Review

Dietary and exercise interventions and glycemic control and maternal and newborn outcomes in women diagnosed with gestational diabetes: Systematic review

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ABSTRACT

Gestational diabetes mellitus (GDM) is one of the most common complication of pregnancy and can lead to significant perinatal mortalities as well as long term risk of comorbidities for both mother and her offspring. This systematic review aimed to explore whether combined diet and exercise interventions are associated with improved glycemic control and/or improved maternal and newborn outcomes in women with GDM when compared to dietary interventions. A search on combined diet and exercise interventions during pregnancy in women with GDM was performed in 3 electronic databases: PubMed (NCBI), ScienceDierct, and the Cochrane Library. Evaluated outcomes were fasting blood glucose levels, postprandial blood glucose levels, glycated hemoglobin percentages, total weight gain during pregnancy, proportion of caesarean delivery, proportion of patients needing insulin, neonatal birth weight, proportion of macrosomia, neonatal hypoglycemia, and preterm birth. This systematic review identified eight randomized, controlled trials involving 592 pregnant women and 350 infants. The risk of bias of the included trials ranged from high to low. The combined diet and exercise interventions reduced fasting and postprandial blood glucose levels when compared to dietary interventions. No significant differences were reported in the selected trials regarding total weight gain during pregnancy, cesarean section, neonatal birth weight, macrosomia, neonatal hypoglycemia, and preterm birth between diet plus exercise and diet groups. The combination of diet and exercise interventions help to control postprandial blood glucose concentration in women diagnosed with GDM, but did not change either maternal or newborn outcomes.
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1. Introduction

Gestational diabetes mellitus (GDM) is one of the most common complication of pregnancy that leads to significant perinatal mortalities and long term risk of comorbidities for both mother and her offspring [1—3]. GDM is associated with higher rates of fetal macrosomia, stillbirth, neonatal metabolic disturbances, gestational preeclampsia, and cesarean delivery [4]. Around a half of the mothers with GDM are expected to develop Type 2 diabetes within five years after delivery [5]. In the offspring, GDM is a major contributor to obesity and glucose intolerance in later life [6,7]. The GDM affects up to 13.2% of pregnant women worldwide. The prevalence of GDM increases with age, it has been reported that its prevalence ranged from 8% to 26% in women aged 45 years or older [8].

Medical nutrition intervention has been considered the basis of GDM management and is recognized as an essential component of an overall healthy lifestyle [9,10]. Reviews related to the effect of different interventions on GDM treatment have been conducted [11—17]. A perspective of these previous reviews showed the wide range of the efficiency of the interventions on maternal glycemic control, some maternal, and newborn health outcomes. The studies involved in these reviews also varied from dietary intervention to lifestyle modification and exercise intervention.

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Nutrition education and counseling during pregnancy could improve maternal nutritional status [18—20]. Thomas et al. [21] documented that nutrition counseling in women with GDM resulted in reducing total energy, refined sugar, and total and saturated fats, monounsaturated fats and trans-fats intakes. Additionally, Artal et al. [22] showed that nutrition counseling decreased weight gain during pregnancy in obese women. Adherence to healthful dietary patterns is related to reduce risk of developing type 2 diabetes among women with a history of GDM [23]. An optimal diet for a pregnant woman with GDM should provide adequate nutrients for fetal growth and maternal health as well as improve glycemic control and prevent further insulin resistance and excess fetal fat accretion [24].

Exercise has been shown to be an effective intervention in preventing and managing GDM [25—29]. International guidelines recommend pregnant women with GDM to engage in aerobic exercise at a moderate intensity for 30 min at least 5 day per week along with medical nutritional therapy [30,31]. Previous reviews demonstrated that women with GDM who underwent exercise intervention had greater blood glucose control and might prevent, reduce or delay using of anti-diabetic medications and or insulin [26,28]. A recent observational study showed that GDM women on exercise intervention had the lowest body mass index (BMI) rise during late and mid-pregnancy and had significantly lower risk of preterm birth, low birth weight, and macrosomia than GDM women without exercise intervention [32].

Dietary or exercise intervention for the prevention and management of GDM has been widely evaluated [12—14,16,20]. However, a shift towards combining diet and exercise interventions have been observed recently [15,33,34]. As a result, systematic reviews that focus on the effect of diet plus exercise interventions on pregnancy outcomes are very limited. Therefore, this systemic review aimed to understand the effect of combined diet and exercise on GDM and their suitability as therapeutic options to improve the glycemic control and fight potential GDM-related adverse health consequences on the mother and her infant. The research questions for this systematic review were:

1. Do diet and exercise interventions normalize maternal blood glucose (fasting and postprandial blood glucose levels and glycated haemoglobin levels), in women diagnosed with GDM when compared to the diet intervention alone?
2. Do diet and exercise interventions decrease cesarean rate, and insulin use for women with GDM?
3. Can diet and exercise interventions reduce the rate of macrosomia, prematurity, and hypoglycemia incidence in newborns of women with GDM?

2. Methods

This systematic review of randomized trials was carried out using a protocol constructed according to the Preferred Reporting Items for systematic Reviews and Meta-Analyses (PRISMA) statement [35].

2.1. Data sources and search strategy

One reviewer (S.S.A.) performed a search to identify randomized clinical trials (RCTs) that reported the glycemic effect, the maternal and newborn outcomes of diet and exercise interventions during pregnancy on women diagnosed with GDM. The search strategy 'gestational diabetes' AND 'diet' AND 'exercise' AND 'glycemic control' AND 'maternal outcomes' AND 'newborn outcomes' was applied to the following three data bases from 1980 until November

2018: PubMed (NCBI), ScienceDierct, and the Cochrane Library. The search was restricted to studies published in English language. In addition, bibliographies of included studies and existing systematic reviews were manually searched to identify any further and relevant RCTs [13,15,36].

2.2. Study selection

All articles retrieved from the electronic databases were imported to Mendeley program and duplicates removed. Two reviewers (S.S.A. and R.F.T.) independently screened titles and abstracts of articles yielded by the search to identify potentially eligible studies based on the inclusion criteria. If eligibility was unclear from the review of title and abstract, full text was obtained for further assessment and discrepancies were resolved by discussion between reviewers. Inclusion criteria consisted of the following: 1) RCTs in which women diagnosed with GDM or impaired glucose tolerance (using any definition) or hyperglycemia were randomized to combined diet with exercise intervention or dietary intervention. 2) The diet and exercise were the primary interventions and interventions duration lasted for at least 4 weeks. 3) Any outcome of blood glucose control and/or maternal and newborn was reported. Studies were excluded if 1) They were not randomized. 2) The dietary and exercise interventions combined with anti-diabetic medications or insulin. 3) They included women with type 1 or type 2 diabetes. 4) The diet and exercise characteristics were not available. 5) They did not evaluate any outcomes of interest for this systematic review (Table 1).

2.3. Data extraction

Data of included RCTs were extracted using a standardized data extraction form. The data were extracted by one reviewer (S.S.A.) and checked independently by second reviewer (R.F.T.). Any disagreement was resolved via review of the original articles. Extracted data included the following: first author's surname, year of publication, study design (randomization method), intervention duration, sample size, participant characteristics (age, body mass index (BMI), gestational age at inclusion, and ethnicity). Diet characteristics (diet type, total energy and macronutrients), the dietary recommendation or prescription, exercise intervention (exercise type, frequency, intensity, session duration, and mode) were also extracted. From each trail, data on mean and standard deviation (SD) for all outcomes of interest including fasting blood glucose level, postprandial blood glucose level, glycated hemoglobin (HbA1c) percentage, weight gain, birth weight, gestational age at delivery were extracted. In addition, the data on rate of cesarean section, number of participants who need insulin, number of newborn with macrosomia (birth weight >4 kg) and the preterm birth were extracted. To provide similar unit measures, fasting blood sugar and postprandial blood glucose levels were transformed from mmol/L to mg/dL and total energy intake was transformed from kilojoules to kilocalories.

