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REVIEW

Review of general suggestions on physical activity to prevent and treat gestational and pre-existing diabetes during pregnancy and in postpartum

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Abstract The aim of this review is to provide general suggestions on physical activity (PA) in pre-gestational and gestational diabetes mellitus (GDM) and encourage women to take part in safe and effective activities throughout pregnancy, in the absence of other contraindications. PA before and during pregnancy and in postpartum has many positive effects on the mother, as it could reduce the risk of GDM, excessive weight gain and lower back pain and also prevents, in the postpartum, diabetes mellitus. It may also reduce the duration of labour and complications at childbirth, fatigue, stress, anxiety and depression, thereby leading to an improved sense of wellbeing. Clinically, it is thought to help prevent preeclampsia and premature birth even though RCTs provide conflicting evidence with regard to the prevention of GDM. The main reason for this rests on the fact that the majority of clinical trials have not been able to replicate the preventive effect of PA on the onset of GDM, such as the different adherence of the patient to PA. Herein, we survey the literature regarding exercise and PA on GDM prevention and treatment as well as on clinical outcomes in pre-GDM in pregnancy. On the basis of the current literature, we also present a series of general recommendations and suggestions on PA and exercise training in pregnancy among both diabetic patients and those at risk for GDM.

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Background

There is evidence that physical activity (PA) during pregnancy has many potential positive effects on the mother: reduced risk of excessive weight gain, gestational diabetes mellitus (GDM), preeclampsia, varicose veins, deep vein thrombosis and lower back pain [1,2]. PA also reduces the duration of labour and complications at childbirth, fatigue, stress, anxiety and depression, thereby leading to an improved sense of wellbeing [3,4]. Other potential benefits for the foetus are improvement in placental function with increased amniotic fluid, flow and volume of the placenta, foetal vascular function, placental villous tissue, speed of foetal growth, neuronal development and reduced percentage of foetal fat [5]. Physicians should advise female patients how to safely perform PA during pregnancy and in the postpartum period. Providing a woman with an adequate prescription of exercise training can encourage her to take part in safe and effective activities throughout pregnancy, in the absence of contraindications [6].

For women at high risk of GDM, initiating an exercise-training program during the preconception phase may be of importance. Risk factors include overweight, obesity, previous GDM, prior macrosomia, age above 35 years, positive family history for diabetes mellitus, polycystic ovary syndrome (PCOS) and high-risk ethnicity [7].

The prevalence of GDM is 4.7%–13.7% [8] Diagnostic criteria for GDM are according to IADPSG (International Association of Diabetes and Pregnancy Study Groups) criteria and Italian National Guidelines, and the woman should be tested between 24th and 28th gestational weeks. A single positive test result is enough for the diagnosis using a 2-h 75-g OGTT: fasting plasma glucose is ≥92 mg/dL (≥5.1 mmol/l), 1-h glucose value ≥180 mg/dL (≥10 mmol/l) and 2-h glucose value ≥153 mg/dL (≥8.5 mmol/l); furthermore, in high-risk women, testing may be carried out before 24–28 gestational weeks [9].

Once GDM is diagnosed, either aerobic or resistance training can improve insulin action and glycaemic control [10]. However, to the best of our knowledge, there are no clear guidelines or clear clinical recommendations. We review the literature and make suggestions regarding areas of prevention of GDM in the general female population, treatment of GDM in gestation and prescription of exercise in pregnancy, with specific attention to type, intensity and volume.

Methods

To identify relevant studies, MEDLINE, EMBASE, Web of Science and the Cochrane Library (1982–2017) databases were searched using MeSH headings and free-text terms for “Exercise” “Pregnancy” “Diabetes”, combined with the terms “prevention,” “Gestational,” “Pre-gestational,” “symptoms,” “management,” “Physical Activity” and “Exercise training.” The reference lists from retrieved articles were also examined for relevant papers. All randomised controlled trials (RCTs), prospective cohort studies, meta-analysis on pregnancy with and without diabetes, case–control studies, randomised trials and systematic reviews published in the English language were included in this review. We also included position statements and guidelines on PA in diabetes published by the main scientific societies such as the American Diabetes Association (ADA), the National Institute for Health and Care Excellence (NICE) and the American College of Obstetricians and Gynaecologists (AGOG) on PA during pregnancy and in the post-partum period.

We then classified the studies and formulated recommendations A–D, based on commonly accepted CONSORT standards [10,11], thus summarising the evaluation method of the current study. Each publication was assigned a level and grade according to Table 1 below:

Two reviewers (N.DB and AN) independently assessed the titles and abstracts of identified studies. Full texts of studies meeting the inclusion criteria (or in the case of uncertainty regarding inclusion) were retrieved, and consensus was achieved on inclusion status.

