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The Potential Impact of Physical Activity During Pregnancy on Maternal and Neonatal Outcomes

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Introduction: Pregnancy is a critical period of body weight regulation. Maternal obesity and excessive gestational weight gain have become increasingly common and contribute to poor obstetrical outcomes for mother and baby. Regular participation in physical activity may improve risk profiles in pregnant women.

Purpose and Methods: Our objectives were to provide an overview of maternal-fetal exercise physiology, summarize current evidence on the effects of physical activity during pregnancy on maternal-fetal outcomes, and review the most recent clinical practice guidelines. In addition, we summarize the findings in the context of the current obesity epidemic and discuss implications for clinical practice. A literature review was completed in which we queried OVID (Medline), EMBASE, and PSYCHINFO databases with title words "exercise or physical activity" and "pregnancy or gestation" from 1950 to March 1, 2010. A total of 212 articles were selected for review.

Recommendations: Care providers should recommend physical activity to most pregnant women (i.e., those without contraindications) and view participation as a safe and beneficial component of a healthy pregnancy.

Target Audience: Obstetricians & Gynecologists and Family Physicians

Learning Objectives: After participating in this CME activity, physicians should be better able to classify the potential impact of physical activity on maternal glycemic control and fetal growth outcomes. Assess maternal lifestyle and provide recommendations on appropriate gestational weight gain, evaluate pregnant women for contraindications to physical activity participation, make individualized recommendations for exercise participation, and educate patients on the merits of physical activity for health benefit.

THE CASE

Susan, a 35-year-old G_2P_1 woman, presented to her family physician for a routine prenatal visit at 25 weeks' gestation. Her pregnancy was uncomplicated to date, and she had no significant past medical history (including glucose intolerance, hypertension, or hypothyroidism). A 1-hour glucose challenge test

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(50-g glucose load) had been performed at 24 weeks, with a resulting plasma glucose value of 7.6 mmol/L (normal: ≤7.8 mmol/L). Because this was below the screening cutoff value, further testing was not indicated. Susan expressed concern about the impact of her weight on the health of her baby. Detailed history was obtained, and physical examination was performed. Susan described a history of inactivity and steady weight gain since her early 20s and was found to have a body mass index (BMI) of 30 kg/m^2. No contraindications to exercise participation were identified.

INTRODUCTION

Obesity and excessive weight gain in pregnancy are known to contribute to poor obstetrical outcomes, including hypertensive disorders, glycemic dysregulation, and aberrant fetal growth.[1] Pregnancy is a critical period of body weight regulation. Gestational weight gain (GWG) often exceeds clinical recommendations, a situation that poses an elevated health risk to mother and fetus.[2,3] Gaining the recommended amount of weight during pregnancy minimizes the incidence of adverse outcomes, including gestational hypertension, casarean delivery, and birth weight <2500 g or ≥4000 g, independent of prepregnancy BMI.[4] Engaging in healthy active behaviors during pregnancy may offer a useful and economical approach to attenuating excessive weight gain, improving obstetrical outcomes, and promoting optimal fetal growth trajectories.

Ideally women should conceive at a healthy body weight (i.e., BMI: 18.5–24.9), taking full advantage of the adage "prevention before conception." Unfortunately, many individuals currently display poor fitness and increased fatness,[5,6] making this goal more challenging. Nonetheless, achieving a healthy prepregnancy body weight must still be considered the ultimate and ideal goal. Care providers should help women achieve a healthy body weight or slow the rate of weight gain, before pregnancy, as individuals with excess weight have increased risk of cardiac and pulmonary disease, gestational hypertension, and diabetes as well as obstructive sleep apnea.[1] Routine physical activity during pregnancy may attenuate some of the comorbidities associated with an increased body weight.[1] This is particularly important for overweight and obese women to optimize their health and longevity as well as that of their baby.[7]

