

Prescribing physical activity to prevent and manage gestational diabetes

Sheri R Colberg, Kristin Castorino, Lois Jovanovič

Sheri R Colberg, Human Movement Sciences Department, Old Dominion University, Norfolk, VA 23529, United States
Kristin Castorino, Sansum Diabetes Research Institute, Santa Barbara, CA 93105, United States
Lois Jovanovič, Sansum Diabetes Research Institute, Santa Barbara, CA 93105, United States
Author contributions: Colberg SR completed the majority of the writing of the manuscript; Castorino K and Jovanovič L edited and revised it.

Correspondence to: Sheri R Colberg, PhD, Human Movement Sciences Department, Old Dominion University, 1006B Student Recreation Center, 48th Street and Powhatan Avenue, Norfolk, VA 23529, United States. scolberg@odu.edu
Telephone: +1-757-6833356 Fax: +1-757-6834270
Received: October 8, 2013 Revised: October 26, 2013
Accepted: November 15, 2013
Published online: December 15, 2013

Abstract

Gestational diabetes mellitus (GDM) is the most prevalent metabolic disorder during pregnancy. Women diagnosed with GDM have a substantially greater risk of developing type 2 diabetes within 5-10 years after delivery, and the risk is increased by excess body weight. Uncontrolled hyperglycemia during pregnancy is potentially harmful to both mother and fetus, resulting in a greater need for Caesarian-section deliveries, delivery of larger infants with more excess body fat, a greater risk of infant death and stillbirth, and an elevated risk of infant hypoglycemia immediately after birth. Fortunately, engaging in physical activity prior to and during pregnancy may lower the risk of developing GDM. Pregnant women should also be advised how to safely increase their physical activity during pregnancy and the postpartum period. An initial approach to becoming more physically active can simply be to encourage women to incorporate more unstructured physical activity into daily living, both before and during pregnancy. Giving women an appropriate exercise prescription can encourage them to participate in physical activity

safely and effectively throughout pregnancy to prevent and/or manage GDM. Engaging in 30 min of moderate intensity physical activity on most, if not all, days of the week has been adopted as a recommendation for all pregnant women.

© 2013 Baishideng Publishing Group Co., Limited. All rights reserved.

Key words: Gestational diabetes; Pregnancy; Physical activity; Exercise prescription; Blood glucose

Core tip: Gestational diabetes mellitus is the most prevalent metabolic disorder during pregnancy. Uncontrolled hyperglycemia during pregnancy is potentially harmful to both mother and fetus. Pregnant women should be advised how to safely increase their physical activity during pregnancy and the postpartum period. Giving women an appropriate exercise prescription can encourage them to participate in physical activity safely and effectively throughout pregnancy to prevent and/or manage gestational diabetes. Engaging in 30 min of moderate intensity physical activity on most, if not all, days of the week has been adopted as a recommendation for all pregnant women.

Colberg SR, Castorino K, Jovanovič L. Prescribing physical activity to prevent and manage gestational diabetes. *World J Diabetes* 2013; 4(6): 256-262 Available from: URL: <http://www.wjgnet.com/1948-9358/full/v4/i6/256.htm> DOI: <http://dx.doi.org/10.4239/wjd.v4.i6.256>

INTRODUCTION

Gestational diabetes mellitus (GDM) is the most prevalent metabolic disorder during pregnancy. Defined as glucose intolerance of varying severity diagnosed during pregnancy that usually resolves postpartum, it typically

occurs during the middle of pregnancy and is diagnosed at 24 to 28 wk of gestation with an oral glucose tolerance test^[1,2]. Currently, gestational diabetes affects 18 percent of pregnancies in the United States and has been increasing in prevalence^[2].

Women diagnosed with GDM have a substantially greater risk of developing type 2 diabetes (T2D) within 5-10 years after delivery, and the risk is increased by excess body weight^[2,3]. Uncontrolled hyperglycemia during pregnancy is potentially harmful to both mother and fetus, resulting in a greater need for Caesarian-section deliveries, delivery of larger infants with more excess body fat, a greater risk of infant death and stillbirth, and an elevated risk of infant hypoglycemia immediately after birth^[4,5].

Sufficient evidence supports the promotion of moderate-to-vigorous prenatal physical activity for maternal health benefits^[6], and physical activity prior to and during pregnancy may lower the risk of developing GDM^[7-11]. When prescribed effectively, physical activity can also be undertaken safely by nearly all pregnant women.

