Letters in Applied NanoBioScience
Platinum Open Access Journal (ISSN: 2284-6808)

Review
Volume 10, Issue 3, 2021, 2605 - 2613
https://doi.org/10.33263/LIANBS103.26052613

Roles of Micronutrients in Pregnancy

Moturayo Tawakalt Shonibare [1], Babatunji Emmanuel Oyinloye [1,2], Basiru Olaitan Ajiboye [1,*]

[1] Phytomedicine, Biochemical Toxicology and Biotechnology Research Laboratories, Department of Biochemistry, Afe Babalola University, Ado-Ekiti, Ekiti State, Nigeria
[2] Biotechnology and Structural Biology (BSB) Group, Department of Biochemistry and Microbiology, University of Zululand, Kwa Dlangezwa 3886, South Africa
* Correspondence: bash1428@yahoo.co.uk;

Scopus Author ID 56103595900
Received: 1.12.2020; Revised: 10.01.2021; Accepted: 12.01.2021; Published: 20.01.2021

Abstract: This study assessed the roles of micronutrients in pregnancy. Micronutrients play a central part in the metabolism and maintenance of tissue functions in human beings. Sources of micronutrients include vegetables and fruits and, as such, categorized under vitamins and minerals. These are required in small amounts in the body but greatly impact healthy growth and development. In pregnancy, these micronutrients' adequate requirements are necessary as inadequate intake could result in adverse maternal conditions such as anemia, hypertension, labor complications, and even death. These could, in turn, affect the fetus resulting in stillbirth, premature delivery, intrauterine growth retardation, congenital malformations, reduced immune competence, and abnormal organ development. The micronutrients include vitamins (such as water-soluble vitamins and fat-soluble) and minerals, classified into micro and macro. Strategies for correcting deficiency of these micronutrients in pregnant women can improve pregnancy outcomes. However, it is more beneficial to consume an adequate micronutrient level before conception to minimize the likely risks associated with their mother and fetus deficiencies.

Keywords: vitamins; minerals; deficiency; premature.

1. Introduction

1.1. Micronutrients.

Globally, more than 1.7 million mortality rate is linked to micronutrient deficiency, ranked 10th risk factor due to insufficient consumption of fruits and vegetables [1]. They act crucially in different metabolisms as well as in the maintenance of tissue functions [2]. Micronutrients are vitamins and minerals needed in minute quantities that are vital for vigorous development and growth. They have exceptional significance for healthy living [3]. These are either fat-soluble vitamins (vitamins A, D, E, and K) or water-soluble vitamins (Vit B1, B2, B6, B12, Vit C, folic acid, etc.) [4].

There are 2 types of micro minerals, namely, micro and macro minerals. Microminerals; are the minerals the body requires in small quantities. It includes copper, zinc, chromium, fluoride, iron, iodine, manganese, selenium, zinc and molybdenum, etc. Macrominerals; are the minerals the body requires in large quantities. It includes sodium, potassium, chloride, phosphorus, calcium, magnesium, sulfur, etc. They are generally co-factors, making them crucial in enzyme function for the human body system. However, they are required in negligible amounts [5]. Micronutrient insufficiencies, especially vitamin A, zinc, iodine, and

iron, currently affect more than 2 billion individuals globally, resulting in premature death, poor health, blindness, stunting, and reduced cognitive development, and low productive capacity [6]. Vitamins are also known as organic constituents that perform regulator roles in the human body system, essential in microgram or milligram amount [7]. It has been established that plants always serve as the primary source of nutrients for human consumption; therefore, these micronutrients' deficiencies may lead to malnutrition. Hence, there is a need for action to prevent insufficient micronutrients in plant foods [8].

1.1.1. Biochemical importance of micronutrients.

Micronutrients can serve as co-factors and coenzymes for the metabolism of nutrients in the pregnancy state. They are also useful as antioxidants in fighting against free radicals, which makes the micronutrients useful in preventing women's pregnancy against diseases. This is illustrated in Figure 1.

