

Exercise guidelines for gestational diabetes mellitus

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Abstract

The prevalence of gestational diabetes mellitus (GDM)

is increasing worldwide. This disease has many detrimental consequences for the woman, the unborn foetus and child. The management of GDM aims to mediate the effects of hyperglycaemia by controlling blood glucose levels. Along with pharmacology and dietary interventions, exercise has a powerful potential to assist with blood glucose control. Due to the uncertainty of risks and benefits of exercise during pregnancy, women tend to avoid exercise. However, under adequate supervision exercise is both safe and beneficial in the treatment of GDM. Therefore it is vital that exercise is incorporated into the continuum of care for women with GDM. Medical doctors should be able to refer to competently informed exercise professionals to aid in GDM treatment. It is important that exercise treatment is informed by research. Hence, the development of evidence-based guidelines is important to inform practice. Currently there are no guidelines for exercise in GDM. This review aims to assess the efficacy of exercise for the management of GDM in order to establish an exercise prescription guideline specific to the condition. It is recommended that women with GDM should do both aerobic and resistance exercise at a moderate intensity, a minimum of three times a week for 30-60 min each time.

Key words: Gestation; Pregnancy; Glucose; Physiology; Guidelines; Physical; Activity

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Core tip: Exercise has been proven to be beneficial in improving pregnancy outcomes in women with gestational diabetes mellitus (GDM). However, there is currently no exercise guidelines published for this population. A review into research outcomes of exercise in pregnant women with and without gestation diabetes as well as guidelines pertaining to type 2 diabetes mellitus has been conducted. This review has shaped the first guidelines pertaining to exercise for GDM management.

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INTRODUCTION

The use of exercise as part of the continuum of treatment in patients with diabetic related disorders is accepted and widely encouraged^[1]. One increasingly prevalent metabolic disorder is gestational diabetes mellitus (GDM). Although exercise prescription as treatment in this population group may be encouraged, a general exercise prescription guideline is lacking. Therefore the purpose of this review is to assess the efficacy of exercises currently being prescribed for the management of GDM in order to establish an exercise prescription guideline specific to GDM.

DEFINITION AND DIAGNOSIS OF GDM

GDM is defined as a "carbohydrate intolerance of varying degrees of severity with onset or first recognition during pregnancy"^[2]. Other variants of this definition further refer to the period of onset of hyperglycaemia, specifically within 24-28 wk of gestation^[3] and a natural dispelling of the hyperglycaemic condition after child birth^[4].

The earliest record of hyperglycaemia during pregnancy is from the 1960's, when a research group led by O' Sullivan (and endocrinologist/gynaecologist) noted that hyperglycaemia in pregnant women was associated with poorer pregnancy outcomes and a higher occurrence of type 2 diabetes in the years ensuing pregnancy^[4]. In 2013, the World Health Organisation (WHO) released a classification and diagnostic criteria for GDM (Table 1)^[5]. The new criteria was developed to take into account a quantifiable relationship between hyperglycaemia and adverse short-term pregnancy outcomes for both mother and newborn, in light of findings from the study of Hyperglycaemia and Adverse Pregnancy Outcomes (HAPO)^[6]. This diagnostic guideline can be used throughout pregnancy and can distinguish GDM from diabetes mellitus in pregnancy (Table 1)^[5]. However, as the new criterion recommends lower fasting plasma glucose levels than what has been previously used, the WHO anticipated an increase in the number of pregnant women diagnosed with GDM^[5]. The effects of these criteria changes are yet to be evaluated, especially in the area of pregnancy outcomes.

RISK FACTORS FOR GDM

There is a range of risk factors that increase the chance of developing GDM. Ethnicity may play a role in GDM development as elevated incidences have been reported in certain ethnic subgroups. In the United States epidemiological studies have reported a higher incidence

of GDM in African Americans, Native Americans, Hispanics and Orientals than in non-white Hispanic women^[7-9]. In Australia, the prevalence of GDM was found to be higher in Aboriginal Australians as well as women who were born in Asia and India^[10-12].

In Europe, a large scale epidemiological study ($n = 11205$) in London found that women of ethnic minority groups had higher prevalence of GDM^[13]. When compared to White women, relative risks ranged from 3.1 for Black, 5.9 for miscellaneous, 7.6 for South Asian and 11.3 for Indian women^[13]. Asian women living in Asia have less proportional incidence than Asian born women living in other continents^[14]. Indian women living in urban areas have greater observed incidence than those living in rural areas of India^[15].

