Influence of Antioxidants on Maternal and Fetal Immune Response: A Review

Article · June 2024

CITATIONS
0

READS
4

3 authors, including:

Emmanuel Ifeanyi Obeagu
Kampala International University (KIU)
1,696 PUBLICATIONS **23,656** CITATIONS
SEE PROFILE

Getrude Uzoma Obeagu
Kampala International University (KIU)
537 PUBLICATIONS **10,752** CITATIONS
SEE PROFILE

Elite Journal of Nursing and Health Sciences. Volume 2 Issue 6(2024), Pp. 1-13
https://epjournals.com/journals/EJNHS

Influence of Antioxidants on Maternal and Fetal Immune Response: A Review

*Emmanuel Ifeanyi Obeagu[1], Teddy Charles Adias[2] and Getrude Uzoma Obeagu[3]

[1]Department of Medical Laboratory Science, Kampala International University, Uganda

[2]Department of Haematology and Blood Transfusion Science, Faculty of Medical Laboratory Science, Federal University Otuoke, Bayelsa State, Nigeria

[3]School of Nursing science, Kampala International University, Uganda

*Corresponding authour: Emmanuel Ifeanyi Obeagu, Department of Medical Laboratory Science, Kampala International University, Uganda, emmanuelobeagu@yahoo.com, ORCID: 0000-0002-4538-0161

Abstract

The maternal immune response during pregnancy is a dynamic system designed to protect both the mother and the developing fetus. This immune modulation is critical for preventing adverse pregnancy outcomes while ensuring fetal growth and development. Oxidative stress, characterized by an imbalance between reactive oxygen species (ROS) production and the body's ability to neutralize them, poses a significant threat to this balance. Antioxidants, which counteract oxidative stress, are essential for maintaining immune homeostasis in both the mother and fetus. Antioxidants such as vitamins C and E, selenium, and polyphenols play a crucial role in modulating immune responses during pregnancy. By neutralizing ROS, these antioxidants help prevent cellular damage and inflammation, which can lead to complications like preeclampsia, gestational diabetes, and preterm labor. Additionally, antioxidants support the proper functioning of immune cells, ensuring a balanced immune response that protects the mother from infections while promoting a healthy environment for fetal development. Research indicates that antioxidant supplementation during pregnancy can reduce the risk of various complications and support fetal immune development. For instance, adequate levels of antioxidants are associated with better immune outcomes for the fetus and may lower the risk of chronic conditions such as asthma and autoimmune diseases later in life. However, it is essential to adhere to recommended dietary allowances to avoid potential adverse effects of excessive intake. Continued research is needed to determine optimal antioxidant types and dosages for different stages of pregnancy, ensuring both maternal and fetal health.

Citation: Obeagu EI, Adias TC, Obeagu GU. Influence of Antioxidants on Maternal and Fetal Immune Response: A Review. Elite Journal of Nursing and Health Science, 2024; 2(6):1-13

Keywords: *Antioxidants, Maternal Immune Response, Fetal Immune Response, Pregnancy, Oxidative Stress, Immune Modulation*

Introduction

Pregnancy is a unique immunological state where the maternal immune system must adapt to tolerate the semi-allogenic fetus while maintaining adequate defenses against pathogens. This dual requirement necessitates a complex and finely tuned immune modulation process. The maternal immune system undergoes significant alterations, shifting from a Th1-dominated response, which is typically pro-inflammatory, to a Th2-dominated response, which is more anti-inflammatory. This shift is crucial for creating a conducive environment for fetal growth and preventing maternal immune cells from attacking fetal tissues.[1-2] Oxidative stress is a condition characterized by an imbalance between the production of reactive oxygen species (ROS) and the body's ability to detoxify these reactive intermediates or repair the resulting damage.[3] During pregnancy, oxidative stress can arise from increased metabolic activity, enhanced mitochondrial respiration, and environmental factors such as poor nutrition and pollution. Excessive oxidative stress has been linked to several adverse pregnancy outcomes, including preeclampsia, gestational diabetes, and preterm birth.[4-6] Antioxidants are molecules that can donate an electron to neutralize ROS, thereby preventing cellular damage.[7] They play a pivotal role in maintaining redox balance within the body. Common antioxidants include vitamins C and E, selenium, and polyphenols, which are available through diet and supplementation. In the context of pregnancy, antioxidants are essential for protecting both maternal and fetal tissues from oxidative damage, supporting immune function, and promoting overall health.