ETIOLOGY OF GESTATIONAL DIABETES

GDM can be considered as a transient form of T2D, with its rapid onset triggered by the metabolic and hormonal changes of pregnancy. Normal pregnancies are associated with increased insulin resistance, which begins in mid-pregnancy and continues until delivery. This resistance is usually compensated by a 200 to 250 percent increase in insulin secretion during pregnancy^[12]. The pregnant woman's placenta releases hormones that block the effect of circulating insulin and making the mother more insulin resistant in order to nurture the growing fetus. While placental growth hormone induces maternal insulin resistance and mobilizes maternal nutrients for fetal growth, human placental lactogen and prolactin increase maternal food intake by inducing central leptin resistance and promoting maternal β -cell expansion and insulin production^[13]. As a result, the mother's insulin needs to increase as much as three or more times normal during pregnancy, resulting in hyperglycemia if her pancreatic β -cells are unable to keep up with heightened insulin demands. A higher body fat percentage, physical inactivity, and diet quality are important modifiable risk factors for GDM^[14].

Given that a sedentary lifestyle can contribute to its development, physical activity prior to and during pregnancy may lower the risk of developing GDM. Although few studies have focused on the mechanisms of exercise-induced benefits in GDM, due to the similarity between GDM and T2D, most of the suggested mechanisms in diabetes can be extrapolated to GDM. The benefits of physical activity to prevent and treat GDM are associated with increased insulin sensitivity, beneficial adipokines changes, and reduced oxidative stress related to the antioxidant effect of exercise^[15].

OVERVIEW OF THE DIAGNOSIS AND TREATMENT OF GESTATIONAL DIABETES

There is a current controversy on the most appropriate diagnostic test(s) for GDM. It is paramount that health care practitioners understand that any degree of abnormal glucose homeostasis in pregnancy independently predicts an increased risk of glucose intolerance postpartum^[16], and women with either GDM or gestational impaired glucose tolerance exhibit declining β -cell function in the first year after giving birth that likely contributes to their future diabetes risk^[17]. Women with a history of GDM should have lifelong screening for T2D or pre-diabetes at least every 3 years^[1].

If maternal hyperglycemia is not controlled, the elevated blood glucose levels are elevated for both the mother and the developing fetus and can lead to macrosomia (a baby weighing more than is appropriate for his or her gestational age). Macrosomia usually occurs as the result of an excessive availability of nutrients and an increase in fetal insulin release^[18]. Such babies can face health problems, including damage to their shoulders during birth, low blood glucose levels following birth, and acute breathing problems. In addition, babies with excess fat and elevated insulin levels are at higher risk for obesity and T2D later in life.

Therefore, the primary goal of treatment of GDM is to keep blood glucose levels within normal limits throughout the pregnancy to ensure appropriate fetal growth. Implementation of lifestyle changes (*i.e.*, diet and exercise) to manage glycemic control is the first management strategy employed^[19-22]. A recommended diet for women with GDM is moderate in fat and protein and provides controlled levels of carbohydrates^[23]. Women should be advised to avoid or limit their intake of refined carbohydrates, sugary drinks, fruit juices, pastries, and other sweets that require large amount of insulin to manage blood glucose levels after ingestion. Pregnant women generally will require no more than 300 extra calories daily to cover their increased energy requirements which they are often already consuming prior to pregnancy^[19].

Pregnant women should also be advised how to safely increase their physical activity during pregnancy and the postpartum period. This is often an overlooked tool to help normalize blood glucose levels and may prevent or delay the need for insulin. Physical activity performed during and after pregnancy benefits a woman's overall health^[24]. Instead of detraining, pregnant women undertaking moderate or higher intensity physical activity can maintain or increase cardiorespiratory fitness^[25]. Maternal exercise during pregnancy does not increase the risk of low birth weight, preterm delivery, or early pregnancy loss; in fact, exercise undertaken on a regular basis may reduce the risk of pregnancy complications, such as

preeclampsia and GDM, and shortens the duration of active labor^[7,8,26-29]. Physical activity is not associated with risks for the newborn and can lead to changes in lifestyle that imply long-term benefits^[30].

If lifestyle changes are not successful in maintaining target glucose values during pregnancy, glucose-lowering medications may additionally be used^[31-33]. Insulin remains the gold standard for pharmacologic therapy and is still recommended by many practitioners over oral hypoglycemic agents^[1]. Both glyburide and metformin have been shown to cross the placenta to the fetus and should be used with caution and patients counseled appropriately^[31]. Regular aerobic training may result in a lowering of the daily insulin dose needed to manage glucose levels in some women with GDM, which often feels like a reward to patients.

PREVENTION OF GESTATIONAL DIABETES WITH PHYSICAL ACTIVITY

Engaging in regular physical activity before pregnancy frequently has been associated with a reduced risk of developing GDM^[7,8,26-29]. A prospective cohort study among 21765 women in the Nurses' Health Study II showed that physical activity before pregnancy is associated with a risk reduction in GDM, and both intense exercise and moderate activity (*e.g.*, brisk walking) bestow a similar risk reduction^[28]. Even engaging in leisure time physical activity in advance of becoming pregnant may reduce glucose intolerance during the pregnancy^[34,35].