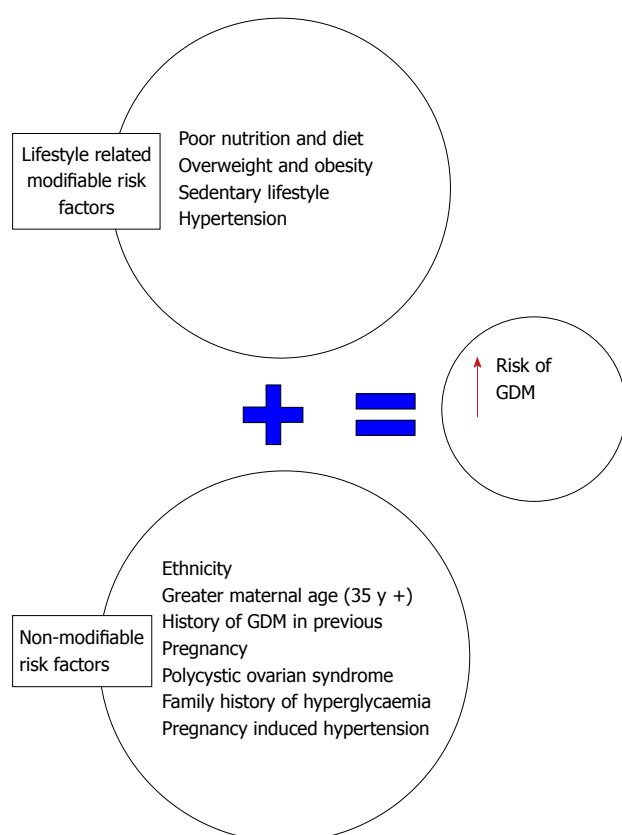
Furthermore, non-modifiable risk factors include greater maternal age (defined as 35 year of age plus)^[16,17], polycystic ovarian syndrome, family history of diabetes mellitus and pregnancy induced hypertension^[17]. Incidence of GDM has also been 30%-60% greater in women who have experienced the disease in a previous pregnancy^[18-22]. In a 16 year longitudinal retrospective study of 651 Canadian women who had GDM during their first pregnancy, 35% developed GDM in their second pregnancy^[23]. Greater pre-maternal weight was a strong predicting factor of GDM re-occurrence in ensuing pregnancies^[23].

This finding leads into a discussion of lifestyle related factors that are largely modifiable. Factors such as overweight and obesity can be modified. Weight gain during pregnancy was investigated using a nested-case control study of 1145 women^[24]. Findings suggested that subjects with greater weight gain during pregnancy (0.27-0.41 kg/wk or more) had an increased risk of developing GDM by 43%-74%. This effect was further exacerbated in overweight and obese women^[24]. Furthermore poor diet and nutrition are reported as mediators of increasing maternal weight and risk of GDM^[25-27]. Diets particularly high in refined sugars, with a high glycaemic index and fat content have been thought to increase the risk of GDM and hypertension during pregnancy^[25,28]. However, the majority of studies reporting these findings are small and have not been able to provide conclusive evidence on the role of diet in increasing the risk of GDM^[25,28]. Even so, one large prospective study ($n = 13475$), investigated the consumption of sugar sweetened beverages and incidence of GDM. After a 10 year follow up and 860 cases of GDM, excessive consumption (≥ 5 servings a week) of sugar sweetened cola was found to increase the risk of GDM by 22%^[29].

In a population based longitudinal study of 824 women, hypertension was found to increase relative risk of developing GDM up to twice as much (relative risk 2.03) as women without hypertension^[30]. The relationship between hypertension and GDM was confirmed in a Danish study of 215 women, in which higher rates of GDM was found in those with hypertension^[31]. Literature surrounding the pathophysiology of hypertension and gestational diabetes does not clearly underpin the

Table 1 Diagnostic criterion for gestational diabetes mellitus (WHO 2013) and diabetes mellitus in pregnancy (WHO 2006)^[5]

	Gestational diabetes mellitus	Diabetes mellitus in pregnancy
Fasting plasma glucose level	≥ 5.1 -6.9 mmol/L	≥ 7.0 mmol/L
	OR	OR
75 g oral glucose tolerance test levels	1 h: ≥ 10.0 mmol/L 2 h: ≥ 8.5 -11.0 mmol/L	1: Not required 2 h: ≥ 11.1 mmol/L
Random plasma glucose level	Not required	≥ 11.0 mmol/L

**Figure 1** Risk factors for gestational diabetes mellitus. GDM: Gestational diabetes mellitus.

mechanisms that cause such complications. However, it has been suggested that hypertension during pregnancy may heighten insulin resistance, alter immune responses and inflammatory pathways^[32]. These responses further encourage hypertension and hyperglycaemia, reminiscent of pathways in the metabolic syndrome^[32,33].

Sedentary behaviour and lifestyles characterised by low levels of physical activity have also been shown to increase the risk of GDM. In the largest reported study documenting physical activity and sedentary behaviour in relation to risk of GDM, Zhang *et al.*^[34] reviewed cases of 21765 women's pregnancies, 1428 of whom had GDM. They controlled for dietary factors and other covariates and found inverse relationships between vigorous activity, higher weekly physical activity levels and risk of GDM^[34].