The mechanisms through which antioxidants influence the immune system are multifaceted.[8] By reducing oxidative stress, antioxidants help maintain the structural and functional integrity of immune cells. This protection is vital for the proper functioning of lymphocytes, macrophages, and other immune cells involved in defending against infections. Additionally, antioxidants can modulate cytokine production, favoring an anti-inflammatory profile that supports fetal tolerance while allowing sufficient immune responsiveness. During pregnancy, the maternal immune system adapts to ensure both maternal and fetal health. These adaptations include changes in cytokine profiles, with a shift towards anti-inflammatory cytokines, and alterations in immune cell populations. Regulatory T cells (Tregs) increase to help mediate immune tolerance to the fetus. Antioxidants support these adaptations by mitigating oxidative stress, which can disrupt these finely balanced immunological changes.[9-11] Oxidative stress has been implicated in various pregnancy complications such as preeclampsia, which is characterized by high blood pressure and organ dysfunction, and gestational diabetes, a condition of impaired glucose metabolism during pregnancy[12]. Antioxidant supplementation has been shown to reduce the incidence of these complications. For example, vitamin C and E supplementation has been associated with a lower risk of developing preeclampsia, likely due to their roles in reducing oxidative stress and inflammation. The fetal immune system is relatively immature and relies heavily on maternal antibodies and immune regulation for protection. Antioxidants play a crucial role in supporting fetal immune development by preventing oxidative damage during critical periods of growth.

Adequate antioxidant levels are essential for the proper development of fetal immune organs and the establishment of a robust immune system that can function effectively after birth.[13-15]

The benefits of antioxidants during pregnancy extend beyond immediate fetal development. Studies suggest that reduced oxidative stress during pregnancy is associated with lower risks of chronic conditions in offspring, such as asthma, allergies, and autoimmune diseases. This suggests that maternal antioxidant status can have long-lasting effects on the child's health, highlighting the importance of adequate antioxidant intake during pregnancy.[16-18] Antioxidants can be obtained from a variety of dietary sources, including fruits, vegetables, nuts, and whole grains.[19] Specific foods rich in antioxidants include berries, citrus fruits, leafy greens, and nuts. While diet is the primary source, supplementation may be necessary in certain cases to ensure adequate intake, particularly when dietary consumption is insufficient. Healthcare providers should assess individual needs and recommend appropriate supplementation to support maternal and fetal health. Despite the recognized importance of antioxidants in pregnancy, more research is needed to fully understand their optimal use. Future studies should focus on determining the most effective types and dosages of antioxidants for different stages of pregnancy. Longitudinal studies could provide valuable insights into the long-term effects of prenatal antioxidant exposure on child health. Additionally, exploring the interactions between various antioxidants and their cumulative effects could enhance the efficacy of supplementation strategies.[20-22]

Oxidative Stress and Immune Function in Pregnancy

Oxidative stress and immune function are closely intertwined during pregnancy.[2] Oxidative stress occurs when there is an imbalance between the production of reactive oxygen species (ROS) and the body's ability to neutralize these reactive molecules with antioxidants. Pregnancy demands heightened metabolic activity to support the growing fetus, which leads to increased mitochondrial respiration and consequently, higher ROS production.[24] Pregnancy is characterized by significant hormonal fluctuations, including elevated levels of estrogen and progesterone, which can influence oxidative stress levels. Inadequate intake of essential nutrients, including antioxidants, can exacerbate oxidative stress. Exposure to pollutants, toxins, and infections can increase oxidative stress.[25-26]

Impact of Oxidative Stress on Maternal Immune Function

High levels of ROS can damage immune cells, impairing their function and viability. For instance, oxidative stress can reduce the efficacy of lymphocytes, macrophages, and neutrophils in responding to infections. Oxidative stress can disrupt the balance of cytokine production, skewing the immune response. This imbalance can lead to an excessive pro-inflammatory state, which is detrimental during pregnancy. Chronic oxidative stress is associated with increased inflammation, which can contribute to pregnancy complications such as preeclampsia and gestational diabetes. Oxidative stress can impair placental development and function, leading to conditions like intrauterine growth restriction (IUGR) and preeclampsia. These conditions can adversely affect fetal development and outcomes. Proper immune tolerance mechanisms are essential to prevent

the maternal immune system from attacking fetal tissues. Oxidative stress can disrupt these mechanisms, potentially leading to adverse outcomes such as miscarriage or preterm birth.[27]