2.4. Quality assessment

The risk of bias of the included randomized controlled studies was assessed using the Cochrane risk of bias tool [37], which focuses on sequence generation, allocation concealment, blinding of participants and medical staff to treatment allocation, blinding of assessors, loss to follow-up, selective reporting of outcomes and other sources of bias. Each criterion was classified as being at low or high risk of bias or unclear. Quality assessment was carried out independently by two reviewers (S.S.A. and R.F.T.).

Table 1
PICOS criteria for inclusion and exclusion of studies.

Parameter	Inclusion criteria	Exclusion criteria
Population	Pregnant women diagnosed with GDM or impaired glucose tolerance (using any definition) or hyperglycemia during the current pregnancy.	Pregnant women with type 1 or type 2 diabetes mellitus
Intervention	Combined diet with exercise were primary interventions. Intervention duration lasted for at least 4 weeks	Combined diet and exercise interventions with medications
Comparator	Diet was primary intervention Intervention duration lasted for at least 4 weeks	Dietary interventions with medications
Outcomes	Fasting and postprandial blood glucose levels Glycated hemoglobin percentages Total weight gain during pregnancy, Proportion of caesarean delivery, Proportion of patients needing insulin therapy, Neonatal birth weight, Proportion of macrosomia, neonatal hypoglycemia, and preterm birth.	None
Study design	Randomized controlled clinical trials Original articles from a peer-reviewed journals published in English	Non-randomized controlled clinical trials Abstracts, review articles or original articles published in non-English language

3. Results

3.1. Literature search

A total of 1258 studies was identified by database searches Fig. 1. These studies were combined with four additional studies identified by previous systematic reviews conducted prior to our first search. After duplication removed, 1206 citations were reviewed. Of these, 1164 were excluded based on title and abstract, leaving 42 articles for further full text evaluation. Thirty four of these studies were excluded, most of them due to intervention focused on prevention not management, research design was not
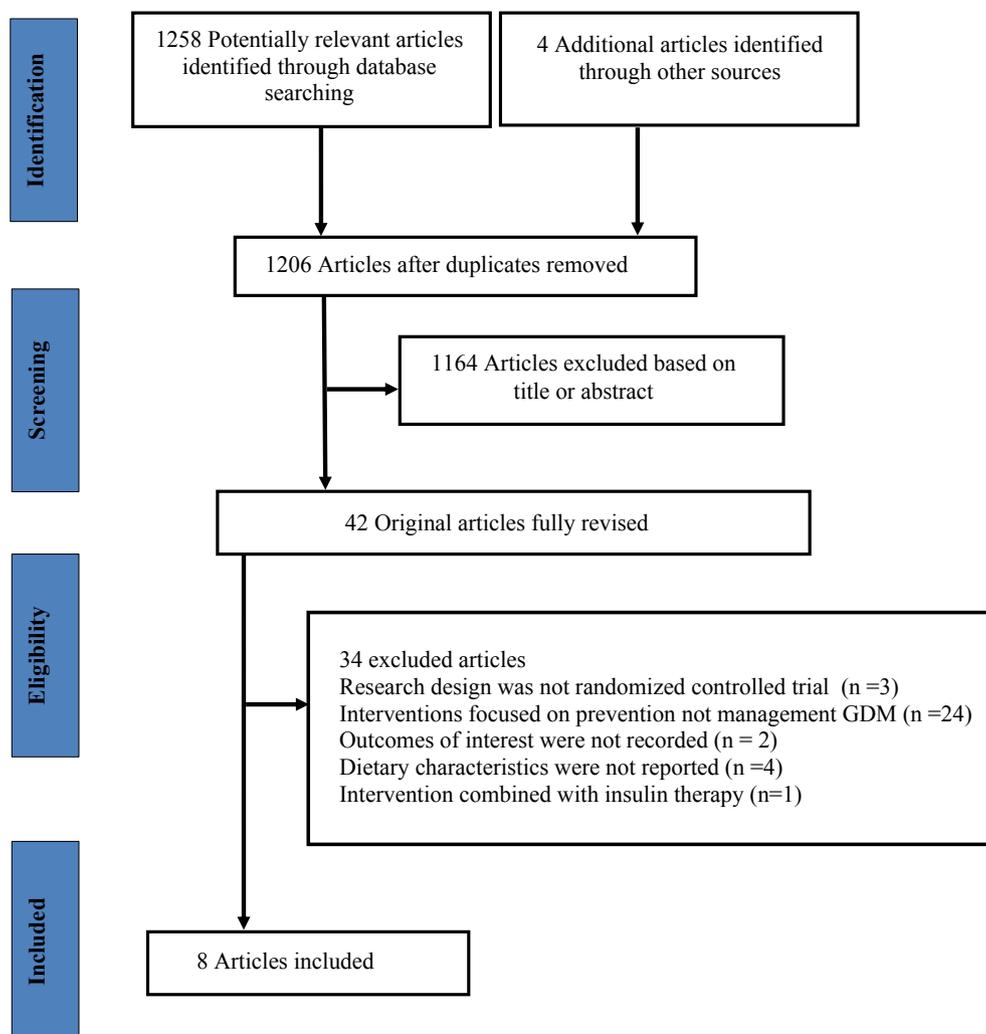
Fig. 1. Flow diagram of the literature search process.

randomized, controlled trials, the outcomes of interest were not reported, the dietary characteristics were not provided, and dietary intervention combined with insulin therapy. Therefore, 8 RCTs were selected to be included in the current systematic review [38—45].

3.2. Characteristics of included RCTs

The characteristics of the 8 included RCTs are summarized in Table 2 [38—45]. All trials were conducted in middle-or high-income countries. Two trials were conducted in USA [38,39], and one trial each in Brazil [40], Canada [41], Italy [42], Australia [43], Thailand [44], and Croatia [45]. Sample sizes of the included RCTs ranged from a minimum of 19 pregnant women [38] to a maximum of 200 pregnant women [42]. A total of 592 pregnant women and 350 infants was included in this systematic review. Three trials did not report any neonatal data [41,43,44]. The mean age of participants in the included trials ranged from 20 to 50 years who had a diagnosis of GDM between 20.8 and 30.0 weeks of pregnancy. Data for maternal weight at trial entry reported in 6 trials. The maternal weight at trial entry ranged from 67.4 to 86.6 kg. Seven trials provided mean pre-pregnancy body mass index with a range of 24.4—28.4 kg/m^2 [39—45]. All trials started in the 3rd trimester and continued for at least 6 weeks [38,39,41,43,44] or to the end of pregnancy or until 38 weeks of gestation [40,42,45].