We excluded papers with few case reports or not justifiable retrospectives studies, studies not in English language or methodologically incorrect and included RCTs, prospective studies in English language, reviews, meta-analyses and Cochrane Collaboration publications.

Consultation among all authors revealed a 99% concordance in the evaluation of the 5 levels of the 153 publications retrieved and in the subsequent grading strengths. Of those retrieved, 93 publications were discarded for unclear procedures or with objectives other than prevention or treatment. Sixty-three publications remained and assessed the level with the grade of RCTs used.

We first discuss the assessed literature regarding prevention before and during pregnancy.

Table 1 Level and grade of evidence.

	Based upon level of evidence
Grade	
A	Further research is unlikely to change our confidence in the estimate of effect
B	Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate
C	Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate
D	Any estimate of effect is very uncertain
Level	
I	RCT with hard end-point
II	RCT with surrogate end-point
III	Non-randomised trial with a control group, or subgroup analysis of an RCT
IV	Before and after study
V	Case series > 10 patients

From Atkins D. British Medical Journal, 2004.

Prevention of gestational diabetes mellitus

Prevention before pregnancy

Epidemiological studies have shown that in the general adult population, approximately 55–60% of time awake is spent in sedentary behaviour [12,13]. Among pregnant women, the situation appears to be similar or even worse [14]. Indeed, a high proportion of pregnant women follow neither PA nor exercise guidelines, thus putting them at increased risk of obesity, other pregnancy-related diseases and complaints [15] and GDM.

Women diagnosed with GDM are at a higher risk of developing type 2 diabetes mellitus (T2DM) in later years. Kjos [16] suggests that approximately 63% of women develop T2DM within 5 years after delivery. Herein, we are not suggesting that PA could reduce this risk, but certainly, this issue is one that merits further study.

Regular PA before pregnancy has been associated with a reduced risk of developing GDM, and a more active lifestyle before pregnancy predicts a similar behaviour during pregnancy [17–19]. Even leisure time PA before pregnancy may reduce the risk of developing GDM [20,21].

During pregnancy

Being physically active also during pregnancy may prevent GDM [26] and delay the onset of T2DM [22]. Women who regularly perform PA in the year before their pregnancy have a decreased risk, reduced to 50% if the exercise is carried out during the first 20 weeks of pregnancy [23]. A more recent study reported that resistance training three times a week for 30 min throughout pregnancy is safe and leads to a reduction in GDM incidence and improves perinatal outcomes [24]. Similarly, the ETIP Trial RCT shows a GDM incidence reduction in the exercise group (27.3% vs 6.1%) as a secondary outcome observed [25].

Despite such positive evidence, not all studies concluded that PA can prevent the onset of GDM [26]. Recently, RCTs have assessed the role of prescribed exercise training on the prevention of GDM in women at high risk (obese with a history of previous GDM) [Table 2]. In Table 2, we present the major RCTs retrieved with information on outcomes and discuss these outcomes in the following paragraphs.

The 'UPBEAT' study [27], which aimed at assessing the role of lifestyle (PA + healthy eating) in obese and multiethnic English women, of whom 3–10% with previous GDM did observe a significantly weight and body fat reduction, but it did not demonstrate any difference in the prevalence of GDM (intervention group vs. standard group 26% vs. 25%) and neonatal macrosomia.

Similarly, the "LIMIT Study" [28], an Australian RCT study of 2212 overweight or obese women (1104 with standard treatment and 1108 with diet + lifestyle), did not demonstrate any differences in maternal (GDM, hypertension and preeclampsia) and neonatal outcomes (large for gestational age and macrosomia); however, there was no difference in total gestational weight gain between the two groups, while the study LIMIT2 showed a reduction in newborns whose weight was above 4.0 kg. Interestingly, the "DALI" pilot study [29], a European multicentre trial involving 150 pregnant women of BMI > 29 kg/m^2, did not show any significant difference in the three treatments, which included a change in lifestyle, healthy eating or both. Only a lower weight gain and lower fasting blood sugar in the diet-only group than the group treated with PA alone was observed. The combination of both interventions did not show any superiority in terms of outcomes.

The 'RADIEL' study [30], a Finnish RCT, assessed the efficacy of an intervention combining diet and PA during pregnancy in 293 women with high risk (BMI ≥ 30 kg/m^2 or previous GDM), recruited before the 20th week of gestation. Women in the intervention group showed a lower prevalence of GDM (13.9% vs. 21.6% in the control group), thereby reducing the risk by 39%. Improvements in increased leisure-time PA, better nutrition and a lower weight gain (−0.58 kg) were seen, but it was not clear whether which improvements were due to PA, diet or both.