Oxidative stress can impair the development of critical fetal immune organs, including the thymus and spleen. This impairment can lead to long-term deficiencies in immune function. Elevated ROS levels can alter the function and differentiation of fetal immune cells, impacting their ability to respond to pathogens after birth. Antioxidants neutralize ROS, reducing oxidative damage to cells and tissues. This protective effect is vital for maintaining the integrity and function of immune cells. By reducing oxidative stress, antioxidants help maintain a balanced cytokine profile, supporting the necessary shift from a Th1 to a Th2 dominant immune response during pregnancy.[28] Antioxidants support the mechanisms of immune tolerance, helping to prevent the maternal immune system from rejecting the fetus. Healthcare providers should assess antioxidant status and recommend appropriate supplementation, particularly for at-risk populations. Common supplements include vitamins C and E, selenium, and polyphenols. A diet rich in antioxidants, including fruits, vegetables, nuts, and whole grains, should be encouraged to support overall health and reduce oxidative stress. Ongoing monitoring of oxidative stress markers and immune function can help tailor interventions. Further research is needed to optimize antioxidant use in pregnancy and understand their long-term effects on maternal and fetal health. Antioxidants play a pivotal role in pregnancy by neutralizing oxidative stress, thus protecting both maternal and fetal health. This section explores the various antioxidants involved, their sources, mechanisms of action, and their impact on pregnancy outcomes.[29-37]

Common Antioxidants and Their Sources

Antioxidants encompass a broad range of substances, both naturally occurring and synthetic, that can prevent or slow the oxidative damage to cells. Key antioxidants beneficial during pregnancy include:

1. **Vitamin C (Ascorbic Acid)**: Found in citrus fruits, strawberries, bell peppers, and broccoli, vitamin C is crucial for tissue repair, enzymatic production of certain neurotransmitters, and immune function.
2. **Vitamin E (Tocopherol)**: Present in nuts, seeds, spinach, and broccoli, vitamin E acts as a powerful antioxidant, protecting cell membranes from oxidative damage.
3. **Selenium**: This trace element, found in nuts (especially Brazil nuts), seafood, and meats, is vital for the proper functioning of antioxidant enzymes like glutathione peroxidase.
4. **Polyphenols**: Abundant in fruits, vegetables, tea, coffee, and red wine, polyphenols have strong antioxidant properties and contribute to reducing inflammation and oxidative stress.

Mechanisms of Action

The primary function of antioxidants is to neutralize reactive oxygen species (ROS) and other free radicals, thereby preventing cellular damage. Their mechanisms of action include:

1. **Scavenging Free Radicals**: Antioxidants donate electrons to free radicals, stabilizing them and preventing them from causing cellular damage.[38]
2. **Supporting Enzymatic Activity**: Antioxidants like selenium are essential components of antioxidant enzymes such as glutathione peroxidase, which detoxify harmful oxidative products.
3. **Modulating Immune Response**: By reducing oxidative stress, antioxidants help maintain a balanced immune response, crucial for preventing excessive inflammation during pregnancy.

Impact on Maternal Immune Response

By neutralizing ROS, antioxidants protect immune cells from oxidative damage, ensuring their proper function and viability. This protection is crucial for maintaining a robust immune response against infections. Antioxidants help modulate the production of cytokines, promoting an anti-inflammatory environment necessary for fetal tolerance.[39] This balance is essential to prevent complications such as preeclampsia, characterized by excessive inflammation. By mitigating oxidative stress, antioxidants help prevent immune dysregulation, reducing the risk of autoimmune responses and other immune-related complications during pregnancy.

Prevention of Pregnancy Complications

Antioxidants have been shown to reduce the risk of various pregnancy complications:

1. **Preeclampsia**: This condition, marked by high blood pressure and organ damage, has been linked to oxidative stress. Studies have indicated that supplementation with vitamins C and E can lower the incidence of preeclampsia by reducing oxidative stress and inflammation.
2. **Gestational Diabetes**: Oxidative stress plays a role in the development of gestational diabetes. Antioxidants help improve insulin sensitivity and reduce oxidative damage to pancreatic cells, thus lowering the risk of gestational diabetes.
3. **Preterm Birth**: Oxidative stress is a risk factor for preterm birth. Antioxidants help maintain the integrity of placental tissues and reduce inflammation, thereby decreasing the likelihood of preterm labor.

Impact on Fetal Immune Response

Adequate antioxidant levels are essential for the proper development of fetal immune organs such as the thymus and spleen, which are crucial for a functional immune system post-birth.[40] By neutralizing ROS, antioxidants protect developing fetal tissues from oxidative damage, ensuring normal growth and development. Adequate antioxidant levels support the maturation and function of fetal immune cells, enhancing the fetus's ability to respond to pathogens after birth.