3.3. Diet characteristics

There were 4 types of dietary intervention which used in the included RCTs in this systematic review (Table 2) [38—45]. Three trials used low carbohydrate diet [38,41,43]. Total daily energy from carbohydrates was around 40% in both of intervention and control groups [38,41,43]. Three trials used total energy—restricted diet [41,43,45]. Energy restriction intervention was a calorie-restricted diet of 24—30 or 30 kcal/ideal body weight based on the pre-pregnancy weight (kg)/day in one of the included RCTs [41]. In other studies, total daily energy intake ranged from 1733 to 1800 kcal/day, which representing 70% of recommended caloric intake for women with GDM [43,45]. One trial used conventional GDM diet [39] and a trial used non-energy—restricted diet [40]. One trial used American Diabetes Association guidelines [44,46]. One trial used mindfulness eating for pregnant women with GDM [44,47,48]. One trial provided all participants an individually-prescribed diet (carbohydrates 48%—50%, proteins 18%—20%, fats 30%—35%, fiber 20—25 g/day, no alcohol) [42]. There were 6 trials reported prescribed diet [38,40—42,44,45] and 2 trials reported actual intake [39,43]. Three RCTs described some types of assessment of diet adherence [39,43,44].

3.4. Exercise characteristics

The types of exercise intervention that used in reviewed RCTs varied, as can be seen in Table 2 [38—45]. Two trials used resistance exercise intervention [40,41], 4 trials used aerobic exercise intervention [38,39,42,43], one of which combined structured aerobic and resistance exercise [45], one trial used a yoga as the exercise intervention [44]. The duration of each exercise session ranged from 15 to 55 min, which included short warm-up and cool-down stages. The frequency of exercise varied from 3 to 7 sessions per week. Exercise intensity was evaluated via different scales. Four trials used an age predicted heart rate maximum ranging from 50 to 85% [38,39,43,45], 2 trials used Borg exertional scale ratings of 12—14 [39,42,49]. One trial used the OMNI exertional scale [40,50] and one trial did not report the exercise intensity [44]. All of the exercise interventions were delivered in individual sessions. One

intervention was supervised directly by investigator [38]. Six trials had both of direct supervised and unsupervised exercise intervention [39—41,43—45]. One exercise intervention was home-based with indirect supervision through phone monitoring [42]. All of the included RCTs reported some information about the level of adherence to exercise in the intervention group. Exercise adherence among participants in the intervention group ranged from 66 to 100% [38—45].

3.5. Risk of bias assessment

Table 3 provides the details of the risk of bias for each included RCT, the quality of the evidence ranged from high to very low quality. Four of the trials were considered to be of low risk of bias for randomization [38,39,41,45]. Two of these trials used a random numbers table [39,41]. Kokic et al. [45] used computer-generated randomization whereas Jovanovic-Peterson et al. [38] randomized by drawing a number. Method of randomization was judged as unclear in 4 trials due to lack of sufficient details [40,42—44]. Three trials were considered to be of low risk of bias for allocation concealment [41—43]. Two of these trials used concealed, sequentially numbered opaque envelopes which selected by each participants [41,43]. Bo et al. [42] used a website (3rd person). Allocation concealment was judged as unclear in 5 trials due to lack of sufficient details [38—40,44,45]. Eight trials were judged to be of high risk of performance bias [38—45]. All included trials involved dietary and exercise interventions, so they were not expected that they would be possible to blind participants [38—45].

Three trials were considered to be of low risk of detection bias [42,44,45]. Bo et al. [42] stated that dietitians and obstetricians who recorded maternal/neonatal complications and laboratory workers were blinded to allocation. Youngwanichsetha et al. [44] reported glycosylated hemoglobin testing was conducted in a hospital laboratory. Kokic et al. [45] reported that physicians and laboratory staff were blinded. One trial provided no details of blinding of outcome assessors and was judged as having an unclear risk of bias [38]. Four trials were judged to be of high risk of bias, they represented home-monitored blood glucose levels which measured by participants [39—41,43]. Three trials were judged to be of low risk for attrition bias [38,40,42]. Jovanovic-Peterson et al. [38], de Barros et al. [40], and Bo et al. [42] showed that all women who were randomized were analyzed or that there were no losses to follow-up. Attrition of less than 10% was reported by Youngwanichsetha et al. [44] (5.5%) and Kokic et al. [45] (9.5%). Blood glucose and plasma insulin responses at post-intervention oral glucose tolerance test were recorded for 52.5% (21/40) participants [43]. There is no explanation as to why the remaining participants did not have results [44]. Avery et al. [39] and Brankston et al. [41] reported only 75.9% (22/29) and 75% (24/32) of women had home-monitored blood glucose levels, respectively. It is unclear why the other participant's results were missing.

Selective reporting was assessed as high, as the some trials presented additional outcomes in the results section that were not prespecified in the methods [38,40,42,45]. Brankston et al. [41], Halsa et al. [43] and Youngwanichsetha et al. [44] showed the effect of dietary and exercise interventions on glycemic control but no other neonatal or maternal outcomes were reported. Six trials were judged to be of low risk of other potential sources of bias [39,40,42—45]. Two trials were judged to be at high risk of other bias [38,41]. Jovanovic-Peterson et al. [38] documented that the women in the diet plus exercise group had a significantly higher 1-h plasma glucose in the diagnostic test at baseline, the intervention and control groups are not balanced for an important baseline prognostic variable. Brankston et al. [41] described that women in diet plus exercise group had a significantly lower body weight at

Table 2
Characteristics of the included trails according to diet and exercise intervention in GDM.

Reference, country	Sample characteristics	Intervention duration	Diet characteristics	Exercise characteristics
Jovanovic-Peterson et al. (1989)[38] USA	Intervention (n = 10) Maternal age = 29.5 ± 2.5 years GDM diagnosis at: 28 weeks Maternal weight at enrollment = 78.4 ± 9.7 kg Pre-pregnancy BMI= NA	**6 weeks**	**Low carbohydrate diet[a]** Energy: 24—30 kcal/kg/day of present pregnant weight. Carbohydrates: 40%, Proteins: 20%, Fats: 40%, Fiber: NA	**Aerobic exercice** 20 min x 3/week of supervised training on an arm ergometer(70% of maximum heart rate)
	Control (n = 9) Maternal age = 31.1 ± 2.8 years GDM diagnosis at: 28 weeks Maternal weight at enrollment = 75.3 ± 8.2 kg Pre-pregnancy BMI= NA	**6 weeks**	**Low carbohydrate diet[a]** Energy: 24—30 kcal/kg/day of present pregnant weight. Carbohydrates:40%, Proteins: 20%, Fats: 40%, Fiber: NA	Usual physical activity
Avery et al. (1997)[39] USA	Intervention (n = 15) Maternal age = 32.2 ± 4.9 years GDM diagnosis at: 28.7 ± 3.0 weeks Maternal weight at enrollment = 81.7 ± 15.2 kg Pre-pregnancy BMI = 28.4 ± 7.6 kg/m²	**6 weeks**	**Conventional diet[b]** Energy: 2301 ± 550 kcal/day Carbohydrates: 276 ± 73 g/day, Proteins: 116 ± 27 g/day, Fats: 86 ± 29 g/day, Fiber: 25 ± 7 g/day	**Aerobic exercice** 30 min x 2/week of supervised training on cycle ergometer. This included 10 min of warm-up and cool down periods, 20 min (70% of maximum heart rate). As well, 30 min x 1—2/week of unsupervised walking sessions at (70% of maximum heart rate via Borg Scale)
	Control (n = 14) Maternal age = 30.4 ± 5.1 years GDM diagnosis at: 26.3 ± 8.1 weeks Maternal weight at enrollment = 76.9 ± 14.2 kg Pre-pregnancy BMI = 25.5 ± 5.5 kg/m	**6 weeks**	**Conventional diet[b]** Energy: 2190 ± 472 kcal/day Carbohydrates: 289 ± 81 g/day, 53% Proteins: 107 ± 25 g/day, 20%, Fats: 72 ± 15 g/day, Fiber: 28 ± 12 g/day	Usual physical activity
de Barros et al. (2010)[40] Brazil	Intervention (n = 32) Maternal age = 31.8 ± 4.9 years GDM diagnosis at: 28.4 ± 2.5 weeks Maternal weight at enrollment: NA Pre-pregnancy BMI = 25.3 ± 4.2 kg/m²	**8 weeks**	**Non-energy-restricted diet[a]** Energy: 35 kcal/kg per day of the participant's ideal b pre-pregnancy body weight, and 300 kcal/day were added in the second and third trimesters of gestation Carbohydrates: NA, Proteins: NA, Fats: NA, Fiber: NA.	**Resistance exercise** 2 sessions/week of supervised and 1 session/week of unsupervised circuit resistance exercise. Each session consisted of 3 rounds of 8 exercises × 15 repetitions for 30—40 min (OMNI perceived exertion scale for resistance exercise "somewhat heavy")
	Control (n = 32) Maternal age = 32.4 ± 5.4 years GDM diagnosis at: 27.5 ± 3.3 weeks Maternal weight at enrollment: NA Pre-pregnancy BMI = 25.4 ± 3.8 kg/m²	**8 weeks**	**Non-energy-restricted diet[a]** Energy: 35 kcal/kg per day of the participant's ideal pre-pregnancy body weight, and 300 kcal/day were added in the second and third trimesters of gestation Carbohydrates: NA, Proteins: NA, Fats: NA, Fiber: NA.	Usual physical activity

