

# Relationship between Physical Activity of Preconception Women and the Incidence of Gestational Diabetes Mellitus: Systematic Literature Review

Mahda Putri Kusumawardhani<sup>1\*</sup>, Anisa Lailatul Fitria<sup>1</sup>

<sup>1</sup>Department of Nutrition, Faculty of Public Health, Universitas Airlangga, Surabaya, 60115, Indonesia

## Article Info

### \*Correspondence:

Mahda Putri  
Kusumawardhani  
[mahda.putri.kusumawardhani-2021@fkm.unair.ac.id](mailto:mahda.putri.kusumawardhani-2021@fkm.unair.ac.id)

Submitted: 05-05-2025

Accepted: 24-11-2025

Published: 01-12-2025

### Citation:

Kusumawardhani, M. P., & Fitria, A. L. (2025). Relationship between Physical Activity of Preconception Women and the Incidence of Gestational Diabetes Mellitus: Systematic Literature Review. *Media Gizi Kesmas*, 14(2), 351-358.  
<https://doi.org/10.20473/mgk.v14i2.2025.351-358>

### Copyright:

©2025 by  
Kusumawardhani and  
Fitria, published by  
Universitas Airlangga.  
This is an open-access  
article under CC-BY-SA  
license.



## ABSTRACT

**Background:** Glucose intolerance is a hallmark of gestational diabetes mellitus in the early stages of pregnancy. Maternal and perinatal problems such as preeclampsia, gestational hypertension, cesarean delivery, macrosomia, and still birth are frequently caused by gestational diabetes mellitus. Another treatment option for preventing gestational diabetes mellitus is exercise, both before and during pregnancy. Physical activity plays a role in regulating glucose homeostasis, indirectly or directly, and impacts insulin sensitivity through several mechanisms.

**Objectives:** This study to assemble strong evidence regarding the relationship between a woman's preconception or prenatal physical activity and her risk of gestational diabetes mellitus.

**Methods:** This research was conducted through a systematic literature review using Google Scholar, EMBASE, MEDLINE, ScienceDirect, and PubMed, compiled according to the PRISMA guidelines. The literature search used the PICO framework with inclusion and exclusion criteria and found seven studies that were included.

**Results:** The results showed that physical activity before or in early pregnancy, such as walking, jogging, cycling, aerobics, swimming, yoga, etc., which routinely performed, reduced the risk of gestational diabetes mellitus. When doing physical activity, muscles will use glucose to reduce stored glucose. In filling the glucose deficiency, the muscles take blood glucose, causing blood glucose to decrease so that it can control one's blood sugar. The best strategy to reduce the risk of gestational diabetes mellitus is to be physically active both before and throughout pregnancy.

**Conclusions:** Exercise during preconception and the first few months of pregnancy lowers the risk of developing gestational diabetes mellitus.

**Keywords:** Gestational Diabetes Mellitus, Maternal Health, Physical Activity, Preconception.

## INTRODUCTION

According to Harizopoulou *et al.* (2010), glucose intolerance that manifests or is initially identified early in pregnancy is known as gestational diabetes mellitus. The National Institute for Health and Care Excellence (NICE) defines it as fasting blood sugar of 5.6 mmol/L or a 2-hour plasma blood sugar of 7.8 mmol/L (Diabetes in pregnancy, 2015). Maternal and perinatal problems such as

preeclampsia, gestational hypertension, cesarean delivery, macrosomia, and stillbirth are primarily caused by gestational diabetes mellitus (American College of Obstetricians and Gynecologists, 2018c). Mothers with diabetes give birth to almost 21 million children globally in 2017 (Cho *et al.*, 2018). In the United States, 6.0% of women who gave birth in 2016 had gestational diabetes mellitus (Deputy *et al.*, 2018). Compared to normal weight women, those who are overweight have a 2-3 and a 5-6 times

higher risk of developing gestational diabetes mellitus, respectively (Aune *et al.*, 2016). Women with decreased pancreatic reserves are unable to produce sufficient insulin to counteract the increased insulin resistance caused by the combined effects of growth hormone, prolactin, placental lactogen, cortisol, and progesterone. This results in glucose intolerance and gestational diabetes mellitus (Marcherya and Prabowo, 2018). The International Diabetes Federation (IDF) reported in 2017 that gestational diabetes mellitus affects more than 14% of pregnancies and is associated with more than 18 million babies born annually (Plows *et al.*, 2018).