Long-term Health Benefits

Children born to mothers with adequate antioxidant intake during pregnancy have a lower risk of developing chronic conditions such as asthma, allergies, and autoimmune diseases later in life. This is likely due to the role of antioxidants in supporting optimal immune development and function. Antioxidants contribute to brain development and cognitive function. Adequate levels during pregnancy are associated with better neurodevelopmental outcomes in children.

Supplementation Guidelines

Proper supplementation is crucial to maximize the benefits of antioxidants during pregnancy:

1. **Recommended Dietary Allowances (RDAs)**: Pregnant women should follow RDAs for antioxidants to avoid deficiencies and potential adverse effects of excessive intake. For instance, the RDA for vitamin C during pregnancy is 85 mg/day, and for vitamin E, it is 15 mg/day.
2. **Individualized Recommendations**: Healthcare providers should tailor antioxidant supplementation based on individual nutritional status, health conditions, and dietary intake to ensure optimal maternal and fetal health.

Impact on Maternal Immune Response

Antioxidants play a crucial role in modulating the maternal immune response during pregnancy.[41] Lymphocytes, including T cells and B cells, are essential for adaptive immunity. Oxidative stress can impair their proliferation and function. Antioxidants such as vitamins C and E help preserve lymphocyte activity, enhancing the body's ability to respond to infections. Macrophages play a vital role in both innate and adaptive immunity by phagocytosing pathogens and presenting antigens. Antioxidants protect these cells from oxidative damage, ensuring they can effectively carry out their immune functions. Neutrophils are critical for the initial immune response to infections. Antioxidants help maintain neutrophil function and viability, crucial for preventing infections during pregnancy. Antioxidants support the production of anti-inflammatory cytokines such as IL-4, IL-10, and TGF-β. These cytokines are crucial for creating a pregnancy-compatible immune environment that supports fetal tolerance. High levels of pro-inflammatory cytokines like TNF-α, IL-6, and IFN-γ can lead to complications such as preeclampsia and preterm labor. Antioxidants help reduce the production of these cytokines, mitigating the risk of inflammation-related complications.

By neutralizing ROS, antioxidants help maintain immune homeostasis, preventing the overactivation of immune responses that can harm the mother and fetus. **Regulatory T Cells (Tregs)** are crucial for maintaining immune tolerance to the fetus. Antioxidants support the function and proliferation of Tregs, helping prevent immune-mediated rejection of the fetus. Characterized by hypertension and organ damage, preeclampsia is associated with elevated oxidative stress and inflammation. Antioxidants help reduce these risks by modulating cytokine production and protecting endothelial cells. Oxidative stress contributes to insulin resistance, a key factor in gestational diabetes. Antioxidants improve insulin sensitivity and reduce oxidative damage, lowering the risk of gestational diabetes. Inflammation and oxidative stress are major risk

factors for preterm birth. Antioxidants help maintain the integrity of placental tissues and reduce inflammation, decreasing the likelihood of preterm labor.[42]

These cells present antigens in a way that promotes tolerance rather than immune activation. Antioxidants support their function, helping to maintain a balanced immune response. By reducing oxidative stress, antioxidants help stabilize immune responses, ensuring that the maternal immune system does not overreact to fetal antigens. Chronic inflammation can have wide-reaching effects on health. Antioxidants help reduce systemic inflammation, promoting overall well-being during pregnancy.[43] Antioxidants can improve the absorption of essential nutrients, which are crucial for maintaining a healthy immune system. A balanced diet rich in fruits, vegetables, nuts, and whole grains ensures adequate antioxidant intake. Specific recommendations may include citrus fruits for vitamin C, nuts for vitamin E, and selenium-rich foods like seafood and meat. For women at risk of antioxidant deficiencies or those with pregnancy complications, targeted supplementation may be necessary. Healthcare providers should tailor these recommendations based on individual needs and health status.

The fetal immune response is significantly influenced by maternal nutrition and oxidative stress levels during pregnancy.[44] Antioxidants, by mitigating oxidative stress, play a vital role in supporting fetal immune development and function. This section explores the impact of antioxidants on various aspects of fetal immune response, including immune organ development, immune cell function, and long-term health outcomes. Oxidative stress can impair the development of immune organs by causing cellular damage and apoptosis. Antioxidants like vitamins C and E neutralize ROS, preventing such damage and ensuring the proper development of these organs. Antioxidants support cellular proliferation and differentiation, processes essential for the growth of immune organs. Adequate antioxidant levels ensure that immune organs develop correctly and attain functional maturity. The thymus is where T cells mature and differentiate. Oxidative stress can disrupt this process, leading to impaired T cell function. Antioxidants protect thymic cells from oxidative damage, ensuring the production of functional T cells. B cells, responsible for antibody production, mature in the fetal liver and bone marrow. Antioxidants support the healthy maturation and differentiation of B cells, crucial for a robust humoral immune response.