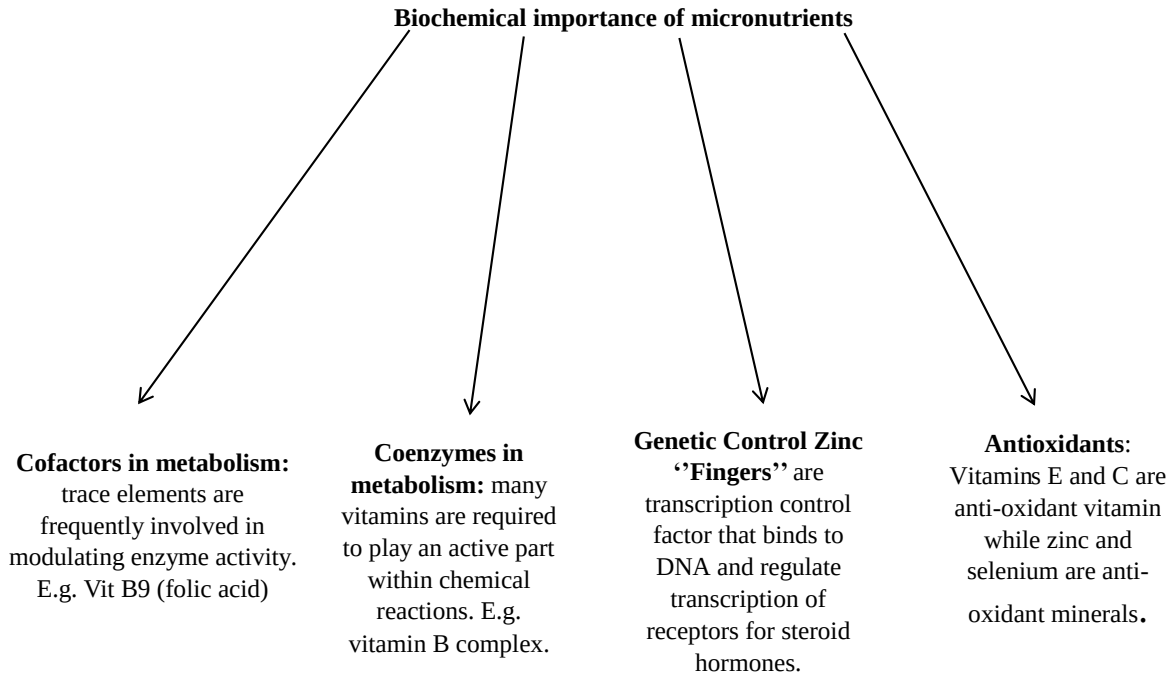

Figure 1. Significant of micronutrients.

1.1.2. Vitamin and mineral metabolism.

Metabolism is an important biochemical process that may be either anabolism or catabolism, leading to ATP or energy generation [9]. Vitamins are organic compounds that function as a metabolic catalyst. A deficiency of the vitamin is called Avitaminoses, while excess is called hypervitaminoses. The human body obtained vitamins through foods or supplementation, which helps the pregnant body system function optimally [9].

1.1.3. Micronutrients and pregnancy.

The pregnancy state has been described as a period of the improved metabolic request due to modifications in the woman's physiology and requests for fetus growing [10]. During this period, insufficient stores or consumption of micronutrients could have negative implications on the mother like anemia, hypertension, different labor complications, and death [11]. This can also affect the fetus, leading to stillbirth, pre-term delivery, intrauterine growth

retardation, congenital malformations, reduced immunocompetence, and irregular organ development. These micronutrients' deficiencies can lead to maternal morbidity and mortality since they are crucial for fetal development.

2. Important Micronutrients in Pregnancy

During the pregnant state, the pregnant woman's metabolic demands increase drastically; thereby, the micronutrient increases to meet the body's nutritional requirement. The micronutrients are divided into two categories as follows

2.1. Minerals.

Minerals are inorganic, naturally occurring substances in the diet.

2.1.1. Iron.

A large proportion of women (both industrialized and developing countries) become anemic during pregnancy. It has been established that 35% to 75% of pregnant women in developing countries and 18% of women in industrialized countries are anemic [12].

