PREVENTING GESTATIONAL DIABETES IN HIGH-RISK PREGNANT WOMEN WITH AEROBIC EXERCISE: A SYSTEMATIC REVIEW

Ibrahim FS[1], Ahmad Fazli NN[2], Muniandy ND[3], and Ariani F[4]

[1]*Department of Basic Sciences, Faculty of Health Sciences, Universiti Teknologi MARA, Puncak Alam Campus, 42300 Puncak Alam, Selangor, Malaysia*

[2]*Centre of Physiotherapy, Faculty of Health Sciences, Universiti Teknologi MARA, Puncak Alam Campus, 42300 Puncak Alam, Selangor, Malaysia*

[3]*Centre of Dietetics, Faculty of Health Sciences, Universiti Teknologi MARA, Puncak Alam Campus, 42300 Puncak Alam, Selangor, Malaysia*

[4]*Departement of Nursing, Faculty of Health Sciences, Aisyiyah Bandung University, Bandung, Indonesia*

Correspondence:
Farrah Shafeera Ibrahim,
Department of Basic Sciences,
Faculty of Health Sciences,
Universiti Teknologi MARA,
Puncak Alam Campus,
42300 Puncak Alam, Selangor, Malaysia
Email: shafeera@uitm.edu.my

Abstract

Gestational diabetes mellitus (GDM) is any glucose intolerance that appears or is diagnoses for the first-time during pregnancy. According to International Diabetes Federation, the worldwide prevalence of gestational diabetes mellitus in 2019 was 14.4%, while in Malaysia for 2019 was 22.5%. The purpose of this study was to review the effectiveness of aerobic exercise in preventing gestational diabetes mellitus among pregnant women at risk towards fasting blood glucose level, insulin resistance level, and oral glucose tolerance test level. This study was designed based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyse (PRISMA) checklist. A total of five databases were used: Scopus, Web of Science (WoS), MEDLINE (EBSCO), PubMed (NCBI) and Cochrane library. Data were extracted based on PICO framework. Study bias was assessed using Physiotherapy Evidence Database (PEDro) scale. The findings of the studies were analysed into three themes according to outcome measures. Five studies from 1,866 studies were included. Three studies showed significant improvement results, while two showed no significant or similar results between groups in related outcome measures.

The result indicates aerobic exercise might prevent gestational diabetes mellitus among at-risk pregnant women. However, ss we focused only on one intervention, we could not analyse the effect of aerobic exercise with resistance or dietary, which could benefit the population.

Keywords**:** Gestational Diabetes Mellitus, Aerobic Exercise, Fasting Blood Glucose, Insulin Resistance, Oral Glucose Tolerance Test

Introduction

The term "gestational diabetes" (GDM) refers to any degree of glucose intolerance that occurs during pregnancy. GDM is connected to increased feto-maternal morbidity as well as long-term repercussions in both mothers and their children (1). GDM can be identified during the second or third trimester of pregnancy (2). In line with the global obesity epidemic, the prevalence of GDM in the United States has been on the rise (3). According to International Diabetes Federation, the worldwide prevalence of gestational diabetes mellitus in 2019 was 14.4%, while in Malaysia, the prevalence for the year 2019 was 22.5%. In 2017, it was estimated that globally 21.3 million live births were affected by GDM (4, 5). The incidence of GDM in Asia across 20 countries was the highest (11.4%; South Asia and 10.8% East Asia), representing the Asian population's burden of GDM (4, 6).

Many factors may contribute to GDM in women during pregnancy. Previous history of GDM, family history with diabetes, increased BMI, advanced maternal age, and parity are identified as high-risk factors in GDM (6, 7). GDM was reported to be more common in women with increased body mass index (BMI > 30kg/m2) and greater prepregnancy weight (8). Being overweight and obese are closely connected to excessive calorie intake, which affects the production of β-cell insulin and insulin signalling pathways (9). Among GDM, this stage is characterised as a chronic dysfunction with rising insulin resistance (IR) and declining islet cell compensation compared to normal pregnancy (10). Inadequate of insulin secretory response will eventually develop hyperglycaemia during pregnancy, which leads to a diagnosis of GDM without pre-existing diabetes (11).

Uncontrolled GDM can have an impact on pregnancy outcomes, as well as the mother's and fetal's long-term health. Pregnant women with GDM are more prone to develop type 2 diabetes mellitus and cardiovascular disease (12). Spontaneous abortion, fetal demise, preterm birth, preeclampsia and caesarean delivery are complications for pregnant women with GDM (3, 9). A child born to a mother with GDM has many complications, such as macrosomia, shoulder dystocia, neonatal hypoglycemia and respiratory distress syndrome (3, 13). Children of mothers with GDM are often overweight or obese. The children will also be prone to be diagnosed with type 2 diabetes and cardiovascular disease later in life (14).

Aerobic exercise in pregnancy has been shown to be beneficial to pregnant women. Aerobic exercise is defined by the American College of Sports Medicine (ACSM) as any movement that involves large muscle groups that can be performed continuously and are rhythmic in nature (15). Aerobic exercise activates a group of muscles that need aerobic metabolism to generate energy as adenosine triphosphate, which comes from amino acids, carbohydrates and fatty acids (16). Aerobic exercise enhances mitochondrial density, insulin sensitivity, oxidative enzymes, blood vessel compliance and reactivity, lung function, immune function, and cardiac output (17). This mode of exercise can be assessed through aerobic capacity or cardiorespiratory fitness. Maximal oxygen uptake (VO_2max) is the criterion measured for aerobic capacity. Standard tests for aerobic capacity include treadmills, cycle ergometers, steps and field tests (15).