A Chinese randomised clinical trial [19], recruited 300 overweight/obese women at 10 weeks' gestational age. They were randomised into an exercise group or a control group, the exercise group engaged in a supervised cycling program involving at least three sessions per week. Women randomised to the exercise group had a significantly lower incidence of GDM (22.0% *vs* 40.6%; $p < 0.001$). This represents a clinically important 45.8% reduction in the incidence of GDM. These women also had significantly less gestational weight gain by 25 gestational weeks and at the end of pregnancy and reduced insulin resistance levels at 25 gestational weeks.

A Spanish randomised clinical trial [2] included 342 women from weeks 10 and 14 to the end of the third trimester. Women who engaged in exercise program during pregnancy compared with the control group experienced a 90% reduced risk of GDM (OR = 0.103; 95% confidence interval (CI), 0.01–0.803). Significant differences were found between groups in excessive maternal weight gain according to pre-pregnancy BMI classes (IG, 22.8%, n = 23), vs CG, 34.8%, n = 54 (W21 = 4.23, p = 0.04). Women in the intervention group exercised for 50–60 min per session, three sessions per week, two on a floor mat in the gym hall and one as an aquatic water-based activity. The exercise intensity was set along the Borg's scale between 6 (without effort) and 20 (maximum effort). For the exercise sessions, Borg 12–14 was maintained. In addition, maternal HR was assessed and exercise intensity was modulated not to surpass 60% of the calculated HR reserve. These publications point to the conclusion that to reduce the incidence of GDM, a mixture of aerobic and muscle conditioning exercise at intensity and frequency utilised is necessary.

The Norwegian FIT for Delivery (NFFD) [31] RCT included 606 and examined the effect of the NFFD intervention on glucose metabolism, including an assessment of the subgroups of normal-weight and overweight/obese participants. The intervention group showed reduced

Table 2 RCTs on the prevention of GDM.

Clinical trials	Country	Patient no.	Patients' characteristics	GDM diagnosis criteria	Exercise type, intensity and duration	Nutritional counselling	GDM incidence reduction	Level and grade
UPBEAT [26]	UK	1555	Weeks' gestation 15–18 week. BMI $\geq$ 30 kg/m^2	IADPSG criteria	Intervention group • Handbook • DVD • Exercise regime • Pedometer • Logbook for recording weekly activities	• Social cognitive theory: 8 sessions $\times$ 1 h/week. • Suggested dietary changes. • Fewer carbohydrate-rich foods for foods with lower glycaemic index. • Restricting dietary intake of saturated fat.	NONE	I A
LIMIT [27]	Australia	2212	Weeks' gestation 10 + 0 to 20 + 0. week BMI $\geq$ 25 kg/m^2	WHO criteria	• Generic recommendations to increase the amount of walking and incidental activity	• Current dietary Australian standards • Reduce intake of refined carbohydrates and saturated fats, and increase intake of fibre, two servings of fruits and five servings of vegetables, each day	NONE	II A
RADIEL [29]	Finland	269	Weeks' gestation 13 week BMI $\geq$ 32 kg/m^2 Previous history of GDM	WHO criteria	Physical activity • 30 min $\times$ 5/week or • 50 min $\times$ 3/week • Moderate Intensity (11–15 on Borg's visual scale)	• Finnish nutritional guidelines • encourage increased intake of vegetables, legumes, fruits and berries; whole grain and fibre; low-fat dairy and vegetable fats.	13.9% in IG vs 21.6% in CG [95% CI 0.40–0.98%] P = 0.044	IA
DALI [28]	9 European Countries	150	Weeks' gestation Before 19 + 6 week BMI $\geq$ 29 kg/m^2	IADPSG criteria	Three random intervention groups • Healthy Eating (HE) • Physical Activity (PA) • At least 30 min per day, for at least 5 days in a week • HE + PA	• Lifestyle coach • Patient empowerment and cognitive behavioural techniques. • Motivational Interviewing	NONE	IA
CHINE [18]	China	300	Weeks' gestation <12 week 24 < BMI < 28 kg/m^2	IADPSG criteria	Supervised cycling • $\geq$3 sessions $\times$ week • At least 30 min/session • Moderate Intensity (12–14 on Borg's visual scale)	• No special dietary recommendations	22.0% vs 40.6%; P < 0.001	I A
Norwegian FIT Study [30]	Norway	606	Weeks' gestation $\leq$20 week Normal weight Overweight Obese	WHO criteria	Exercise training • 2 sessions/week at a GYM Physical Activity • 30 min $\times$ 3 day/week	• Dietary counselling 2$\times$ by phone • Recommendations (food choices; portion sizes; limiting snacks; increasing intake of water, fruits and vegetables)	NONE	I A