The frequency of anemia in women upsurges usually by 15 to 20% during pregnancy. A normal pregnancy needs an additional calorie of 840 mg of iron, with the second trimester's highest needs. Iron is required for the placenta, increase in uterine size, expansion of the red blood cell mass, and the fetus. The lack of adequate iron during pregnancy may lead to fatigue, shortness of breath, pale or yellowish skin, headache, chest pain, etc. And the daily recommended allowance (RDA) for pregnant women is 27 mg. The sources of iron in food include red meat, green vegetables, whole grains, egg yolk, etc.

2.1.2. Zinc.

Studies in pregnant women show that severe zinc deficiency can cause profound effects on its outcome [13]. This is linked to different pregnancy complications and delivery, like pre-eclampsia, premature rupture of membranes, cleft lip, premature delivery with fetal growth hindrance, and congenital irregularities [14]. Severe zinc insufficiency causes persistent labour, teratogenesis, and embryonic or fetal death [15]. The deficiency of zinc in the uterus has a series of negative effects on the fetal immune system's development. Consumption of zinc supplements during pregnancy always helps babies with improved immune function, decreased diarrhea, and respiratory illnesses [16]. The RDA for zinc for pregnant women is 12 mg. The sources of zinc are meat, seafood, oysters, whole grains, egg, nuts, etc.

2.1.3. Iodine.

There is a link between iodine and thyroid function in pregnancy. Its deficiency is called cretinism and perhaps fetal wastage or premature delivery [17]. This deficiency during pregnancy is accountable for progress defects of the fetus and the pathologies linked with endemic goiter, cretinism, deafness, hypothyroidism, miscarriage, etc. It has been documented that iodine supplementation during pregnancy can ameliorate all the described irregularities [18]. Acceptable consumption of this mineral is required for maternal thyroid hormone production. Thyroid hormone is necessary for myelination of the central nervous system and is thus crucial for normal fetal brain development. The mental hindrance obtaining from iodine

insufficiency during pregnancy is irremediable [19]. The RDA for iodine for pregnant women is 220 µg. Sources of iodine are iodized salt, dairy products, seafood, baked potato, etc.

2.1.4. Magnesium.

The magnesium levels during pregnancy are linked with the risk of seizures in pre-eclampsia, prematurity, and low birth weight [20]. Low magnesium level is a risk factor for premature labor as magnesium inhibits myometrium contraction [21]. Lowered plasma Mg^{2+} concentration in pregnancy has been reported to contribute to hypertension development in pregnancy [22].

Studies have shown that dietary magnesium supplementation throughout pregnancy is advantageous [22]. The RDA for magnesium for a pregnant woman is 400 mg. Foods that contain magnesium; green leafy vegetables (spinach) and non-leafy vegetables (green beans, cabbage), fruits(banana), nuts and seeds, legumes, seafood (tuna, mackerel), etc.

2.1.5. Sodium.

Sodium is a nutrient found naturally that is necessary for many bodily functions. Sodium maintains fluid levels and pH balance, which helps in the development of the fetus. A pregnant woman should take adequate sodium, and the RDA is 3.8 g. In the absence of sodium, the nerves, muscles, and organs would not function properly. However, high sodium consumption during pregnancy can cause cardiovascular diseases, high blood pressure, etc. [22].

2.1.6. Other minerals.

The pregnant woman's body adjusts to the fetal requirements and rises in calcium absorption in the early pregnancy state, getting to a peak in the last trimester. Calcium is vital for the skeletal improvement of the fetus [11]. Moreover, calcium plays an important role in the bone and mineral development of the fetus; its deficiency changes membrane permeability and smooth muscle contractility, which could affect blood pressure and lead to premature uterine contractions and subsequent delivery [11].

Table 1. Deficiency of minerals during pregnancy condition.

Minerals	Deficiency
Magnesium	Cramps, abdominal pain
Potassium	Hypokalemia
Calcium	Osteoporosis
Sodium	Hyponatremia
Iron	Anemia
Phosphorus	Hypophosphatemia
Iodine	Congenital abnormalities, maternal and fetal goitre, etc.
Zinc	Fetal loss, congenital malformations, low birth weight, intrauterine growth retardation, etc.

Table 2. Benefits of minerals during pregnancy condition.