There are few randomized controlled trials or systematic reviews[8,9] specifically addressing the effects of physical activity on maternal and neonatal outcomes, making precise clinical recommendations difficult. Most recommendations are based on observational studies, consensus guidelines, or extrapolations from animal models.[10–15] A recent systematic review of 14 trials involving 1014 pregnant women evaluated the effect of aerobic exercise on maternal and neonatal outcomes.[8] Although largely inconclusive, the authors noted that those who engage in 2 to 3 episodes of weekly exercise have similar pregnancy duration, risk of cesarean delivery, and infant birth weight, as those who maintain their habitual activity level. The authors felt that they were unable to confidently show whether exercise has other effects on maternal-fetal outcomes due to a lack of available evidence, methodological flaws, and small sample sizes of the included studies. They suggest that the available literature lacks power and consistency to allow evaluation of the potential risks or benefits of physical activity during pregnancy for the mother or infant but concluded that aerobic exercise during pregnancy can maintain or improve physical fitness, a known contributor to reduced cardiovascular morbidity and all-cause mortality.[16] There is presently a need to evaluate the evidence on the impact of a physically active pregnancy on the mother and baby.

Pregnancy is a unique state in which women are often highly motivated to institute behavior change.[17] However, many women are unaware of what constitutes "safe and effective" exercise in pregnancy and have difficulty overcoming common barriers to participation.[18,19] In addition, health care providers may fail to recognize the benefits of being physically active during pregnancy and may be unaware of available screening tools such as the "Physical Activity Readiness Medical Exam for Pregnancy."[14] This pregnancy-specific tool, endorsed by several North American obstetrics and exercise societies, considers medical and obstetrical history and provides a list of absolute and relative contraindications to exercise in pregnancy in a check list format. It also includes aerobic and muscular conditioning guidelines, safety considerations, and guidelines to patients as to when to stop exercise and seek medical advice. Providers should be aware of the benefits of nonsedentary pursuits during gestation and in light of the obesity epidemic, ensure their patients attempt to overcome the challenges presented to them in our modern obesogenic environment.

The purpose of this review is to provide a synopsis of the physiology of pregnancy and summarize the evidence concerning physical activity during pregnancy and its effects on maternal and fetal health, incorporating both novel emerging literature and ex-

isting practice guidelines in the context of obesity prevention and management.

METHODS

OVID (Medline), EMBASE and PSYCHINFO data bases were queried from 1950 to March 1, 2010 with the title search words "exercise," "physical activity," "pregnancy" and "gestation." After limiting the search to studies involving human subjects in the English language, a total of 505 relevant articles were retrieved. Each abstract was screened for relevance to the purpose of the review leaving a total of 212 articles. Each abstract was then systematically reviewed. Reference lists were reviewed to identify additional articles. Relevant studies were grouped according to maternal (i.e., gestational diabetes mellitus (GDM), preeclampsia, pregnancy complications) and fetal outcomes (i.e., small for gestational age [SGA], large for gestational age [LGA], medical complications).

DISCUSSION

Section 1: Overview of Physical Activity in Pregnancy

Exercise Physiology and Pregnancy

Pregnancy and exercise are independently associated with significant physiologic and metabolic changes. It is important to recognize that pregnant women are capable of benefiting from physical activity to a similar extent as nonpregnant women,[20] as the physiological response to physical exertion does not differ significantly compared with the nonpregnant state. Table 1 outlines the activity-induced changes in maternal physiology relative to the pregnant resting state to help the reader understand the basic physiological adaptations to maternal physical activity in pregnancy.

TABLE 1
Activity-induced changes in maternal physiology relative to the resting state

Parameter	Change
Heart rate (HR)	↑
Stroke volume (SV)	↑
Cardiac output (Q)	↑
Tidal volume (V_T)	↑
Core temperature	↑
Placental perfusion	↑
Hemoconcentration	↑
Plasma volume	↓
Blood pressure	↑
Absolute energy expenditure for a given work load	↑ (as a result of ↑ weight gain)