Gestational Diabetes: the Role of Exercise in the Prevention [2]	Spain	342	Weeks' gestation 10–12 week BMI 22–23 kg/m^2	The national diabetes data group criteria	Intervention Group (IG) • 3 sessions/week • 2 sessions × 60 min on land • 1 session × 50 min for aquatic activities Intensity • Between 6 and 20 Borg's scale at <60% Heart Rate Reserve Control Group (CG) • Generic recommendations to increase the physical activity	• NONE	90% P = 0.009	IA

insulin (adj. mean difference − 0.91 mU/l, p = 0.045) and leptin levels (adj. mean difference − 207 pmol/l, p = 0.021) compared to routine care, while glucose concentrations were unchanged. However, the effect of intervention on both fasting and 2-h glucose was influenced by pre-pregnancy BMI (interaction p = 0.030 and p = 0.039, respectively). For overweight/obese women (n = 158), the intervention was associated with increased risk of at least one glucose measurement exceeding International Association of Pregnancy and Diabetes Study Group thresholds (33.7% vs. 13.9%, adj. OR 3.89, p = 0.004).

Finally, a recent review and meta-analysis [32] that included five RCTs involving 1872 patients in the exercise intervention was found to significantly reduce the risk of GDM (std. mean difference 0.62; 95% CI 0.43–0.89; p < 0.01) compared with control intervention.

The inability to draw definitive conclusions about the risk of developing GDM in women who received a combination of diet and exercise intervention is likely dependant on the individual characteristics of the interventions, such as objectives, intensity, frequency, timing and type of PA as well as on the differences of the studied populations, without considering the pathogenesis of GDM and different P.A. patients' adherence [26].

In our opinion, further studies are required to assess the relationship between lifestyle change in gestation and GDM incidence, including data on women with varying degrees of insulin resistance and on women with reduced insulin-secreting capacity.

Post-partum

Physical exercise is highly recommended to the broad population before and after pregnancy, especially for women suffering from GDM and populations at risk [33]. It is advised to continue physical exercise in the postpartum period. PA increases cardio-respiratory fitness and improves mood without any negative effects on maternal milk volume and composition [34]. Continuing PA after the pregnancy helps women in achieving and maintaining ideal weight, when combined with caloric restriction, and can prevent and/or delay diabetes onset in women who previously suffered from GDM for up to 10 years after delivery [35,36].

In the following section, we discuss what treatment outcomes are desirable and the characteristics of the exercise intervention required to achieve the outcome in pregnancy.

Treatment outcomes

The primary goal of GDM treatment is to keep blood glucose concentrations within the normal range throughout pregnancy to ensure appropriate foetal growth in women receiving personalised diet prescriptions.

Exercise interventions may be useful in helping with glycaemic control and may improve maternal and foetal outcomes. In Table 3, we present the following studies on treatment outcomes. The majority of exercise intervention

Table 3 Studies on treatment outcomes of GDM.

Clinical trials	Country	Study Patient no.	Patients' Characteristics	GDM diagnosis criteria	Exercise type, intensity and duration	Nutritional counselling	Outcomes	Level and grade
RADIEL [30]	Finland	RCT 269	Weeks' gestation 13 week BMI $\geq$ 32 kg/m^2 Previous history of GDM	WHO criteria	Physical activity • 30 min $\times$ 5/week or • 50 min $\times$ 3/week • Moderate Intensity (11 −15 on Borg's visual scale)	• Finnish nutritional guidelines • Encourage increased intake of vegetables, legumes, fruits and berries; whole grain and fibre; low-fat dairy and vegetable fats.	Reduction in fasting plasma glucose (P = 0.011); the increase in 2-h glucose value from baseline to the second trimester was significantly lower in the intervention group (P = 0.42)	IA
COCHRANE DATABASE SYST.REW [37]	Canada Thailand Italy USA Canada Thailand Italy	4 RCTs, 363 3 RCTs, 344 women	Weeks' gestation From 13 to 24 week Weeks' gestation From 13 to 24 week	–	Physical activity • From low to moderate Intensity • Aerobic and resistance exercise	–	Reduction in fasting blood glucose concentrations (average standardised mean difference (SMD) −0.59, 95% CI −1.07 to −0.11; four RCTs, 363 women; I^2 = 73%; T^2 = 0.19) Reduction postprandial blood glucose concentration (average SMD −0.85, 95% CI −1.15 to −0.55; I^2 = 34%; T^2 = 0.03).	IA
Barakat R [41]	Spain	RCT 510	Weeks' gestation 10−12 week BMI 24 kg/m^2	WHO and IADPSG criteria	Physical activity • 50−55 min $\times$ 3/week • Moderate Intensity (10 −12 on Borg's visual scale)	Patients received advice on a 2000 kcal diet	Reduction by 58% of macrosomia (OR 1.76, 95% CI 0.04−78.90 vs 4.22, 95% CI 1.35−13.19) and by 34% of acute and elective caesarean delivery (OR 1.30, 95% CI 0.44−3.84 vs 1.99, 95% CI 0.98−4.06)	IA
Ehrlich SF [40]	USA	Prospective cohort study 1055	Weeks' gestation 24 week BMI > 25 kg/m^2	Carpenter and Coustan criteria	Physical activity • Moderate intensity 3−6 MET/h • Vigorous intensity >6 MET/h	Patients received advice on a 1600 kcal diet	Vigorous exercise was associated with 57% decreased odds of GWG above the recommended ranges [0.43, (0.23, 0.92)] p = 0.03	