Reference, country	Sample characteristics	Intervention duration	Diet characteristics	Exercise characteristics
Brankston et al. (2004)[41] Canada	Intervention (n = 16) Maternal age = 30.5 ± 4.4 years GDM diagnosis: NA Maternal weight at enrollment = 76.3 ± 11.9 kg Pre-pregnancy BMI = 25.9 ± 3.4 kg/m²	**8 weeks**	**Energy-restricted and low carbohydrate diet[a]** Energy: 24—30 kcal/kg per day of the participant's ideal pre-pregnant body weight. Carbohydrates: 40%, Proteins: 20%, Fats:40%, Fiber: NA	**Resistance exercise** Circuit resistance exercise session supervised for 3 session, then unsupervised 2 to 3 sets x 15 to 20 repetitions x 3/week (a perceived exertion scale for resistance exercise "somewhat hard")
	Control (n = 16) Maternal age = 31.3 ± 5.0 years GDM diagnosis: NA Maternal weight at enrollment = 86.6 ± 24.0 kg Pre-pregnancy BMI = 28.0 ± 5.7 kg/m²	**8 weeks**	**Energy-restricted and low carbohydrate diet[a]** Energy: 24—30 kcal/kg per day of the participant's ideal pre-pregnant body weight. Carbohydrates: 40%, Proteins: 20%, Fats:40%, Fiber: NA	Usual physical activity
Bo et al. (2014)[42] Italy	Intervention (n = 101) Maternal age = 18—50 years GDM diagnosis: 24—26 weeks Maternal weight at enrollment = 73.1 ± 11.2 kg Pre-pregnancy BMI = 27.6 ± 4.1 kg/m²	**12—14 weeks**	**Prescribed diet[a]** Energy: NA, Carbohydrates: 48%—50%, Proteins: 18%—20%, Fats:30%—35%, Fiber:20—25 g/day, no alcohol ± behavioral advice	**Aerobic exercise** 20 min x 7/week of unsupervised brisk walking, (Borg's scale target rating 12 to 14)
	Control (n = 99) Maternal age = 18—50 years GDM diagnosis: 24—26 weeks Maternal weight at enrollment = 74.0 ± 12.2 kg Pre-pregnancy BMI = 27.5 ± 4.4 kg/m²	**12—14 weeks**	**Prescribed diet[a]** Energy: NA, Carbohydrates: 48%—50%, Proteins: 18%—20%, Fats:30%—35%, Fiber:20—25 g/day, no alcohol ± behavioral advice	NA

Table 2 (continued)

Reference, country	Sample characteristics	Intervention duration	Diet characteristics	Exercise characteristics
Halsa et al. (2014)[43] Australia	Intervention (n = 20) Maternal age = 34.0 ± 5.0 years GDM diagnosis at: 28.8 ± 1.0 weeks Maternal weight at enrollment: NA Pre-pregnancy BMI = 25.2 ± 6.7 kg/m²	**6 weeks**	**Energy-restricted and low carbohydrate diet**[b] Energy: 1733 ± 492 kcal/day Carbohydrates: 181 ± 49 g/day(43% of total energy intake), Proteins: 98 ± 32 g/day, Fats: 63 ± 24 g/day, Fiber: 30 ± 13 g/day	**Aerobic exercise** 25–45 min x 5/week of home cycle ergometer, supervised for 3 sessions/week and unsupervised for 2 sessions/week (55–85% of maximum heart rate)
	Control (n = 20) Maternal age = 32.0 ± 3.0 years GDM diagnosis: 28.8 ± 1.0 weeks Maternal weight at enrollment: NA Pre-pregnancy BMI = 26.4 ± 7.1 kg/m²	**6 weeks**	**Energy-restricted and low carbohydrate diet**[b] Energy: 1772 ± 577 kcal/day Carobhydrates:170 ± 50 g/day (38% of total energy intake); Proteins: 113 ± 48 g/day, Fats: 66 ± 37, g/day, Fiber: 25 ± 8 g/day	Usual physical activity

Reference, country	Sample characteristics	Intervention duration	Diet characteristics	Exercise characteristics
Youngwanichsetha et al. (2014)[44] Thailand	Intervention (n = 85) Maternal age = 32.6 ± 5.0 years GDM diagnosis: 24–30 weeks Maternal weight at enrollment = 67.8 ± 10.1 kg Pre-pregnancy BMI = 27.1 ± 3.6 kg/m²	**8 weeks**	**Mindfulness eating for pregnant women with GDM + American Diabetes Association guidelines**[a]	**Yoga training** 15–20 min x 5/week of some supervised yoga breathing, postures and movements
	Control(n = 85) Maternal age = 31.2 ± 4.5 years GDM diagnosis: 24–30 weeks Maternal weight at enrollment = 67.4 ± 11.7 kg Pre-pregnancy BMI = 27.1 ± 4.1 kg/m²	**8 weeks**	**Mindfulness eating for pregnant women with GDM + American Diabetes Association guidelines**[a]	NA
Kokic et al. (2018)[45] Croatia	Intervention (n = 18) Maternal age = 32.8 ± 3.8years GDM diagnosis: 22.4 ± 6.6 weeks Maternal weight at enrollment = 68.0 ± 13.7 kg Pre-pregnancy BMI = 24.4 ± 4.9 kg/m²	**6 weeks**	**Energy-restricted and moderate carbohydrate diet**[a] Energy: 1800 kcal per day. Carbohydrates: 50% (225 g/day), Proteins: 20% (90 g/day), Fats: 30% (60 g/day)	**Combined aerobic and resistance exercise** 50–55 min x 2 sessions/week of supervised aerobic exercise (20 min) (65–75% of maximum heart rate), resistance exercises (20–25 min), pelvic floor and stretching exercises, and followed by a short period of relaxation to end the session (10 min). In addition, 30 min x 7/week of unsupervised aerobic brisk walking (65–75% of maximum heart rate).
	Control(n = 20) Maternal age = 32.0 ± 4.9 years GDM diagnosis:20.8 ± 6.1weeks Maternal weight at enrollment = 71.6 ± 15.5 kg Pre-pregnancy BMI = 25.3 ± 4.7 kg/m²	**6 weeks**	**Energy-restricted and moderate carbohydrate diet**[a] Energy: 1800 kcal per day: Carbohydrates: 50% (225 g/day), Proteins: 20% (90 g/day), Fats: 30% (60 g/day)	Usual physical activity

Abbreviations: n, number of participants; GDM: gestational diabetes mellitus; BMI, body mass index; NA: not available.
[a] Dietary prescription.
[b] Actual intake.