Enhancement of Antioxidant Enzyme Systems

Selenium is a key component of glutathione peroxidase, an enzyme that detoxifies peroxides. Maternal selenium intake ensures adequate enzyme activity in the fetus, protecting against oxidative damage. This enzyme converts superoxide radicals into less harmful molecules. Antioxidants support the activity of SOD, enhancing the fetus's ability to manage oxidative stress.

Prevention of Immune Dysregulation

Excessive oxidative stress can promote inflammatory responses, leading to immune dysregulation. Antioxidants help regulate these responses, preventing chronic inflammation and associated

immune disorders. Cytokines are critical for immune signaling. Antioxidants modulate cytokine production, ensuring a balanced immune environment that supports proper immune development.

Long-term Health Benefits for Offspring

Adequate antioxidant intake during pregnancy is associated with a lower risk of allergies and asthma in children.[45] This is likely due to the role of antioxidants in preventing immune dysregulation and promoting a balanced immune response. Oxidative stress is a risk factor for autoimmune diseases. By mitigating oxidative stress during fetal development, antioxidants can reduce the risk of autoimmune conditions in later life.

Epigenetic Modifications

Antioxidants can modulate DNA methylation patterns, which play a role in regulating gene expression. Proper DNA methylation is crucial for the development of a healthy immune system. Antioxidants can influence histone modification, another mechanism regulating gene expression. These modifications can impact the expression of genes involved in immune function and inflammation.

Dietary and Supplementation Recommendations

A diet rich in fruits, vegetables, nuts, and whole grains provides a wide range of antioxidants. Specific recommendations include consuming berries, citrus fruits, leafy greens, and nuts to meet antioxidant needs. In cases where dietary intake is insufficient, supplementation may be necessary. Healthcare providers should assess individual needs and recommend appropriate antioxidant supplements to ensure both maternal and fetal health.

Clinical Implications and Monitoring

Regular assessments of maternal antioxidant status can help identify deficiencies and inform dietary and supplementation interventions. Tailoring antioxidant recommendations based on individual health status and risk factors can enhance the effectiveness of interventions and support optimal fetal immune development.

Therapeutic Applications and Considerations

The therapeutic use of antioxidants during pregnancy holds significant promise for improving maternal and fetal health outcomes. This section explores the various therapeutic applications of antioxidants, their potential benefits, and important considerations for their use during pregnancy.

Dietary Recommendations and Supplementation

Ensuring adequate antioxidant intake during pregnancy is crucial for maximizing health benefits for both the mother and fetus.

1. **Dietary Sources**: A balanced diet rich in antioxidant-containing foods, such as fruits, vegetables, nuts, and whole grains, is recommended. Specific foods like berries, citrus fruits, leafy greens, and nuts are excellent sources of essential antioxidants.
2. **Supplementation Guidelines**: In cases where dietary intake is insufficient, targeted antioxidant supplementation may be necessary. Healthcare providers should assess individual needs and recommend appropriate supplements, such as vitamins C and E, selenium, and polyphenols, to ensure optimal antioxidant levels.

Safety and Potential Risks

While antioxidants offer significant benefits, their use must be carefully managed to avoid potential risks.

1. **Dosage Considerations**: High doses of certain antioxidants can have adverse effects. For example, excessive vitamin E intake has been associated with an increased risk of hemorrhagic stroke. It is essential to adhere to recommended dietary allowances (RDAs) and avoid excessive supplementation.
2. **Interactions with Medications**: Antioxidants can interact with certain medications, potentially altering their efficacy or causing adverse effects. Pregnant women should consult with healthcare providers before starting any new supplements.

Personalized Antioxidant Therapy

Personalized approaches to antioxidant therapy can enhance its efficacy and safety during pregnancy.

1. **Individual Assessments**: Healthcare providers should conduct thorough assessments of antioxidant status and oxidative stress levels in pregnant women to tailor dietary and supplementation recommendations.
2. **Targeted Interventions**: Personalized interventions based on individual risk factors, health conditions, and nutritional status can optimize antioxidant intake and maximize health benefits for both mother and fetus.