Being physically active during pregnancy may prevent both GDM and possibly later-onset T2D^[56], but studies have shown mixed results^[7,26,27]. Women who perform recreational physical activity during the year before becoming pregnant experience a reduced risk, but participating in any physical activity during the first 20 wk of pregnancy has been shown to lead to close to a 50 percent risk reduction in GDM^[7]. Engaging in physical activity both before and during pregnancy likely leads to the greatest reduction in GDM risk^[7].

Exogenous insulin requirements can be lowered and glycemic control improved after a four- to eight-week period of exercise in the last half of pregnancy, even when exercise is milder in terms of duration and frequency^[37]. In women with GDM unresponsive to dietary changes, eight weeks of moderate, supervised exercise undertaken three times a week maintained blood glucose levels within normal limits without the need for exogenous insulin^[38]. However, exercise must be performed on a chronic basis to have a sustained impact on glycemic control.

When compared with less vigorous activities, an exercise intensity that reaches at least 60 percent of heart rate reserve (HRR) during pregnancy, while gradually increasing physical activity energy expenditure, reduces the risk of developing GDM^[22]. The more vigorous the exercise, the less total exercise time is required. In a recent clinical trial, a moderate physical activity program performed thrice weekly during pregnancy improved

levels of maternal glucose tolerance in healthy, pregnant women^[39], and higher levels of physical activity participation before pregnancy or in early pregnancy significantly lowered the risk of developing GDM^[10]. Moreover, a recent study reported that women can safely engage in aerobic exercise and resistance training for muscular endurance 3 d per week for 30 min throughout gestation and doing so reduces the incidence of GDM^[11]. Thus, it appears that higher levels of moderate physical activity (aerobic or resistance training) may reduce the risk of developing GDM during pregnancy and lower blood glucose levels in women who do develop it.

To achieve the best decline in glucose concentrations, pregnant women may need to walk for 25 min per session at a vigorous intensity or for 35 to 40 min per session at low intensity if they are at risk for GDM and for at least 25 min at either low or vigorous intensity if they have a low risk to achieve optimal benefits related to glycemic control and prevention of GDM^[9].

Not all studies have shown that physical activity can prevent the onset of GDM. For example, a recent review of five randomized controlled trials in 2012 reported limited evidence available on the effect of exercise during pregnancy for preventing pregnancy-induced hyperglycemia, although at least seven additional trials are currently underway^[40]. Similarly, a 12-wk exercise program (30-35 min low impact aerobics, 20-25 min of strength exercises using body weight as resistance and 5-10 min of stretching, breathing, and relaxation exercises) undertaken during the second trimester of pregnancy did not reduce the prevalence of gestational diabetes in pregnant women with a body mass index in the normal range^[41]. In a recent study involving moderate-intensity resistance and aerobic exercises (done three times per week for 50 to 55 min per session), the risk of developing GDM also was not lowered^[42]. Larger, well-designed randomized trials, with standardized behavioral interventions are definitely needed to assess the effects of exercise on preventing GDM or other adverse pregnancy outcomes.

MANAGEMENT OF GESTATIONAL DIABETES WITH PHYSICAL ACTIVITY

Women with diagnosed GDM can experience greater blood glucose uptake through increased insulin sensitivity from both aerobic and resistance training^[43,44]. A meta-analysis reported that pregnant women with GDM who exercised on a cycle or arm ergometer or performed resistance training three times a week for 20 to 45 min experience better glycemic control, lower fasting and postprandial glucose levels, and improve cardiorespiratory fitness^[25]. Nevertheless, being active doing any type of activity did not necessarily prevent the need for supplemental insulin to manage blood glucose levels or change pregnancy outcomes.

On the other hand, at least one study reported that resistance exercise training may help to avoid insulin therapy for overweight women with GDM^[44]. In addi-

Table 1 Contraindications to physical activity during pregnancy and warning signs for termination

Contraindications to exercise ^[19]	Significant cardiopulmonary disease, restrictive lung disease, incompetent cervix/cerclage, multiple gestation at risk for premature labor, persistent second- or third-trimester bleeding, placenta previa after 26 wk of gestation, premature labor during the current pregnancy, ruptured membranes, and preeclampsia/pregnancy-induced hypertension
Warning signs to terminate or avoid exercise	Vaginal bleeding, dyspnea prior to exertion, dizziness, headache, chest pain, muscle weakness, calf pain or swelling, preterm labor, decreased fetal movement, or amniotic fluid leakage

tion, regular physical activity may improve other pregnancy outcomes, such as lowering the GDM-related risk of having a newborn with macrosomia by 58 percent, and the risk of having acute elective caesarean delivery by 34 percent^[42]. The intensity of activities undertaken may also impact glycemic management. For example, a low-intensity walking program has been shown to lower capillary blood glucose measurements in women with GDM^[20]; however, a higher intensity of exercise may provide additional benefits.

