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Diet and physical activity in pregnancy carbohydrate metabolism disorders

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ABSTRACT

Introduction and objective : Carbohydrate metabolism disorders are a serious problem during pregnancy. They are a complication in approximately 15-20% of pregnancies. The body has difficulty processing and using carbohydrates, leading to abnormal levels of glucose (sugar) in the blood. Two common pregnancy-related disorders are gestational diabetes mellitus (GDM) and pre-existing diabetes. Hypoglycemia and insulin resistance are also very common problems during pregnancy. Complications affect both the mother and the child, so it is important to know them and be able to prevent their occurrence and complications. The purpose of this literature review is to evaluate the influence of carbohydrate metabolism disorders during pregnancy and diet and physical exercise in the light of most up to date research.

Review methods. This article is a review of publications obtained from the PubMed database, published between 2011-2024, based on the keywords.

Brief description of the state of knowledge. In recent years, many studies have examined the potential use of diet and exercise to reduce the risk of complications of carbohydrate metabolism disorders. Most clinical studies generally confirm the existence of a correlation between diet, exercise and carbohydrate metabolism disorders. Most studies confirm the positive impact of diet and exercise.

Summary. The correlation between a healthy diet and physical activity and the prevention of carbohydrate metabolism disorders is important. There is a need for further research to determine the specific diet and exercise that will be most helpful.

Keywords: "carbohydrate metabolism disorders", “physical activity in pregnancy” and "diet in pregnancy"

1. Introduction and purpose

Treating carbohydrate metabolism disorders during pregnancy, particularly conditions like gestational diabetes mellitus (GDM) and pre-existing diabetes, is crucial for the well-being of both the mother and the baby. The influence of diet and physical activity on reducing the risk of complications is more often emphasized. Treatment during pregnancy is tailored to each woman's specific needs, taking into account factors such as gestational age, overall health, and personal preferences. This individualized approach enhances the effectiveness of the treatment plan. There are many diets and exercises to choose from, so every pregnant woman should try to find the activity that gives her the most benefits.

2. Carbohydrate metabolism during pregnancy

2.1 Changes in pregnancy

During pregnancy, many changes occur in the body. Some of them concern carbohydrate metabolism. Due to the disorder, many complications can arise, including gestational diabetes. The consequences of these changes can include fetal macrosomia, neonatal hypoglycemia, preterm birth, respiratory distress syndrome, or preeclampsia. Managing carbohydrate metabolism disorders during pregnancy involves careful monitoring of blood glucose levels,

maintaining a balanced diet, regular physical activity, and, in some cases, the use of insulin or other medications.

It is crucial for pregnant women with these conditions to work closely with their healthcare team to optimize outcomes for both the mother and the baby. Gestational diabetes is associated with a higher rate of pregnancy complications compared to those without diabetes, even after adjusting for maternal and pregnancy characteristics. However, gestational diabetes does not increase the risk of stillbirth, hypoxic-ischemic encephalopathy, or neonatal death[1].

2.2 Gut Microbiome Changes

Medical nutritional therapy is the primary approach in managing gestational diabetes mellitus (GDM). Diet plays a crucial role in modulating the gut microbiota, which significantly affects insulin resistance and the host's inflammatory response. Alterations in the composition of the gut microbiota have been observed in pregnancies both prior to the onset of GDM and following its diagnosis. The potential to modulate the gut microbiota through dietary interventions during pregnancy is an emerging area of interest, given the possible positive effects on maternal and neonatal health[2,3].

The most commonly observed alteration in the microbiome of patients with GDM is an increase in the Firmicutes phylum, along with a decrease in the Bacteroidetes and Actinobacteria phyla. This gut dysbiosis often persists postpartum and can influence the development of the newborn, as demonstrated in several studies. In managing GDM, probiotic supplementation and regular physical activity have shown the strongest evidence for effective blood glucose control, promoting fetal development and a healthy postpartum outcome [4,5].

2.3 Gestational diabetes mellitus

Gestational diabetes mellitus (GDM), defined as hyperglycemia first recognized during pregnancy, is currently the most common medical complication in pregnancy. GDM affects approximately 15% of pregnancies worldwide, accounting for about 18 million births annually. Mothers with GDM are at risk of developing gestational hypertension, pre-eclampsia, and may require delivery via Caesarean section. Additionally, GDM increases the risk of long-term complications such as cardiovascular disease, obesity, and impaired carbohydrate metabolism, potentially leading to type 2 diabetes (T2DM) in both the mother and infant. The rising incidence of GDM also imposes a significant economic burden, highlighting the need for increased attention and awareness[6].