Vigorous activity and brisk walking both had protective effects against developing GDM (RR = 0.77 and RR = 0.66 for each respectively). Women who were sedentary had a greater than two fold increase in developing GDM (RR = 2.30)^[34]. A more recent randomised control trial involving pregnant women had an exercise group ($n = 40$) which engaged in moderate land based resistance activity combined with aquatic aerobic activity^[35]. The control group ($n = 43$) was not given physical activity advice or exercise supervision. During 24-28 wk of gestation the women underwent a 50g maternal glucose screening test of which the exercise group had significantly better glucose levels (5.76 ± 1.13) than the control group (7.05 ± 1.73 mmol/L)^[35]. A case-control study by Dempsey *et al.*^[36] found a large reduction in GDM diagnosis in non-diabetic women who participated in recreational physical activity in the first 20 wk of pregnancy by 48%-78%. Further prospective studies of 909 non-diabetic American women, found that recreational exercise leading up to pregnancy, when performed for at least one year can induce a 56%-76% reduction in the risk of developing GDM^[37]. A large meta-analysis investigating seven pre-pregnancy and five early pregnancy studies found that pre-pregnancy exercise gave a pooled odds ratio of 0.45, a high protective effect against GDM^[38]. Furthermore, exercise in early pregnancy was also significantly protective of developing GDM with an odds ratio of 0.76^[38]. For a summary of risk factors see Figure 1.

EFFECTS OF GDM IN MOTHER AND CHILD

GDM affects the health of the women, the foetus and even after birth, the baby or child. Hyperglycaemic placental environments increase the risk of traumatic pregnancies influenced by macrosomia (larger than usual birth weight)^[39,40]. This in turn increases the risk of the baby having shoulder damage during birth^[40]. Macrosomia can be further exacerbated by excess levels of insulin circulating in the placenta^[3,41]. This is due to the increased growth effects of insulin on the foetus^[41]. Therefore care must be taken when prescribing anti-glycaemic maternal medication. The uses of different types of medications are still being investigated and there is a body of evidence yet to be filled regarding the direct impact of anti-glycaemic agents on foetal health. However, reviews have suggested that the use of insulin secretagogues is the safest form of pharmacological treatment in GDM, as they have little to no perfusion across the placenta^[41-43]. However, oral hypoglycaemic agents including metformin and glyburide have been used as alternative pharmacological treatment to insulin therapy^[44,45].

Further complications for the baby directly after birth include acute breathing difficulty, jaundice and nerve palsy^[46-48]. Babies born of women with poorly controlled GDM are likely to experience hypoglycaemia after birth due to an immediate impairment of environmental

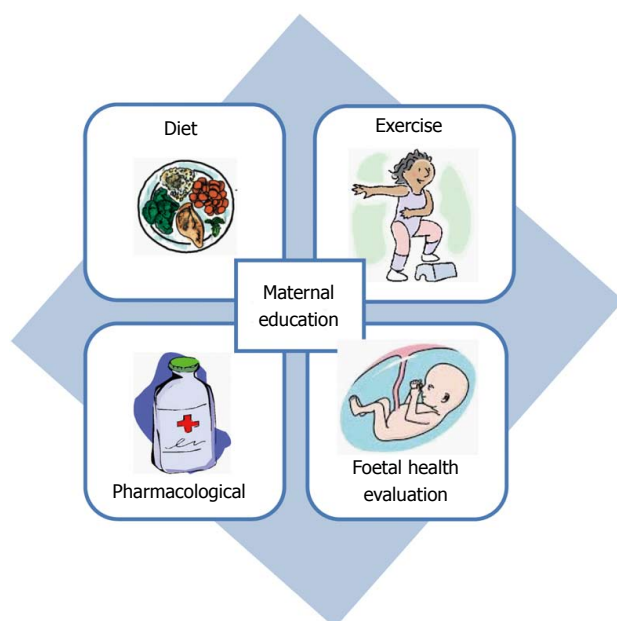


Figure 2 Gestational diabetes mellitus quintet management model.

glucose^[46,49]. Because of the complications presented, babies are more likely to be admitted to intensive care units and endure longer hospital stay times^[48,49]. As the child grows they are more likely to develop obesity as well as metabolic disorders such as type 2 diabetes^[50,51].

Traumatic births caused by the compounding effects of GDM also present complications for the women's immediate health^[47]. Women are more likely to undergo an emergency caesarean section, particularly with the presence of preeclampsia^[49]. Preeclampsia is a combination of high blood pressure and excessive protein in urine, also the second leading cause of maternal death^[49]. Due to the increased size of the baby, they are also more likely to have a longer active labour times, instrumental vaginal delivery as well as third degree perineal trauma and tearing^[49,51]. These traumatic events generally lead to post-partum haemorrhage and hence longer hospital stay times^[49]. Furthermore, women with GDM have greater weight retention post-partum leading to a greater risk of overweight and obesity^[51,52]. This has also been shown to correlate with increased risk of developing chronic hypertension, type 2 diabetes and GDM is ensuing pregnancies^[49,51,52].

Because of the vast effects of GDM on the health of both mother and child, the management of GDM is critical in minimising the effects of hyperglycaemia during pregnancy.