Women with this disease are managed with nutritional counseling that includes calorie reduction or insulin therapy when diet alone is not enough to control normoglycemia (American Diabetes Association, 2004). Recently, physical activity prior to and during pregnancy can be an alternative therapy to prevent gestational diabetes mellitus (Aune *et al.*, 2016). Exercise has a benefit in controlling glucose homeostasis, directly or indirectly, and impacts insulin sensitivity through several mechanisms (Tobias *et al.*, 2011). This is very important, especially during the preconception and pregnancy period. The preconception period is an important moment when physical activity can help prepare the body for a healthy pregnancy in the future (Ngongalah *et al.*, 2018). Currently, women are advised to do exercise for 150-300 minutes/week at moderate intensity during pregnancy and after giving birth (Mijatovic-Vukas *et al.*, 2018). Studies have shown that insufficient physical activity before pregnancy is linked to a continued pattern of low activity throughout the gestational period. This decline in physical activity results in decreased cardiovascular fitness and muscle weakness (Gaston and Cramp, 2011).

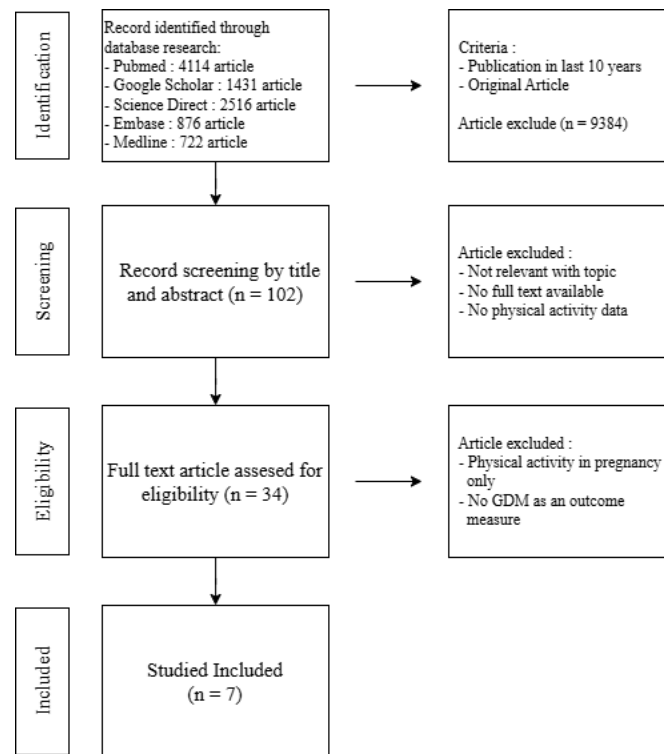
With the increasing prevalence of gestational diabetes mellitus, researchers are encouraged to better identify lifestyle factors that may contribute to, increase, or prevent this disease (Gaston and Cramp, 2011). According to the Gestational Diabetes Prevention Study (RADIEL), consuming various fruits, vegetables, grains, and leading an active lifestyle as advised can lower the risk of developing gestational diabetes mellitus by about 40% (Koivusalo *et al.*, 2016). According to WHO guidelines, between the ages of 16 and 64, people should engage in vigorous activity for 75 minutes per week or 150 minutes of moderate exercise (WHO, 2010). Physical activity can also be performed during leisure time, such as walking, dancing, gardening, mountain climbing, swimming, and cycling. Frequent exercise reduces the likelihood of adverse pregnancy outcomes, supports healthy pregnancy conditions, and aids in maintaining a healthy weight (da Silva *et al.*, 2017).