studies including RCTs [37] show that exercise decreases both fasting (average standardised mean difference (SMD) −0.59) and postprandial blood glucose concentrations compared with control interventions (average SMD −0.85). In the Radiel [30] study, the intervention group had a significant reduction in fasting plasma glucose ($p = 0.011$) and gestational weight gain ($p = 0.037$); Davenport [38] showed that exercise decreases glucose concentrations in the fasting state and 1 h after meals and achieved a lower insulin requirement (0.50 ± 0.37 U kg^{-1} vs 0.16 ± 0.13 U kg^{-1}; $p < 0.05$).

In support of these findings, both aerobic and strength, exercise improves insulin sensitivity and increases glucose uptake. In late pregnancy, biopsies of the vastus lateralis muscle show that GLUT 4 expression is higher in exercise-trained women (30% VO_2 peak) who started exercising from 16 to 20 weeks' gestation until delivery [39].

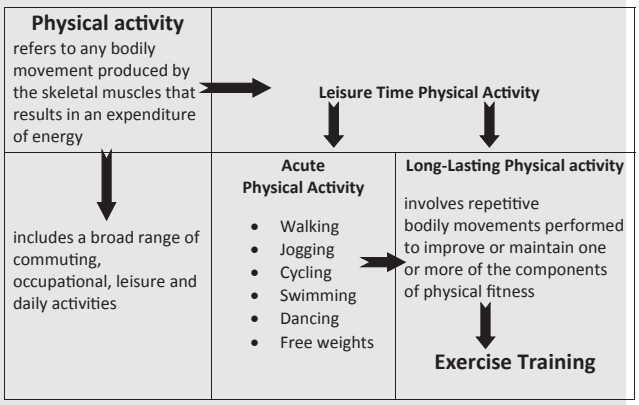
Vigorous intensity exercise is associated with a decreased number of women with a weight gain exceeding IOM recommendations (OR = 0.63 (0.40, 0.99)) as compared to no participation [40]. One interventional study has shown that regular PA during pregnancy in women with GDM can improve other outcomes such as having an infant with macrosomia (58% risk reduction) or a preterm delivery (34% risk reduction) [41].

Exercise training prescription: characteristics of exercise training and PA

PA practiced during pregnancy is frequently insufficient to insure the benefits of an active lifestyle even in normal-weight women. Among the overweight/obese, both volume and type of PA are strikingly low [42].

An initial approach to helping women become more physically active can simply be to encourage them to incorporate more unstructured PA into daily living, both before and during pregnancy, as outlined in Table 4, in the absence of contraindications. This would be considered as a starting point from which to progress towards the prescription of exercise training, if there are no other contraindications. The prescription should consider not only type and intensity but also frequency, duration and progression [10], which we discuss below.

Table 4 Definition of physical activity.



Type of exercise

Most pregnant women with and without GDM can safely perform aerobic (strengthens heart, vascular and respiratory systems) and strength exercises (increases the amount of muscle fibres used within a muscle to increase strength). These exercises include walking; running; dancing; strength machines and weightless body activities such as cycling, different aquatic activities and exercises on the chair or hand-crank ergometer [40] (level IIIB).

Resistance exercises are safe and effective when adapting insulin dose (where necessary) and checking for hyperglycaemia; weightlifting exercises are done using progressive resistance elastic bands for arms, legs, abdomen and back [43].