Minerals	Benefits
Calcium	Reduction in pre-term delivery, maternal morbidity and infant mortality, etc.
Phosphorus	Prevents skeletal muscle diseases
Magnesium	It serves as a coenzyme, regulates glucose level, relieves inflammation, etc.
Sodium	For maintaining water balance
Potassium	To maintain blood vessel function, prevent cardiovascular diseases, etc.

Foods that contain calcium include milk, cheese, egg, etc. Moreover, the RDA for calcium is 1000 mg. Chromium has the potential of enhancing the action of insulin in the pregnancy state. Selenium and copper insufficiencies may be linked to adverse outcomes on pregnancy and abridged fetal growth (as indicated in Tables 1 and 2).

2.2. Vitamins.

This is an organic molecule essential for the proper functioning of different pregnant individuals' metabolisms [9]. They are divided into two forms: water-soluble and fat-soluble.

2.2.1. Folate.

This is critically essential for fetal development. It is a co-factor essential in the nucleotide biosynthesis and in the metabolism of homocysteine to methionine, which is used in the methylation process of DNA, proteins, and lipids [23]. The deficiency of folate is connected with an enhanced risk of pre-eclampsia, premature delivery, low birth weight, congenital malformations, etc.[24, 25]. The RDA for folate for pregnant women is 600 µg. Examples of folate containing foods are leafy green vegetables, legumes, etc.

2.2.2. Vitamin D.

Vitamin D plays an important role in disease prevention and the health of an individual. Deficient vitamin D in pregnant women using ultrasound revealed splaying of the distal metaphysis of the fetal femur as early as 19 weeks, similar to rickets [26]. According to FNB (Food and Nutrition Board), in 2010, the RDA of vitamin D for all pregnant women was 15 µg. Recent data suggest an association between vitamin D deficiency and cesarean section [27]. A recent study showed that supplementation with vitamin D during pregnancy was associated with a reduced risk of combined morbidities, such as maternal infections, cesarean section, and premature delivery [28]. The main vitamin D source is sunlight exposure, and other sources include egg yolk, liver, tuna, etc.

2.2.3. Vitamin A.

The type of vitamin A (called retinoid) is required to regulate gene expression, cellular proliferation and differentiation, growth and development, vision, and immunity, especially during the pregnant state. This vitamin's deficiency is significantly connected with spontaneous premature delivery, increased susceptibility to infection, and night blindness. Due to its role in the absorption of iron, its deficiency is implicated in pregnancy-associated moderate to severe anemia. The RDA is 750 µg. Vitamin A deficiency has an immunosuppressive effect and predisposes pregnant women to reproductive tract infections [29].

Also, vitamin A deficiency during pregnancy can lead to fetal wastage, although high doses in early pregnancy can be teratogenic [30]. Foods that contain vitamin A include liver, butter, eggs, carrot, leafy greens.

2.2.4. Vitamins C and E.

These vitamins are very important in preventing oxidative stress (also known as antioxidant vitamins) associated with the pathogenesis of pre-eclampsia. Antioxidants

safeguard the body from free radicals. Adequate intake of antioxidant vitamins is important throughout pregnancy.

The RDA for vitamin C for a pregnant woman is 80 mg, while vitamin E is 15 mg. Foods that contain Vit C are citrus fruits, green peppers, strawberries, etc. Foods that contain Vit E are vegetable oil, seeds, nuts, etc. [30]

2.2.5. Vitamin K.

All infants are born with a low concentration of Vit K due to low placental transfer of vitamin K. This proportion means that the newborns do not have enough vitamin K for blood clotting leading to vitamin K deficiency bleeding (VKDB). The VKDB is more common and present as bruising, gastrointestinal blood loss, bleeding from the umbilicus, skin, or site of circumcision. The RDA for vitamin K for a pregnant woman is 90 µg. Foods that contain Vit K are vegetable oil, leafy greens, etc. [30].

2.2.6. Vitamins B.

Vitamin B2 is a constituent of flavoenzymes required in energy metabolism as well as antioxidant functions. The RDA is 1.4 mg. Riboflavin deficiency has been implicated in pre-eclampsia. It can be found in some foods; liver, dairy products, meat, eggs, etc.

Table 3. Micronutrient toxicities during pregnancy condition.