The potential risk of gestational diabetes mellitus also includes hypoglycemia, obese offspring, and later type 2 diabetes mellitus (Lehnen, Zechner and Haaf, 2013). For women who are not pregnant, there is substantial evidence that physical activity helps prevent and control type 2 diabetes mellitus. Physical activity before pregnancy or throughout the preconception period has also been shown to lower the incidence of gestational diabetes mellitus (Dempsey *et al.*, 2004). Therefore, engaging in physical exercise prior to pregnancy may help avoid the development of gestational diabetes mellitus and its associated health consequences. The goal of this systematic literature review is to gather robust evidence about the association between a woman's preconception or prenatal physical activity and her risk of gestational diabetes mellitus.

## METHODS

This study employs a systematic literature review approach. A systematic literature review is prepared using the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA). Article were identified using the databases Google Scholar, EMBASE, Medline, ScienceDirect, and PubMed as part of the data collection process. This systematic literature review's keywords were modified to align with the Medical Subject Heading (MeSH), using the following terms: ('physical activities' or 'physical activity') and ('preconception care' or 'preconception' or 'before pregnancy') and ('gestational diabetes mellitus' or 'gestational diabetes' or 'gestational diabetes mellitus'). The PICO (Population, Intervention, Comparison, and Outcome) paradigm was utilized to determine the inclusion and exclusion criteria for this article search. The inclusion criteria include preconception women, incident gestational diabetes mellitus related to lack of physical activity, original article, and publications from the last 10 years. Pregnant women with diabetes mellitus due to dietary factors or a history of disease were not included in this literature review.

The first step in this research was to search for and identify articles through the databases Google Scholar, EMBASE, Medline, ScienceDirect, and PubMed. The second step was the selection of the identified articles. Based on the search results, there were 9,659 articles, and title screening resulted in 275 articles. The articles were then selected based on the abstract, population, and research design, resulting in 7 articles that were in accordance with the PICO framework. Figure 1 displays the PRISMA diagram of the literature search approach employed in this investigation.



**Figure 1.** PRISMA flow diagram for study inclusion, screening, and selection

## RESULTS AND DISCUSSION

Multiple variables, such as lifestyle, physical activity, and diet, contribute to gestational diabetes mellitus (Gou *et al.*, 2019). Pregnancy-related morbidity, reduced glucose tolerance, type 2 diabetes mellitus, and a markedly elevated risk of long-term problems for both the child and the mother are all linked to gestational diabetes mellitus (Tobias *et al.*, 2011). Gestational diabetes mellitus was diagnosed in the 8<sup>th</sup> week of pregnancy (Jenum *et al.*, 2010). Gestational diabetes mellitus is identified if fasting blood sugar is  $\geq 5.1$  mmol/L or 2-hours plasma glucose is  $\geq 8.5$  mmol/L (Metzger, 2010). Physical activity is an effort to prevent long-term changes in insulin sensitivity by increasing free fat metabolism (Małkowska, 2024). The rate at which muscle blood sugar returns is directly correlated with physical exercise. Muscles will utilize glucose during exercise, causing stored glucose to drop. In addressing the glucose deficiency, muscles take blood glucose, resulting in a decrease in blood glucose levels. This helps control a person's blood sugar (Nurayati and Adriani, 2017). Pregnant women should do moderate-intensity physical activity for at least 150 minutes each week (Piercy *et al.*, 2022). Exercise is therefore strongly advised for women both before and during the first few months of pregnancy. One can engage in aerobics, swimming, yoga, cycling, jogging, walking, and other physical activities.