Although the literature suggests Aerobic exercise during pregnancy may help to prevent GDM, however, it is not a common practice for healthcare practitioners to include aerobic exercise in their management of prenatal care. This systematic review is designed to evaluate the evidence on the effectiveness of aerobic exercise in preventing GDM. To our knowledge, there has not been any SLR on the effectiveness of aerobic exercise in preventing GDM before this. Since GDM poses short and long-term complications to the mother and child, hence it is hoped that the evidence may serve as a baseline guideline to be included in prenatal care. We examine the impact on changes in fasting blood glucose levels, insulin resistance levels, and oral glucose tolerance test levels as those are the GDM diagnosis that could be accomplished with either one-step or two-step strategies (18). On the other hand, insulin resistance was measured because, during pregnancy, the panel of hormones released by the placenta will stimulate the abnormality of insulin secretion and insulin antagonism, which contribute to pancreatic beta cell dysfunction (19).

Methods

Study design

This is a systematic review study. A systematic review is a study that involves a comprehensive plan and search strategy to reduce bias by identifying, appraising, and synthesising all relevant studies on a particular topic. This study design was chosen to evaluate the evidence regarding the effectiveness of aerobic exercise in preventing GDM among pregnant women at risk.

Search strategy

A broad search strategy was applied in this study. A total of five databases were searched: Scopus, Web of Science (WoS), MEDLINE (EBSCO), PubMed (NCBI) and Cochrane library. A specific search string was formed and used to emphasise and be precise on the related topic. Phrase searching ("_") was used to search the articles that contain the exact phrase. Boolean logic concepts of OR and AND were also used in the search string. The boolean operator of OR was used to broaden the search result when searching on the database. At the same time, the Boolean operator of AND has limited the search result that specific only to the related topic. Certain words in the search string were replaced with truncation symbol (*) for singular or plural spelling. The search string was formed by using a similar meaning of the word or synonym word to widen the search result. The exact search string was used in five databases. Table 3 shows the search string that was used. Duration of the study from 1 January 2010 – 31 December 2020.

Table 1: Search string

Database	Search String
Scopus Web of Science (WoS) MEDLINE (EBSCO) PubMed (NCBI) Cochrane Library	(("aerobic exercise*" OR "aerobic training" OR "aerobic workout" OR "aerobic activit*" OR "physical exercise*" OR "physical fitness" OR "physical activit*" OR "exercise*" OR "exercise* training" OR "endurance exercise*" OR "endurance training" OR "endurance workout" OR "endurance activit*") AND ("gestational diabetes mellitus" OR "gestational diabetes" OR "pregnancy diabetes mellitus" OR "diabetes in pregnancy" OR "hyperglycemia in pregnancy" OR "GDM"))

Type of studies included

This systematic review study only included randomised controlled trial studies. A systematic review and non-randomised controlled trial studies were excluded from this study. The studies were selected based on the inclusion and exclusion criteria. As outlined in Table 2, oral glucose tolerance test (OGTT), fasting blood glucose (FBG) and insulin resistance (HOMA-IR) were the outcome measures chosen to reflect the effectiveness of aerobic exercise. Studies focused only on Pregnant women at risk of gestational diabetes mellitus. The trials were excluded if pregnant women with gestational diabetes mellitus were the subjects. The trial should only receive one intervention; aerobic exercise. Intervention group which received strengthening exercise or resistance training exercise or combined exercise of aerobic exercise and resistance training or diet program or any physical exercise that not related to aerobic exercise were excluded.

Table 2: Inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
• **Population (P):** Pregnant women at risk of gestational diabetes mellitus. • **Intervention (I):** Intervention group was received aerobic exercise or endurance exercise. • **Comparison (C):** Control group was received standard care or other treatments. • **Outcome (O):** Outcome measures that were used (1) oral glucose tolerance test (OGTT), (2) fasting blood glucose (FBG) and (3) insulin resistance (HOMA-IR). • Pregnant women were not contraindicated to any exercise. • A randomised controlled trial study was included in this study. • Articles must from 1 January 2010 until 31 December 2020. • Articles must in English language.	• Pregnant women with gestational diabetes mellitus. • Intervention group was received strengthening exercise or resistance training exercise or combined exercise of aerobic exercise and resistance training or diet program or any physical exercise that not related to aerobic exercise. • Non-randomised controlled trial studies and review studies were excluded. • Studies that were unable to assess in full-text.

Selection of study

Preferred Reporting Items for Systematic Reviews and Meta-Analyse (PRISMA) checklist was used in this study (20). PRISMA was applied in this study to retrieve all the articles according to eligibility criteria to answer the research questions. This allows for minimising bias by using comprehensive and systematic methods.