Micronutrients	Toxicities
Vitamin A	Congenital disabilities, liver abnormalities, reduced bone density, etc.
Vitamin D	Calcium imbalance that can lead to calcium deposit in the soft tissues.
Vitamin E	It can lead to bleeding problems.
Vitamin B3	It can lead to lead to liver damage, impaired glucose intolerance, etc.
Vitamin B6	Skin lesion, skin degeneration, etc.
Vitamin C	Diarrhea, gastrointestinal tract disturbance, etc.
Folate	It can mask vitamin B12 deficiency, which may lead to anemia
Calcium	It may lead to kidney stones
Sodium	High sodium intake can trigger cardiovascular disease, hypertension, etc
Copper	Liver damage
Manganese	Neurotoxicity

Table 4. Deficiency of vitamins during pregnancy condition.

Vitamins	Deficiency
Vitamin A	Night blindness, foetal growth retardation
Vitamin D	Rickets, pre-eclampsia, gestational diabetes mellitus, pre-term birth, etc.
Vitamin E	
Vitamin K	Placental ageing, vascular endothelial injury, premature birth, etc.
Vitamin B1	Haemorrhage
Vitamin B3	Beriberi
Vitamin B6	Pellagra
Vitamin B7	Anaemia
Vitamin C	Dermatitis
	Scurvy

Vitamin B6 has diverse roles in the body: red blood cell formation, steroid hormone function, nucleic acid synthesis, etc., and the RDA is 1.9 mg. Meat, fish, legumes, whole grains are examples of foods that contain Vit B6.

Vitamin B12 is useful as a co-factor for some enzymes; it also converts homocysteine to amino acids. DNA methylation that occurs during embryonic and fetal development

modulates gene expression, cell differentiation, and organs' formation. The RDA is 2.6ug, and it can be found in some foods: animal products, liver, etc.

Insufficiencies in vitamin B2, B6, and B12 are known to be related to placental abruption, stillbirth, very low birth weight, and premature deliveries, as well as higher rates of pre-eclampsia in the offspring [31]. As shown in Tables 3-5.

Table 5. Benefits of vitamins during pregnancy condition.

Vitamins	Health benefits
Vitamin A	Beneficial in treating eye disorders, skin infection, etc
Vitamin D	Aids in treating arthritis, diabetes mellitus, rickets, etc.
Vitamin B12	Ameliorating anaemia, kidney and liver disorders, etc.
Vitamin E	Improves blood circulation
Vitamin B2	Aids in energy production, thyroid activity, the formation of red blood cells
Vitamin K	Helps in blood clotting, brain function, and bone density
Vitamin C	Help in treatments of scurvy, diabetes mellitus, cancer, common cold, etc.

3. Strategies for Correction of Micronutrients Malnutrition

3.1. Fortification.

This is an act of increasing the content of essential nutrients in food to enhance the nutritional value of the food supply and afford a public health value with negligible menace to health. This helps an individual to avoid vitamin and mineral deficiencies.

3.2. Supplementation.

A dietary supplement is a manufactured product intentionally added to supplement the diet when consumed by mouth as a pill, capsule, tablet, or liquid. A supplement can provide nutrients either extracted from food sources or synthetic, individually or in combination, to increase the quantity of their consumption [32].

3.3. Dietary modification.

This is a change made during food preparation, processing, and consumption to increase the bioavailability of micronutrients and reduce micronutrient deficiencies in food at a commercial or individual/household level [32].

4. Conclusions

Existing and emerging research connecting micronutrient deficiencies in pregnancy state with adverse birth outcomes is a stimulating development. Strategies for correcting the deficiency of these micronutrients in pregnant women have gone a long way in improving pregnancy outcomes over the years. However, it is more beneficial to consume adequate micronutrients before conception to minimize the likely risks associated with their deficiencies in both the mother and the fetus. Also, consume it while being pregnant to meet the adequate levels of the micronutrients that the mother and fetus need.

Funding

This research received no external funding.

Acknowledgments

This research has no acknowledgment.

Conflicts of Interest

The authors declare no conflict of interest.

