Exercise Guidelines in Pregnancy
New Perspectives

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Abstract

In 2002, the American College of Obstetricians and Gynecologists published exercise guidelines for pregnancy, which suggested that in the absence of medical or obstetric complications, 30 minutes or more of moderate exercise a day on most, if not all, days of the week is recommended for pregnant women. However, these guidelines did not define 'moderate intensity' or the specific amount of weekly caloric expenditure from physical activity required. Recent research has determined that increasing physical activity energy expenditure to a minimum of 16 metabolic equivalent task (MET) hours per week, or preferably 28 MET hours per week, and increasing exercise intensity to ≥60% of heart rate reserve during pregnancy, reduces the risk of gestational diabetes mellitus and perhaps hypertensive disorders of pregnancy (i.e. gestational hypertension and pre-eclampsia) compared with less vigorous exercise. To achieve the target expenditure of 28 MET hours per week, one could walk at 3.2 km per hour for 11.2 hours per week (2.5 METs, light intensity), or preferably exercise on a stationary bicycle for 4.7 hours per week (~6-7 METs, vigorous intensity). The more vigorous the exercise, the less total time of exercise is required per week, resulting in ≥60% reduction in total exercise time compared with light intensity exercise. Light muscle strengthening performed over the second and third trimester of pregnancy has minimal effects on a newborn infant's body size and overall health. On the basis of this and other information, updated recommendations for exercise in pregnancy are suggested.

1. Introduction

Regular aerobic exercise is an important component for the maintenance of overall health. Exercise is especially important in pregnancy, as women of childbearing age are at increased risk of gestational diabetes mellitus (GDM), which has been strongly linked with obesity.¹,² As more women tend to gain an excessive amount of weight during pregnancy, they also tend to retain the weight after delivery.³,⁴ Gaining an excessive amount of weight during pregnancy can result in obesity-associated co-morbidities, which are a major health concern in the US.⁵

In 2002, the American College of Obstetricians and Gynecologists (ACOG) published exercise guidelines for pregnancy.⁶ These suggested that in the absence of medical or obstetric complications, 30 minutes or more of moderate exercise a day on most, if not all, days of the week is recommended for pregnant women. These guidelines were based on the 1995 joint recommendations...
by the Centers of Disease Control and Prevention (CDC) and the American College of Sports Medicine (ACSM). However, these were general public health recommendations, with no clarity on the definition of ‘moderate intensity’ exercise or the recommended amount of weekly physical activity energy expenditure.

It has been 15 years since those initial CDC and ACSM recommendations were established, and 9 years since their adoption by ACOG. Since then, new science has emerged that has enhanced our understanding of the amount of physical activity expenditure per week required and the intensity of exercise needed to improve health outcome and quality of life. In 2007, updated physical activity recommendations were published by the ACSM and the American Heart Association (AHA). These included definitions of ‘moderate’ and ‘vigorous’ exercise, and provided recommendations for muscle strengthening activities (table I).

As such, we believe these updated 2007 recommendations should be used to establish new ACOG guidelines for pregnancy in the absence of medical or obstetric complications. Pregnancy is not a state of confinement, yet pregnant women spend less time performing vigorous exercise with less duration and frequency than non-pregnant women. Indeed, women who maintain their exercise regimen during pregnancy continue to exercise at a higher intensity than those who stop. Over time, these women gain less weight, deposit less fat, have increased fitness and have a lower cardiovascular risk profile in the perimenopausal period than women who cease to exercise in pregnancy.

Therefore, the purpose of this clinical opinion is 2-fold: (i) to provide evidence that increasing weekly physical activity expenditure while incorporating vigorous exercise provides the best health outcome for pregnant women and their infants; and (ii) to create new exercise guidelines for pregnancy that are relatively specific, and that incorporate the emerging research findings over the past decade.

### Table I. The American College of Sports Medicine (ACSM) and American Heart Association (AHA)'s physical activity recommendations for men and non-pregnant women

<table>
<thead>
<tr>
<th>Aerobic activity</th>
<th>Muscle strengthening activity</th>
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<tbody>
<tr>
<td>Adults aged 18–65 y perform a minimum of 30 min moderate intensity exercise for 5 d/wk or 20 min vigorous intensity exercise 3 d/wk</td>
<td>For adults aged 18–65 y, 8–12 repetitions each of 8–10 muscular strength exercises should be performed on 2 or more non-consecutive d/wk using the major muscle groups</td>
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<tr>
<td>For adults &gt;65 y, moderate intensity = 12–14 on the Borg RPE 6–20 point scale; vigorous intensity = 15–16 on the Borg RPE 6–20 point scale</td>
<td>For adults &gt;65 y, 10–15 repetitions each of 8–10 exercises on 2 or more non-consecutive d/wk using the major muscle groups with an effort level of 12–14 to 15–16 on the Borg RPE 6–20 point scale</td>
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</table>

a These are the 2007 updated ACSM and AHA recommendations from Haskell et al. and Nelson et al. Moderate intensity is now classified as activities that require 3–6 METs (10.5–21 mL/kg/min) and vigorous activity is classified as >6 METs (>21 mL/kg/min). Moderate intensity exercise can be walking at 4.8 km/h, 3.3 METs; walking briskly at 6.4 km/h (5 METs); washing a car, garage, sweeping floors or washing windows (3 METs); slow to fast ballroom dancing (3–4.5 METs); badminton (4.5 METs); or swimming leisurely (6 METs). Vigorous intensity can be walking at a very brisk pace at 7.2 km/h (6.3 METs); jogging at 8.0 km/h (8 METs); walking on a treadmill at 5.6 km/h (5% grade, 6.1 METs); swimming at a moderate/hard feeling of effort (8–11 METs). Moderate = 3–6 METs; vigorous >6 METs. METs = metabolic equivalent tasks; RPE = rating of perceived exertion.