EXERCISE PRESCRIPTION FOR WOMEN WITH GESTATIONAL DIABETES

An initial approach to helping women become more physically active can simply be to encourage them to incorporate more unstructured physical activity into daily living, both before and during pregnancy^[45]. While such lifestyle activity does not entirely take the place of traditional structured exercise, it can be highly effective in preventing excessive weight gain, increasing daily activity levels, and building a fitness base from which to progress to prescribed exercise, as follows.

Unless a woman has medical reasons to avoid physical activity during pregnancy, such as premature labor, significant cardiopulmonary disease, or preeclampsia, she can begin or continue moderate-intensity aerobic physical activity during her pregnancy and after giving birth to help manage her blood glucose levels^[10,14,20,21,23,25,43,44,46]. Warning signs to terminate exercise while pregnant include vaginal bleeding, dyspnea prior to exertion, dizziness, headache, chest pain, muscle weakness, calf pain or swelling, preterm labor, decreased fetal movement or amniotic fluid leakage^[19]. Contraindications to and warning signs to end physical activity are listed in Table 1.

Mode of physical activity

Most pregnant women with and without GDM can safely undertake moderate and vigorous aerobic activities. These include both weight-bearing activities like walking, jogging, running, conditioning machines (*e.g.*, elliptical trainers), and dancing and non-weight-bearing ones like, cycling, swimming, water aerobics, aquatic activities, chair exercises, and rowing^[19].

Resistance training can also be safely and effectively undertaken by pregnant women with GDM and may reduce the need for exogenous insulin to control hyperglycemia^[21]. The most recent guidelines propose increasing weekly physical-activity expenditure while incorporating

vigorous exercise and adding light strength training to the exercise routine of healthy pregnant women^[22]. Most of these exercises can be completed either standing or sitting, as desired for comfort and safety. Low- to moderate-intensity muscle-strengthening exercises performed during the second and third trimesters of pregnancy have a minimal effect on newborn body size and overall health^[22,47]. Thus, women with GDM can experience greater blood glucose uptake through increased insulin sensitivity from both aerobic and resistance training^[43,44].

During pregnancy, however, women should avoid doing exercises involving lying on their backs during the second and third trimesters. They should also avoid activities that increase the risk of falling or abdominal trauma, including contact or collision sports, horseback riding, downhill skiing, water skiing, soccer, and basketball. Late in pregnancy, non-weight-bearing activities may be preferable to weight-bearing activities in some women, especially if low back pain is present^[48].

Intensity of physical activity

For most healthy women who are not already highly active or doing vigorous-intensity activity, moderate-intensity aerobic activity is recommended during pregnancy and the postpartum period, corresponding to 40%-59% HRR, "somewhat hard," or 5-6 on a 10-point rating scale^[49,50]. A more deconditioned woman may start as low as 30% HRR and progress to moderate levels. Women who are already highly active or doing regular vigorous activity (60%-89% HRR, "hard," or a rating of 7-8) can continue these activities during pregnancy.

Because the effects of vigorous-intensity aerobic activity during pregnancy have not been studied carefully, there is no basis for recommending that women should begin such activities during pregnancy if they already were not doing so. Women who habitually engage in vigorous or high amounts of activity or strength training should continue to be physically active during pregnancy and after giving birth; they generally do not need to drastically reduce their activity levels, provided that they remain healthy and discuss with their health-care provider how to adjust activity levels during this time^[19] (Table 2).

Frequency of physical activity

According to current guidelines, pregnant women should engage in physical activity on most, if not all, days of the week, including both aerobic and resistance training^[19,22,47]. Current guidelines for adults generally recommend five sessions of moderate activity, which would

Table 2 Example using heart rate reserve to determine target hazard ratio range

Target HR range (40%-89% HRR)
Example patient: 30-year-old female
Resting HR: 78 beats per minute (bpm)
Maximum HR: 190 bpm (estimated as 220 minus age)
Formula for sample calculation:
Target HR = [(Max HR-Resting HR) × Desired Intensity] + Resting HR
Lower end of HR range (40%) = [(190-78) × 0.40] + 78
(Low end of moderate intensity) = [112 × 0.40] + 78
= 45 + 78
= 123 bpm
Higher end of HR range (89%) = [(190-78) × 0.85] + 78
(High end of vigorous intensity) = [112 × 0.89] + 78
= 100 + 78
= 178 bpm
Target HR range (40%-89% HRR) = 123 to 178 bpm

HRR: Heart rate reserve.

also apply to women with GDM^[49,50]. Daily exercise may enhance glucose metabolism further and, therefore, the recommended frequency for any type of physical activity for women with GDM is a minimum of three and up to seven days per week, spread throughout the week^[19].