Overweight and obesity are associated with a clustering of metabolic risk factors for GDM, including elevated fasting plasma glucose, high HbA1c levels, insulin resistance, increased plasma triglycerides, and elevated blood pressure in FPV. There is a positive correlation between the number of these metabolic risk factors and the incidence of GDM. The odds ratios for HbA1c and diastolic blood pressure are higher in overweight or obese women compared to those in women of normal weight[7].

For this reason, overweight/obesity is associated with clustering of metabolic risk factors in early pregnancy, which is correlated with higher risk of GDM.

2.4 Hypogycemia

Animal studies clearly indicate that hypoglycemia can be potentially teratogenic during organogenesis. Despite near-normal HbA1c levels, increased rates of macrosomia continue to be observed, possibly due to rebound hyperglycemia triggered by hypoglycemia. In utero exposure to hypoglycemia may have long-term effects on offspring, including neuropsychological defects. The extent to which the benefits of tight glycemic control outweigh the increased risk of severe hypoglycemia during type 1 diabetic pregnancy remains unclear. Therefore, efforts must be made to avoid low blood glucose levels (i.e., below 3.9 mmol/l) when tightening glycemic control[8].

Research shows that hypoglycemia and hyperglycemia are dangerous to the fetus. It is important to achieve a balanced carbohydrate metabolism.

2.5 Insulin resistance in pregnancy

Maternal overweight and obesity significantly contribute to the development of gestational diabetes, posing risks to both the mother and fetus. The prevalence of gestational diabetes is increasing sharply worldwide[9]. Combining low-carbohydrate dietary patterns with intermittent fasting may help individuals with insulin resistance not only lose weight but also increase their insulin sensitivity[10]. Insulin resistance may be one of the direct causes of recurrent abortion. Women with a history of recurrent miscarriage are at an increased risk for insulin resistance during the first trimester of a new pregnancy [11, 12]. To prevent miscarriages, it is important to prevent insulin resistance during pregnancy. One of the basic treatment recommendations is an appropriate, healthy diet and physical exercise.

2.6 Possible consequences

The mean maternal BMI was 27.7, with 13.7% classified as obese (BMI ≥33.0 kg/m²), and gestational diabetes mellitus (GDM) was diagnosed in 16.1% of the participants. Compared to women without GDM and who were not obese, the odds ratio for birth weight >90th percentile was 2.19 (95% CI: 1.93-2.47) for GDM alone, 1.73 (95% CI: 1.50-2.00) for obesity alone, and 3.62 (95% CI: 3.04-4.32) for both GDM and obesity combined. Similar trends were observed for primary cesarean delivery, preeclampsia, cord C-peptide levels, and newborn percent body fat >90th percentile.

The odds for birth weight >90th percentile increased progressively with higher glucose levels from oral glucose tolerance tests (OGTT) and higher maternal BMI. Babies born to obese women with GDM had a 339-gram higher birth weight compared to babies born to normal or underweight women with normal glucose levels based on composite OGTT measures (64.2% of all women had normal/underweight and normal glucose; 61.8% of all women had this profile)[13].

Gestational diabetes mellitus (GDM) is linked to numerous adverse health outcomes for both women and their infants in both the short and long term. Given the rising prevalence of GDM

globally, there is a pressing need to evaluate prevention strategies, including combined diet and exercise interventions. Studies examining these interventions have utilized diverse diet and exercise programs and reported various health outcomes.

Based on primary review outcomes, there appears to be a potential reduction in the risk of developing GDM among participants receiving diet and exercise interventions compared to those receiving standard care[14].

Gestational diabetes mellitus (GDM), characterized by elevated blood sugar levels first recognized during pregnancy, is currently the most common medical complication in pregnancy. GDM affects around 15% of pregnancies globally, totaling about 18 million births each year. Women with GDM are prone to developing gestational hypertension, pre-eclampsia, and often undergo Caesarean section for delivery. Additionally, GDM increases the likelihood of complications such as cardiovascular disease, obesity, and impaired carbohydrate metabolism, which can lead to the onset of type 2 diabetes (T2DM) in both the mother and child. The rising incidence of GDM also imposes a significant economic burden, underscoring the need for heightened attention and awareness of this condition[15].