Pregnancy-induced changes in maternal physiology are primarily designed to protect the developing fetus by ensuring that the metabolic demands of both mother and fetus are met. Recent evidence suggests that the fetus is not deprived of substrate during periods of maternal physical activity in the presence of adequate maternal nutrition.[11,21] This protective effect may be mediated by changes in substrate delivery across the placenta arising from activity-induced alterations in placental form and function. Jackson et al[22] compared the histomorphometry of term placentas from women who exercised regularly throughout either the entire or solely the first half of pregnancy and made comparisons with matched controls. Using stereological techniques to assess placental volumetric composition, surface area, and villous and vascular differences between the groups, it was noted that exercise throughout pregnancy increased the parenchymal component of the placenta, the total vascular volume, and site-specific capillary volume, as well as the surface area and other parameters associated with an enhanced rate of placental perfusion, and transfer function. They noted that exercise-induced placental changes were confined to villi >80 μm in diameter and attributed the lack of change in smaller villi to adaptive mechanisms, chiefly increased rates of blood flow in the midtrimester, that maintain fetal oxygenation and substrate delivery for the remainder of pregnancy. As such, pregnancy-induced, placenta-mediated adaptation occurs to balance the maternal-fetal energy demands during exercise and optimize fetal growth in active mothers. Studies of placental perfusion and function show an improvement in blood flow and gas exchange in the placentas of women who engage in regular physical activity.[22]

Maternal blood glucose levels are also affected by exercise in pregnancy. Seminal work by Clapp and Capeless[13,23] demonstrated that sustained weight-bearing activity during pregnancy elicits a transient reduction in placental glucose. This occurs, as placental blood flow and maternal blood glucose concentrations are decreased, and blood is redirected to active muscles and skin. This effect was demonstrated to be strongest at moderate intensity exercise, in late pregnancy and shortly after a meal. This effect differs from the nonpregnant state, during which exercise elicits a hyperglycaemic response at the onset of activity. Reduction in blood glucose may be observed, as hepatic glucose output is balanced with increased skeletal muscle uptake due to the demands

of physical exertion. Although there are few studies addressing causal mechanisms, these findings suggest that inadequate nutrition or a combination of factors (e.g., contraindications to exercise during pregnancy), rather than simply maternal physical activity, must be present for strenuous physical activity to adversely affect delivery of substrate to the fetus.[24] Adequate ingestion of nutrients throughout the day, ideally several hours before engaging in structured physical activity, may ensure optimal substrate availability for mother and baby.

Methodological constraints make it difficult to predict whether an acute period of fetal hypoglycemia occurs at the onset or during the course of maternal physical activity, and whether this results in any long-term negative consequences. Additionally, there is a paucity of data from well-designed randomized controlled trials examining the long-term effects of maternal physical activity on downstream child health. However, ample experimental data in both humans and sheep have demonstrated that glucose and oxygen delivery to the fetus is not compromised due to maternal exercise in uncomplicated singleton pregnancies.[12,13,15,25–27] Although an acute period of fetal hypoglycemia may occur at the onset of maternal exercise, fetal glucose delivery is likely to be enhanced by the greater placental surface area available for uptake in active women. This leads one to speculate that the fetus is protected from hypoglycemia as a result of this compensatory mechanism. The physiologic processes responsible for the maintenance of placental blood flow, cord blood oxygen saturation, and glucose delivery during exercise include maternal hemoconcentration (via decreased plasma volume), increased cardiac output, and improved perfusion balance at the placenta.[13] As such, there seem to be protective mechanisms in place that compensate for the theoretical risks associated with hypoglycemia due to physical activity.

A recent clinical study by May et al[28] compared low-risk pregnant women who exercised regularly throughout pregnancy (>30 minutes of aerobic exercise, 3 ×/wk) with healthy nonexercising controls and found, using fetal magnetocardiograms, that the fetal heart rate (HR) at 36 weeks' gestational age was significantly lower, and the variability was significantly increased during maternal physical activity in the exercise group. This finding counters previous research suggesting that a decrease in fetal HR that occurs during or immediately after maternal aerobic exercise is due to chronic fetal hypoxia[29]; one would expect decreased HR variability indicative of an adverse stress on fetal autonomic nervous system development if chronic hypoxia were present.[28] Previous work examining the effect of regular exercise over the course of pregnancy in largely sedentary patients found that maternal physical activity did not impair uteroplacental blood flow as measured by Doppler ultrasound scans of the uterine and umbilical artery pulsatility index immediately following a graded exercise test in the third trimester.[30] Because serum erythropoietin can be a marker for acute and/or chronic hypoxia, investigators have also looked at these levels in association with maternal exercise. In one study, continuous exercise throughout gestation did not alter maternal serum erythropoietin concentration, although a small acute elevation was observed after exercise in mid and late pregnancy.[31] Other studies have similarly found that markers of fetal stress, such as levels of erythropoietin in cord blood and amniotic fluid, are not increased at the time of delivery in women who exercised throughout pregnancy,[12] suggesting that fetal oxygenation was not impaired.