GENERAL MANAGEMENT OF GDM

The primary aim of GDM management is to optimise glucose control and improve pregnancy outcomes^[53]. Generally speaking the initial management of GDM involves diet modification and implementation of an exercise regime^[49,54]. If adequate glucose control has not been achieved, the woman will generally be prescribed

anti-diabetic medications to directly reduce blood glucose levels maternally and hence indirectly for the foetus^[42].

Although it is not a treatment method, constant evaluation of the foetus' health and development is recommended to continually assess for deformities and macrosomia^[54]. This includes foetal surveillance using ultrasound and Doppler of umbilical blood flow measurement^[49,54,55]. In a large randomly controlled trial, 1000 women diagnosed with GDM were randomly assigned gestational diabetes care ($n = 490$) or routine care ($n = 510$). The gestational diabetes care group received dietary advice, blood glucose monitoring and insulin therapy. The control group received no standard pregnancy care. Pregnancy outcomes were assessed and after controlling for various factors including ethnicity and age, the diabetes care group had lower rates of serious perinatal complications (1% vs 4%)^[49]. However, this intervention did not include maternal exercise or education. There were also no protective effects on admittance to the intensive care unit, induced labour or risk of caesarean delivery. A more recent and larger meta-analysis by Poolsup *et al.*^[56] investigated ten studies regarding the outcomes of GDM treatment methods including pharmaceutical and dietary care. It was found that such treatment significantly reduced the risk of macrosomia (RR = 0.47), shoulder damage during birth (RR = 0.42) and gestational hypertension (RR = 0.68). However alongside the absence of exercise from these treatments, there was no change in the risk of neonatal mortality, neonatal hypoglycaemia, birth trauma, premature births, preeclampsia, caesarean section and induced labour^[56].

The recommended quintet approach for GDM (Figure 2) includes maternal education, diet modification, exercise, pharmacology and foetal surveillance. This has been developed in light of the confounding evidence of increased positive pregnancy outcomes in studies of these areas independently. A study investigating the efficiency and practicality of this complete model of maternal and foetal care is yet to be investigated.

ROLE OF EXERCISE IN GDM MANAGEMENT

In regards to evidence specific to GDM treatment, exercise has been shown to be an effective tool in glucose control which may prevent, reduce or delay the need for insulin^[57,58]. Tight glucose control is considered especially important in the gestational patient, considering the increased risk of poor health outcomes for both mother and child in the presence of hyperglycaemia. For future ramifications, it has been found that any degree of abnormal glucose homeostasis during gestation can also independently predict diabetic re-occurrence in women with GDM^[57].

Although currently there are no GDM specific exercise prescription guidelines published, research has been conducted in general pregnancy and exercise.

Table 2 Absolute and relative contraindications for exercise during pregnancy^[75,82]

Absolute contraindications	Relative contraindications (aerobic exercise)
Restrictive lung disease	Heavy smoking
Ruptures membranes	History of extremely sedentary lifestyle
Preeclampsia	Orthopaedic limitations
Pregnancy-induced hypertension	Poorly controlled hypertension
Premature labour during current pregnancy	Extreme morbid obesity
Persistent bleeding (second or third trimester)	Extremely underweight (BMI < 12 kg/m ²)
Incomplete cervix or cerclage	Poorly controlled type 1 diabetes
Placenta previa (placental implanting into lower uterus) after 26 wk of gestation	Chronic bronchitis
Hemodynamically significant heart disease	Severe anaemia
High order multiple gestation (\geq triplets)	Unevaluated maternal cardiac arrhythmia
	Intrauterine growth restriction in current pregnancy
	Poorly controlled seizure disorder
	Poorly controlled hyperthyroidism
	Previous spontaneous abortion
	Anaemia (hb < 100 g/L)
	Twin pregnancy after 28 wk
	Malnutrition or eating disorder

BMI: Body mass index.

There has been no suggestion of the need to any extra precautions than the precautions taken when exercising pregnant women without GDM. However, considering the added hyperglycaemia, the same considerations and precautions concerning type 2 diabetes should also be considered when exercising women with GDM. Hence the FITT (frequency, intensity, time/duration and type) principles of exercise examined and presented in this review will take into consideration research including women with GDM, without GDM and type 2 diabetes. Given the lack of large cohort studies implementing exercise as management of GDM, recommendations have been drawn from exercise in pregnancy guidelines and exercise in type 2 diabetes guidelines.

For women who were previously sedentary before pregnancy, it is advised that they consult their medical practitioner who may assess their suitability to exercise. It is recommended that a suitability qualified exercise physiologist be actively involved in exercise prescription and delivery. This person would then be able to liaise with the medical practitioner to apply advice regarding suitability. As with any clinical population there are some contraindications to exercise in pregnancy. The absolute contraindications as recommended by the American Congress of Obstetricians and Gynaecologists (ACOG) are medical conditions which may be exacerbated by engaging in exercise. It is important that to educate patients that these conditions are not caused by exercise and until the condition is stabilised, they should not engage in exercise. Furthermore, ACOG has developed relative contraindications for engaging in aerobic exercise during pregnancy. Clinical knowledge and expertise must be applied when assessing each individual situation in regards to exercising with relative contraindications. It is recommended that advice from the medical practitioner is carefully interpreted by the exercise physiologist to determine if the benefits outweigh any risks of exercise.