3. Diet and physical activity

3.1 Diet in pregnancy

Diets such as the Mediterranean Diet (MedDiet), Dietary Approaches to Stop Hypertension (DASH) diet, and Alternate Healthy Eating Index (AHEI) diet have been linked to a 15–38% reduced relative risk of gestational diabetes mellitus (GDM). Conversely, frequent consumption of potatoes, meat/processed meats, and a higher percentage of energy derived from animal sources is associated with an increased risk of GDM. In terms of physical activity (PA), engaging in any level of physical activity before pregnancy or during early pregnancy was associated with a 30% and 21% reduced odds of developing GDM, respectively. In conclusion, diets resembling the MedDiet, DASH diet, or AHEI, as well as higher levels of physical activity before or in early pregnancy, are associated with lower risks or odds of developing gestational diabetes mellitus[16].

High-quality systematic reviews indicate that there are no significant advantages between low-carbohydrate or calorie-restricted diets for managing gestational diabetes mellitus (GDM). However, the low glycemic index (GI) diet, which emphasizes high-quality, complex carbohydrates, has shown benefits such as reduced insulin use and decreased risk of macrosomia in multiple reviews. Recent evidence suggests that the Mediterranean diet is generally safe during pregnancy, although more trials are necessary to determine its effectiveness compared to standard dietary advice. Currently, there is insufficient data to support the safety and efficacy of the ketogenic diet for treating GDM. The low GI diet appears to improve both maternal and neonatal outcomes in GDM. It offers a less restrictive approach to carbohydrate intake, which is culturally adaptable and may enhance long-term adherence among pregnant women[17]. A study conducted in Great Britain evaluated the UPBEAT intervention, which aimed to provide intensive, theory-based support to obese pregnant women. Despite successfully reducing dietary glycemic load (GL), the intervention did not result in a reduced risk of gestational diabetes mellitus (GDM) or decrease the number of deliveries of large-for-gestational-age (LGA) infants. This suggests that while reducing

dietary glycemic load may have positive impacts on nutritional factors, it may not independently mitigate the risk of GDM or reduce the likelihood of delivering LGA infants in obese pregnant women[18]. More research is needed to determine the best type of diet for pregnant women to prevent complications

3.2 Physical activity in pregnancy

Engaging in >90 min/week of leisure time PA before pregnancy was associated with 46% decreased odds of GDM[16].

This review highlighted that interventions involving dietary advice and blood glucose monitoring for women with pregnancy hyperglycemia, not meeting gestational diabetes mellitus (GDM) or type 2 diabetes mellitus (T2DM) diagnostic criteria, were effective in reducing the number of macrosomic and large-for-gestational-age (LGA) babies. Importantly, these interventions did not increase rates of cesarean section or operative vaginal births. It's crucial to note that the findings of this review were based on four small randomized trials with moderate to high risk of bias, and there were no follow-up outcomes reported for both women and their babies. Regarding combined diet and physical activity interventions, although they were able to limit the incidence of GDM, they did not reduce fasting blood glucose levels. This suggests that lifestyle changes alone may not be sufficient to prevent GDM in women with a BMI of 29 kg/m² or higher. The review also indicated variability in the types of exercises studied and the diverse shapes of pregnant women, making it difficult to recommend a specific type of exercise. However, any form of physical activity that is of adequate intensity and duration can benefit pregnant women with GDM. The recommendation is for pregnant women with gestational diabetes mellitus to engage in physical activity for at least 20-50 minutes, a minimum of two times per week, at least at a moderate intensity level[20].

It is important for women to be physically active also before pregnancy, because it also affects the course of pregnancy and possible complications. Scientific research is inconclusive, but the positive impact is usually emphasized.

3.3 Diet, physical exercise and carbohydrate metabolism disorders – current state of knowledge

In recent years, many studies have examined the potential use of diet and exercise to reduce the risk of complications of carbohydrate metabolism disorders. Most clinical studies generally confirm the existence of a correlation between diet, exercise and carbohydrate metabolism disorders.

A correlation has been shown between obesity, gestational diabetes and pregnancy outcomes[21].

Pregnancy hyperglycemia that does not meet the diagnostic criteria for gestational diabetes mellitus (GDM) affects a substantial number of pregnant women annually. These women have also been found to benefit from physical exercise[22].

The wide variety and availability of physical exercise make randomized research difficult. There are problems with the equation of various physical activities[23].

The same applies to the wide availability and diversity of diets. It is possible reduction in caesarean section for women receiving a DASH diet compared with a control diet[24].