The occurrence of gestational diabetes mellitus is also correlated with unhealthy lifestyles

such as lack of exercise and smoking. The results of research by Cuilin Zhang *et al.* (2014) show that women who combine three low-risk variables (healthy diet,  $\geq 150$  minutes of moderate-to-intense physical activity, and avoiding smoking) during the preconception period have a 41% decreased risk of developing gestational diabetes mellitus. Every physical activity measured by the amount of time spent engaging in exercise each week, including brisk walking, is included in the physical activity that women engage in during the preconception period (Zhang *et al.*, 2014). This is consistent with studies carried out by Vicentia CH *et al.*, which showed that "inactive" women prior to or throughout the first trimester of pregnancy had an Odds Ratio (OR) of 7.9 [95% CI 3.7–16.56] and 1.3 (95% CI 1.2–1.4). This implies that women who do not exercise before or during the early stages of pregnancy are 7.9 times more likely to develop gestational diabetes mellitus than women who were "slightly active" or "active" when exercising (Ehrlich, S. F *et al.*, 2021). Avoidance and treatment of gestational diabetes mellitus, physical activity is advised both before and throughout pregnancy (Aune *et al.*, 2016). Physical activity enhances insulin response to glucose load and glucose tolerance, hence avoiding the development of type 2 diabetes mellitus, according to strong evidence from observational research. In addition, a higher risk of gestational diabetes mellitus is linked to insufficient or inactive physical activity prior to pregnancy (Sitzberger *et al.*, 2020).

**Table 1.** Author, year, country of origin, study cases, number of cases GDM, activity measure, type of physical activity, and main results on physical activity in pre-conception and gestational diabetes.

| No. | Title                                                                                                                  | Author, Year                 | Country           | Sample           | Physical Activity Measurement                                                                                          | Exposure Groups                                                                                                                                                                                                                                                                                                                                   | Physical activity                                                                                                                                                                                            | Main Results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|-----|------------------------------------------------------------------------------------------------------------------------|------------------------------|-------------------|------------------|------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | Adherence to healthy lifestyle and risk of gestational diabetes mellitus: prospective cohort study                     | Zhang <i>et al.</i> , 2014   | United States     | 20136; 270 cases | Frequency min/week)                                                                                                    | ≥150 min/week                                                                                                                                                                                                                                                                                                                                     | Aerobic exercises include jogging, running, tennis, squash or racquetball, cycling, calisthenics or using a rowing machine, and lap swimming. Walking (includes walking to work) or trekking in the outdoors | <ul style="list-style-type: none"> <li>- The chance of developing gestational diabetic mellitus is substantially correlated with moderate to intense exercise prior to pregnancy.</li> <li>- A decreased chance of GDM is substantially correlated with regular exercise prior to pregnancy.</li> <li>- GDM is a risk factor for 11% (7% to 21%) of pregnant women who do not exercise.</li> </ul>                                                                                                                                                                                                                   |
| 2   | Leisure Time Physical Activity and Gestational Diabetes Mellitus in the Omega Study                                    | Badon <i>et al.</i> , 2017   | Washington States | 3209; 745 cases  | <ul style="list-style-type: none"> <li>- LTPA energy expenditure in MET hours/week</li> <li>- LTPA duration</li> </ul> | <ul style="list-style-type: none"> <li>- Energy expenditure:               <ul style="list-style-type: none"> <li>1= 0.03-3.11</li> <li>2= 3.12-5.99</li> <li>3= 6-32.5</li> </ul> </li> <li>- LTPA duration:               <ul style="list-style-type: none"> <li>1= 0.15-14.5</li> <li>2= 14.6-29</li> <li>3= 29.1-279.7</li> </ul> </li> </ul> | LTPA (weightlifting, jogging, swimming, walking, cycling, trekking, yoga, and aerobic and dance exercises)                                                                                                   | <ul style="list-style-type: none"> <li>- LTPA during preconception and the first trimester of pregnancy is associated with a decreased risk of GDM.</li> <li>- Compared to women who did not undertake LTPA, 45% of women who had a long duration of LTPA or energy expenditure had a lower chance of developing GDM.</li> <li>- Among women with longer LTPA durations, 41% had a lower risk of developing GDM.</li> <li>- Compared to women who are inactive during both the preconception and early pregnancy phases, active women have a decreased chance of acquiring gestational diabetes mellitus.</li> </ul> |
| 3   | Exercise During the First Trimester of Pregnancy and the Risks of Abnormal Screening and Gestational Diabetes Mellitus | Ehrlich <i>et al.</i> , 2021 | California Utara  | 2246; 147 cases  | Physical activity volume (MET hours/week)                                                                              | <ul style="list-style-type: none"> <li>1= moderate to vigorous intensity (≥13.2 MET-h/week)</li> <li>2= moderate exercise (≥7.5 MET-h/week)</li> <li>3= any vigorous activity</li> </ul>                                                                                                                                                          | Walking, swimming, walking quickly up hills, jogging, and resistance exercise                                                                                                                                | GDM risk can be effectively decreased by exercise during the first trimester of pregnancy. Higher exercise suggestions are necessary, though. Doing moderate-intensity exercise for at least 38 minutes each day can help prevent GDM.                                                                                                                                                                                                                                                                                                                                                                               |