Table 3
Risk of bias assessment: review authors' judgements about each risk of bias item for each included trial.

Reference	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Jovanovic-Peterson et al. (1989)[38]	Low risk	Unclear risk	High risk	Unclear risk	Low risk	High risk	High risk
Avery et al. (1997)[39]	Low risk	Unclear risk	High risk	High risk	High risk	Unclear risk	Low risk
de Barros et al. (2010)[40]	Unclear risk	Unclear risk	High risk	High risk	Low risk	High risk	Low risk
Brankston et al. (2004)[41]	Low risk	Low risk	High risk	High risk	High risk	High risk	High risk
Bo et al. (2014)[42]	Unclear risk	Low risk	High risk	Low risk	Low risk	High risk	Low risk
Halsa et al. (2014)[43]	Unclear risk	Low risk	High risk	High risk	High risk	High risk	Low risk
Youngwanichsetha et al. (2014)[44]	Unclear risk	Unclear risk	High risk	Low risk	Low risk	High risk	Low risk
Kokic et al. (2018)[45]	Low risk	Unclear risk	High risk	Low risk	Low risk	High risk	Low risk

baseline, they allocated participants to groups in a way that was not truly random.

3.6. Effect of combined diet and exercise on glycemic control

3.6.1. Fasting blood glucose

Data from 7 trials with a total of 528 participants, compared the effect of the diet plus exercise interventions with the effect of diet interventions on the fasting blood glucose level (Table 4) [38,39,41—45]. Three trials showed that the fasting blood glucose level reduced in both of diet plus exercise and diet groups, with a significant difference between groups [38,44,45]. No statistical significant difference between diet plus exercise and control participants was observed in the fasting blood glucose level in 3 trials [39,41,42]. There was a tendency for lower daily fasting blood glucose levels in the diet plus exercise group as compared to those in diet group, with no significant difference between groups [43].

3.6.2. Postprandial blood glucose

Data from 8 trials with a total of 592 participants, compared the effect of the diet plus exercise interventions with the effect of the diet interventions on the postprandial blood glucose level (Table 4) [38—45]. Six trials showed that mean postprandial blood glucose level was significantly lower in the diet plus exercise group compared with that in the diet group [38,41—45]. No statistical difference between the diet plus exercise and the diet participants was found in the postprandial blood glucose in 2 trials [39,40].

3.6.3. Glycated haemoglobin (HbA1c)

Data from 5 trials with a total of 458 participants, compared the effect of the diet plus exercise interventions with the effect of the diet interventions on HbA1c (Table 4) [38,39,42—44]. Three RCTs reported that the HbA1c percentage decreased in both of the diet plus exercise and diet groups, with a significant difference between groups [38,42,44]. Whereas, Halsa et al. [43] found that HbA1c

Table 4
Glycemic, maternal and newborn outcomes of the included trials.

Reference	Glycemic outcomes Intervention versus Control group	Maternal outcomes Intervention versus Control group	Newborn outcomes Intervention versus Control group
Jovanovic-Peterson et al. (1989)[38]	Fasting blood glucose level: ↓ Improved Postprandial blood glucose level: ↓ Improved HbA1c: ↓ Improved	Total weight gain: NA Cesarean section: NA Insulin need: No difference	Birth weight: No difference Macrosomia: NA Hypoglycemia: NA Preterm Birth: No difference
Avery et al. (1997)[39]	Fasting blood glucose level: No difference Postprandial blood glucose level: No difference HbA1c: No difference	Total weight gain: NA Cesarean section: No difference Insulin need: No difference	Birth weight: No difference Macrosomia: No difference Hypoglycemia: No difference Preterm Birth: No difference
de Barros et al. (2010)[40]	Fasting blood glucose level: NA Postprandial blood glucose level: No difference HbA1c: NA	Total weight gain: No difference Cesarean section: No difference Insulin need: ↓ Improved	Birth weight: No difference Macrosomia: No difference Hypoglycemia: NA Preterm Birth: No difference
Brankston et al. (2004)[41]	Fasting blood glucose level: No difference Postprandial blood glucose level: ↓ Improved HbA1c: NA	Total weight gain: No difference Cesarean section: NA Insulin need: No difference	Birth weight: NA Macrosomia: NA Hypoglycaemia: NA Preterm Birth: NA
Bo et al. (2014)[42]	Fasting blood glucose level: No difference Postprandial blood glucose level: ↓ Improved HbA1c: ↓ Improved	Total weight gain: NA Cesarean section: No difference Insulin need: No difference	Birth weight: NA Macrosomia: NA Hypoglycemia: NA Preterm Birth: No difference
Halsa et al. (2014)[43]	Fasting blood glucose level: No difference Postprandial blood glucose level: ↓ Improved HbA1c: No difference	Total weight gain: NA Cesarean section: NA Insulin need: No difference	Birth weight: NA Macrosomia: NA Hypoglycemia: NA Preterm Birth: NA
Reference	Glycemic outcomes Intervention versus Control group	Maternal outcomes Intervention versus Control group	Newborn outcomes Intervention versus Control group
Youngwanichsetha et al. (2014)[44]	Fasting blood glucose level: ↓ Improved Postprandial blood glucose level: ↓ Improved HbA1c: ↓ Improved	Total weight gain: NA Cesarean section: NA Insulin need: NA	Birth weight: NA Macrosomia: NA Hypoglycemia: NA Preterm Birth: NA
Kokic et al. (2018)[45]	Intervention Fasting blood glucose level: ↓ Improved Postprandial blood glucose level: ↓ Improved HbA1c: NA	Intervention Total weight gain: No difference Cesarean section: No difference Insulin need: No difference	Intervention Birth weight: No difference Macrosomia: NA Hypoglycemia: No difference Preterm Birth: No difference

Abbreviations: HbA1c, glycated hemoglobin NA: not available.

percentage was higher at the post-intervention assessment in both groups as compared with pre-intervention values, with no significant difference between groups. One trial showed that mean HbA1c percentage was not significantly different between the diet plus exercise and the diet groups [39].

3.7. Effect of combined diet and exercise on maternal outcomes

Three trails with a total of 134 participants reported total weight gain during pregnancy (Table 4) [40,41,45]. There was no statistical difference in the total weight gain during pregnancy between the pregnant women who participated in the diet plus exercise interventions and those who received only dietary interventions [40,41,45]. Data from 4 trials with a total of 331 participants found that frequency of cesarean section was not significantly different between the diet plus exercise and diet groups [39,40,42,45]. Seven trials with a total of 422 participants, compared the effect of the diet plus exercise with the effect of the diet on the number of participants requiring insulin therapy (Table 4) [38–43,45]. No significant difference was found regarding the number of participants who needed insulin therapy between the two groups (Table 4) [38,39,41–43,45]. One trial observed a significant reduction in the number of women who required insulin therapy in the diet plus exercise group compared with diet-alone group [40].