The exercise should be tailored to each woman's physical condition, with mild to moderate intensity. One systematic review identified eight RCTs involving 588 participants: aerobic or resistance exercise, performed at a moderate intensity at least three times per week, safely helps to control postprandial blood glucose concentrations and other measures of glycaemic control in women diagnosed with GDM [44]. Activities with high risk of falling (horse riding, downhill skiing, etc.) or abdominal trauma should be discouraged. Sports with high potential for physical contact (such as ice hockey, football and basketball) can cause severe trauma to both mother and foetus and should therefore be discouraged. Diving should be avoided during pregnancy because the foetus is at risk of decompression sickness. Caution should be observed in practising physical exercise at a high altitude (>2500 m).

Intensity

We propose three simple methods to evaluate the intensity of aerobic exercise: the target heart rate zones, the Borg's scale and the Talk test. Heart rate is a relatively simple way to prescribe aerobic exercise in a manner that corresponds with perceived exertion and thus intensity. However, during pregnancy, heart rate is elevated by 10–15 beats and is blunted at maximal exercise levels; the Royal College of Obstetricians and Gynaecologists (RCOG), the Society of Obstetricians and Gynaecologists of Canada (SOCG) and Canadian Society for Exercise Physiology (CSEP) have all recommended the use of a modified heart rate target zone developed by the CSEP, when prescribing moderate intensity aerobic exercise.

In Table 5, we report the Modified Heart Rate Target Zone for aerobic exercise in pregnancy proposed by Padayachee [33], which refers to Joint SOGC/CSEP clinical practice guideline of Davies 2003 [45] and the validated works of Mottola [46] and Davenport [47] for sedentary overweight and obese pregnant women. This model aims to provide exercise to previously sedentary pregnant women at 20%–39% VO_2 reserve as recommended by

Table 5 Modified heart rate target zone for aerobic exercise in pregnancy.

Maternal age (years)	Heart rate target zone (beats/min)	Heart rate target zone (beats/10 s)	Heart rate target zone (SOwt/Sob)
<20	140–155	23–26	–
20–29	135–150	22–25	102–124
30–39	130–145	21–24	101–120
≥40	125–140	23–26	–

SOwt: Sedentary Overweight; Sob: Sedentary obese.
From Padayachee C, Coombes JS. World J Diabetes 2015 [33].

American College of Sports Medicine (ACSM). When the heart rate is not usable, the ACOG recommends using Borg's Modified Rate of Perceived Exertion Scale instead.

The Borg scale [48], as shown in Table 6, is used to assess the intensity of different training sessions, and it represents the subjective assessment index and perception of fatigue and is recommended in pregnancy. For most healthy women who are not already highly active or doing vigorous-intensity activity, moderate intensity aerobic activity is recommended during pregnancy and in the postpartum period, corresponding to 4–5 BORG-modified RPE scale level or 14–15 BORG RPE scale level. A poorly conditioned woman may start as low, as 3 BORG-modified RPE scale level or 12–13 BORG RPE scale level, and then progress to moderate levels. Women who are already highly active or doing regular vigorous activity can continue these activities during pregnancy [46].

A further measure of the intensity of exercise is the 'Talk test' [49]. This is a simple system, alternative or complementary to the previous tests used to evaluate the adequacy of exercise intensity, as follows: If a woman can maintain a conversation while exercising, the intensity of PA is adequate. Intensity should be reduced whenever the conversation is not possible.

Frequency

Existing guidelines encourage PA throughout gestation, involving both aerobic and strength work during most, if not all, days. This also applies to women with GDM [10]. A daily physical exercise improves glucose metabolism. The muscular contractions associated with PA can increase glucose uptake through increased glucose transporter type four (GLUT 4) production and increased insulin signalling within the skeletal muscle, thus increasing insulin sensitivity. The increased muscular sensitivity, due to insulin, lasts for at least 24 h after exercising [50]. It is therefore suggested that the recommended frequency for any kind of PA in women suffering from GDM is from 3 to 7 days a week [51].

Table 6 The Borg scale is used to assess the intensity of the various training sessions, and it is the index subjective of fatigue evaluation and perception.

BORG RPE	Modified RPE	Breathing
6	0	No exertion
7		Very light
8	1	
9		
10	2	Deeper but comfortable breathing.
11		Able to hold a conversation
12	3	
13		Aware that breathing is harder;
14	4	able to talk but difficult to hold conversation
15	5	Starting to breath hard and getting
16	6	uncomfortable
17	7	Deep and forceful breathing.
18	8	Uncomfortable and not wanting to talk
19	9	Extremely hard
20	10	Maximum exertion

Duration

Pregnant women without medical and/or obstetrical complications should be allocated at least 150 min per week to PA.