| No. | Title                                                                                                                           | Author, Year                     | Country       | Sample         | Physical Activity Measurement                       | Exposure Groups                                                                                              | Physical activity                                                                   | Main Results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|-----|---------------------------------------------------------------------------------------------------------------------------------|----------------------------------|---------------|----------------|-----------------------------------------------------|--------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 4   | Physical activity before and during pregnancy and risk of abnormal glucose tolerance among Hispanic women                       | Chasan, Silveira and Lynch, 2016 | Puerto Riko   | 1241; 57 cases | Total energy expenditure in MET-hours/day           | - Moderate intensity activity 3-6 METs<br>- Vigorous activity as >6 METs                                     | - Domestic/caregiving<br>- Employment<br>- Sports/exercise                          | - There was no obvious connection between physical activity before pregnancy, intensity, or type with the risk of GDM in the Hispanic group.                                                                                                                                                                                                                                                                                                                                                                                          |
| 5   | The Association Between Physical Activity and Maternal and Neonatal Outcomes: A Prospective Cohort                              | Currie <i>et al.</i> , 2014      | Canada        | 1749; 33 cases | KPAS (Kaiser Physical Activity Survey) score 3 – 15 | Prepregnancy:<br>1= <7.72<br>2= 7.72-<9.3<br>3= ≥ 9.39<br>Pregnancy<br>1= <6.44<br>2= 6.44-<7.97<br>3= ≥7.79 | - Active living<br>- Caregiving and household duties<br>- Sports/exercise           | - The risk of GDM was lower for women in the middle-high tertile [OR (CI): 0.29 (0.12–0.74) and 0.33 (0.12–0.88), respectively].<br>- Physical activity before pregnancy is linked to an increase in gestational weight, but not during the first trimester of pregnancy; pregnant women who were physically active prior to becoming pregnant typically become less active while pregnant.                                                                                                                                           |
| 6   | Objectively recorded physical activity and the association with gestational diabetes                                            | Morkrid K <i>et al.</i> , 2014   | Norwegia      | 759; 239 cases | Frekuensi (min/week)                                | ≥150 min/week                                                                                                | Swimming, brisk walking, dancing, ball games, aerobic classes, running, and cycling | - Women identified as having GDM at week 28 had a lower average number of steps per day compared to those with moderate-high physical activity (P<0.005).                                                                                                                                                                                                                                                                                                                                                                             |
| 7   | Maternal Moderate-to-Vigorous Physical Activity before and during Pregnancy and Maternal Glucose Tolerance: Does Timing Matter? | Mcdonald <i>et al.</i> , 2021    | United States | 2388; NR cases | Total energy expenditure in MET-min/week            | 1= ≤220.5<br>2= 220.5-643.5<br>3= 643.5-1329.75<br>4= ≤1329.75                                               | Sports/exercise activities                                                          | - Maternal MVPA decreases during the prenatal and postconception phases.<br>- Elevated MVPA levels during the first trimester and preconception are not linked to an increased risk of GDM.<br>- High MVPA levels from the beginning to the 2nd trimester are not associated with GDM risk.<br>- There is no correlation between the risk of GDM and elevated MVPA levels from preconception to late pregnancy.<br>- Moreover, MVPA levels in the middle to late stages of pregnancy did not correlate with the chance of having GDM. |