Duration of physical activity

Engaging in 30 min of moderate intensity physical activity on most days of the week, reaching a minimal total of 150 min per week, has been adopted as a recommendation for pregnant women without medical or obstetrical complications^[19]. Health benefits can be derived from daily sessions lasting 20 to 45 min^[25]. Compared with less vigorous activities, engaging in an exercise intensity that is at least 60 percent of HRR during pregnancy, while gradually increasing physical activity energy expenditure, reduces the risk of GDM, and the more vigorous the exercise, the less total exercise time is required. Prolonged duration physical activity (*i.e.*, lasting over 60 to 90 min when done continuously) usually is not recommended for pregnant women due to heightened concern over possible hypoglycemia or hyperthermia, however^[29].

Progression of physical activity

Sedentary and deconditioned women with GDM should start out on the low end of the intensity scale (30%-39% HRR) and gradually progress to moderate-intensity exercise (40%-59% HRR) or higher. Initially, they should be advised to increase frequency and duration of activities rather than intensity. For previously inactive women, moderate-intensity workouts are an appropriate endpoint, but if just starting physical activity during pregnancy, women should progress gradually over time to that intensity. Women who have been active before and during pregnancy and before diagnosis of GDM should continue doing moderate-to-vigorous intensity activities^[47].

During a normal postpartum period, regular physical activity continues to benefit a woman's overall health. Moderate-intensity physical activity undertaken after giv-

Table 3 Recommended exercise prescription for women with gestational diabetes

Mode	Aerobic: Walk, stationary cycle, swim, aquatic activities, conditioning machines, prenatal exercise classes, prenatal yoga, seated exercises, and possibly jogging or running (if highly active before pregnancy) Resistance: Light or moderate resistance exercises Exercises to Avoid: Activities lying flat on the back and any that increase the risk of falling or abdominal trauma (<i>e.g.</i> , contact or collision sports, horseback riding, downhill skiing, water skiing, soccer, outdoor cycling, basketball, most racquet sports, and scuba diving)
Intensity	If inactive: moderate-intensity aerobic activity (40%-59% HRR, or "somewhat hard") during pregnancy and postpartum If already active or doing vigorous activity: moderate- to vigorous-intensity activity (40%-89% HRR, or "somewhat hard" to "hard")
Frequency	3-7 d, spread throughout the week Better done on most, if not all, days of the week
Duration	30 min/session (range of 20-45 min) At least 150 min of moderate-intensity physical activity spread throughout the week
Progression	If just starting, increase duration of moderate exercise slowly; if already more active, maintain or lower intensity during pregnancy rather than attempting to progress to higher levels

HRR: Heart rate reserve. Reprinted by permission from (Colberg SR. Exercise and Diabetes: A Clinician's Guide to Prescribing Physical Activity, American Diabetes Association, Alexandria, VA, United States, 2013. p. 110.).

ing birth increases cardiorespiratory fitness and improves mood, with no adverse effects on breast milk volume, breast milk composition, or infant growth^[51]. An added benefit is that it helps women achieve and maintain a healthy weight postpartum and can promote weight loss when combined with caloric restriction. Pregnant women who habitually engage in vigorous-intensity aerobic activity or are highly active can continue such physical activity during pregnancy and the postpartum period, provided that they remain healthy and avoid activities that increase risk of falls and traumatic injury (Table 3).

CONCLUSION

In conclusion, women at high risk for GDM may be able to prevent it with lifestyle management before and during pregnancy. In those who develop GDM, dietary improvements and regular physical activity are frequently sufficient to manage hyperglycemia, although insulin may be used when these changes are not enough. Management of blood glucose levels ensures better pregnancy outcomes and improves the health of both the mother and the fetus. Giving pregnant women an appropriate exercise prescription can encourage them to participate in physical activity safely and effectively throughout pregnancy to prevent and/or manage gestational diabetes. Engaging in 30 min of moderate intensity physical activity on most, if not all, days of the week has been adopted as a recommendation for all pregnant women.