Conclusion

Antioxidants are essential in maintaining maternal and fetal health during pregnancy by mitigating oxidative stress and supporting immune function. The therapeutic applications of antioxidants span from preventing pregnancy complications such as preeclampsia, gestational diabetes, and preterm birth, to enhancing the development and function of the fetal immune system. Their role extends to modulating maternal immune responses, protecting immune cells from oxidative damage, and maintaining cytokine balance, which is critical for fetal tolerance and overall maternal health. The impact of antioxidants on fetal immune development is profound, contributing to the proper development of immune organs, protection against oxidative damage, and the long-term health of the offspring. By influencing epigenetic modifications, antioxidants can reduce the risk of chronic

diseases and promote better health outcomes throughout the child's life. Dietary sources of antioxidants, including fruits, vegetables, nuts, and whole grains, are vital for ensuring adequate intake. In cases where dietary intake is insufficient, targeted supplementation can provide necessary support, although it must be carefully managed to avoid potential risks associated with excessive dosages or interactions with medications. Personalized antioxidant therapy, based on individual assessments of oxidative stress levels and nutritional status, offers a promising approach to optimizing health benefits while minimizing risks. Healthcare providers play a critical role in tailoring dietary and supplementation recommendations to the specific needs of pregnant women.

References

1. Obeagu EI, Adepoju OJ, Okafor CJ, Obeagu GU, Ibekwe AM, Okpala PU, Agu CC. Assessment of Haematological Changes in Pregnant Women of Ido, Ondo State, Nigeria, J Res Med Dent Sci, 2021; 9 (4):145-148
2. Orefice R. Immunology and the immunological response in pregnancy. Best practice & research Clinical obstetrics & gynaecology. 2021; 76:3-12.
3. Adwas AA, Elsayed A, Azab AE, Quwaydir FA. Oxidative stress and antioxidant mechanisms in human body. J. Appl. Biotechnol. Bioeng. 2019;6(1):43-47.
4. Obeagu EI, Agreen FC. Anaemia among pregnant women: A review of African pregnant teenagers. J Pub Health Nutri. 2023; 6 (1). 2023;138. links/63da799664fc860638054562/Anaemia-among-pregnant-women-A-review-of-African-pregnant-teenagers.pdf.
5. Obeagu EI, Ezimah AC, Obeagu GU. Erythropoietin in the anaemias of pregnancy: a review. Int J Curr Res Chem Pharm Sci. 2016;3(3):10-8. links/5710fae108ae846f4ef05afb/ERYTHROPOIETIN-IN-THE-ANAEMIAS-OF-PREGNANCY-A-REVIEW.pdf.
6. Obeagu EI, Adepoju OJ, Okafor CJ, Obeagu GU, Ibekwe AM, Okpala PU, Agu CC. Assessment of Haematological Changes in Pregnant Women of Ido, Ondo State, Nigeria. J Res Med Dent Sci. 2021;9(4):145-8. links/608a6728a6fdccaebdf52d94/Assessment-of-Haematological-Changes-in-Pregnant-Women-of-Ido-Ondo.pdf.
7. Lü JM, Lin PH, Yao Q, Chen C. Chemical and molecular mechanisms of antioxidants: experimental approaches and model systems. Journal of cellular and molecular medicine. 2010;14(4):840-860.
8. Kovacic P, Somanathan R. Multifaceted approach to resveratrol bioactivity: focus on antioxidant action, cell signaling and safety. Oxidative medicine and cellular longevity. 2010;3(2):86.
9. Obeagu EI, Obeagu GU. Sickle Cell Anaemia in Pregnancy: A Review. International Research in Medical and Health Sciences. 2023 ;6(2):10-3. http://irmhs.com/index.php/irmhs/article/view/111.
10. Jakheng SP, Obeagu EI. Seroprevalence of human immunodeficiency virus based on demographic and risk factors among pregnant women attending clinics in Zaria Metropolis, Nigeria. J Pub Health Nutri. 2022; 5 (8). 2022;137. links/6317a6b1acd814437f0ad268/Seroprevalence-of-human-immunodeficiency-virus-based-on-demographic-and-risk-factors-among-pregnant-women-attending-clinics-in-Zaria-Metropolis-Nigeria.pdf.