There is no difference between a higher complex carbohydrate diet compared to a conventional diet in treating gestational diabetes and preventing complications[25].
Further research is needed to establish the optimal, most sustainable, and most acceptable medical nutrition therapy for management of women with GDM[26].

Physical activity has beneficial effects on glucose and insulin levels and it can contribute to a better glycaemic control[27].
Physical activity programs started before the 20th week of gestation can significantly decrease the incidence of GDM among women at high risk[28].
Regular exercise during pregnancy is associated with appropriate gestational weight gain, which contributes to delivering infants with appropriate birth weights, thereby reducing the risk of large-for-gestational-age (LGA) babies without increasing the risk of small-for-gestational-age (SGA) infants. This, in turn, helps mitigate risk factors associated with chronic diseases later in the child's life, such as cardiovascular disease, obesity, and diabetes[29].
Insulin resistance might be one of the direct causes that lead to recurrent abortion[11].
Women with a history of recurrent miscarriage are at an increased risk for insulin resistance during the first trimester of a new pregnancy[12].
Specific gut microbiota species themselves may not directly contribute to gestational diabetes mellitus (GDM) in overweight or obese women. However, the presence of GDM can disrupt the flexibility of maternal gut microbiota, potentially limiting the ability of women with GDM to respond effectively to dietary interventions. This disruption is evidenced by observed alterations in gut microbiota that are typically seen in women without GDM[19].
Preventive measures to mitigate the risk of metabolic syndrome and its complications in children born to obese or diabetic mothers, or those who experienced antenatal growth disturbances, appear to include stringent dietary control and regular physical activity[30].

Summary

In conclusion, despite new data and numerous studies examining the relationship between diet and carbohydrate metabolism disorders, the results are still inconclusive. The impact of physical exercise on reducing the risk of carbohydrate metabolism disorders is better documented. It has been shown that physical activity of more than 90 minutes a week reduces the risk of carbohydrate metabolism disorders by approximately 46%. It is important to take care of your metabolism before getting pregnant. Ongoing and future long-term, randomized, controlled trials are required to determine which diet and physical activity will best prevent complications.

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References

1. Karkia R, Giacchino T, Shah S, Gough A, Ramadan G, Akolekar R. Gestational Diabetes Mellitus: Association with Maternal and Neonatal Complications. Medicina (Kaunas). 2023 Nov 29;59(12):2096. doi: 10.3390/medicina59122096. PMID: 38138200; PMCID: PMC10744613..
2. Ponzo V, Fedele D, Goitre I, Leone F, Lezo A, Monzeglio C, Finocchiaro C, Ghigo E, Bo S. Diet-Gut Microbiota Interactions and Gestational Diabetes Mellitus (GDM). Nutrients. 2019 Feb 3;11(2):330. doi: 10.3390/nu11020330. PMID: 30717458; PMCID: PMC6413040.
3. Alvernaz SA, Wenzel ES, Nagelli U, Pezley LB, LaBomascus B, Gilbert JA, Maki PM, Tussing-Humphreys L, Peñalver Bernabé B. Inflammatory dietary potential is associated with vitamin depletion and gut microbial dysbiosis in early pregnancy. medRxiv [Preprint]. 2024 Jan 16:2023.12.02.23299325. doi: 10.1101/2023.12.02.23299325. PMID: 38076865; PMCID: PMC10705629.
4. Ionescu RF, Enache RM, Cretoiu SM, Gaspar BS. Gut Microbiome Changes in Gestational Diabetes. Int J Mol Sci. 2022 Oct 25;23(21):12839. doi: 10.3390/ijms232112839. PMID: 36361626; PMCID: PMC9654708.
5. Ponzo V, Fedele D, Goitre I, Leone F, Lezo A, Monzeglio C, Finocchiaro C, Ghigo E, Bo S. Diet-Gut Microbiota Interactions and Gestational Diabetes Mellitus (GDM). Nutrients. 2019 Feb 3;11(2):330. doi: 10.3390/nu11020330. PMID: 30717458; PMCID: PMC6413040.
6. Modzelewski R, Stefanowicz-Rutkowska MM, Matuszewski W, Bandurska-Stankiewicz EM. Gestational Diabetes Mellitus-Recent Literature Review. J Clin Med. 2022 Sep 28;11(19):5736. doi: 10.3390/jcm11195736. PMID: 36233604; PMCID: PMC9572242
7. Hernandez TL, Farabi SS, Fosdick BK, Hirsch N, Dunn EZ, Rolloff K, Corbett JP, Haugen E, Marden T, Higgins J, Friedman JE, Barbour LA. Randomization to a Provided Higher-Complex-Carbohydrate Versus Conventional Diet in Gestational Diabetes Mellitus Results in Similar Newborn Adiposity. Diabetes Care. 2023 Nov 1;46(11):1931-1940. doi:

10.2337/dc23-0617. PMID: 37643311; PMCID: PMC10620537.
8. Morton A. Hypoglycaemia in non-diabetic pregnancy. Obstet Med. 2023 Jun;16(2):123-125. doi: 10.1177/1753495X211032787. Epub 2021 Aug 14. PMID: 37441658; PMCID: PMC10334043.
9. Sissala N, Myllymäki E, Mohr F, Halmetoja R, Kuvaja P, Dimova EY, Koivunen P. Hypoxia ameliorates maternal diet-induced insulin resistance during pregnancy while having a detrimental effect on the placenta. Physiol Rep. 2022 May;10(9):e15302. doi: 10.14814/phy2.15302. PMID: 35535947; PMCID: PMC9088222.
10. Arbour MW, Stec M, Walker KC, Wika JC. Clinical Implications for Women of a Low-Carbohydrate or Ketogenic Diet With Intermittent Fasting. Nurs Womens Health. 2021 Apr;25(2):139-151. doi: 10.1016/j.nwh.2021.01.009. PMID: 33838849.
11. Hong Y, Xie QX, Chen CY, Yang C, Li YZ, Chen DM, Xie MQ. Insulin resistance in first-trimester pregnant women with pre-pregnant glucose tolerance and history of recurrent spontaneous abortion. J Biol Regul Homeost Agents. 2013 Jan-Mar;27(1):225-31. PMID: 23489701.
12. Wang Y, Zhao H, Li Y, Zhang J, Tan J, Liu Y. Relationship between recurrent miscarriage and insulin resistance. Gynecol Obstet Invest. 2011;72(4):245-51. doi: 10.1159/000325165. Epub 2011 Sep 24. PMID: 21952420.
13. Catalano PM, McIntyre HD, Cruickshank JK, McCance DR, Dyer AR, Metzger BE, Lowe LP, Trimble ER, Coustan DR, Hadden DR, Persson B, Hod M, Oats JJ; HAPO Study Cooperative Research Group. The hyperglycemia and adverse pregnancy outcome study: associations of GDM and obesity with pregnancy outcomes. Diabetes Care. 2012 Apr;35(4):780-6. doi: 10.2337/dc11-1790. Epub 2012 Feb 22. PMID: 22357187; PMCID: PMC3308300..
14. Shepherd E, Gomersall JC, Tieu J, Han S, Crowther CA, Middleton P. Combined diet and exercise interventions for preventing gestational diabetes mellitus. Cochrane Database Syst Rev. 2017 Nov 13;11(11):CD010443. doi: 10.1002/14651858.CD010443.pub3. PMID: 29129039; PMCID: PMC6485974..
15. Modzelewski R, Stefanowicz-Rutkowska MM, Matuszewski W, Bandurska-Stankiewicz EM. Gestational Diabetes Mellitus-Recent Literature Review. J Clin Med. 2022 Sep 28;11(19):5736. doi: 10.3390/jcm11195736. PMID: 36233604; PMCID: PMC9572242.
16. Mijatovic-Vukas J, Capling L, Cheng S, Stamatakis E, Louie J, Cheung NW, Markovic T, Ross G, Senior A, Brand-Miller JC, Flood VM. Associations of Diet and Physical Activity with Risk for Gestational Diabetes Mellitus: A Systematic Review and Meta-Analysis. Nutrients. 2018 May 30;10(6):698. doi: 10.3390/nu10060698. PMID: 29849003; PMCID: PMC6024719..
17. Mahajan A, Donovan LE, Vallee R, Yamamoto JM. Evidenced-Based Nutrition for Gestational Diabetes Mellitus. Curr Diab Rep. 2019 Aug 31;19(10):94. doi: 10.1007/s11892-019-1208-4. PMID: 31473839.
18. Poston L, Bell R, Briley AL, Godfrey KM, Nelson SM, Oteng-Ntim E, Sandall J, Sanders TAB, Sattar N, Seed PT, Robson SC, Trépel D, Wardle J. Improving pregnancy outcome in obese women: the UK Pregnancies Better Eating and Activity randomised controlled Trial. Southampton (UK): NIHR Journals Library; 2017 Apr. PMID: 28671801.