REFERENCES

- 1 **American Diabetes Association.** Standards of medical care in diabetes--2013. *Diabetes Care* 2013; **36** Suppl 1: S11-S66 [PMID: 23264422 DOI: 10.2337/dc13-S011]
- 2 **American Diabetes Association.** Diagnosis and classification of diabetes mellitus. *Diabetes Care* 2013; **36** Suppl 1: S67-S74 [PMID: 23264425 DOI: 10.2337/dc13-S067]
- 3 Centers for Disease Control and Prevention. 2011 National Diabetes Fact Sheet. Available from: URL: http://www.cdc.gov/diabetes/pubs/pdf/ndfs_2011.pdf
- 4 **Metzger BE,** Persson B, Lowe LP, Dyer AR, Cruickshank JK, Deerochanawong C, Halliday HL, Hennis AJ, Liley H, Ng PC, Coustan DR, Hadden DR, Hod M, Oats JJ, Trimble ER. Hyperglycemia and adverse pregnancy outcome study: neonatal glycemia. *Pediatrics* 2010; **126**: e1545-e1552 [PMID: 21078733 DOI: 10.1542/peds.2009-2257]
- 5 **Metzger BE,** Lowe LP, Dyer AR, Trimble ER, Chaovarindr U, Coustan DR, Hadden DR, McCance DR, Hod M, McIntyre HD, Oats JJ, Persson B, Rogers MS, Sacks DA. Hyperglycemia and adverse pregnancy outcomes. *N Engl J Med* 2008; **358**: 1991-2002 [PMID: 18463375 DOI: 10.1056/NEJMoa0707943]
- 6 **Downs DS,** Chasan-Taber L, Evenson KR, Leiferman J, Yeo S. Physical activity and pregnancy: past and present evidence and future recommendations. *Res Q Exerc Sport* 2012; **83**: 485-502 [PMID: 23367811]
- 7 **Dempsey JC,** Sorensen TK, Williams MA, Lee IM, Miller RS, Dashow EE, Luthy DA. Prospective study of gestational diabetes mellitus risk in relation to maternal recreational physical activity before and during pregnancy. *Am J Epidemiol* 2004; **159**: 663-670 [PMID: 15033644]
- 8 **Dempsey JC,** Butler CL, Sorensen TK, Lee IM, Thompson ML, Miller RS, Frederick IO, Williams MA. A case-control study of maternal recreational physical activity and risk of gestational diabetes mellitus. *Diabetes Res Clin Pract* 2004; **66**: 203-215 [PMID: 15533588]
- 9 **Ruchat SM,** Davenport MH, Giroux I, Hillier M, Batada A, Sopper MM, McManus R, Hammond JA, Mottola MF. Effect of exercise intensity and duration on capillary glucose responses in pregnant women at low and high risk for gestational diabetes. *Diabetes Metab Res Rev* 2012; **28**: 669-678 [PMID: 22865627 DOI: 10.1002/dmrr.2324]
- 10 **Tobias DK,** Zhang C, van Dam RM, Bowers K, Hu FB. Physical activity before and during pregnancy and risk of gestational diabetes mellitus: a meta-analysis. *Diabetes Care* 2011; **34**: 223-229 [PMID: 20876206 DOI: 10.2337/dc10-1368]
- 11 **White E,** Pivarnik J, Pfeiffer K. Resistance Training During Pregnancy and Pregnancy and Birth Outcomes. *J Phys Act Health* 2013 Aug 19; Epub ahead of print [PMID: 23962890]
- 12 **Metzger BE,** Buchanan TA, Coustan DR, de Leiva A, Dungan DB, Hadden DR, Hod M, Kitzmiller JL, Kjos SL, Oats JN, Pettitt DJ, Sacks DA, Zouzas C. Summary and recommendations of the Fifth International Workshop-Conference on Gestational Diabetes Mellitus. *Diabetes Care* 2007; **30** Suppl 2: S251-S260 [PMID: 17596481 DOI: 10.2337/dc07-s225]
- 13 **Newbern D,** Freemerk M. Placental hormones and the control of maternal metabolism and fetal growth. *Curr Opin Endocrinol Diabetes Obes* 2011; **18**: 409-416 [PMID: 21986512 DOI: 10.1097/MED.0b013e32834c800d]
- 14 **Iqbal R,** Rafique G, Badruddin S, Qureshi R, Cue R, Gray-Donald K. Increased body fat percentage and physical inactivity are independent predictors of gestational diabetes mellitus in South Asian women. *Eur J Clin Nutr* 2007; **61**: 736-742 [PMID: 17180158]
- 15 **Golbidi S,** Laher I. Potential mechanisms of exercise in gestational diabetes. *J Nutr Metab* 2013; **2013**: 285948 [PMID: 23691290 DOI: 10.1155/2013/285948]