Exercise prior to or during the preconception period is also linked to gestational weight gain, but not during pregnancy (Currie *et al.*, 2014). Groups based on gestational weight gain were created by the Institute of Medicine (IOM) guidelines. Gestational weight gain of <12.5 kg for underweight women, <7 kg for overweight women, 11.5 kg for normal-weight women, and <5 kg for obese women was categorized as insufficient gestational weight gain (Gou, B. H *et al.*, 2019). In research by Lisa M. *et al.*, it was reported that physical activity, including exercise (p-value 0.01) and active living (p-value 0.03), was associated with the likelihood of significant gestational weight gain prior to pregnancy. According to Badon *et al.* (2017), the study reported that although many women were physically active before pregnancy, their level of physical activity tended to decrease during pregnancy. This decline may be due to factors such as fatigue, physical changes, or concerns about the baby's health. Therefore, even though women who were active before pregnancy tend to remain active, their activity levels may decrease during pregnancy. A lower risk of gestational diabetes mellitus is closely linked to exercise both prior to and during pregnancy. Being active prior to or during the early months of pregnancy alone is not sufficient. This relationship becomes more significant when physical activity is performed in both periods, namely before pregnancy (preconception) and during early pregnancy (McDonald *et al.*, 2021). According to studies by Ehrlich *et al.* (2021), pregnant women without health issues or contraindications to physical exercise should engage in increased levels of exercise in the early stages of their pregnancy. Preventing GDM during pregnancy can be achieved by increasing moderate-intensity exercise by at least 38 minutes, each day (Ehrlich, S. F *et al.*, 2021).

A previous study reported no relationship between physical activity before and during the first few months of pregnancy and the risk of gestational diabetes mellitus. However, this contradicts the findings of other studies. Although not statistically significant, this study also showed that women with moderate physical activity and active jobs had a lower risk of glucose abnormalities than those who engaged in light physical activity (Chasan, Silveira, and Lynch, 2016). According to a study by L. Chasan-Taber *et al.* (2016), healthy lifestyle choices during pregnancy can reduce the risk of gestational diabetes mellitus and postpartum complications. There is a 50% likelihood of a reduction in abnormal glucose tolerance in women who engage in physical activity before and during the early months of pregnancy (Mørkrid *et al.*, 2014).

## CONCLUSION

The risk of gestational diabetes mellitus may be reduced by physical exercise before or during the preconception period. One can engage in

aerobics, swimming, yoga, cycling, jogging, walking, and other physical activities. Physical activity prior to or during the preconception period is also associated with gestational weight gain. Therefore, engaging in physical exercise prior to becoming pregnant helps prevent excessive weight gain, which reduces the risk of developing gestational diabetes. Exercise will, however, have a greater impact on lowering the risk of gestational diabetes mellitus both before and during the first few months of pregnancy. In preparing for pregnancy, engaging in regular physical activity before conception has a positive impact on the health of both the mother and the child. This habit of regular physical activity is likely to continue during pregnancy, which can help reduce the risk of gestational diabetes mellitus in pregnant women.

## Acknowledgement

The authors are grateful to the Department of Nutrition, Faculty of Public Health, Universitas Airlangga for support.

## Conflict of Interest and Funding Disclosure

None

## Author Contributions

MPK: data retrieval/investigation, data analysis, writing-original draft, writing-review, editing, visualization; ALF: supervision, validation.

## REFERENCES

- American College of Sports Medicine (ACSM). (2018) 'ACSM's Guidelines for Exercise Testing and Prescription'.
- Aune, D. *et al.* (2016) 'Physical activity and the risk of gestational diabetes mellitus: a systematic review and dose-response meta-analysis of epidemiological studies', *European Journal of Epidemiology*, 31(10), pp. 967–997. doi: 10.1007/s10654-016-0176-0.
- Badon, S. *et al.* (2017) 'Leisure Time Physical Activity and Gestational Diabetes Mellitus in the Omega Study', *Med Sci Sports Exerc*, 48(6), pp. 1044–1052. doi: 10.1249/MSS.0000000000000866.
- Chasan, L., Silveira, M. and Lynch, K. (2016) 'Physical activity before and during pregnancy and risk of abnormal glucose tolerance among Hispanic women', *Physiology & behavior*, 176(1), pp. 139–148. doi: 10.1016/j.diabet.2013.09.005.
- Cho, N. H. *et al.* (2018) 'IDF Diabetes Atlas: Global estimates of diabetes prevalence for 2017 and projections for 2045', *Diabetes*