The PRISMA was divided into four phases which were identification, screening, eligibility, and included studies. The identification phase was conducted to record all the search results by five databases after being filtered. Table 3 shows the item filtered by five databases. Second screening phase. In this phase, duplicated articles were removed, and the result after duplication was recorded. After the duplication process, the remaining articles were screened by title and abstract according to inclusion and exclusion criteria. Third eligibility phase. During this phase, the full-text articles included were examined thoroughly to ensure that the articles fulfilled the inclusion criteria and were able to answer the research questions of the study. The fourth or last phase included studies. The finalised articles included in the study were recorded. Figure 3.1 shows the PRISMA flow diagram.

Table 3: Item filtered by five databases

Filter (1 Jan 2010 – 31 Dec 2020)	Scopus	Web of Science (WOS)	MEDLINE (EBSCO)	PubMed (NCBI)	Cochrane Library
Open access/ Full-text	Open access	Open access	Full-text	Full-text	-
Document type	Article	Article	-	-	-
Source type	Journal		Journal	-	-
Type of Study	-	-	-	RCT	
Language	English	English	English	English	English

Note: - filter is not available in the database.

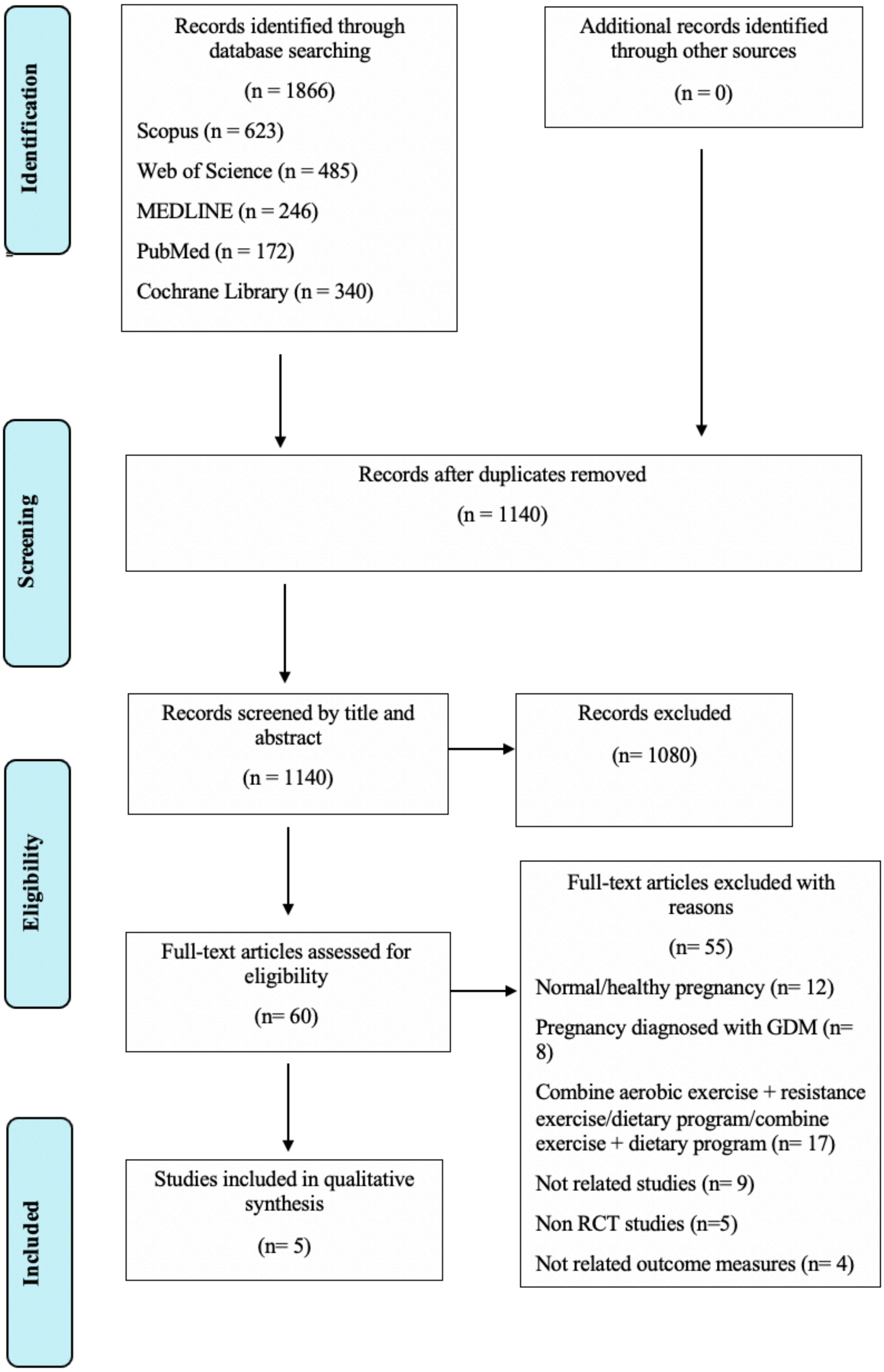

Figure 1: PRISMA flow diagram.