During the second and third trimesters of pregnancy, the fetal parasympathetic and sympathetic nervous systems are maturing, which leads to increased HR variability and decreased HR.[32] Furthermore, regular maternal aerobic exercise in healthy, low-risk pregnancies seems to positively influence the development of fetal cardiac autonomic control, an effect that has been hypothesized to arise from chronic exposure to norepinephrine and other catecholamines essential for fetal development.[28] This evidence, together with the developmental origins hypothesis, which states that the fetus makes adaptations in response to the in utero environment, suggests that maternal exercise may induce an adaptive response in utero that yields cardiovascular health benefits later in life.[28]

Energy Expenditure During Pregnancy

During pregnancy, energy expenditure is altered, both at rest and with physical activity. Total energy expenditure, quantified by oxygen uptake (VO_2), is the sum total of calories used at rest plus those expended when performing a given amount of external work. Pregnancy is generally associated with appreciable weight gain; this added mass contributes to the increase in energy expended at rest and during submaximal weight-bearing activity (i.e., walking, running, stepping, etc.) relative to the nonpregnant state.[33] As such, the metabolic cost of physical activity progressively increases from early to late pregnancy in proportion to the amount of GWG and is independent of maternal physical activity status.[34]

Therefore, it is expected that the VO_2 values relative to body weight (i.e., mL/kg/min) will remain similar or increase slightly when compared with the nonpregnant condition with similar exertion,[33,35–37] suggesting that pregnancy does not impair oxidative metabolism but rather impedes activity capacity due to the added weight of pregnancy.

To examine the effect of added pregnancy weight on maternal energy expenditure during submaximal exertion, Carpenter et al had women perform cycling and treadmill exercise tests at 34 weeks' gestation and 8 weeks postpartum. Although absolute VO_2 at the same workload was higher during pregnancy than postpartum with both activities, none of the differences persisted when VO_2 was expressed per kilogram body weight. In fact, increased body weight during pregnancy compared with the postpartum period accounted for 75% of the increased VO_2 during submaximal activity.[33] During pregnancy, there is a need to provide a continuous supply of energy to the utero-placental unit and to the developing fetus. The energy demands associated with fetal growth, increasing maternal body weight, and the increased work of breathing, collectively contribute to the overall rise in oxygen consumption (i.e., VO_2) and thus pregnancy-related energy expenditure during physical activity.[34]

Cardiorespiratory Adaptations to Physical Activity During Pregnancy

Pregnancy-related maternal cardiovascular adaptations include an increase in blood volume, HR, stroke volume, and consequently cardiac output (HR × stroke volume).[38] Changes in the anatomy of the chest wall (e.g., increased elasticity, flaring and expansion as well as elevated diaphragm) allow pregnant women to compensate (more so than nonpregnant women) during exercise with an increase in minute ventilation (tidal volume × breaths/min) and tidal volume (inspired volume of air/breath).[39] As the developing fetus presses upward against the diaphragm, breathing may be more labored, resulting in mild discomfort due to dyspnea.

Concern has been raised that the redistribution of blood flow to active muscle during physical exertion could result in inadequate delivery of nutrients and oxygen to the fetus, with potentially lasting negative effects.[24] However, in an uncomplicated pregnancy, moderate-to-vigorous physical activity (i.e., movements that result in the participant feeling quite warm and increasing their respiratory rate) has been deemed acceptable and beneficial for both pregnant women and their developing offspring, provided there are no contraindications (Table 2).[14,24,40] However, fetal cardiac autonomic control may be affected by the intrauterine milieu, as aberrant measures have been documented in growth-restricted fetuses,[41] signifying that assessing the fetal autonomic response to maternal exertion may be an avenue of research worth pursuing to better understand fetal cardiovascular adaptations to physical activity. As discussed earlier, a prospective longitudinal trial by May et al found that a decrease in fetal HR and increased HR variability during aerobic exercise are indicative of normal healthy development. This suggests that, in addition to maternal benefits, there may be positive fetal cardiovascular adaptations as a result of regular maternal physical activity[28] because physical conditioning has been demonstrated to improve HR and HR variability measures in previously sedentary adults.[42]