11. Obeagu EI, Obeagu GU, Chukwueze CM, Ikpenwa JN, Ramos GF. Evaluation of Protein C, Protein S and Fibrinogen of Pregnant Women with Malaria in Owerri Metropolis. Madonna University journal of Medicine and Health Sciences. 2022;2(2):1-9.
12. Phoswa WN, Khaliq OP. The role of oxidative stress in hypertensive disorders of pregnancy (preeclampsia, gestational hypertension) and metabolic disorder of pregnancy (gestational diabetes mellitus). Oxidative medicine and cellular longevity. 2021;2021(1):5581570.
13. Obeagu EI, Ikpenwa JN, Chukwueze CM, Obeagu GU. Evaluation of protein C, protein S and fibrinogen of pregnant women in Owerri Metropolis. Madonna University Journal of Medicine and Health Sciences. 2022;2(1):292-8. https://madonnauniversity.edu.ng/journals/index.php/medicine/article/view/57.
14. Obeagu EI, Obeagu GU, Adepoju OJ. Evaluation of haematological parameters of pregnant women based on age groups in Olorunsogo road area of Ido, Ondo state. J. Bio. Innov11 (3). 2022:936-941.
15. Obeagu EI. An update on utilization of antenatal care among pregnant Women in Nigeria. Int. J. Curr. Res. Chem. Pharm. Sci. 2022;9(9): 21-6.DOI: 10.22192/ijcrcps.2022.09.09.003
16. Okoroiwu IL, Obeagu EI, Obeagu GU. Determination of clot retraction in preganant women attending antenatal clinic in federal medical centre Owerri, Nigeria. Madonna University Journal of Medicine and Health Sciences. 2022;2(2):91-97. https://madonnauniversity.edu.ng/journals/index.php/medicine/article/view/67.
17. Obeagu EI, Hassan AO, Adepoju OJ, Obeagu GU, Okafor CJ. Evaluation of Changes in Haematological Parameters of Pregnant Women Based on Gestational Age at Olorunsogo Road Area of Ido, Ondo State. Nigeria. Journal of Research in Medical and Dental Science. 2021;9(12):462-.links/61b1e32f0c4bfb675178bfa7/Evaluation-of-Changes-in-Haematological-Parameters-of-Pregnant-Women-Based-on-Gestational-Age-at-Olorunsogo-Road-Area-of-Ido-Ondo-State-Nigeria.pdf.
18. Anyiam AF, Obeagu EI, Obi E, Omosigho PO, Irondi EA, Arinze-Anyiam OC, Asiyah MK. ABO blood groups and gestational diabetes among pregnant women attending University of Ilorin Teaching Hospital, Kwara State, Nigeria. International Journal of Research and Reports in Hematology. 2022;5(2):113-121.
19. Akbarirad H, Ardabili AG, Kazemeini SM, Khaneghah AM. An overview on some of important sources of natural antioxidants. International food research journal. 2016;23(3).
20. Obeagu EI. Gestational Thrombocytopaenia. J Gynecol Women's Health. 2023;25(3):556163. links/64b01aa88de7ed28ba95fccb/Gestational-Thrombocytopaenia.pdf.
21. Obeagu EI, Ogbonna US, Nwachukwu AC, Ochiabuto O, Enweani IB, Ezeoru VC. Prevalence of Malaria with Anaemia and HIV status in women of reproductive age in Onitsha, Nigeria. Journal of Pharmaceutical Research International. 2021;33(4):10-9.
22. Obeagu EI, Abdirahman BF, Bunu UO, Obeagu GU. Obsterics characteristics that effect the newborn outcomes. Int. J. Adv. Res. Biol. Sci. 2023;10(3): 134-43.DOI: 10.22192/ijarbs.2023.10.03.016