Critical appraisal instrument

Three reviewers independently have used the Physiotherapy Evidence Database (PEDro) scale to appraise the included studies critically. PEDro scale can use to evaluate the quality of methodological and risk of bias in studies for physiotherapy and other healthcare interventions. It includes eleven items which are eligibility criteria, random allocation, concealed allocation, similarity at baseline data, subjects blinding, therapists blinding, assessors blinding, less than 15% of dropout subjects; analysis of intention-to-treat, statistical comparison of between groups and lastly, point measures and measures of variability data. Figure 2 shows PEDro scale items. Items are scored as "yes" or "no" (1 or 0) if the criterion is clearly stated in the study. The total PEDro score is summed by adding "yes" responses for items 2-11. Item 1 is not included in the calculation of the PEDro score because it is associated with external validity. The scoring system is divided into four scores: 9 to 10 (excellent), 6 to 8 (good), 4 to 5 (fair) and less than 4 (poor). The PEDro scale has a scoring system that is simple and easy to interpret (21).

Inter-rater reliability of PEDro score for clinical trials of physiotherapy interventions illustrated fair to excellent. For pharmacological interventions, studies showed excellent inter-rater reliability. Inter-rater reliability of PEDro scale items ranged between fair to almost perfect for physiotherapy trials and moderate to almost perfect in pharmacological intervention studies (21).

PEDro scale

1. eligibility criteria were specified — no ❑ yes ❑ where:
2. subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated an order in which treatments were received) — no ❑ yes ❑ where:
3. allocation was concealed — no ❑ yes ❑ where:
4. the groups were similar at baseline regarding the most important prognostic indicators — no ❑ yes ❑ where:
5. there was blinding of all subjects — no ❑ yes ❑ where:
6. there was blinding of all therapists who administered the therapy — no ❑ yes ❑ where:
7. there was blinding of all assessors who measured at least one key outcome — no ❑ yes ❑ where:
8. measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups — no ❑ yes ❑ where:
9. all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analysed by "intention to treat" — no ❑ yes ❑ where:
10. the results of between-group statistical comparisons are reported for at least one key outcome — no ❑ yes ❑ where:
11. the study provides both point measures and measures of variability for at least one key outcome — no ❑ yes ❑ where:

Figure 2: PEDro scale items.

Data extraction

Data from the included studies were analysed and tabulated. Data were extracted on the following details: (1) authors' name; (2) number of participants in each intervention and control group; (3) nature of the intervention (type, intensity, duration and frequency); and (4) outcome measures relevant to the review. The findings of the studies were analysed into three themes according to outcome measures within the PICO structure. Baseline characteristics and findings of outcome measures were tabulated. Lastly, a narrative synthesis of studies meeting the inclusion criteria was conducted due to sample variation (22).

Results

A total of 1,866 studies were identified, of which 1,140 studies were screened by title and abstract after removing duplication. About 1080 studies did not meet the eligibility criteria after screening by title and abstract. Next, 60 full-text articles studies were assessed for eligibility criteria. 55 studies were excluded with reasons; normal/healthy pregnancy (n = 12), pregnancy diagnosed with GDM (n = 8), combined exercises (aerobic + resistance)/dietary program/combined (exercise + dietary) (n = 17), not related studies (n = 9), not related outcome measures (n = 4) and non-randomized controlled trial studies (n = 5). Only five studies that included in this study.

Descriptive of studies

The number of participants in both exercise and control groups was tabulated. Information regarding the frequency, intensity, duration, and types of exercises in the intervention program for both the exercise group and control group of the included studies are presented in Table 4. Majority of the included studies, the frequency of the exercise programs was three times per week (23, 24). Most studies carried out exercise programs at moderate intensity (23-27)body mass index ranged from 30-35 kg/m2. Women were divided into two equal groups: intervention group (A. The duration of the exercises in each session was various; 20 minutes (25, 26)glucose was measured up to 48 h after the OGTT. Glucose, insulin, and C-peptide were determined at baseline and after 1 and 2 h. One hour after glucose intake, mean blood glucose was significantly lower after cycling compared with rest (p = 0.002, 30 minutes (24, 27) and 45 minutes (23)body mass index ranged from 30-35 kg/m2. Women were divided into two equal groups: intervention group (A. All these studies carried out aerobic exercise programs. Two out of five studies chose a walking intervention (23, 27), while three did cycling programs (24-26)glucose was measured up to 48 h after the OGTT. Glucose, insulin, and C-peptide were determined at baseline and after 1 and 2 h. One hour after glucose intake, mean blood glucose was significantly lower after cycling compared with rest (p = 0.002. Two studies did not mention the progression of exercises (23, 25)body mass index ranged from 30-35 kg/m2. Women were divided into two equal groups: intervention group (A. FBG was used as the outcome measure (23,26)psychological well-being, and obstetric and neonatal outcomes. A sample size of 180 (90 in each group. HOMA-IR was used in the studies (24, 26)psychological well-being, and obstetric and neonatal outcomes. A sample size of 180 (90 in each group. Lastly, OGTT was used to measure the effect of aerobic exercise in four studies (24-27).