Musculoskeletal Adaptations of Pregnancy and Physical Activity

Physical discomfort is common during pregnancy and has been shown to be attenuated or prevented with routine activity.[43,44] The anatomical changes that occur during pregnancy include anterior shift in the center of gravity, exaggerated lordosis of the spine, protruding abdomen, rectus diastasis, and altered gait. Discomfort may be caused or exacerbated by ligament laxity from increased progesterone and relaxin that prepare the musculoskeletal system for

TABLE 2
Contraindications for exercise during pregnancy

Absolute	Relative
Ruptured membranes	Previous spontaneous abortion
Preterm labor	Previous preterm birth
Hypertensive disorders of pregnancy	Mild/moderate cardiovascular disorder
Incompetent cervix	Mild/moderate respiratory disorder
Growth-restricted fetus	Anemia (Hb: <100 g/L)
High-order multiple gestation ([≥]triplets)	Malnutrition or eating disorder
Placenta previa after 28th wk	Twin pregnancy after 28th wk
Persistent second or third trimester bleeding	Other significant medical conditions
Uncontrolled type I diabetes, thyroid disease, or other serious cardiovascular, respiratory, or systemic disorder	

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delivery. Excessive GWG often leads to increased lower back, pelvis, and/or joint pain. Musculoskeletal pain can be attenuated with physical activity in some women who present with mild pelvic and lumbar discomfort.[44,45]

Section 2: Impact of Physical Activity on Maternal Pregnancy Outcome

Maternal Physical Activity and Gestational Diabetes Mellitus

Aerobic exercise improves insulin sensitivity in pregnant women.[46] Those who report continuous activity before and during pregnancy have a lower risk of developing GDM, particularly when the physical activity is performed at a moderate-to-vigorous intensity level.[47–49] These protective effects may be attributed to the regulation of glycemic control.[21] In a randomized controlled trial of treatment of GDM, exercise and diet were compared with insulin therapy and diet, with euglycemia as the primary outcome. There were no significant differences in maternal-fetal outcomes, suggesting that exercise and diet can be a safe and effective alternative treatment for GDM during pregnancy.[50,51] Physical activity was also examined in a case-control study of 155 pregnant women with GDM compared with 386 healthy pregnant controls. Engagement in physical activity before and during pregnancy was associated with a reduced incidence of GDM, with pronounced benefits especially in those with an increased prepregnancy (BMI: $\geq$25).[52]

Considerable population and clinical level data indicate that continuous long-term engagement in physical activity optimizes outcomes with respect to glycemic control during pregnancy regardless of glucose tolerance status.[39,53–61] Pregnant women with an increased BMI who are physically active during pregnancy have approximately a 50% reduction in risk for developing GDM when compared with sedentary controls,[62] suggesting a protective effect against the development of GDM.[63] To gain the greatest protective benefit, physical activities should be initiated early in life, strongly recommended to all women of childbearing age (particularly those who carry excess weight), and be maintained throughout the life course.

Maternal Physical Activity and Preeclampsia

Several investigators have demonstrated that women who engage in moderate-to-vigorous intensity physical activity before and during uncomplicated pregnancies are at a reduced risk of hypertensive disorders.[61,63–67] Physical conditioning and preeclampsia have opposite effects on critical physiological functions, such as placental growth and vascularity and susceptibility to oxidative stress and endothelial dysfunction.[68] Evidence suggests that physical activity has the greatest beneficial effects for preeclampsia prevention when performed at a moderate-to-vigorous intensity before and during gestation.[21] Women who are active during pregnancy seem to have roughly a 40% reduction in risk of developing preeclampsia.[62] Thus, appropriate physical activity seems to be a promising preventive strategy. However, one recent observational cohort study did suggest that extreme amounts of aerobic exercise (>270 min/wk) during the first trimester of pregnancy may increase the risk of developing preeclampsia. Although evidence is limited to this one study, it seems reasonable that women should be advised not to exceed physical activity recommendations.[69]