- 16 **Retnakaran R,** Qi Y, Sermer M, Connelly PW, Hanley AJ, Zinman B. Glucose intolerance in pregnancy and future risk of pre-diabetes or diabetes. *Diabetes Care* 2008; **31**: 2026-2031 [PMID: 18628572 DOI: 10.2337/dc08-0972]
- 17 **Retnakaran R,** Qi Y, Sermer M, Connelly PW, Hanley AJ, Zinman B. Beta-cell function declines within the first year postpartum in women with recent glucose intolerance in pregnancy. *Diabetes Care* 2010; **33**: 1798-1804 [PMID: 20484133 DOI: 10.2337/dc10-0351]
- 18 **Vambergue A,** Fajardy I. Consequences of gestational and pregestational diabetes on placental function and birth weight. *World J Diabetes* 2011; **2**: 196-203 [PMID: 22087356 DOI: 10.4239/wjd.v2.i11.196]
- 19 **Committee on Obstetric Practice.** ACOG committee opinion. Exercise during pregnancy and the postpartum period. Number 267, January 2002. American College of Obstetricians and Gynecologists. *Int J Gynaecol Obstet* 2002; **77**: 79-81 [PMID: 12053898]
- 20 **Davenport MH,** Mottola MF, McManus R, Gratton R. A walking intervention improves capillary glucose control in women with gestational diabetes mellitus: a pilot study. *Appl Physiol Nutr Metab* 2008; **33**: 511-517 [PMID: 18461104 DOI: 10.1139/H08-018]
- 21 **de Barros MC,** Lopes MA, Francisco RP, Sapienza AD, Zugaib M. Resistance exercise and glycemic control in women with gestational diabetes mellitus. *Am J Obstet Gynecol* 2010; **203**: 556.e1-556.e6 [PMID: 20864072 DOI: 10.1016/j.ajog.2010.07.015]
- 22 **Zavorsky GS,** Longo LD. Adding strength training, exercise intensity, and caloric expenditure to exercise guidelines in pregnancy. *Obstet Gynecol* 2011; **117**: 1399-1402 [PMID: 21606752 DOI: 10.1097/AOG.0b013e31821b1f5a]
- 23 **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 Metab* 2007; **32**: 596-601 [PMID: 17510701]
- 24 **Davenport MH,** Giroux I, Sopper MM, Mottola MF. Postpartum exercise regardless of intensity improves chronic disease risk factors. *Med Sci Sports Exerc* 2011; **43**: 951-958 [PMID: 21085038 DOI: 10.1249/MSS.0b013e3182051155]
- 25 **Ceysens G,** Rouiller D, Boulvain M. Exercise for diabetic pregnant women. *Cochrane Database Syst Rev* 2006; **(3)**: CD004225 [PMID: 16856038]
- 26 **Dyck R,** Klomp H, Tan LK, Turnell RW, Bector MA. A comparison of rates, risk factors, and outcomes of gestational diabetes between aboriginal and non-aboriginal women in the Saskatoon health district. *Diabetes Care* 2002; **25**: 487-493 [PMID: 11874935]
- 27 **Oken E,** Ning Y, Rifas-Shiman SL, Radesky JS, Rich-Edwards JW, Gillman MW. Associations of physical activity and inactivity before and during pregnancy with glucose tolerance. *Obstet Gynecol* 2006; **108**: 1200-1207 [PMID: 17077243]
- 28 **Zhang C,** Solomon CG, Manson JE, Hu FB. A prospective study of pregravid physical activity and sedentary behaviors in relation to the risk for gestational diabetes mellitus. *Arch Intern Med* 2006; **166**: 543-548 [PMID: 16534041]
- 29 **Melzer K,** Schutz Y, Boulvain M, Kayser B. Physical activity and pregnancy: cardiovascular adaptations, recommendations and pregnancy outcomes. *Sports Med* 2010; **40**: 493-507 [PMID: 20524714 DOI: 10.2165/11532290-000000000-00000]
- 30 **Nascimento SL,** Surita FG, Cecatti JG. Physical exercise during pregnancy: a systematic review. *Curr Opin Obstet Gynecol* 2012; **24**: 387-394 [PMID: 23014142 DOI: 10.1097/GCO.0b013e328359f131]
- 31 **Paglia MJ,** Coustan DR. The use of oral antidiabetic medications in gestational diabetes mellitus. *Curr Diab Rep* 2009; **9**: 287-290 [PMID: 19640341]
- 32 **Dhulkotia JS,** Ola B, Fraser R, Farrell T. Oral hypoglycemic agents vs insulin in management of gestational diabetes: a systematic review and metaanalysis. *Am J Obstet Gynecol* 2010; **203**: 457.e1-457.e9 [PMID: 20739011 DOI: 10.1016/