Table 4: Summary of included studies of Nobles et al. (2015), Guelfi et al. (26)psychological well-being, and obstetric and neonatal outcomes. A sample size of 180 (90 in each group, Embaby et al. (23)body mass index ranged from 30-35 kg/m2. Women were divided into two equal groups: intervention group (A, Wang et al. (24) and Andersen et al. (25)

Author	Number of Participants	Intervention Group	Control Group	Outcome Measures
Nobles et al. (27)	Total (n = 290) EG (n = 143) CG (n = 147)	**Frequency:** Most days / week **Intensity:** Moderate intensity **Time:** 30 minutes or more **Type:** Physical activities included walking, dancing and yard work **Progression:** Weekly increase the time by 10% in moderate intensity	Received health and wellness intervention	OGTT
Guelfi et al. (26) psychological well-being, and obstetric and neonatal outcomes. A sample size of 180 (90 in each group	Total (n = 172) EG (n = 85) CG (n = 87)	**Frequency:** 3 days/week **Intensity:** • Warm-up = 5 minutes of cycling (55-65% HRmax; 9-11 RPE) • 5 minutes continuous cycling (moderate intensity at 65-75% HRmax; 12-13 RPE) • 5 minutes interval cycling • Two types of interval; (1) increase in pedalling rate for 15 seconds and (2) increase in resistance of cycling for 30 seconds (75-85% HRmax; 14-16 RPE) repeated every 2 minutes	Standard care	FBG HOMA-IR OGTT

Table 4: Summary of included studies of Nobles et al. (2015), Guelfi et al. (26)psychological well-being, and obstetric and neonatal outcomes. A sample size of 180 (90 in each group, Embaby et al. (23)body mass index ranged from 30-35 kg/m2. Women were divided into two equal groups: intervention group (A, Wang et al. (24) and Andersen et al. (25) (continued)

Author	Number of Participants	Intervention Group	Control Group	Outcome Measures
		• • Cool down = 5 minutes of cycling (55-65% HRmax; 9-11 RPE) followed by light stretching **Time:** 20 minutes **Type:** Supervised home-based stationary cycling **Progression:** Increase 5 minutes every 2-3 weeks (from 20-30 minutes toc60 minutes)		
Embaby et al. (23) body mass index ranged from 30-35 kg/m2. Women were divided into two equal groups: intervention group (A	Total (n = 40) EG (n = 20) CG (n = 20)	**Frequency:** 3 days/week Intensity: Warm-up = 10 minutes of walking in place Active walking = 30 minutes of walking with moderate intensity (speed at 0.7km/hour and increase speed till 60% HRmax) Cool down = 5 minutes of walking (gradually decrease speed at 40% HRmax) **Time:** 45 minutes **Type:** Supervised walking on treadmill exercise **Progression**:-	Traditional care and diet control.	FBG
Wang et al. (24)	Total (n = 300) EG (n = 150) CG (n = 150)	**Frequency:** 3 sessions/week **Intensity:** Warm-up = 5 minutes of cycling at low intensity (55-65% HRmax; 9-11 RPE) 5 minutes continuous cycling (65-75% HRmax; 12-14 RPE) 30 seconds interval cycling with rapid pedalling (sprints, higher intensity at 75-85% HRmax; 15-16 RPE) every 2 minutes for 3-5 intervals 5 minutes continuous cycling (60-70% HRmax; 10-12 RPE) Continuous cycling during interval phase (65-75% HRmax; 12-14 RPE) with 1 minute of pedaling against resistance (75-85% HRmax; 13-15 RPE) alternated every 2 minutes for 3 repetitions Cool down = 5 minutes of easy cycling **Time:** 30 minutes **Type:** Supervised stationary cycling program **Progression:** 45-60 minutes (add 5 minutes either during intervals or continuous cycling phase depend on subject's capability	Usual daily activities and standard prenatal care.	HOMA-IR OGTT
Andersen et al. (25)	Total (n = 15)	**Frequency:** 2x (2nd day and 5th day of experimental days) **Intensity:** Moderate intensity (65-75% HRmax) Began pedalling at comfortable rate, gradually increase resistance over 2-3 minutes until achieved target heart rate **Time:** 20 minutes **Type:** Stationary cycling **Progression:** -	Resting in seated position	OGTT

"-" = not stated

HRmax = maximum heart rate

RPE = rating perceived exertion according to Borg scale

EG = exercise group

CG = control group

Effect of aerobic exercise on fasting blood glucose

Two out of five studies used FBG as an outcome measure to analyse the effect of aerobic exercise on blood glucose levels (23, 26)psychological well-being, and obstetric and neonatal outcomes. A sample size of 180 (90 in each group. Baseline data of FBG level between groups were no different in both studies. One study showed a significant decrease in FBG levels when comparing the exercise group to the control group (23)body mass index ranged from 30-35 kg/m2. Women were divided into two equal groups: intervention group (A. However, the second study showed no similar difference in FBG levels between groups (26)psychological well-being, and obstetric and neonatal outcomes. A sample size of 180 (90 in each group. Table 5 shows the baseline data and findings of FBG levels between groups.

Table 5: Baseline data and findings of fasting blood glucose level between groups

Study	Baseline		*P*	Findings		*P*
	Exercise Group	**Control Group**		**Exercise Group**	**Control Group**	
Embaby et al. (23)	6.45±0.91	6.55±0.95	0.750	4.26±0.67	5.07±0.54	<0.0001
Guelfi et al. (26)	4.3±0.4	4.3±0.3	0.780	4.5±0.5	4.4±0.5	>0.05

Data are mean ± standard deviation.