Both absolute and relative contraindications for exercise in pregnancy are summarised in Table 2.

BENEFITS OF EXERCISE DURING PREGNANCY

Benefits to the mother

Exercise has been proved to be a beneficial therapeutic tool during pregnancy. Records as early as the 17th and 18th Centuries have shown encouragement of exercise during pregnancy as it was thought to ensure good health and prevent miscarriage^[59]. Further in the late 18th Century maternal physical activity was thought to help encourage an easier labour and reduce the baby size, also advantageous during delivery^[60]. In the early 20th Century particular the 1920's and 1930's, scientific studies began to investigate the impact of physical activity on pregnancy outcomes. These studies found inverse relationships between birth weight and household physical activity^[61]. In the 1920's studies began to inform prenatal exercise programs with benefits recorded as increased ease of labour, improved muscle tone, increased foetal oxygenation and facilitating post-partum weight loss^[62].

Key epidemiological studies came later in the 1990's. Clapp *et al.*^[63] found that women who exercised during pregnancy had babies with a significant lower birth weight than those who had decreased their physical activity during pregnancy. In 1991 Bung *et al.*^[64] investigated the use of exercise in women with GDM. This randomised control trial was one of the first of its kind and findings were imperative to influence future research into the efficacy of exercise in GDM management. Seventeen of the twenty-one women in the exercise group, of whom were all previously insulin dependent were able to maintain normal glucose levels without using insulin^[64]. Maternal complications did not differ between the

Table 3 Benefits of maternal exercise for the foetus and the child

Benefits to the foetus ^[100-104]	Benefits to the foetus ^[1,58,73,104,105]
Lower heart rate response to acute maternal exercise	Lower birth weights
Increased amniotic fluids	Increased gestational ages (lower risk of preterm birth)
Increased in placenta viability and volume	Improved neurodevelopment and lower body fat percentage
Increase in vascular function	Infants have higher behaviour regulatory ability and orientation
Faster placental growth and greater villous tissue	At the age of five children have less body fat, higher general language intelligence and oral language
Higher tolerance to labour	

Table 4 Modified heart rate target zone for aerobic exercise in pregnancy^[82,95]

Maternal age	Heart rate target zone (beats/min)	Heart rate target zone (beats/10 s)	Heart rate target zone (beats/min) (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	20-30	-

SOwt: Sedentary overweight; SOb: Sedentary obese.

exercising group and the control group. Exercise was now deemed to be safe and advantageous for glucose control for women with GDM^[64]. These findings were also confirmed by Jovanovic-Peterson *et al.*^[65] in a smaller study of women with GDM utilising exercise and diet ($n = 10$) and those using diet alone ($n = 10$). The findings of this study concluded that women engaged in diet plus exercise had lower fasting plasma glucose after 6 wk of training than women who underwent the diet only intervention (diet = 4.87 mmol/L, exercise and diet = 3.89 mmol/L)^[65]. This was further confirmed in a more recent study in which physical activity and diet interventions resulted in a lessened dependence on insulin for glucose control in women with GDM^[66]. Since there is little more exercise interventional trials conducted in women with GDM, this review is also informed by exercise in pregnancy.

Multiple studies have reported the positive effects of exercise on decreased lower back pain in pregnant women, two of which were recent randomised controlled trials^[67,68]. Other physiological studies have reported exercise in pregnant women to improve cardiovascular functions such as fitness, blood pressure, and peripheral oedema^[69]. Preeclampsia has also been shown to decrease with an increase in physical activity^[70,71]. As previously demonstrated exercise may decrease the risk of developing GDM and type 2 diabetes^[36,72]. Furthermore, by increasing blood glucose control, exercise reduces the vast effects of hyperglycaemia on the women, foetus and child (see above section Benefits to the mother). As pregnancy is a period associated with physiological and psychological change, the benefits on mood and psychological wellbeing are also well documented. Due to a limitation in weight gain and fat retention, exercise has also been shown to improve self-image^[73]. The ACOG have also recently report an improvement in constipation

and bloating as well as fatigue and insomnia^[74].

Benefits to the foetus and child

Pregnancy outcomes are largely associated with foetal health and upon birth, the health of the child as well. Maternal exercise has also been shown to provide significant benefits to both the health of the foetus and the child. Because neonatology and paediatrics is beyond the scope of this review, these findings are summarised in the Table 3.

