk. (12)

Poor maternal nutrition significantly increases the risk of pregnancy complications. Vitamin D deficiency has been directly linked to preeclampsia, a serious hypertensive disorder that can lead to maternal and fetal mortality. According to the MoBa study, consuming 15–20 µg of vitamin D daily can reduce preeclampsia risk by 23%, yet many women fail to meet this requirement (13) Similarly, gestationaldiabetes is becoming increasingly common due to poor dietary habits and obesity. A lack of proper nutrition education often results in excessive weight gain during pregnancy, increasing the likelihood of developing insulin resistance.

Poor maternal nutrition is also contribute to reduce birth weight and fetal growth

Challenges in maternal nutrition and health care practice:

Maternal nutrition is influenced by several challenges, including socio-economic barriers, healthcare system limitations, and harmful lifestyle factors. Addressing these issues is crucial for improving pregnancy outcomes and reducing maternal and neonatal complications.

Socioeconomic status plays a significant role in maternal nutrition. In low-income regions, poverty and food insecurity prevent pregnant women from accessing nutrient- rich diets. Many women enter pregnancy already malnourished, increasing their risk of complications such as low birth weight and preterm labor (14).

Additionally, early marriages and adolescent pregnancies contribute to poor maternal

health. Young mothers often have inadequate nutritional knowledge, limited healthcare access, and a higher risk of complications due to their underdeveloped bodies (15). Lack of awareness about the importance of maternal nutrition also leads to dietary deficiencies, as many women do not receive proper guidance on essential nutrients during pregnancy (UNICEF.2022)

A well-functioning healthcare system is essential for ensuring proper maternal nutrition, yet many pregnant women face challenges in accessing quality care. In developing countries, especially in rural areas, prenatal care services are limited due to a lack of healthcare infrastructure and trained professionals (16).

Even when maternal health services are available, underutilization continues to be significant problem. In Pakistan, for example, a significant number of women do not seek antenatal care due to financial constraints, cultural beliefs, or lack of transportation.Without proper medical guidance, many women remain unaware of the dietary changes needed for a healthy pregnancy (17).

Apart from external barriers, lifestyle choices and cultural dietary restrictions also impact maternal nutrition. Harmful habits such as smoking, alcohol consumption, excessive caffeine intake, and drug use negatively affect fetal development, leading to complications like intrauterine growth restriction and preterm labor (18)

Cultural dietary restrictions, particularly in South Asian and Middle Eastern communities, often prevent pregnant women from consuming essential nutrients. Some cultures discourage the consumption of dairy products during pregnancy, leading to calcium deficiencies. Unavailability of nutrient-rich foods or the preference for highly processed diets further contributes to micronutrient deficiencies.(19)

restrictions. Deficiencies in iron, folic acid, and protein-energy intake contribute to developmental delays, increased infant mortality, and long-term health issues such as stunted growth and poor cognitive development (20).

Maternal Nutrition Buffering Model

Thayer et al. (2020) explored the concept of the Pregnant Woman's Nutrition Buffering Model, which has generated growing interest in nutritional innovations tailored to pregnancy. Their research underscores that fetal nutrition has a profound influence on long-term adult health outcomes. The authors began by examining the evolution of complex vertebrate defense mechanisms that protect against environmental fluctuations during development, with a particular focus on the development of the eutherian placenta. Similar to other placental mammals, human females have evolved sophisticated physiological systems that buffer the fetus from short-term changes in maternal energy and nutrient levels. The Maternal Nutritional Buffering Model posits that internal buffering mechanisms within the maternal system help maintain a stable supply of essential nutrients during pregnancy. These mechanisms aim to minimize the harmful effects of short-term variations in macronutrient intake—whether due to deficiency or supplementation. In contrast, many micronutrients must be acquired directly from dietary sources and are less effectively buffered (21).

Long-Term Nutritional Impact on Pregnancy

There is increasing evidence suggesting that long-term dietary patterns prior to conception and during early development play a more significant role in improving pregnancy outcomes than short-term macronutrient supplementation. Consequently, interventions aiming to improve fetal nutrient delivery may be most effective if they

target maternal metabolism prior to conception and continue throughout early gestation (5).