For inactive women, increase duration of moderate exercise slowly; if they are already more active, then maintain or lower the intensity during pregnancy and increase the frequency or duration.

Prolonged duration of PA (*i.e.* lasting for 60–90 min when performed continuously) usually is not recommended for pregnant women due to heightened concern over possible hypoglycaemia or hyperthermia.

To reach and maintain a metabolic effect, aerobic exercise should last for a minimum of 15 min per session, three times a week, and it should be gradually increased during the second trimester up to approximately 30–40 min per session, four times or more a week [10]. Aerobic activity should be preceded by a short warm-up (10–15 min) and followed by a short cool down phase (10–15 min), including stretching and relaxation exercises [45].

Progression

Sedentary women with GDM should begin with low intensity (3 BORG modified RPE scale level or 12–13 BORG RPE scale level) and gradually progress to moderate intensity (4–5 BORG modified RPE scale level or 14–15 BORG RPE scale level), if there are no obstetrical contraindications. At the beginning of pregnancy, it is recommended to increase activity frequency and duration rather than its intensity [10]. Women, who were active before and during pregnancy, should continue to engage in moderate to vigorous intensity even after being diagnosed with GDM, if there are no obstetrical contraindications [10,33].

Patients with diabetes

In the following section, we turn our attention to diabetic patients with diabetes and summarise current recommendations for prescribing PA for both type 1 diabetes mellitus (T1DM) and T2DM patients in pregnancy.

Type 1 diabetes patients in pregnancy

During pregnancy, a structured PA program may assist T1DM women without complications in achieving optimal metabolic control [52].

Table 7 shows general contraindications to PA, even though safety and dose adjustments must be considered according to the severity of complications [53].

The impact of exercise on glucose homeostasis is influenced by the type, intensity and duration of the activity; hence, any exercise program for pregnant diabetic women must consider type, duration, frequency, intensity and timing, similar to those for GDM as outlined in Section 2 above.

Participation in aerobic PA, sprint and resistance training can result in widely varying blood glucose responses [54,55]. Differences in exercise intensity also influence outcomes, with high-intensity activities causing a greater release of counter-regulatory hormones like epinephrine and glucagon that can cause immediate and lasting elevations in blood glucose concentrations [56]. The exercise intensity modulates effects on blood glucose, namely, marked activation of the sympathetic nervous system, which causes hyperglycaemia after strenuous exercise. It should be remembered that sub-maximal (70–85% VO_{2max}) or moderate (50–70% VO_{2max}) PA in the presence of adequate insulinisation lowers blood glucose, with an effect dependent on duration and intensity.

Duration also has an impact, with longer periods of exercise generally resulting in greater blood glucose use and the risk of hypoglycaemia, although large individual variations in hormonal responses to prolonged exercise of varying types have been demonstrated in athletes with T1DM [57]. Exercising more than once in a day or on sequential days can also affect blood glucose outcomes during the exercise itself and afterwards [55].

Long-term effects on the metabolism of glucose, lipids and proteins in individuals with T1DM are difficult to assess, as such patients are frequently unable to adequately alter endogenous insulin levels and experience normal hormonal glucose counter regulation during and following exercise. Consequently, they are at risk for early and late hypoglycaemia and also hyperglycaemia [58].

Table 7 Contraindications to physical activity in type 1 diabetes outside of pregnancy.

Diabetic complications	Contraindicated sports
Proliferative retinopathy	Sports with heavy work and power: weightlifting, throwing
Severe nephropathy	Intense physical activity, need strict blood pressure
Peripheral neuropathy	Running, jogging
Autonomic neuropathy	exercise restrictions for hypotension risk and high cardiovascular risk

In addition, exercise induces the activation of antiregulatory hormones that might trigger an acute metabolic disorder in individuals with severe insulin deficiency. In the setting of T1DM, in which exogenous insulin is required to maintain glucose control, the combined effects of exercise and insulin-mediated glucose disposal increase the risk of hypoglycaemia during exercise and in the late post-exercise period. Insulin therapy during exercise during pregnancy of T1DM women should ensure, first, a close-as-possible simulation of the normal physiological response to exercise and, second, a reduction in basal insulin during aerobic exercise of moderate or submaximal intensity.

Continuous glucose monitoring during PA in pregnant female patients with insulin-dependent diabetes mellitus could be useful in performing PA safely. Monitoring should aim at maintaining blood glucose approximately 6.7 mmol/l [53]. Additionally, continuous glucose monitoring may play an important role in detecting delayed, including nocturnal, hypoglycaemia that may otherwise go unnoticed when exercise is performed during evening hours.