EXERCISE GUIDELINES

Type

Safety during pregnancy is paramount and studies have shown a variety of exercises ranging from low exerting forces such as Yoga to higher exerting forces such as aerobic classes and jogging can be safe for both mother and foetus^[75]. Considering the importance of safety, it is advised that some forms of exercise should not be practiced during pregnancy, including the following: recreational sports with increased risk of forceful contact or falling (*i.e.*, basketball, rugby, horseback riding and gymnastics), exercising in a supine position after the first trimester (may obstruct inferior vena cava flow), motionless standing and scuba diving (risk of foetal decompression sickness)^[75]. Recreational physical activity is encouraged and has been shown to improve general wellbeing, pregnancy outcomes^[76]. Furthermore maternal mood and mental health have been shown to benefit from recreational physical activity^[76] (Table 4).

Programmed exercise is also very important in pregnancy and is vital to aid in glucose control for women with GDM^[76].

Exercise guidelines for pregnancy stress the prescription of aerobic exercise and to a lesser extent the prescription of resistance strength training. Women who regularly exercise during pregnancy have more positive pregnancy outcomes and fewer negative adverse events^[77]. However, there is little evidence of what is the physiological role of aerobic exercise in these relationships^[77]. The only truly quantifiable relationship thus far is that of aerobic exercise and significantly improved maternal fitness during pregnancy^[77]. Positive foetal outcomes are yet to be quantified as the majority of this research area has focused on foetal safety during exercise^[75]. There is a general agreement that appropriate exercise does not induce any harm on the

foetus^[75]. However, in regards to elevate fasting glucose, aerobic exercise can indeed reduce blood glucose levels in individuals with hyperglycaemia, potentially reducing and delaying the need for insulin medication^[78]. These effects may last for more than 24 h but less than 72 h. Furthermore, following aerobic exercise insulin levels also drop, reducing the chance of hypoglycaemia^[78]. However, after an intense bout of exercise, a hyperglycaemic response may be observed for up to 2 h post exercise^[78-80]. This may be important to consider when measuring blood glucose levels after exercise.

Aerobic exercise can consist of any activity that uses large muscle groups in a continuous rhythmic manner, *i.e.*, walking, jogging, aerobic dance, swimming, hydrotherapy aerobics, rope skipping, hiking, rowing, *etc*^[75]. However, clinical judgement should be exercised when choosing the appropriate and practical mode of aerobic exercise. This is particularly important in the first stages of an exercise program if intensity is to be tightly controlled (see below in intensity).

In addition to aerobic exercise, resistance strength training (*i.e.*, weightlifting) and flexibility exercise are also beneficial and safe for gestational women and foetus^[75,81,82]. Although the Royal College of Obstetricians and Gynaecologists (RCOG), ACOG, the Society of Obstetricians and Gynaecologists of Canada (SOGC) and Canadian Society for Exercise Physiology (CSEP) all recommend the use of resistance training for pregnant women, they are yet to provide specific guidelines for practice. However, Hall *et al*^[83] investigated the effects of moderate intensity strength training in healthy pregnant women. They used a protocol of 12 reps and one set of 8-10 exercises and found pregnancy outcomes were improved with no adverse effects to foetal health^[75,83]. Women who used resistance band exercise training at a moderate intensity three days a week had improved glucose control. This was reflected in lower capillary glucose levels and significantly less users of insulin ($n = 18$ control vs $n = 7$ exercise group)^[84]. Pregnancy specific pelvic floor exercise training has also been shown to reduce incontinence and bladder weakness after pregnancy^[69]. However, in the treatment of elevated fasting glucose, the American College of Sports Medicine (ACSM) and Exercise and Sports Science Australia (ESSA) both recognise that resistance training lowers fasting blood glucose levels for 24 h after exercise^[78,85]. This response is further exaggerated with an increase in training volume and intensity^[78,85]. Mode of exercise used in resistance training may include but is not limited to, resistance machines, free weights and body weight exercises^[78,85].

The ACOG reports hydrotherapy exercise to be considered safe during pregnancy with the potential to improve positive outcomes and pregnancy management^[75]. It has been shown that aerobic water based exercise at a moderate intensity may improve fitness, strength and decrease peripheral oedema^[75]. With the added effects of increased buoyancy, hydrotherapy

may minimise the risk of musculoskeletal joint injuries and provide a pain relieving manner of exercise for suffers of pregnancy induced lower back pain^[1,75]. Thermoregulatory issues should also be considered. Although significant research has not yet been conducted on humans, animal studies have shown that an increase in core temperature by as little as 1.5 °C during embryogenesis (in early stages of pregnancy) may result in major congenital malformations^[86]. Although these findings have not yet been supported in human studies, it may highlight the importance of remaining adequately hydrated and exercise in environments that are cool, shaded and well ventilated. During pregnancy it is important to note that core temperature is already raised due to an increase in the basal metabolic rate^[87]. Furthermore during exercise increases in body temperature strongly correlate with work intensity^[87]. Therefore, prolonged intensity workouts that encourage temperature fluctuations and an accelerated loss of fluid through perspirations may need to be avoided^[75].