References

1. WHO. *Nutrition-related health products and the World Health Organization Model List of Essential Medicines.* Practical considerations and feasibility Meeting report. Geneva, Switzerland. **2019.**
2. Lori, A.; Smolin, M.B.G. *Nutrition Science and Applications.* 2nd ed. USA: John Wiley and Sons, Wiley. **2010.**
3. Best, C.; Neufingerl, N.; Del Rosso, J.M.; Transler, C.; van den Briel, T.; Osendarp, S. Can multi-micronutrient food fortification improve the micronutrient status, growth, health, and cognition of schoolchildren? A systematic review. *Nutrition reviews* **2011**, *69*, 186-204, https://doi.org/10.1111/j.1753-4887.2011.00378.x.
4. Dinçer, Y. *Vitamins*. Ist Uni Cerrahpaşa Medical Faculty, Department of Biochemistry. **2014**.
5. Naik, P. *Biochemistry textbook.* 3rd ed. New Delhi, India: Jaypee Brothers Medical Publishers Ltd. **2010.**
6. Das, J.K.; Salam, R.A.; Kumar, R.; Bhutta, Z.A. Micronutrient fortification of food and its impact on woman and child health: a systematic review. *Systematic reviews* **2013**, *2*, https://doi.org/10.1186/2046-4053-2-67.
7. Corvallis, O.R. Micronutrient information center, Linus Pauling Institue, Oregon State University. **2018**
8. Blancquaert, D.; De Steur, H.; Gellynck, X.; Van Der Straeten, D. Metabolic engineering of micronutrients in crop plants. *Annals of the New York Academy of Sciences* **2017**, *1390*, 59-73.
9. Shenkin, A. Micronutrients in health and disease. *Postgraduate Medical Journal* **2006**, *82*, 559–567, https://doi.org/10.1136/pgmj.2006.047670.
10. King, J.C. Physiology of pregnancy and nutrient metabolism. *Am J Clin Nutr* **2000**, *71*, 1218-1225, https://doi.org/10.1093/ajcn/71.5.1218s.
11. Ramakrishna, U.; Manjrekar, R.; Rivera, J.; Gonzales-Cossio, T.; Martorell, R. Micronutrients and pregnancy outcome: A review of the literature. *Nutr. Res.* **1999**, *19*, 103-159, https://doi.org/10.1016/S0271-5317(98)00178-X.
12. Allen, L.H. Anemia and iron deficiency: effects on pregnancy outcome. *Am J Clin Nutr* **2000**, *71*, 1280s-1284s, https://doi.org/10.1093/ajcn/71.5.1280s.
13. Karimi, A.; Bagheri, S.; Nematy, M.; Saeidi, M. Zinc Deficiency in Pregnancy and Fetal - Neonatal Outcomes and Impact of the Supplements on Pregnancy Outcomes. *Iranian Journal of Neonatology IJN* **2012**, *3*, 77-83, https://doi.org/10.22038/ijn.2012.270.
14. Caulfield, L.E.; Zavaleta, N.; Shankar, A.H.; Merialdi, M. Potential contribution of maternal zinc supplementation during pregnancy to maternal and child survival. *Am J Clin Nutr* **1998**, *68*, 499s-508s, https://doi.org/10.1093/ajcn/68.2.499S.
15. Neggers, Y.H.; Singh, J. Zinc supplementation to protein-deficient diet in CO-exposed mice decreased fetal mortality and malformation. *Biological Trace Element Research* **2006**, *114*, 269-279, https://doi.org/10.1385/BTER:114:1:269.
16. Osendarp, S.J.; van Raaij, J.M.; Arifeen, S.E.; Wahed, M.; Baqui, A.H.; Fuchs, G.J. A randomized, placebo-controlled trial of the effect of zinc supplementation during pregnancy on pregnancy outcome in Bangladeshi urban poor. *Am J Clin Nutr* **2000**, *71*, 114-119, https://doi.org/10.1093/ajcn/71.1.114.
17. Dunn, J.T. Iodine supplementation and the prevention of cretinism. *Annals of the New York Academy of Sciences* **1993**, *678*, 158-168.
18. Pearce, E.N.; Lazarus, J.H.; Moreno-Reyes, R.; Zimmermann, M.B. Consequences of iodine deficiency and excess in pregnant women: an overview of current knowns and unknowns. *Am J Clin Nutr* **2016**, *104 Suppl 3*, 918s-923s, https://doi.org/10.3945/ajcn.115.110429.
19. Zimmermann, M.B. Iodine deficiency in pregnancy and the effects of maternal iodine supplementation on the offspring: a review. *Am J Clin Nutr* **2009**, *89*, 668s-672s, https://doi.org/10.3945/ajcn.2008.26811C.
20. Makrides, M.; Crowther, C.A. Magnesium supplementation in pregnancy (Review). *Cochrane Database Syst Rev*. **2012**, *10*, https://doi.org/10.1002/14651858.CD000937.pub2.
21. Lotfalizadeh, M.; Ghomian, N.; Dadgar, S.; Halimi, F. Maternal Magnesium Level Effect on Pre-term Labor Treatment. *International Journal of Women's Health and Reproduction Sciences* **2018**, *6*, 55–59, https://doi.org/10.15296/ijwhr.2018.10.
22. Zarean, E.; Tarjan, A. Effect of Magnesium Supplement on Pregnancy Outcomes: A Randomized Control Trial. *Advanced biomedical research* **2017**, *6*, https://doi.org/10.4103/2277-9175.213879.
23. Mahmood, L. The metabolic processes of folic acid and Vitamin B12 deficiency. *Journal of Health Research and Reviews*. **2014**, *1*, 5-10, https://doi.org/10.4103/2394-2010.143318.
24. Scholl, T.O.; Johnson, W.G. Folic acid: influence on the outcome of pregnancy. *Am J Clin Nutr* **2000**, *71*, 1295s-1303s, https://doi.org/10.1093/ajcn/71.5.1295s.