Maternal Physical Activity and Preterm Delivery

Physical activity during pregnancy has been demonstrated to have no or a slight protective effect on gestational age at delivery and incidence of preterm birth (<37 weeks' gestational age). A recent systematic review of aerobic exercise interventions during pregnancy did not show a significant adverse effect of maternal activity on preterm birth or mean gestational age,[8] and concluded that aerobic exercise maintained or improved fitness for women, but that data are insufficient to infer other important risks (such as preterm birth) or benefits for the mother or infant. A large population-level cohort study that used self-report measures of aerobic, resistance, low-, and high-impact physical activity found that physical activity during pregnancy had no effect on risk of preterm birth and that, when compared with nonexercisers, the 40% of women who participated in some kind of physical activity demonstrated a reduced risk of preterm birth.[70] Another randomized controlled trial suggested that the effects of resistance training during pregnancy on previously sedentary, healthy women carrying singletons did not alter gestational age at delivery when compared with inactive controls.[71] Taken together, these results support the notion that healthy pregnant women, without contraindications to physical activity, are able to engage in these active behaviors without undue risk of preterm birth. Whether such activities confer a benefit in reducing the rate of preterm birth requires further study.

Maternal Physical Activity and Mode of Delivery

Although one prospective study of 800 pregnant women found that sedentary mothers were 4 times more likely to have a cesarean delivery compared with women who exercised regularly,[72] this finding has not been replicated in other investigations.[73,74] Further, light-moderate resistance training during the second and third trimesters had no effect on the rate of normal, instrumental, or cesarean delivery when compared with inactive controls.[75] Although the evidence is limited, maternal physical activity does not seem to impact mode of delivery.

Section 3: Impact of Physical Activity on Neonatal Outcomes

Physical Activity and Fetal Growth

Physical activity during pregnancy seems to be protective against birth weight extremes (i.e., SGA and LGA) and thus increases the likelihood of delivering an appropriate-for-gestational-age infant. Most studies have not shown a significant detrimental effect on birth weight with moderate amounts of exercise,[74,76–83] suggesting that regular physical activity is safe and does not compromise fetal growth. Furthermore, a recently published randomized controlled trial concluded that exercise training may attenuate adverse consequences of excess maternal body weight on infant birth size.[84] The optimization of infant birth weight in women who engage in regular physical activity is thought to occur as a result of an increased functional capacity of the placenta to appropriately deliver nutrients via an increase in placental surface area, improvements in blood flow, and an enhanced-perfusion balance.[13,22] Importantly, physical activity may prove most advantageous for overweight or obese pregnant women as a way to reduce their risk of delivering an LGA infant. Observational data from a large birth cohort demonstrated that routine engagement in exercise during pregnancy protects the developing infant from birth weight extremes (i.e., SGA or LGA).[85] Some studies have demonstrated a link between maternal physical activity and low birth weight.[73,86–88] In these studies, an important limitation was lack of controlling for dietary intake. Many of these classical studies have focused on lean, healthy active women,[13,89–91] and therefore results may not be generalizable to the other populations. Clapp noted an asymmetric reduction in birth weight of exercising mothers, a difference that was entirely accounted for by a reduction of neonatal fat mass with no changes in lean mass compared with the offspring of matched controls.[89]

Currently, there is a dearth of evidence from well-designed, appropriately powered randomized controlled trials to address the effects of maternal physical activity on fetal growth outcomes. The inconsistency of results from studies examining the effect of activity on infant birth weight likely arises from differences in the type, frequency, timing, and duration of the activity program imposed.[45] Further, lack of control for confounding variables, including maternal nutritional status (i.e., caloric intake during pregnancy), gestational age at birth, and socioeconomic status may contribute to the discrepancy in the literature.[8]

Physical Activity and Long-Term Child Health

Recent findings suggest that the downstream effects of maternal physical activity may trigger beneficial adaptations to environmental stressors, which may lead to health benefits later in life.[7,28,92,93] The intrauterine environment plays a critical role in downstream child health and as such, there is a need for strategies aimed at preventing childhood adiposity by managing maternal weight gain during pregnancy.