3.8. Effect of combined diet and exercise on newborn outcomes

Five trails with a total of 350 infants, compared the effect of diet plus exercise interventions with the effect of diet interventions on newborn outcomes (Table 4) [38–40,42,45]. Newborn birth weights were not significantly different between the exercise plus diet and diet groups [38–40,42,45]. Two trials reported number of newborn who had a birthweight greater than 4000 g (Table 4) [39,40]. There were no episodes of neonatal hypoglycemia documented in 2 trials (Table 4) [39,45]. Data from 5 trials with a total of 350 infants, found that the preterm birth was not significantly different between the intervention and control groups (Table 4) [38–40,42,45].

4. Discussion

Eight intervention studies met the inclusion criteria for this systematic review were included in this review [38–45]. Evidence from the 8 RCTs showed that the diet plus exercise interventions improved glycemic outcomes and lowered fasting and postprandial blood glucose levels for women with GDM compared with dietary interventions. Glycated haemoglobin level, which measure longer-term (8–12 weeks) glycemic control [51], also improved significantly in diet plus exercise group when compared with diet group among 3 trials [38,42,44]. More recently, two systematic reviews found that exercise as an adjunct to standard care improved capillary blood glucose concentrations specifically postprandial blood glucose among pregnant women with GDM as compared with standard care alone [13,36] The last published systematic review from Cochrane on exercise for pregnant women with GDM revealed that exercise interventions were associated with reduced fasting and postprandial blood glucose concentrations compared with conventional interventions [52].

The Evidence from the 8 RCTs found that the diet plus exercise interventions had beneficial effect mainly on postprandial blood glucose level in women diagnosed with GDM. Lifestyle modification based on behavior therapy is the primary therapeutic strategy for women with GDM and most commonly includes healthy eating, exercise, and self-monitoring of blood glucose levels [15]. It has been suggested that 70%–85% of pregnant women diagnosed with

GDM can control GDM with lifestyle modification alone [53]. Medical nutritional therapy is the basis of standard GDM management for maintaining euglycemia, optimizing fetal/neonatal and maternal health outcomes, and promoting appropriate gestational weight gain [53]. Women with GDM who achieved a fasting glucose ≤ 95 mg/dL (≤ 5.4 mmol/L) within 2 weeks of diet therapy were less likely to prescribe insulin or oral anti-diabetic medication [54,55]. Beside medical nutrition therapy, exercise is a key component in GDM management. According to our results, the adoption of low carbohydrate or total energy restricted diet with aerobic or resistance exercise improved glycemic control and reduced postprandial glucose levels [38,41,43–45]. Energy restriction is a dietary approach for controlling blood glucose levels and preventing macrosomia in infants of women with GDM [56]. It has been demonstrated that prescribing a low carbohydrate diet decreased risk of postprandial hyperglycemia and lower risk of requiring insulin to control blood glucose among pregnant women with GDM [57]. In contrast, Cypryk et al. [58] compared a lower-carbohydrate diet (45% of total energy intake) to a higher-carbohydrate diet (65% of total energy intake) and showed there was no significant difference in blood glucose control between the two groups. Moreno-Castilla et al. [59] found that treatment of women with GDM using a low-carbohydrate diet (40% of total energy intake) did not influence insulin requirement or pregnant outcomes.

Some dietary approaches are based on the modification of carbohydrates quality and their glycemic load and glycemic index. Three trials described the recommended dietary fiber intake and it ranged from 20 to 30 g/day [39,42,43]. Dietary reference intake of fiber is 14 g/1000 kcal in all trimesters of pregnancy [60]. Two of 3 trials showed beneficial effect on postprandial glycemic control [42,43]. Afaghi et al. [61] noted that low-glycemic load diet by adding a supplement of fiber reduced postprandial blood glucose concentration and need to commence insulin.

The American Diabetes Association, American College of Obstetricians and Gynecologists, and Endocrine Society guidelines recommend that pregnant women who have no obstetric or medical contraindications should be encouraged to start a program of moderate exercise consisting of 30 min most days of the week as part of treatment for GDM [10,30,62]. Both aerobic and resistance exercise are beneficial, and it is optimal to do both types of exercise to improve glycemic regulation [63]. Investigators have revealed that exercise increases the rate of glucose uptake into the skeletal muscle, both during the exercise bout and for some hours post exercise. This increase occurs as a results of glucose transport protein GLUT-4 being translocated from intracellular sites to the sarcolemma and T tubules, thus increasing the sites at which glucose can diffuse into the muscle cell [63–67]. Exercise training also increases insulin action by promoting glucose uptake in muscle and increasing use of intracellular fatty acids [68,69]. This improves insulin sensitivity, stimulates glucose uptake and results in a decrease in blood glucose level for more than 24 h but less than 72 h [70]. Glucose uptake is also regulated by the duration and intensity of exercise performed. More intense exercise has stronger glycemic lowering effect [71,72].

Most of the included trials found no significant difference between the diet plus exercise and the diet groups in number of women whose required insulin treatment [38,39,41–43,45]. Except one trial revealed that women who followed diet plus exercise treatment were prescribed less insulin ($P < 0.01$) [40]. Exercise is associated with improved insulin sensitivity which might improve both fasting and postprandial glucose concentrations and obviating the use of insulin in some women with GDM [73].

Overall, there no notable differences were reported in the included trials regarding other maternal and infant outcomes

across the diet plus exercise and the diet groups. A previous systematic review and meta-analysis of four trials involving 141 pregnant women with GDM conducted a decade ago concluded that there was insufficient evidence to determine whether exercise should be recommended to reduce maternal and perinatal morbidity in women with GDM [74]. The last publish systematic review from Cochrane on exercise for pregnant women with GDM could not find any significant benefits for both mother and her infant [52]. Like results reported in this systematic review, the exercise did not influence weight gain in pregnancy, rate of cesarean section, use of additional pharmacotherapy, macrosomia, preterm birth, and neonatal hypoglycemia [52].

A possible limitation of our systematic review could be related to different types of diet and exercise used in the included studies. Additionally, in the included studies, the studied outcomes were not always the same, not equally standardized or even not available, particularly maternal and newborn outcomes. Finally, the adherence of dietary interventions was not assessed or reported in 5 trials [38,40—42,45].

5. Conclusion

In conclusion, this review indicates that combined diet and exercise interventions can exert a beneficial effect on glycemic control specifically in controlling postprandial blood glucose levels among women diagnosed with GDM. Calorie and carbohydrate restriction diet plus aerobic or resistance exercise interventions were effective for management of GDM. Therefore, the present available evidence supports recommendation that exercise, as an adjunct to medical nutritional therapy for GDM. There are currently insufficient data to determine if the combined diet and exercise interventions are also benefits for the infant.

6. Suggestion

The authors suggest that there is a need to conduct further researches to evaluate the effect of different types of diet plus exercise interventions on infant outcomes as listed in this review.

Conflicts of interest

The authors declare that they have no conflict of interests.

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Conflicts of interest

The authors declare that they have no any competing or conflict of interest.

Authors' contributions

SSA and RFT were contributed to the conception and design of the manuscript. SSA established the methodology and was responsible for data extraction. RFT rechecked the data extraction. SSA and RFT did quality assessment and SSA produced the first draft of the manuscript. SSA, RFT, ASB and FFA reviewed and critically revised the draft of manuscript. All authors read and approved the final version of the manuscript for publication.

References

[1] Gabbe SG, Graves CR. Management of diabetes mellitus complicating pregnancy. Obstet Gynecol 2003;102(4):857—68.