25. Copp, A.J.; Greene, N.D.E. Genetics and development of neural tube defects. *The Journal of Pathology* **2010**, *220*, 217-230, https://doi.org/10.1002/path.2643.
26. Novakovic, B.; Sibson, M.; Ng, H.K.; Manuelpillai, U.; Rakyan, V.; Down, T.; Beck, S.; Fournier, T.; Evain-Brion, D.; Dimitriadis, E.; Craig, J.M.; Morley, R.; Saffery, R. Placenta specific methylation of the vitamin D 24-hydroxylase gene: implications for feedback autoregulation of active vitamin D levels at the feto-maternal interface. *J. Biol. Chem.* **2009**; *284*, 14838-14848, https://doi.org/10.1074/jbc.m809542200.
27. Merewood, A.; Mehta, S.D.; Chen, T.C.; Bauchner, H.; Holick, M.F. Association between vitamin D deficiency and primary cesarean section. *J Clin Endocrinol Metab* **2009**, *94*, 940-945, https://doi.org/10.1210/jc.2008-1217.
28. Curtis, E.M.; Moon, R.J.; Harvey, N.C.; Cooper, C. Maternal vitamin D supplementation during pregnancy. *British Medical Bulletin* **2018**, *126*, 57-77, https://doi.org/10.1093/bmb/ldy010.
29. Radhika, M.S.; Bhaskaram, P.; Balakrishna, N.; Ramalakshmi, B.A.; Devi, S.; Kumar, B.S. Effects of vitamin A deficiency during pregnancy on maternal and child health. *BJOG : an international journal of obstetrics and gynaecology* **2002**, *109*, 689-693, https://doi.org/10.1111/j.1471-0528.2002.01010.x.
30. Bastos Maia, S.; Rolland Souza, A.S.; Costa Caminha, M.D.; Lins da Silva, S.; Callou Cruz, R.D.; Carvalho dos Santos, C.; Batista Filho, M. Vitamin A and Pregnancy: A Narrative Review. *Nutrients* **2019**, *11*, https://doi.org/10.3390/nu11030681.
31. Mousa, A.; Naqash, A.; Lim, S. Macronutrient and Micronutrient Intake during Pregnancy: An Overview of Recent Evidence. *Nutrients* **2019**, *11*, https://doi.org/10.3390/nu11020443.
32. Beck, K.L.; Heath, A.L. Dietary approaches to assessing iron-related nutrition. *Current opinion in clinical nutrition and metabolic care* **2013**, *16*, 712-718, https://doi.org/10.1097/MCO.0b013e328364f382.