- j.ajog.2010.06.044]
- 33 **Nicholson W**, Bolen S, Witkop CT, Neale D, Wilson L, Bass E. Benefits and risks of oral diabetes agents compared with insulin in women with gestational diabetes: a systematic review. *Obstet Gynecol* 2009; **113**: 193-205 [PMID: 19104375 DOI: 10.1097/AOG.0b013e318190a459]
 - 34 **Retnakaran R**, Qi Y, Sermer M, Connelly PW, Zinman B, Hanley AJ. Pre-gravid physical activity and reduced risk of glucose intolerance in pregnancy: the role of insulin sensitivity. *Clin Endocrinol (Oxf)* 2009; **70**: 615-622 [PMID: 18793347 DOI: 10.1111/j.1365-2265.2008.03393.x]
 - 35 **Baptiste-Roberts K**, Ghosh P, Nicholson WK. Pregravid physical activity, dietary intake, and glucose intolerance during pregnancy. *J Womens Health (Larchmt)* 2011; **20**: 1847-1851 [PMID: 21951267 DOI: 10.1089/jwh.2010.2377]
 - 36 **Dyck RF**, Sheppard MS, Cassidy H, Chad K, Tan L, Van Vliet SH. Preventing NIDDM among aboriginal people: is exercise the answer? Description of a pilot project using exercise to prevent gestational diabetes. *Int J Circumpolar Health* 1998; **57** Suppl 1: 375-378 [PMID: 10093309]
 - 37 **Jovanovic-Peterson L**, Durak EP, Peterson CM. Randomized trial of diet versus diet plus cardiovascular conditioning on glucose levels in gestational diabetes. *Am J Obstet Gynecol* 1989; **161**: 415-419 [PMID: 2764059]
 - 38 **Bung P**, Artal R, Khodiguian N, Kjos S. Exercise in gestational diabetes. An optional therapeutic approach? *Diabetes* 1991; **40** Suppl 2: 182-185 [PMID: 1748256]
 - 39 **Barakat R**, Cordero Y, Coteron J, Luaces M, Montejó R. Exercise during pregnancy improves maternal glucose screen at 24-28 weeks: a randomised controlled trial. *Br J Sports Med* 2012; **46**: 656-661 [PMID: 21948120 DOI: 10.1136/bjsports-2011-090009]
 - 40 **Han S**, Middleton P, Crowther CA. Exercise for pregnant women for preventing gestational diabetes mellitus. *Cochrane Database Syst Rev* 2012; **7**: CD009021 [PMID: 22786521 DOI: 10.1002/14651858.CD009021.pub2]
 - 41 **Ramírez-Vélez R**. A 12-week exercise program performed during the second trimester does not prevent gestational diabetes in healthy pregnant women. *J Physiother* 2012; **58**: 198 [PMID: 22884188 DOI: 10.1016/S1836-9553(12)70112-1]
 - 42 **Barakat R**, Pelaez M, Lopez C, Lucia A, Ruiz JR. Exercise during pregnancy and gestational diabetes-related adverse effects: a randomised controlled trial. *Br J Sports Med* 2013; **47**: 630-636 [PMID: 23365418 DOI: 10.1136/bjsports-2012-091788]
 - 43 **Avery MD**, Walker AJ. Acute effect of exercise on blood glucose and insulin levels in women with gestational diabetes. *J Matern Fetal Med* 2001; **10**: 52-58 [PMID: 11332421]
 - 44 **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**: 188-193 [PMID: 14749658]
 - 45 **Levine JA**, McCrady SK, Lanningham-Foster LM, Kane PH, Foster RC, Manohar CU. The role of free-living daily walking in human weight gain and obesity. *Diabetes* 2008; **57**: 548-554 [PMID: 18003759]
 - 46 **Chasan-Taber L**, Schmidt MD, Pekow P, Sternfeld B, Manson JE, Solomon CG, Braun B, Markenson G. Physical activity and gestational diabetes mellitus among Hispanic women. *J Womens Health (Larchmt)* 2008; **17**: 999-1008 [PMID: 18582171 DOI: 10.1089/jwh.2007.0560]
 - 47 **Zavorsky GS**, Longo LD. Exercise guidelines in pregnancy: new perspectives. *Sports Med* 2011; **41**: 345-360 [PMID: 21510713 DOI: 10.2165/11583930-000000000-00000]
 - 48 **Noon ML**, Hoch AZ. Challenges of the pregnant athlete and low back pain. *Curr Sports Med Rep* 2012; **11**: 43-48 [PMID: 22236825 DOI: 10.1249/JSR.0b013e31824330b6]
 - 49 **Haskell WL**, Lee IM, Pate RR, Powell KE, Blair SN, Franklin BA, Macera CA, Heath GW, Thompson PD, Bauman A. Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Med Sci Sports Exerc* 2007; **39**: 1423-1434 [PMID: 17762377]
 - 50 **Garber CE**, Blissmer B, Deschenes MR, Franklin BA, Lamonte MJ, Lee IM, Nieman DC, Swain DP. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. *Med Sci Sports Exerc* 2011; **43**: 1334-1359 [PMID: 21694556 DOI: 10.1249/MSS.0b013e318213fefb]
 - 51 **Davies GA**, Wolfe LA, Mottola MF, MacKinnon C. Joint SOGC/CSEP clinical practice guideline: exercise in pregnancy and the postpartum period. *Can J Appl Physiol* 2003; **28**: 330-341 [PMID: 12955862]

P- Reviewers: Tskitishvili E, Wahabi HA
S- Editor: Wen LL **L- Editor:** A **E- Editor:** Liu XM





百世登

Baishideng®

Published by **Baishideng Publishing Group Co., Limited**

Flat C, 23/F., Lucky Plaza,

315-321 Lockhart Road, Wan Chai, Hong Kong, China

Fax: +852-65557188

Telephone: +852-31779906

E-mail: bpgoffice@wjgnet.com

<http://www.wjgnet.com>