19. Mokkala K, Paulin N, Houttu N, Koivuniemi E, Pellonperä O, Khan S, Pietilä S, Tertti K, Elo LL, Laitinen K. Metagenomics analysis of gut microbiota in response to diet intervention and gestational diabetes in overweight and obese women: a randomised, double-blind, placebo-controlled clinical trial. Gut. 2021 Feb;70(2):309-318. doi: 10.1136/gutjnl-2020-321643. Epub 2020 Aug 24. PMID: 32839200.
20. Laredo-Aguilera JA, Gallardo-Bravo M, Rabanales-Sotos JA, Cobo-Cuenca AI, Carmona-Torres JM. Physical Activity Programs during Pregnancy Are Effective for the Control of Gestational Diabetes Mellitus. Int J Environ Res Public Health. 2020 Aug 24;17(17):6151. doi: 10.3390/ijerph17176151. PMID: 32847106; PMCID: PMC7503359.
21. Zehravi M, Maqbool M, Ara I. Correlation between obesity, gestational diabetes mellitus, and pregnancy outcomes: an overview. Int J Adolesc Med Health. 2021 Jun 18;33(6):339-345. doi: 10.1515/ijamh-2021-0058. PMID: 34142511.
22. Han S, Crowther CA, Middleton P. Interventions for pregnant women with hyperglycaemia not meeting gestational diabetes and type 2 diabetes diagnostic criteria. Cochrane Database Syst Rev. 2012 Jan 18;1(1):CD009037. doi: 10.1002/14651858.CD009037.pub2. PMID: 22258997; PMCID: PMC8939248.
23. Brown J, Ceysens G, Boulvain M. Exercise for pregnant women with gestational diabetes for improving maternal and fetal outcomes. Cochrane Database Syst Rev. 2017 Jun 22;6(6):CD012202. doi: 10.1002/14651858.CD012202.pub2. PMID: 28639706; PMCID: PMC6481507.
24. Han S, Middleton P, Shepherd E, Van Ryswyk E, Crowther CA. Different types of dietary advice for women with gestational diabetes mellitus. Cochrane Database Syst Rev. 2017 Feb 25;2(2):CD009275. doi: 10.1002/14651858.CD009275.pub3. PMID: 28236296; PMCID: PMC6464700.
25. Hernandez TL, Van Pelt RE, Anderson MA, Daniels LJ, West NA, Donahoo WT, Friedman JE, Barbour LA. A higher-complex carbohydrate diet in gestational diabetes mellitus achieves glucose targets and lowers postprandial lipids: a randomized crossover study. Diabetes Care. 2014;37(5):1254-62. doi: 10.2337/dc13-2411. Epub 2014 Mar 4. PMID: 24595632; PMCID: PMC3994935.
26. Mahajan A, Donovan LE, Vallee R, Yamamoto JM. Evidenced-Based Nutrition for Gestational Diabetes Mellitus. Curr Diab Rep. 2019 Aug 31;19(10):94. doi: 10.1007/s11892-019-1208-4. PMID: 31473839.
27. Rasmussen L, Poulsen CW, Kampmann U, Smedegaard SB, Ovesen PG, Fuglsang J. Diet and Healthy Lifestyle in the Management of Gestational Diabetes Mellitus. Nutrients. 2020 Oct 6;12(10):3050. doi: 10.3390/nu12103050. PMID: 33036170; PMCID: PMC7599681.
28. Doi SAR, Furuya-Kanamori L, Toft E, Musa OAH, Mohamed AM, Clark J, Thalib L. Physical activity in pregnancy prevents gestational diabetes: A meta-analysis. Diabetes Res Clin Pract. 2020 Oct;168:108371. doi: 10.1016/j.diabres.2020.108371. Epub 2020 Aug 20. PMID: 32827593.
29. Vargas-Terrones M, Nagpal TS, Barakat R. Impact of exercise during pregnancy on gestational weight gain and birth weight: an overview. Braz J Phys Ther. 2019 Mar-Apr;23(2):164-169. doi: 10.1016/j.bjpt.2018.11.012. Epub 2018 Nov 22. PMID: 30527949; PMCID: PMC6428912

30. Ornoy A. Prenatal origin of obesity and their complications: Gestational diabetes, maternal overweight and the paradoxical effects of fetal growth restriction and macrosomia. Reprod Toxicol. 2011 Sep;32(2):205-12. doi: 10.1016/j.reprotox.2011.05.002. Epub 2011 May 19. PMID: 21620955.