- Research and Clinical Practice*, 138, pp. 271–281. doi: 10.1016/j.diabres.2018.02.023.
- Currie, L. M. *et al.* (2014) 'The association between physical activity and maternal and neonatal outcomes: A prospective cohort', *Maternal and Child Health Journal*, 18(8), pp. 1823–1830. doi: 10.1007/s10995-013-1426-3.
- Da Silva, S. G. *et al.* (2017) 'Leisure-Time Physical Activity in Pregnancy and Maternal-Child Health: A Systematic Review and Meta-Analysis of Randomized Controlled Trials and Cohort Studies', *Sports Medicine*, 47(2), pp. 295–317. doi: 10.1007/s40279-016-0565-2.
- Dempsey, J. C. *et al.* (2004) 'A case-control study of maternal recreational physical activity and risk of gestational diabetes mellitus', *Diabetes Research and Clinical Practice*, 66(2), pp. 203–215. doi: 10.1016/j.diabres.2004.03.010.
- Deputy, N. *et al.* (2018) 'Prevalence and Changes in Preexisting Diabetes and Gestational Diabetes Among Women Who Had a Live Birth — United States, 2012–2016', *Centers for Disease Control and Prevention. MMWR*, 67(43), pp. 1–7.
- Diabetes in pregnancy. (2015) 'Management of diabetes and its complications from preconception to the postnatal period'. *NICE Clinical Guideline*.
- Gaston, A. and Cramp, A. (2011) 'Exercise during pregnancy: A review of patterns and determinants', *Journal of Science and Medicine in Sport*, 14(4), pp. 299–305. doi: 10.1016/j.jsams.2011.02.006.
- Gou, B. H. *et al.* (2019) 'Gestational diabetes: Weight gain during pregnancy and its relationship to pregnancy outcomes', *Chinese Medical Journal*, 132(2), pp. 154–160. doi: 10.1097/CM9.0000000000000036.
- Harizopoulou, V. C. *et al.* (2010) 'Maternal physical activity before and during early pregnancy as a risk factor for gestational diabetes mellitus', *Acta Diabetologica*, 47(SUPPL. 1). doi: 10.1007/s00592-009-0136-1.
- Hu, F. B. *et al.* (2003) 'Television Watching and Other Sedentary Behaviors in Relation to Risk of Obesity and Type 2 Diabetes Mellitus in Women', *Jama*, 289(14), pp. 1785–1791. doi: 10.1001/jama.289.14.1785.
- Jenum, A. K. *et al.* (2010) 'The STORK Gørudalen research programme: A population-based cohort study of gestational diabetes, physical activity, and obesity in pregnancy in a multiethnic population. Rationale, methods, study population, and participation rates', *Scandinavian Journal of Public Health*, 38(5\_suppl), pp. 60–70. doi: 10.1177/1403494810378921.
- Koivusalo, S. B. *et al.* (2016) 'Gestational Diabetes Mellitus Can Be Prevented by Lifestyle Intervention: The Finnish Gestational Diabetes Prevention Study (RADIEL): A Randomized Controlled Trial', *Diabetes Care*, 39(1), pp. 24–30. doi: 10.2337/dc15-0511.
- Lehnen, H., Zechner, U. and Haaf, T. (2013) 'Epigenetics of gestational diabetes mellitus and offspring health: The time for action is in early stages of life', *Molecular Human Reproduction*, 19(7), pp. 415–422. doi: 10.1093/molehr/gat020.
- Małkowska, P. (2024) 'Positive Effects of Physical Activity on Insulin Signaling', *Current Issues in Molecular Biology*, 46(6), pp. 5467–5487. doi: 10.3390/cimb46060327.
- Marcherya, A. and Prabowo, A. Y. (2018) 'Khasiat Senam Hamil Sebagai Terapi dan Pencegahan Diabetes Melitus Gestasional The Effect of Gymnastics Pregnancy As Therapy and Prevention Of Gestational Diabetes Melitus', *Majority*, 7, pp. 273–277. Available at: <http://juka.kedokteran.unila.ac.id/index.php/majority/article/view/1889/1857>.
- Mcdonald, S. M. *et al.* (2021) 'Maternal Moderate-to-Vigorous Physical Activity before and during Pregnancy and Maternal Glucose Tolerance: Does Timing Matter?', *Medicine and Science in Sports and Exercise*, 53(12), pp. 2520–2527. doi: 10.1249/MSS.00000000000002730.
- Metzger, B. E. (2010) 'International Association of Diabetes and Pregnancy Study Groups recommendations on the diagnosis and classification of hyperglycemia in pregnancy', *Diabetes Care*, 33(3), pp. 676–682. doi: 10.2337/dc09-1848.
- Mijatovic-Vukas, J. *et al.* (2018) 'Associations of diet and physical activity with risk for gestational diabetes mellitus: A Systematic review and meta-analysis', *Nutrients*, 10(6). doi: 10.3390/nu10060698.
- Mørkrid, K. *et al.* (2014) 'Objectively recorded physical activity and the association with gestational diabetes', *Scandinavian Journal of Medicine and Science in Sports*, 24(5), pp. e389–e397. doi: 10.1111/sms.12183.
- Ngongalah, L. *et al.* (2018) 'Dietary and physical activity behaviours in African migrant women living in high income countries: A