Effect of aerobic exercise on insulin resistance

Two studies used HOMA-IR to analyse the effect of aerobic exercise on insulin resistance levels (24, 26)and indeed, the proportion of such women of reproductive age has increased in recent times. Being overweight or obese prior to pregnancy is a risk factor for gestational diabetes mellitus, and increases the risk of adverse pregnancy outcome for both mothers and their offspring. Furthermore, the combination of gestational diabetes mellitus with obesity/overweight status may increase the risk of adverse pregnancy outcome attributable to either factor alone. Regular exercise has the potential to reduce the risk of developing gestational diabetes mellitus and can be used during pregnancy; however, its efficacy remain controversial. At present, most exercise training interventions are implemented on Caucasian women and in the second trimester, and there is a paucity of studies focusing on overweight/obese pregnant women. Objective We sought to test the efficacy of regular exercise in early pregnancy to prevent gestational diabetes mellitus in Chinese overweight/obese pregnant women. Study Design This was a prospective randomized clinical trial in which nonsmoking women age >18 years with a singleton pregnancy who met the criteria for overweight/obese status (body mass index 24≤28 kg/m2. Both studies had similar baseline data of HOMA-IR levels between groups. One study showed a significantly lower HOMA-IR level in the exercise group compared to the control group (24). Nevertheless, another study showed similar HOMA-IR levels between groups (26)psychological well-being, and obstetric and neonatal outcomes. A sample size of 180 (90 in each group. Table 6 shows baseline data and findings of HOMA-IR levels between groups.

Table 6: Baseline data and findings of insulin resistance level between groups

Study	**Baseline**		***P***	**Findings**		***P***
	Exercise Group	**Control Group**		**Exercise Group**	**Control Group**	
Guelfi et al. (26)	1.2±0.7	1.1±0.8	0.549	1.56 (1.09-2.18)	1.25 (0.84-2.05)	> 0.05
Wang et al. (24)	2.70±1.33	2.69±1.25	0.9	2.92±1.27	3.38±2.00	0.033

Data are mean ± standard deviation, or median (interquartile range).

Effect of aerobic exercise on oral glucose tolerance test

Four studies used OGTT as an outcome measure to analyse the effect of aerobic exercise on glucose levels (24-26). A significant lower OGTT level in the exercise group than in the control group at 1-hour and 2-hour OGTT (24). A study has shown that the exercise group has lower OGTT than the control group, but it is not statistically significant (27). A significant lower in the exercise group than the control group after 1-hour OGTT. However, the exercise group was significantly higher than the control group after a 2-hour OGTT (25). There was no difference in glucose levels between groups after 2-hour OGTT (26)psychological well-being, and obstetric and neonatal outcomes. A sample size of 180 (90 in each group. Table 7 shows the findings of OGTT levels between the exercise group and the control group.

Table 7: Findings of oral glucose tolerance test level between groups

Study	Exercise Group	Control Group	*P*
Nobles et al. (27)	1-h = 117.8±26.5[a]	1-h = 119.7±33.7[a]	0.61
Guelfi et al. (26)	2-h = 7.6±1.6[b]	2-h = 7.7±1.5[b]	>0.05
Wang et al. (24)	1-h = 7.99±1.67[b] 2-h = 6.57±1.18[b]	1-h = 8.57±1.86[b] 2-h = 7.03±1.62[b]	0.009 0.009
Andersen et al. (25)	1-h = 7.9±1.7[b] 2-h = 7.2±1.3[b]	1-h = 8.7±1.5[b] 2-h = 6.7±0.9[b]	0.002 0.04

[a]50g oral glucose tolerance test (OGTT)

[b]75g oral glucose tolerance test (OGTT)

Data are mean ± standard deviation

Quality of studies

The quality of included studies was assessed by using the PEDro scale. One study got scored 5 out of 10, which is considered a fair quality (27). Meanwhile, four studies scored between 6 and 7 out of 10, which are considered as good quality (24-26). All these studies clearly stated the eligibility criteria of subjects and randomly allocated the subjects into intervention and control groups. Only one study clearly mentioned that allocation was concealed (24). There was one study that was not clearly mentioned baseline similarity between groups (27). All studies were not blinding the subjects, therapists and assessors; hence the studies got no points for criteria 5, 6 and 7. No dropout of subjects in all studies. There was an intention-to-treat analysis in all studies. All studies scored one point for between-group statistical comparison and point measures and measures of variability criteria. Table 8 shows the score of the criteria for each study.

Table 8: Study quality by using PEDro scale

Study	Eligibility criteria	Random allocation	Concealed allocation	Baseline similarity	Subjects blinding	Therapist blinding	Assessor blinding	<15% dropout	Intention-to-treat analysis	Between group statistical comparison	Point measures and measures of variability	Total score
Nobles et al. (27)	Yes	Yes	No	No	No	No	No	Yes	Yes	Yes	Yes	5/10
Guelfi et al. (26)	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	6/10
Embaby et al. (23)	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	6/10
Wang et al. (24)	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	7/10
Andersen et al. (25)	Yes	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	6/10

Yes = 1

No = 0

Discussion

Effectiveness of aerobic exercise on fasting blood glucose

This systematic review seeks to analyse the effectiveness of aerobic exercise in preventing GDM among women at risk. This study is required because it affects maternal, fetal, and long-term health, which is the future development of type 2 diabetes mellitus and CVD. Currently, 25 % of pregnancies are affected worldwide (28).