[2] Bellamy L, Casas JP, Hingorani AD, Williams D. Type 2 diabetes mellitus aftergestational diabetes: a systematic review and meta-analysis. Lancet 2009;373(9677):1773—9.

[3] Reece EA, Leguizamon G, Wiznitzer A. Gestational diabetes: the need for a common ground. Lancet 2009;373(9677):1789—97.

[4] Bener A, Saleh NM, Al-Hamaq A. Prevalence of gestational diabetes and associated maternal and neonatal complications in a fast-developing community: global comparisons. Int J Womens 2011;3:367—73.

[5] Kim C, Newton KM, Knopp RH. Gestational diabetes and the incidence of type 2 diabetes: a systematic review. Diabetes Care 2002;25(10):1862—8.

[6] Lawlor DA, Lichtenstein P, Langstrom N. Association of maternal diabetes mellitus in pregnancy with offspring adiposity into early adulthood: sibling study in a prospective cohort of 280,866 men from 248,293 families. Circulation 2011;123(3):258—65.

[7] Kawasaki M, Arata N, Miyazaki C, Mori R, Kikuchi T, Ogawa Y, Ota E. Obesity and abnormal glucose tolerance in offspring of diabetic mothers: a systematic review and meta-analysis. PLoS One 2018;13(1):e0190676.

[8] Melchior H, Kurch-Bek D, Mund M. The Prevalence of gestational diabetes. Dtsch Arztebl Int 2017;114(24):412—8.

[9] Reader DM. Medical nutrition therapy and lifestyle interventions. Diabetes Care 2007;30(Suppl 2):S188—93.

[10] Blumer I, Hadar E, Hadden DR, Jovanovič L, Mestman JH, Murad MH, Yogev Y. Diabetes and pregnancy: an endocrine society clinical practice guideline. J Clin Endocrinol Metab 2013;98(11):4227—49.

[11] Falavigna M, Schmidt MI, Trujillo J, Alves LF, Wendland ER, Torloni MR, et al. Effectiveness of gestational diabetes treatment: a systematic review with quality of evidence assessment. Diabetes Res Clin Pract 2012;9(3):396—405.

[12] Viana LV, Gross JL, Azevedo MJ. Dietary intervention in patients with Gestational diabetes mellitus: a systematic review and meta-analysis of randomized clinical trials on maternal and newborn outcomes. Diabetes Care 2014;37(12):3345—55.

[13] Harrison AL, Shields N, Taylor NF, Frawley HC. Exercise improves glycaemic control in women diagnosed with gestational diabetes mellitus: a systematic review. J Physiother 2016;62(4):188—96.

[14] 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;2:CD009275.

[15] Brown J, Alwan NA, West J, Brown S, McKinlay CJD, Farrar D, Crowther CA. Lifestyle interventions for the treatment of women with gestational diabetes (Review). Cochrane Database Syst Rev 2017;5:CD011970.

[16] Xu T, He Y, Dainelli L, Yu K, Detzel P, Silva-Zolezzi I, et al. Healthcare interventions for the prevention and control of gestational diabetes mellitus in China: a scoping review. BMC Pregnancy Childbirth 2017;17:171.

[17] Yamamoto JM, Joanne E, Kellett JE, García-Patterson A, Hadar E, Solà I, et al. Gestational diabetes mellitus and diet: a systematic review and meta-analysis of randomized controlled trials examining the impact of modified dietary interventions on maternal glucose control and neonatal birth weight. Diabetes Care 2018;41(7):1346—61.

[18] Garg A, Kashyap S. Effect of counseling on nutritional status during pregnancy. Indian J Pediatr 2006;73(8):687—92.

[19] Girard AW, Olude O. Nutrition education and counselling provided during pregnancy: effects on maternal, neonatal and child health outcomes. Paediatr Perinat Epidemiol 2012;26(Suppl 1):191—204.

[20] Guelinckx I, Devlieger R, Mullie P, Vansant G. Effect of lifestyle intervention on dietary habits, physical activity, and gestational weight gain in obese pregnant women: a randomized controlled trial. Am J Clin Nutr 2010;91(2):373—80.

[21] Thomas B, Ghebremeskel K, Lowy C, Crawford M, Offley-Shore B. Nutrient intake of women with and without gestational diabetes with a specific focus on fatty acids. Nutrition 2006;22(3):230—6.

[22] Artal R, Catanzaro RB, Gavard JA, Mostello DJ, Friganza JC. A lifestyle intervention of weight-gain restriction: diet and exercise in obese women with gestational diabetes mellitus. Appl Physiol Nutr Metabol 2007;32(3):596—601.

[23] Tobias DK, Hu FB, Chavarro J, Rosner B, Mozaffarian D, Zhang C. Healthful dietary patterns and type 2 diabetes mellitus risk among women with a history of gestational diabetes mellitus. Arch Intern Med 2012;172(20):1566—72.

[24] Hernandez TL, Anderson MA, Chartier-Logan C, Friedman JE, Barbour LA. Strategies in the nutritional management of gestational diabetes. Clin Obstet Gynecol 2013;56(4):803—15.

[25] Artal R. Exercise: the alterative therapeutic intervention for gestational diabetes. Clin Obstet Gynecol 2003;46(2):479—87.

[26] Bung P, Artal R. Gestational diabetes and exercise: a survey. Semin Perinatol 1996;20(4):328—33.

[27] Jacqueminet S, Jannot-Lamotte MF. Therapeutic management of gestational diabetes. Diabetes Metab 2010;36(6 Pt 2):658—71.

[28] Prather H, Spitznagle T, Hunt D. Benefits of exercise during pregnancy. PM.R 2012;4(11):845—50.

[29] Colberg SR, Castorino K, Jovanovic L. Prescribing physical activity to prevent and manage gestational diabetes. World J Diabetes 2013;4(6):256—62.

[30] American College of Obstetricians and Gynecologists. ACOG practice bulletin No. 190: gestational diabetes mellitus. Obstet Gynecol 2018;131(2):e49—64.

[31] National Institute for Health and Care Excellence. Gestational diabetes: risk assessment, testing, diagnosis and management. Manchester: NICE; 2015.

[32] Wang C, Zhu W, Wei1 Y, Feng H, Su R, Yang H. Exercise intervention during pregnancy can be used to manage weight gain and improve pregnancy outcomes in women with gestational diabetes mellitus. BMC Pregnancy Childbirth 2015;15:255.

[33] Bain E, Crane M, Tieu J, Han S, Crowther CA, Middleton P. Diet and exercise interventions for preventing gestational diabetes mellitus. Cochrane Database Syst Rev 2015;4:CD10443.

[34] 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;11:CD010443.

[35] Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, Ioannidis JP, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. BMJ 2009;339:b2700.

[36] Cremona A, O'Gorman C, Cotter A, Saunders J, Donnelly A. Effect of exercise modality on markers of insulin sensitivity and blood glucose control in pregnancies complicated with gestational diabetes mellitus: a systematic review. Obes Sci Pract 2018;4(5):455—67.

[37] Higgins JPT, Altman DG, Peter C, Jüni P, Moher D, Oxman AD, et al. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. BMJ 2011;343:d5928.

[38] Jovanovic-Petersen L, Durak EP, Petersen CM. Randomized trial of diet versus diet plus cardiovascular conditioning on glucose levels in gestational diabetes. Am J Obstet Gynecol 1989;161(2):415—9.