23. Alcala M, Gutierrez-Vega S, Castro E, Guzman-Gutiérrez E, Ramos-Álvarez MP, Viana M. Antioxidants and oxidative stress: Focus in obese pregnancies. Frontiers in Physiology. 2018; 9:413463.
24. Holland O, Nitert MD, Gallo LA, Vejzovic M, Fisher JJ, Perkins AV. Placental mitochondrial function and structure in gestational disorders. Placenta. 2017; 54:2-9.
25. Obeagu EI, Ogunnaya FU. PREGNANCYINDUCED HAEMATOLOGICAL CHANGES: A KEY TO MARTERNAL AND CHILD HEALTH. European Journal of Biomedical. 2023;10(8):42-43. links/64c890bddb38b20d6dad2c5c/PREGNANCY-INDUCED-HAEMATOLOGICAL-CHANGES-A-KEY-TO-MARTERNAL-AND-CHILD-HEALTH.pdf.
26. Okamgba OC, Nwosu DC, Nwobodo EI, Agu GC, Ozims SJ, Obeagu EI, Ibanga IE, Obioma-Elemba IE, Ihekaire DE, Obasi CC, Amah HC. Iron Status of Pregnant and Post-Partum Women with Malaria Parasitaemia in Aba Abia State, Nigeria. Annals of Clinical and Laboratory Research. 2017;5(4):206. links/5ea97df145851592d6a8acf2/Iron-Status-of-Pregnant-and-Post-Partum-Women-with-Malaria-Parasitaemia-in-Aba-Abia-State-Nigeria.pdf.
27. Duhig K, Chappell LC, Shennan AH. Oxidative stress in pregnancy and reproduction. Obstetric medicine. 2016;9(3):113-116.
28. Talukdar A, Sharma KA, Rai R, Deka D, Rao DN. Effect of coenzyme Q10 on Th1/Th2 paradigm in females with idiopathic recurrent pregnancy loss. American Journal of Reproductive Immunology. 2015;74(2):169-180.
29. Obeagu EI, Obeagu GU. The Vital Role of Antioxidants in Enhancing Fertility and Pregnancy Success: A Review. Elite Journal of Nursing and Health Science. 2023;1(1):1-2.
30. Obeagu EI, Ubosi NI, Uzoma G. Antioxidant Supplementation in Pregnancy: Effects on Maternal and Infant Health. Int. J. Adv. Multidiscip. Res. 2023;10(11):60-70.
31. Obeagu EI, Obeagu GU. Harnessing the Power of Antioxidant-Rich Diet for Preconception Health: A Review. Elite Journal of Health Science. 2023;1(1):1-3.
32. Obeagu EI, Obeagu GU. Enhancing Maternal and Fetal Well-being: The Role of Antioxidants in Pregnancy. Elite Journal of Medical Sciences. 2024;2(4):76-87.
33. Obeagu EI, Obeagu GU. Antioxidants and Gestational Diabetes Mellitus: A Comprehensive Review of Preventive Strategies. Elite Journal of Health Science. 2024;2(5):19-29.
34. Obeagu EI, Batisani K, Obeagu GU. Antioxidants and Postpartum Complications: Preventions. Elite Journal of Nursing and Health Science. 2024;2(5):30-40.
35. Obeagu EI, Obeagu GU. Harnessing the Power of Antioxidants: Enhancing Gamete Quality and Fostering Successful Pregnancy. Elite Journal of Nursing and Health Science. 2024;2(3):73-83.
36. Obeagu EI, Batisani K, Obeagu GU. Antioxidants and Neurodevelopmental Outcomes in Offspring: A Review of Maternal Interventions. Elite Journal of Health Science. 2023;2(5):1-9.
37. Obeagu EI, Obeagu GU. Oxygen Deprivation in Pregnancy: Understanding Hypoxia's Impact on Maternal Health. Journal home page: http://www. journalijiar. com.;12(01).

38. Silva JP, Coutinho OP. Free radicals in the regulation of damage and cell death--basic mechanisms and prevention. Drug discoveries & therapeutics. 2010;4(3).
39. Chitimus DM, Popescu MR, Voiculescu SE, Panaitescu AM, Pavel B, Zagrean L, Zagrean AM. Melatonin's impact on antioxidative and anti-inflammatory reprogramming in homeostasis and disease. Biomolecules. 2020;10(9):1211.
40. Balistreri CR, Garagnani P, Madonna R, Vaiserman A, Melino G. Developmental programming of adult haematopoiesis system. Ageing Research Reviews. 2019; 54:100918.
41. Sebastiani G, Navarro-Tapia E, Almeida-Toledano L, Serra-Delgado M, Paltrinieri AL, García-Algar Ó, Andreu-Fernández V. Effects of antioxidant intake on fetal development and maternal/neonatal health during pregnancy. Antioxidants. 2022;11(4):648.
42. Menon R. Oxidative stress damage as a detrimental factor in preterm birth pathology. Frontiers in immunology. 2014; 5:116722.
43. Saucedo R, Ortega-Camarillo C, Ferreira-Hermosillo A, Díaz-Velázquez MF, Meixueiro-Calderón C, Valencia-Ortega J. Role of oxidative stress and inflammation in gestational diabetes mellitus. Antioxidants. 2023;12(10):1812.
44. Perrone S, Tataranno ML, Santacroce A, Bracciali C, Riccitelli M, Alagna MG, Longini M, Belvisi E, Bazzini F, Buonocore G. Fetal programming, maternal nutrition, and oxidative stress hypothesis. Journal of Pediatric Biochemistry. 2016;6(02):96-102.
45. Nwaru BI, Erkkola M, Ahonen S, Kaila M, Kronberg-Kippilä C, Ilonen J, Simell O, Knip M, Veijola R, Virtanen SM. Intake of antioxidants during pregnancy and the risk of allergies and asthma in the offspring. European journal of clinical nutrition. 2011;65(8):937-943.