Blood glucose response to PA among TID patients is highly variable based on activity type and timing and require different adjustments. Before carrying out a PA session, it is necessary to assess blood glucose and ketone levels [53]. The optimal time to begin an exercise session is 2 h after a fast-acting administration or 8–10 h after a long-acting insulin administration [53].

With regard to aerobic exercise, muscles use up glucose, which causes an immediate need to release glucose from the liver. If the insulin dose has not been reduced before physical exercise, the insulin concentration will be relatively high and glucose hepatic production inhibited [53]. Therefore, blood glucose concentrations should always be checked before exercise. The ADA Position statement suggests carbohydrate intake or other actions based on blood glucose concentrations at the start of exercise in nonpregnant T1DM patients [53]. As there is no literature supporting these actions in pregnancy, hyperglycaemia and ketone presence should be managed differently. Information about the early and late glycaemic response to exercise can be collected by checking blood glucose at the end of the session and in the following hours until the next morning [53,55,57–59]. In this way, it is possible to adjust subsequent exercise sessions in both duration and intensity and to reduce insulin therapy in response to PA. With this information, the patient can tailor adjustments of insulin therapy and carbohydrate intake in relation to these variables.

For these reasons, in T1DM, PA requires two caveats: first, clear knowledge about the effects of PA on glycaemic levels and, second, a thorough understanding of what kinds of adjustment should be made to both food and insulin therapy. Any adjustment should be linked to recorded blood glucose before exercise, with consideration of the type and timing of prior insulin therapy, as well as

type, duration, intensity and progression of exercise. As can be seen, the complexity of these factors explains the difficulty in defining guidelines applicable to all diabetics, particularly to pregnant women with T1DM [60].

Type 2 diabetes patients in pregnancy

Obesity has been increasing worldwide, contributing to a growing number of women of childbearing age with T2DM and a further deterioration in outcome among diabetic women. Generally speaking, exercise improves blood glucose control in T2DM, reduces cardiovascular risk factors, contributes to weight loss and improves wellbeing [58–61].

All pregnant women with T2DM should ideally perform both aerobic and resistance exercise training for optimal glycaemic and health outcomes in the absence of contraindications. Any exercise prescription should consider the type, intensity, frequency, duration and progression, just as those outlined above for GDM in section 2.2 to 2.6.

Insulin therapy may increase the risks of exercise-related hypoglycaemia and doses may need to be adjusted based on exercise training; therefore, it is appropriate to apply the same recommendations as that for T1DM women who are pregnant.

Summary of recommendations and conclusions

Exercise aimed at preventing and/or treating gestational diabetes mellitus

Pre-pregnancy: Physical exercise improves insulin sensitivity and reduces plasma levels of glucose through several insulin-mediated and non-insulin-mediated mechanisms (level IA).

With regard to the positive effects

- The combined intervention of exercise and diet in gestational diabetes mellitus limits the maternal weight gain and foetal overgrowth (level IB).
- Physical activity prevents gestational diabetes mellitus in obese women belonging to certain ethnicities or genetic characteristics (level IA).

The quality of exercise

- Aerobic and strength exercise can determine delayed start of insulin therapy, reduced insulin need and better cardio-respiratory fitness (level IIIB).
- Encouraging women to do physical activity throughout the day, before and during pregnancy, is a precondition for a personalised exercise prescription in the absence of contraindications (level IA).

Physical exercise for pregnant women with pre-existing diabetes

Type 1

- Physical exercise during pregnancy is useful in diabetic women (level IIIB).
- Continuous monitoring of blood glucose in type 1 diabetes mellitus patients during exercise is a useful method (level IIA).
- Physical exercise is contraindicated in diabetic women with severe disease complications (level IA).
- Any exercise prescription should consider the type, intensity, frequency, duration and progression.

Type 2

- Physical exercise during pregnancy is useful n diabetic women as well as in non-diabetic women (level IIIB).
- Physical exercise and diet in patients with type 2 diabetes mellitus may help improve glycaemic control during pregnancy (level IIB).

Post-partum physical exercise

- Physical activity increases cardio-respiratory fitness and improves mood without having any negative effects on maternal milk volume and composition (level IA).
- Physical activity helps women achieve and maintain ideal weight after childbirth, and it promotes weight loss when combined with an adequate caloric restriction (level IA).
- Physical activity combined with a proper nutrition can prevent and/or delay diabetes onset in women who previously suffered from gestational diabetes mellitus (level IB).

List of abbreviations

RCOG	Royal College of Obstetricians & Gynaecologists
SCOG	Society of Obstetricians and Gynaecologists of Canada
CSEP	Canadian Society for Exercise Physiology
ACSM	*American College of Sports Medicine*

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