- systematic review and framework synthesis', *Nutrients*, 10(8). doi: 10.3390/nu10081017.
- Nurayati, L. and Adriani, M. (2017) 'Hubungan Aktivitas Fisik dengan Kadar Gula Darah Puasa Penderita Diabetes Melitus Tipe 2', *Amerta Nutrition*, 1(2), p. 80. doi: 10.20473/amnt.v1i2.6229.
- Piercy, K. *et al.* (2022) 'The Physical Activity Guidelines for Americans.', 320(19), pp. 2020–2028. doi: 10.1001/jama.2018.14854.The.
- Plows, J. F. *et al.* (2018) 'The pathophysiology of gestational diabetes mellitus', *International Journal of Molecular Sciences*, 19(11), pp. 1–21. doi: 10.3390/ijms19113342.
- Sitzberger, C. *et al.* (2020) 'Gestational Diabetes: Physical Activity Before Pregnancy and Its Influence on the Cardiovascular System', *Frontiers in Pediatrics*, 8(August), pp. 1–8. doi: 10.3389/fped.2020.00465.
- Shulman, G. *et al.* (1990) 'Quantitation of muscle glycogen synthesis in normal subjects and subjects with non-insulindependent diabetes by <sup>13</sup>C nuclear magnetic resonance spectroscopy', *The New English Journal of medicine*, 323(16), pp. 1120–1123. doi: 10.1056/NEJM199001253220403.
- The American College of Obstetricians and Gynecologists. (2020) 'Physical activity and exercise during pregnancy and the postpartum period: ACOG committee opinion, number 804', *Obstet Gynecol*, 135, pp 178–188
- Tobias, D. K. *et al.* (2011) 'Physical activity before and during pregnancy and risk of gestational diabetes mellitus: A meta-analysis', *Diabetes Care*, 34(1), pp. 223–229. doi: 10.2337/dc10-1368.
- World Health Organization. (2010) 'Global Recommendations on Physical Activity for Health; *World Health Organization*: Geneva, Switzerland, 2010; pp. 34–58.
- Zhang, C. *et al.* (2014) 'Adherence to healthy lifestyle and risk of gestational diabetes mellitus: Prospective cohort study', *BMJ (Online)*, 349(September), pp. 1–11. doi: 10.1136/bmj.g5450.