Human and animal studies have shown that babies born LGA are more likely to be overweight in childhood,[94] adolescence,[95] and adulthood.[96] In contrast, babies born SGA are more likely to have increased truncal adiposity, develop insulin resistance, type 2 diabetes mellitus, and early onset cardiovascular disease.[97] Thus, modifying risk factors and increasing physical activity, which have been suggested to optimize birth weight,[84,85] may improve downstream child health. It has been observed that maternal prepregnancy weight, high GWG, and GDM are all positively and independently associated with offspring weight.[98] Therefore, intrauterine nutrition, mediated by these factors, may play an important role in subsequent risk for obesity. Recently, Fraser et al[99] demonstrated that children of mothers who gained in excess of the GWG recommendations had elevated BMI, waist circumference, greater fat mass, blood pressure, and inflammatory markers in their circulation at age 9 when compared with offspring of mothers who met the recommendations. This preliminary evidence suggests that gaining within the current recommendations may confer health benefits later in life for the child. Overall, physical activity provides an accessible and affordable outlet by which the predisposing factors for the development of obesity may be modified during the course of pregnancy.

TABLE 3
Target heart rates for exercising overweight/obese pregnant women

Age (yr)	Zone (beats/min)
20–29	110–131
30–39	108–127

Adapted from *Obstet Gynecol Clin North Am*. 2009;36:301–316.[93]

Section 4: Recommendations for Physical Activity and Lifestyle in Pregnancy

An ideal physical activity program for pregnancy must ensure that recommendations are appropriate for the individuals' fitness level, stage of pregnancy, and degree of motivation while anticipating potential risks and identifying necessary pregnancy modifications. Promotion of individualized, activity-specific behaviors may discourage women from adopting excessively sedentary pursuits during pregnancy. Physical activity may also prevent or manage chronic conditions, such as hypertension, obesity, gestational diabetes, dyspnea, and preeclampsia.[20,61] Table 3 highlights exercise HR training zones for overweight and obese pregnant women who choose to incorporate physical activity into their lifestyle as a way to manage GWG and improve their overall health. Regular physical activity may help women meet GWG targets[53,100] and thus positively influence maternal-fetal outcomes.

The known benefits of physical activity on maternal-fetal health obligate healthcare practitioners to provide advice to women regarding best practices for these healthy behaviors throughout pregnancy. To assist in this endeavor, several clinical practice guidelines have been published. In North America, the Canadian Society for Exercise Physiology in partnership with the Society of Obstetricians and Gynaecologists of Canada,[14] and the American College of Obstetricians and Gynecologists[10] are key organizations who have developed an example of such guidelines that support participation in regular physical activity during uncomplicated pregnancies. Their respective position statements describe the contraindications that would preclude exercise participation as highlighted in Table 2. The guidelines also provide information on the type, frequency, intensity, and duration of routine exercises suitable for women and their developing baby. However, it is important for clinicians to individually assess and monitor each patient and review their history to avoid potentially limiting physical activity in otherwise healthy women who have previously presented with a contraindication to participation.

Table 4 provides a synopsis of recommendations for exercise in pregnancy. Of greatest importance before commencing physical activity during pregnancy is appropriate medical screening. An example of an appropriate useful screening tool is the "Physical Activity Readiness Medical Examine for Pregnancy" or the PARmed-X for Pregnancy.[101] This user-friendly tool was designed to be a guideline for health screening before participation in a prenatal fitness class or any other type of exercise or physical activity during pregnancy. The PARmed-X for Pregnancy, endorsed by the Canadian Society for Exercise Physiology, Society of Obstetricians and Gynaecologists of Canada, and the American College of Sports Medicine,[14] is readily available free of charge and is encouraged to be reproduced in clinical settings (http://www.csep.ca/cmfiles/publications/parq/parmed-xpreg.pdf).

Appropriate nutrition and regular physical activity are critical mediators of weight gain and weight maintenance at all ages and have been specifically identified as predictors of excessive GWG.[102] In fact, one of the strongest predictors of GWG is self-reported caloric intake, and although not the purpose of this review, one cannot discount the importance of caloric intake when discussing energy balance and weight management. However, the contributions of nutrition for a healthy pregnancy outcome are thoroughly reviewed elsewhere.[103,104]

The Institute of Medicine has recently published updated GWG guidelines based on prepregnancy BMI (Table 5) that decreased the upper limit of the

TABLE 4
Sample exercise prescription for pregnant women without contraindications

Program	Previously Sedentary	Active
Frequency*	3 d/wk	4 d/wk
Intensity†	Low-moderate	Moderate-vigorous
Duration	15 min gradually ↑ to 30 min sessions	≥30 min per session
Type‡	Low impact aerobics (swim, walk, cycle) Resistance/strength training	Low impact aerobics Resistance/strength training

Adapted from *Can J Appl Physiol*. 2003;28:330–341.[14]

*Brief warm-up and cool-down should be incorporated with each bout of activity.