Both ACSM and ESSA recommend that combined aerobic and resistance exercise are more effective if blood glucose management, body composition improvement and fitness outcomes^[78,85]. However, training using both of these modes may be more time consuming and greatly dependent on the individual's comorbidities, complications, accessibility to equipment and preference^[88-90]. Even so, combination training shows improvements in blood glucose control utilising different physiological mechanisms that may be of greater use when activated together^[78]. Resistance training resulting in an increased muscle mass can increase blood glucose uptake independent of intrinsic insulin response as insulin does not have influence on musculature glucose uptake^[84,88]. Aerobic training increases insulin stimulatory action and thus increases blood glucose uptake *via* a different pathway^[88]. Activating both of these metabolic pathways may be more physiologically beneficial than utilising only one pathway or exercising using only resistance training or aerobic training^[78].

Performing a warm up before exercise is recommended for all clinical populations^[91]. Warm up's of between 5-10 min at a low to moderate intensity using aerobic activities can increase body temperature and reduce post-exercise muscle soreness and stiffness^[91]. Warm ups are an important stage in exercise, as physiological systems gradually adjust to meet the bioenergetics and biomechanical demands of the working component of the exercise session^[91]. Performing a post exercise cool down is recommended if vigorous exercise is performed to reduce the risk of a vasovagal response which may lead to syncope^[92]. Stretching and flexibility training is distinct from the warm up or cool down phase and can be performed after either^[91]. Although there are limited studies investigating the role of warm up and cool down phases in exercise during pregnancy, there is no evidence to suggest that this may cause any harm. Considering the general benefits implicated for most populations,

Table 5 Exercise guidelines for gestational diabetes mellitus

Type of exercise	Intensity	Duration	Frequency
Aerobic (large muscle activities in a rhythmic manner) <i>e.g.</i> , walking, running, swimming and cycling	Moderate 60%-90% of APHRM RPE 12-14 Previously sedentary Owt/Ob should begin training at 20%-30% of APVO ₂ R RPE 12-14 Vigorous RPE 14-16	≤ 30 min continuously (up to 45 min if self-paced)	No more than two consecutive days without exercising
Resistance (multi joint exercises, large muscle groups) <i>e.g.</i> , dumbbells, resistance band and pregnancy Pilates	Moderate 50% 1RM 5-10 exercises 8-15 repetitions 1-2 sets	60 min	At least 2 but ideally 3 times a week

APHRM: Age predicted heart rate maximum; RPE: Rate of perceived exertion; Owt: Overweight; Ob: Obese; APVO₂R: Age predicted VO₂ reserve; RM: Repetition maximum.

it can be safe to assume the same would apply for pregnant women.

Frequency and duration

When prescribing exercise it is important to take into consideration the woman's previous physical activity history, cardiorespiratory fitness and strength^[1]. For women who were previously sedentary it may be more convenient for them to start an exercise program in the second trimester, after which most of the initial discomforts of morning sickness, nausea and fatigue have settled down^[81]. This is recommended so that extra discomforts of initiating an exercise program may not in turn impair adherence or compliance. Yet, as previously discussed, exercise in early pregnancy can reduce the risk of GDM, therefore sooner the woman can comfortably exercise the better^[35-37]. Women with little physical activity history should begin with 15 min of continuous aerobic exercise three times a week with a graded increase to 30 min at least four times a week^[78]. This was also previously recommended in the 2002 ACOG and is also supported in by the Society of Obstetricians and Gynaecologists of Canada (SOGC) and Canadian Society of Exercise Physiologists (CSEP) guidelines^[75,82]. There is no recommendation of an upper limit of time spent performing aerobic exercise, but the ACOG advises against exercising for more than 45 min continually because of a risk of increased foetal temperature^[75]. However this temperature rise is seen to be negligible when the exercise is self-paced in an environment that has adequate temperature control^[75]. Exercise guidelines for Type 2 Diabetes from the American College of Sports Medicine (ACSM) and Exercise and Sports Science Australia (ESSA) are generally the same as the pregnancy guidelines. However ACSM and ESSA have an additional note that there exercise should be conducted with no more than 2 consecutive days between aerobic exercise sessions^[78,85]. This is due to the transient improvement of insulin action and passive glucose uptake after exercise for up to 48 h^[78,85]. In regards to resistance

training, ACSM and ESSA recommend a minimum of twice a week on non-consecutive days and ideally three times a week^[78,85]. Each training session should include 5-10 (ACSM) or 8-10 (ESSA) exercises involving the major muscle groups (upper body, lower body, and core) and 10-15 repetitions (ACSM) or 8-10 repetitions (ESSA) each set at a minimum of one (ACSM) or two (ESSA) sets for strength gains, but up to four sets for optimal glucose uptake and strength gains. Considering that it is recommended that women do not train for optimal gains during pregnancy, up to three sets at moderate intensity may be more appropriate.