A moderate intensity of aerobic exercise demonstrated a significant reduction in fasting blood glucose levels in the exercise group compared to the control group (23)body mass index ranged from 30-35 kg/m2. Women were divided into two equal groups: intervention group (A. In the study also stated that low and moderate-intensity of aerobic exercise in pregnant women with GDM had a decrease in blood glucose levels compared to rest (29)at rest (control condition. Exercise lowered the fasting glucose level in the intervention group more than in the control group at 28 weeks (30). In addition, a recent systematic review reported similar findings in which aerobic, resistance exercise or a combination of both effectively controlled fasting glucose, postprandial glucose, HbA1c and insulin among pregnant women with GDM (31)Superior Council of Scientific Investigations (CSIC. Exercise can increase muscle glucose uptake by approximately 100-fold from resting level. Glucose enters skeletal muscle cells happens when GLUT4 enhances diffusion and a concentration gradient of glucose from the outside to the inside of the muscle cell when exercising (32). A few factors influence glucose utilisation by muscle cells during aerobic exercise, including promoting glucose phosphorylation in muscle cells, increasing insulin sensitivity, and converting blood glucose to monosaccharide (33). Thus, this mechanism will eventually help reduce the fasting blood glucose level among pregnant women at risk of GDM. However, the insulin findings in the present report are inconsistent with other studies (19) that varied in the length of the intervention and the type of aerobic exercise. However, the insulin findings in the present report are inconsistent with other studies (19) that varied in the length of the intervention and the type of aerobic exercise

However, a 14-week supervised, home-based aerobic exercise program found no similar difference in fasting blood glucose levels between the exercise and control groups (26)psychological well-being, and obstetric and neonatal outcomes. A sample size of 180 (90 in each group. The author explained there was no difference since an increase in exercise frequency could have influenced the results, and the appropriate duration and intensity of exercise for GDM prevention remains unknown. Two RCT studies found that moderate-intensity aerobic, strength and flexibility exercises conducted three times per week for 45-60 minutes had no influence on the incidence of GDM (34, 35). The results systematic review study stated that the mean of fasting blood glucose had no significant difference between exercise and control groups (36).

Effectiveness of aerobic exercise on insulin resistance

In normal pregnancy, alterations in the mother's glucose metabolism guarantee optimal glucose delivery to the foetus. As pregnancy progresses, insulin sensitivity diminishes, resulting in insulin resistance. This insulin resistance is caused by increased maternal and placental anti-insulinemic hormones, such as progesterone, cortisol, tumour necrosis factor (TNF), and placental growth hormone, and a decrease in plasma adiponectin. The glucose homeostasis is later maintained by the mother's secretion, which is of human placental lactogen (hPL), and prolactin increases beta cell mass and glucose-stimulated insulin (37). However, GDM develops when insulin secretion fails to overcome the physiologic insulin resistance during pregnancy (38). Furthermore, insulin resistance in women with GDM could be developed by TNF-α, a pro-inflammatory cytokine produced by various cells including monocytes, macrophages, T-cells, neutrophils, fibroblasts, adipocytes, and the placenta. TNF-A inhibits insulin receptor tyrosine kinase activity by phosphorylating IRS-1 through serine (39).

The review showed aerobic exercise reduced insulin resistance among overweight and obese pregnant women at 25 weeks. Hence this could prevent GDM. These can be explained by increased in insulin sensitivity during the exercises. The activity caused muscle contraction possibly later changed the adipokines profile and upregulated antioxidant defence mechanism (40). Another study also presented a similar result in which a group of mothers with aerobic exercise and diet therapy showed a significant improvement in insulin resistance levels compared to diet therapy alone among obese pregnant women. A study has shown that aerobic exercise increases systemic insulin sensitivity (41). Hence, it helps in reducing insulin resistance in an individual. Exercise also benefits in improving metabolic disturbances and mitochondrial quality, reducing inflammation and chronic oxidative stress that is influenced by obesity and hyperglycaemia, and enhancing health in insulin resistance states (42).

Effectiveness of aerobic exercise on oral Glucose tolerance test

The glucose tolerance test is an essential diagnostic tool for detecting various conditions related to carbohydrate metabolism, including GDM. It measures how fast glucose is removed from the bloodstream (43).

A cycling exercise conducted at least 30 minutes three times per week resulted in a significant reduction in the 1-hour and 2-hour of oral glucose tolerance test levels than the control group (24). The timing of the intervention at an early stage of pregnancy may have influenced and altered the findings of this study. In line with this finding, a moderate-intensity exercise programme during pregnancy improved maternal glucose tolerance test levels (44). A study supported the finding that aerobic, strength, and flexible exercise programs showed lower oral glucose tolerance test levels at 180 minutes than the control group (45). Exercise increases blood flow in muscles and capillary demand, which both increase glucose delivery (42)exercise is safe and can affect the pregnancy outcomes beneficially. A single exercise bout increases skeletal muscle glucose uptake, minimizing hyperglycemia. Regular exercise training promotes mitochondrial biogenesis, improves oxidative capacity, enhances insulin sensitivity and vascular function, and reduces systemic inflammation. Exercise may also aid in lowering the insulin dose in insulin-treated pregnant women. Despite these benefits, women with GDM are usually inactive or have poor participation in exercise training. Attractive individualized exercise programs that will increase adherence and result in optimal maternal and offspring benefits are needed. However, as women with GDM have a unique physiology, more attention is required during exercise prescription. This review (i. This could be a possible factor in reducing glucose tolerance levels in pregnant women at risk of GDM.