†The "talk test" may also confirm that women are not over exerting.

‡Avoid exercise in the supine position after approximately 16 weeks' gestation.

TABLE 5
Target gestational weight gain for singleton pregnancies

Prepregnancy Body Mass Index (BMI)	Range (kg)	Range (lbs)
Underweight (<18.5 kg/m^2)	12.5–18	28–40
Normal weight (18.5–24.9 kg/m^2)	11.5–16	25–35
Overweight (25–29.9 kg/m^2)	7–11.5	15–25
Obese (≥30 kg/m^2)	5–9	11–20

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recommended GWG for obese women.[2] "Project Viva," a large prebirth longitudinal cohort found no increased risk of adverse birth outcomes when comparing adequate versus inadequate GWG in the subgroup of obese women, thereby supporting the revision.[105]

Although some interventions aimed at attenuating GWG have been unsuccessful in preventing women from exceeding the Institute of Medicine recommendations,[106,107] others have had success.[53,100] In a community-based randomized controlled trial during pregnancy, for example, home-based moderate intensity cycling exercise reduced offspring birth weight and growth promoting factors (i.e., insulin-like growth factor-1 and -2), without alterations in maternal insulin sensitivity.[92] These findings suggest that routine activity yields protective benefits in offspring of overweight women.

FUTURE DIRECTIONS

Our understanding of the influence of maternal physical activity on short- and long-term pregnancy outcomes is far from complete. Further, knowledge of the underlying mechanisms is limited. The physiologic processes driving substrate delivery from mother through placenta to fetus are not known. The extent to which energy is partitioned in utero in the presence of excessive prepregnancy weight, rapid and/or excessive GWG, and maternal exercise at the molecular level remains unclear. Recent advances in our understanding of developmental plasticity and epigenetics are shedding new light on critical molecular pathways, which may provide insight into novel therapeutic targets[108–110] that may in turn be modified with physical activity.

Historically, the major clinical focus has been protection from fetal undernutrition, yet in today's society, we must consider prevention strategies for women who have a high prepregnancy weight and are at increased risk for excessive GWG. Promotion of physical activity is one such strategy that must continue to be studied during pregnancy to determine the effects that maternal physical activity has on downstream child growth and development. There is considerable evidence to suggest that lifestyle interventions during pregnancy are safe and may provide both maternal and fetal benefits.

THE CASE REVISITED

Following discussion and prescreening using the PARmed-X for pregnancy, Susan was advised to engage in aerobic activity at low-to-moderate intensity 3 times per week. Given her previous sedentary lifestyle, she was encouraged to exercise for 15 minutes per session for 2 weeks and to increase the duration of activity to 30 minutes per session thereafter. Providing this regimen was well tolerated for 2 weeks, her plan was to increase the frequency of physical activity to 4 times per week. Options for physical activity were discussed, including outdoor walking programs, upright stationary cycling in her home, and/or water aerobics for mild resistance training. Modification of physical activity for pregnancy was reviewed, as were methods to assess intensity including the "talk test"—a surrogate marker of physical exertion. It was also suggested that a low-intensity warm-up and cooldown period be included in any type of physical activity. Maintenance of the exercise program in the postpartum period was strongly recommended to help offset the severity of weight retention.

KEY POINTS

- Exercise during pregnancy is safe for pregnant women and their babies in the absence of specific contraindications.
- Being physically active before becoming pregnant and continuing to exercise during pregnancy may help minimize the risk of developing GDM, preeclampsia, and abnormal fetal growth.
- Maternal physical activity may help limit GWG to the recommended targets.
- Emerging evidence suggests that the developing child has the ability to positively adapt to the physiological stress imposed by maternal physical activity and thereby may reduce their risk of excessive and restricted growth; an effect that may confer adaptive benefits for the child later in life.

This effect may be more beneficial to overweight or obese women who tend to have larger babies.

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