Policy and Public Health Implications

The model further predicts that maternal pre-pregnancy nutrition exerts a greater influence on birth weight than dietary intake during pregnancy itself. This insight emphasizes the need for public health policies that focus not only on enhancing nutrient intake during pregnancy but also on optimizing women's nutritional status before conception to ensure intergenerational health benefits (7).

CONCLUSION

Although pregnancy is widely acknowledged as a metabolically demanding process, studies on maternal nutrition interventions have yielded mixed outcomes. These inconsistencies have led some researchers to propose that the fetus functions as an "obligate parasite," whose development is largely protected from maternal nutritional imbalances. From a life-history perspective, maternal energy allocation strategies are shaped to maximize lifetime reproductive success, potentially prioritizing future reproductive potential over immediate investment in a current pregnancy.

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Conflict of Interest

The authors have no conflict of interest.

REFERENCES

1. Goodarzi-Khoigani M, et al. A nutrition education intervention for pregnant women: findings from a randomized controlled trial. Nutr Res Pract. 2017;11(2):115-124.

2. de Seymour JV, et al. Maternal nutrition and its impact on pregnancy outcomes. Nutrients. 2019;11(8):1736.

3. Moreno-Fernández J, et al. Maternal obesity and cognitive development outcomes in offspring: a systematic review. Nutrients. 2020;12(8):2400.

4. Tinker A, et al. Improving women's health: the importance of nutrition. Health Policy Plan. 1994;9(2):161-167.

5. Xu J, et al. Global patterns and trends in maternal malnutrition: a multi-country analysis. Lancet Glob Health. 2024;12(3):e450-e462.

6. Scholl TO, Johnson WG. Folic acid: influence on the outcome of pregnancy. Am J Clin Nutr. 2000;71(5 Suppl):1295S-1303S.

7. Georgieff MK. Iron deficiency in pregnancy. Am J Obstet Gynecol. 2020;223(4):516-524.

8. Bath SC. The role of iodine in pregnancy and infant development. Br J Nutr. 2019;122(S1):S3-S9.

9. Andersson M, Brægger C. Iodine deficiency and supplementation in pregnancy. Eur J Clin Nutr. 2021;75(2):295-302.

10. Kiely ME, et al. Vitamin D in pregnancy: maternal health and fetal outcomes. Proc Nutr Soc. 2020;79(2):115-125.

11. World Health Organization. Vitamin and mineral requirements in pregnancy. Geneva: WHO; 2023

(updated Aug 9).

12. Hinga B. Maternal vitamin B12 deficiency and fetal neural development. J Obstet Gynecol Res. 2025;51(1):67-75.

13. Arcot J, et al. Vitamin B12 nutrition in pregnancy: risks and recommendations. Nutrients. 2024;16(1):121.

14. Brantsæter AL, et al. Maternal vitamin D status and risk of preeclampsia: findings from the MoBa cohort. Am J Clin Nutr. 2012;95(4):1000-1008.

15. World Health Organization. Maternal nutrition: key recommendations. Geneva: WHO; 2019.

16. Khan Y, Bhutta ZA. Nutritional deficiency in pregnant adolescents. Paediatr Perinat Epidemiol. 2009;23(6):542-551.

17. UNICEF. State of maternal nutrition. New York: UNICEF; 2022.

18. Midhet F, et al. Antenatal care utilization and maternal health outcomes in Pakistan. BMC Pregnancy Childbirth. 2023;23:112.

19. Institute of Medicine. Nutrition during pregnancy. Washington (DC): National Academy Press; 1990.

20. Olajide R, et al. Cultural dietary practices and maternal nutrition outcomes. Int J Public Health Nutr. 2024;9(1):33-42.

21. Thayer ZM, et al. Nutritional buffering in pregnancy: the maternal-fetal trade-off model. Evol Med Public Health. 2020;2020(1):116-129.