A significant lower 1-hour glucose tolerance test level in the aerobic exercise group compared to at rest group (25). However, after a 2-hour oral glucose tolerance test level was significant slightly higher in the aerobic exercise group than in the control group. The 1-hour oral glucose tolerance test level could be reduced because, during exercise, catecholamine is released and causes insulin production to become reduced. Additionally to this, glucose intake by muscles may result in reducing insulin demand (46). Exercise stimulates greater glucose uptake in the muscle cell, which reduces hyperglycemia. A higher glucose uptake absorption happens during the post-exercise recovery period (42). As for a slightly higher 2-hour oral glucose tolerance test level, exercise-induced the catecholamines to be released, stimulating endogenous production and delayed gastric emptying during exercise. It fuels utilisation in peripheral tissue during and after exercise, which may influence glucose consumption and utilisation. Therefore, it influences the circulation of glucose levels (46).

In contrast, Nobles had shown that the aerobic exercise group had a lower oral glucose tolerance test level than the control group, but it was not statistically significant (27). This is because the subjects in the exercise group self-selected their exercise. This would have influenced the study's result since exercise's advantage in preventing GDM is restricted to pregnant women who engage in high-intensity exercise before pregnancy and keep doing it during early pregnancy (47)childhood obesity, and adulthood obesity, and diabetes. Therefore, we aimed to systematically review and synthesize the current evidence on the relation between physical activity and the development of GDM. RESEARCH DESIGN AND METHODS - Medline, EMBASE, and Cochrane Reviews were searched from inception to 31 March 2010. Studies assessing the relationship between physical activity and subsequent development of GDM were included. Characteristics including study design, country, GDM diagnostic criteria, ascertainment of physical activity, timing of exposure (prepregnancy or early pregnancy. Another reason for the insignificant result was possibly due to the goal of the exercise was too average in order to prevent GDM or less adherence level to the exercise (48). Exercising three times a week or less had significantly better outcomes than overdoing it in preventing GDM (36). The aerobic exercise program was performed most days of the week (27). This could lead to an insignificant result in reducing oral glucose tolerance test levels. This may be because the body's metabolism moves into a fat intake, and energy when doing exercise is gained by burning the fat. As a result, the blood glucose levels may remain unchanged or higher (36).

Other research found no difference in the 2-hour glucose tolerance test level between groups (26)psychological well-being, and obstetric and neonatal outcomes. A sample size of 180 (90 in each group. The present study started the intervention at 14 weeks of gestation. Despite the fact that it is considered as a strength of this study, it has been suggested that in the first trimester, the placental function and gene expression are programmed (49). For instance, two recent well-designed RCTs proved there was no effect in preventing the occurrence of GDM when the exercise (50, 51). The interventions in both studies began in the second trimester. It may be too late to prevent the GDM from occurring because the endocrine and metabolic changes and placental function may be altered to begin in the first trimester (49). Thus, early intervention is possibly more effective.

There are controversial elements that could be contributing to the inconsistency of the result. Various factors demonstrate a significant impact on the accuracy and reproducibility of the OGTT. The aspects that have the most variability and the slightest consideration when influencing the interpretation of the OGTT are sample collection, storage, and transit during the preanalytical phase. Studies showed, in vitro glycolysis, which is the change of glucose to pyruvic acid inside cells to make energy, can cause a considerable loss of glucose (5–7% per hour) if it is not taken care of before analysis (52, 53).

The strength of this systematic review study is that only an RCT study can be included. Furthermore, this study did not include other interventions such as resistance exercise, dietary or a combination of interventions. This is able to identify the effectiveness of aerobic exercise on outcome measures to prevent GDM among pregnant women at risk.

The limitation of this study is that the population is only focused on pregnant women at risk of GDM, which does not include pregnant women with GDM. Next, this study focused on aerobic exercise alone. It cannot analyse the strength of other interventions, such as resistance exercise, dietary programmes or combined interventions in preventing GDM.

Conclusions

In summary, this systematic review study has shown that aerobic exercise effectively prevented GDM among at-risk pregnant women. Aerobic exercise effectively reduces FBG, HOMA-IR, and OGTT levels in pregnant women at risk of GDM. It is recommended for pregnant women at risk of GDM to do aerobic exercise such as walking, stationary cycling or walking on a treadmill at moderate intensity (60% - 75% maximum heart rate), which should be practised early in pregnancy. Policymakers and healthcare providers may educate women about the advantages of exercise during pregnancy and the risks of GDM. Community initiatives, health promotion campaigns, and tailored treatments for high-risk groups can accomplish this. Future research should seek to implement aerobic exercise combined with resistance exercise or dietary intervention or vice versa to determine the strength of other interventions in preventing GDM.

Conflict of interest

The authors declare that there is no conflict of interest.

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