Intensity

During pregnancy, the majority of guidelines indicate the use of moderate intensity, but even low intensity exercise such as Yoga and Tai-Chi has shown benefits on mood, balance, lower back pain and urinary incontinence^[93,94]. As cardiorespiratory fitness is vitally important in encouraging positive outcomes during pregnancy and post pregnancy, moderate aerobic exercise is highly recommended^[1,94]. 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^[82]. RCOG, SCOG and CSEP have all recommended the use of a modified heart rate target zone developed by the CSEP, when prescribing moderate intensity aerobic exercise (see Table 5)^[1,82]. This target zone aims for an exercising level of 60%-90% of age predicted maximal heart rate. Furthermore, Davenport *et al.*^[95] have developed and validated an exercise target heart rate zone especially for sedentary overweight and obese pregnant women (Table 5). This model aims to exercise previously sedentary pregnant women at 20%-39% VO₂ reserve for as recommended by ACSM. Even so, it is interesting to know why this was only recommended for sedentary overweight and obese women and not previously sedentary normal weighted women. Furthermore, during

pregnancy heart rate variability increases^[75]. Therefore, ACOG recommends that prescribers exercise caution using heart rate to guide intensity and should consider using Borg's Modified Rate of Perceived Exertion Scale instead^[75]. Exercisers are recommended to aim for a working intensity of 12 to 14 (somewhat hard) on a 6-20 scale^[75]. McMurray also reported that women who self-paced exercise intensity would gradually reduce intensity as pregnancy progressed^[96].

High intensity short duration interval training has also been shown to be safe with showing no added complications during pregnancy but caution should be exercised for previously sedentary women^[75,82,97]. Furthermore, it may have protective effects from the foetus developing macrosomia and risk of preterm birth^[98].

ACSM's also recommends high intensity interval training for those exercising using moderate intensity and are in need of more glucose control^[78].

Resistance strength training has also been shown to positively influence the mother's general health and pregnancy outcomes^[81,99]. It is especially important to consider the physiological changes during pregnancy when prescribing resistance training and that high intensity resistance training should be avoided. Changes include increased urinary tract pressure (cause of urinary incontinence) and increased laxity in joints^[69]. Therefore care must be taken not to induce Valsalva manoeuvres that may increase the risk of injury or adverse event^[82]. There are few recommendations for resistance training guidelines during pregnancy, due to a lack of large quality studies. Therefore in accordance to other general pregnancy exercising guidelines, a recommended intensity of a moderate level is suggested. In regards to impaired fasting glucose, ACSM recommends strength training at a moderate (50% of 1-repetition maximum) or vigorous (75%-80% of 1-repetition maximum) intensity for optimal gains in strength and insulin action^[78]. ESSA generally recommends similar intensity of resistance exercise, yet with a greater inclination encourage vigorous intensity in light of dose related glucose control^[85]. Considering the added physiological changes in pregnant women, a moderate intensity training model is more appropriate. Furthermore, to avoid injury a slow progression of intensity, frequency and duration of strength training sessions occur^[78].

PRECAUTIONS AND RECOMMENDATIONS TO TERMINATE EXERCISE

Although there are vast benefits from exercising during pregnancy, some precautions need to be observed to encourage safety for both mother and child. As previously noted, the ACOG has advised against some forms of exercise including the following: recreational sports with increased risk of forceful contact or falling (*i.e.*, basketball, rugby, horseback riding and gymnastics), exercising in a supine position after the first trimester,

motionless standing and scuba diving^[69,75].

Furthermore, if any of the following warning signs occur, it is advised that exercise should be terminated: vaginal bleeding, dizziness, headache, chest pain, muscle weakness, preterm labour, decreased foetal movement, amniotic fluid leakage, calf pain or swelling and dyspnoea without exertion. It is important to regain stability of the mother's and foetus' condition as soon as possible. Treatment and advice from a medical practitioner should be incorporated in the exercise program^[69,75].

Exercising individuals with impaired fasting glucose presents its own sense of challenges and special considerations. Preventative measures should be in place to minimise the risk of an adverse event occurring and not prevent individuals from exercising. One especially important possible complication, however rare is hypoglycaemia. It is suggested that continual self-monitoring of blood glucose levels with physician consultation should be encouraged. Furthermore, if at pre-exercise the blood glucose level is ≤ 4.0 mmol/L this should be considered low and exercise should not begin till administration of some long and short acting glucose in food or drink^[85]. In order to take advantage of the hyperglycaemic effect of food, it may be advantageous to exercise an hour after a meal^[85]. It also may be important to consider taking insulin medication well before exercise to further reduce the risk of hypoglycaemia.

CONCLUSION

All pregnant women should engage in physical activity and may benefit from planned and programmed exercise. Women with GDM have extra physiological challenges that when left unattended to, have the potential to increase negative pregnancy outcomes for both mother and child. When used effectively, exercise can be used as a tool of treatment as part of the continuum of care for women with GDM. General guidelines encourage these women to engage in moderate intensity aerobic and strength training along with recreational physical activity. Exercise programs should be tailored by appropriately trained and qualified professionals (*e.g.*, Exercise Physiologists) who have knowledge, training and experience to understand the individual's physiological needs and associated risks.

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