[39] Avery MD, Leon AS, Kopher RA. Effects of a partially home-based exercise program for women with gestational diabetes. Obstet Gynecol 1997;89(1):10—5.

[40] de Barros MC, Lopes MAB, Francisco RPV, Sapienza AD, Zugaib M. Resistance exercise and glycemic control in women with gestational diabetes mellitus. Am J Obstet Gynecol 2010;203(6):e1—6.

[41] Brankston GN, Mitchell BF, Ryan EA, Okun NB. Resistance exercise decreases the need for insulin in overweight women with gestational diabetes mellitus. Am J Obstet Gynecol 2004;190:188—93.

[42] Bo S, Rosato R, Ciccone G, Canil S, Gambino R, Poala CB, et al. Simple lifestyle recommendations and the outcomes of gestational diabetes. A 2 x 2 factorial randomized trial. Diabetes Obes Metab 2014;16(10):1032—5.

[43] Halse RE, Wallman KE, Newnham JP, Guelfi KJ. Home-based exercise training improves capillary glucose profile in women with gestational diabetes. Med Sci Sport Exerc 2014;46(9):1702—9.

[44] Youngwanichsetha S, Phumdoung S, Ingkathawornwong T. The effects of mindfulness eating and yoga exercise on blood sugar levels of pregnant women with gestational diabetes mellitus. Appl Nurs Res 2014;27(4):227—30.

[45] Kokic SI, Ivanisevic M, Biolo G, Simunic B, Kokic T, Pisot R. Combination of a structured aerobic and resistance exercise improves glycaemic control in pregnant women diagnosed with gestational diabetes mellitus. A randomised controlled trial. Women Birth 2018;31(4):e23—8.

[46] American Association of Diabetes. Standards of medical care in diabetes-2012. Diabetes Care 2012;35(Suppl 1):S11—63.

[47] Solloway SG, Fisher WP. Mindfulness practice: a rasch variable construct innovation. J Appl Meas 2007;8(4):359—72.

[48] Daubenmier J, Kristeller J, Hecht FM, Maninger N, Kuwata M, Jhaveri K, et al. Mindfulness intervention for stress eating to reduce cortisol and abdominal fat among overweight and obese women: an exploratory randomized controlled study. J Obes 2011:651936. 2011.

[49] Borg GA. Psychophysical bases of perceived exertion. Med Sci Sport Exerc 1982;14(5):377—81.

[50] Robertson RJ, Goss FJ, Rutkowski J, Lenz B, Dixon C, Timmer J, et al. Concurrent validation of the OMNI perceived exertion scale for resistance exercise. Med Sci Sport Exerc 2003;35(2):333—41.

[51] Nathan DM, Turgeon H, Regan S. Relationship between glycated haemoglobin levels and mean glucose levels over time. Diabetologia 2007;50(11):2239—44.

[52] Brown J, Ceysens G, Boulvain M. Exercise for pregnant women with gestational diabetes for improving maternal and fetal outcomes (Review). Cochrane Database Syst Rev 2017;6. CD012202.

[53] American Association of Diabetes. Management of diabetesin pregnancy: standards of medical care in diabetes-2018. Diabetes Care 2018;41:S137—43.

[54] McFarland MB, Langer O, Conway DL, Berkus MD. Dietary therapy for gestational diabetes: how long is long enough? Obstet Gynecol 1991;93(6):978—82.

[55] Barnes RA, Wong T, Ross GP, Jalaludin BB, Wong VW, Smart CE, et al. A novel validated model for the prediction of insulin therapy initiation and adverse perinatal outcomes in women with gestational diabetes mellitus. Diabetologia 2016;59(11):2331—8.

[56] Magon N, Seshiah V. Gestational diabetes mellitus: non-insulin management. Indian J Endocrinol and Metab 2011;15(4):284—93.

[57] Major CA, Henry MJ, de Veciana M, Morgan MA. The effects of carbohydrate restriction in patients with diet-controlled gestational diabetes. Obstet Gynecol 1998;91(4):600—4.

[58] Cypryk K, Kaminska P, Kosinski M, Pertyńska-Marczewska M, Lewiński A. A comparison of the effectiveness, tolerability and safety of high and low carbohydrate diets in women with gestational diabetes. Endokrynol Pol 2007;58(4):314—9.

[59] Moreno-Castilla C, Hernandez M, Bergua M, Alvarez MC, Arce MA, Rodriguez K, et al. Low-carbohydrate diet for the treatment of gestational diabetes mellitus: a randomized controlled trial. Diabetes Care 2013;36(8):2233—8.

[60] Trumbo P, Schlicker S, Yates AA, Poos M. Food and Nutrition Board of the Institute of Medicine, and the National Academies. Dietary reference intakes for energy, carbohydrates, fiber, fat, fatty acids, cholesterol, protein and amino acids. J Am Diet Assoc 2002;102(11):1621—30.

[61] Afaghi A, Ghanei L, Ziaee A. Effect of low glycemic load diet with and without wheat bran on glucose control in gestational diabetes mellitus: a randomized trial. Indian J Endocrinol Metab 2013;17(4):689—92.

[62] Colberg SR, Sigal RJ, Fernhall B, Regensteiner JG, Blissmer BJ, Rubin RR, et al. Exercise and type 2 diabetes: the American College of sports medicine and the American diabetes association: joint position statement. Diabetes Care 2010;33(12):e147—67.

[63] Bird SR, Hawley JA. Update on the effects of physical activity on insulin sensitivity in humans. BMJ Open Sport Exerc Med 2016;2(1):e000143.

[64] Barnard RJ, Youngren JF. Regulation of glucose transport in skeletal muscle. FASEB J 1992;6(14):3238—44.

[65] Goodyear LJ, Kahn BB. Exercise, glucose transport, and insulin sensitivity. Annu Rev Med 1998;49:235—61.

[66] Hayashi T, Wojtaszewski JF, Goodyear LJ. Exercise regulation of glucose transport in skeletal muscle. Am J Physiol 1997;273(6 Pt 1):E1039—51.

[67] Ryder JW, Chibalin AV, Zierath JR. Intracellular mechanisms underlyingincreases in glucose uptake in response to insulin or exercise in skeletal muscle. Acta Physiol Scand 2001;171(3):249—57.

[68] Santos JM, Ribeiro SB, Gaya AR, Appell HJ, Duarte JA. Skeletal muscle pathways ofcontraction-enhanced glucose uptake. Int J Sports Med 2008;29(10):785—94.

[69] Turcotte LP, Fisher JS. Skeletal muscle insulin resistance: roles of fatty acid-metabolism and exercise. Phys Ther 2008;88(11):1279—96.

[70] Colberg SR, Sigal RJ, Fernhall B, Regensteiner JG, Blissmer BJ, Rubin RR, et al. Exercise and type 2 diabetes: the American College of sports medicine and the American diabetes association: joint position statement. Diabetes Care 2010;33(12):e147—67.

[71] Richter EA, Derave W, Wojtaszewski JF. Glucose, exercise and insulin: emerging concepts. J Physiol 2001;535(Pt 2):313—22.

[72] Mul JD, Stanford KI, Hirshman MF, Goodyear LJ. Exercise and regulation of carbohydrate metabolism. Prog Mol Biol Transl Sci 2015;135:17—37.

[73] Horton ES. Exercise in the treatment of NIDDM. Applications for GDM? Diabetes 1991;40(Suppl 2):175—8.

[74] Ceysens G, Rouiller D, Boulvain M. Exercise for diabetic pregnant women. Cochrane Database Syst Rev 2006;3:CD004225.