#### 2. Increasing the Amount of Vigorous Intensity Exercise is an Important Goal for Pregnant Women, Especially Those Who are Overweight or Obese

Obese women have an increased risk of fetal, neonatal and maternal morbidity; therefore, prevention of excessive weight gain during pregnancy is important for the welfare of both mother and child. Regular physical activity

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1 Excessive weight gain during pregnancy is defined as ≥9.0 kg in overweight women (pre-pregnancy body mass index [BMI] = 25.0–29.9 kg/m²), or ≥5.9 kg in obese women (pre-pregnancy BMI ≥30 kg/m²). For pregnant women of normal pre-pregnancy bodyweight (BMI = 20.0–24.9 kg/m²), optimal weight gain during pregnancy is between 2.1 and 9.9 kg. For pregnant women whose pre-pregnancy BMI is <20 kg/m², optimal weight gain during pregnancy is 4.1–9.9 kg.© 2011 Adis Data Information BV. All rights reserved. Sports Med 2011; 41 (5)
performed before\textsuperscript{[1,25,27]} and during pregnancy\textsuperscript{[1]} has been shown to reduce the incidence of GDM, for example, by at least 30%, depending on the amount of weekly physical activity energy expenditure and intensity of exercise. Vigorous exercise is important to prevent weight gain in pregnancy and throughout life.\textsuperscript{[2]} Recent data demonstrate that skeletal muscle work efficiency changes dramatically when bodyweight is altered.\textsuperscript{[28]} With weight gain from lack of physical activity, efficiency of skeletal muscle decreases,\textsuperscript{[28]} which at the outset is fine as more calories are burned with heavier weight. However, weight gain from physical inactivity usually means an increase in fat mass, which, biochemically, has been found to decrease the body’s ability to gain future muscle due to the attenuation of anabolic processes;\textsuperscript{[29]} therefore, an obese individual has an impeded ability to gain muscle. With weight loss through physical activity, caloric expenditure decreases, not just because muscles have less weight to carry around, but due to a reduction in the ratio of glycolytic to oxidative enzymes in muscle without significant changes in enzymatic activity related to fatty acid oxidation.\textsuperscript{[28]} As such, with weight loss, significantly fewer calories are expended with physical activity,\textsuperscript{[28]} and an increase in weight will occur once again. A programme of vigorous intensity exercise may stop the yo-yo effect of the weight gain/weight loss cycle.\textsuperscript{[30]}

Non-oxidative type IIB muscle fibres (which minimally burn fat) are increased in obese women,\textsuperscript{[31,32]} and are directly related to body mass index (BMI). The larger the BMI, the more type IIB muscle fibres a woman possesses. In addition, the larger the BMI, the lower the percentage of type I oxidative (fat burning) fibres.\textsuperscript{[33]} Weight loss by itself\textsuperscript{[34]} or weight loss with physical activity\textsuperscript{[35,36]} can, but not always,\textsuperscript{[28]} improve muscle oxidative capacity in obese women with or without diabetes. If the muscle oxidative capacity is increased with physical activity, then the capacity to burn fat throughout the day is increased.

Vigorous intensity exercise that increases the energy expenditure post-exercise compared with low-intensity exercise,\textsuperscript{[37,38]} should limit weight gain in overweight and obese pregnant women. In fact, for a given energy expenditure, vigorous exercise programmes induce a greater loss of subcutaneous fat compared with a programme of moderate intensity.\textsuperscript{[39]} Thus, we propose that higher intensity exercise may be an alternative means to improve oxidative capacity and increase post-exercise oxygen consumption (VO\textsubscript{2}) so that body fat percentage is reduced to a greater extent compared with traditional low-intensity exercise, and weight gain is limited in overweight and obese pregnant women.

Considerable evidence supports the use of higher intensity exercise to reduce body fat percentage. Specifically, in overweight individuals, a 14-week exercise programme consisting of moderate-intensity exercise (60–70% aerobic capacity) was compared with an exercise programme of high-intensity exercise (75–90% aerobic capacity). Both groups exercised three times per week, and both expended the same amount of calories.\textsuperscript{[40]} The high-intensity group reduced their total body fat percentage from 27% to 22% (\(p<0.05\)), while the moderate-intensity group did not see a reduction.\textsuperscript{[40]} Another study demonstrated that moderate exercise intensity (40–55% of aerobic capacity) for 8 months did not reduce total fat mass (\(-2 \pm 3 \text{ kg}\)) to the same extent as vigorous exercise (65–80% of aerobic capacity,\( \sim -5 \pm 3 \text{ kg}\)), even when controlled for the same weekly distance and the same total training time.\textsuperscript{[41]} This has been shown elsewhere,\textsuperscript{[42]} although, the exercise bouts were not isocaloric.

Another compelling reason why pregnant women should perform vigorous exercise as tolerated, is that the duration of labour is inversely associated with aerobic capacity after adjusting for birthweight (\(p=0.03\)).\textsuperscript{[43]} Kardel and colleagues\textsuperscript{[43]} investigated the effect of aerobic capacity on duration of labour in 40 nulliparous women (aged 30 ± 4 years)

\begin{itemize}
\item Vigorous exercise is defined by the ACSM as an oxygen consumption (VO\textsubscript{2}) of >21 mLO\textsubscript{2}/kg/min, which is taken to be >6-fold greater than the resting metabolic rate (>6 METs). However, this article shows that some pregnant women are not able to exercise at that VO\textsubscript{2}. Therefore, the definition of vigorous exercise should be defined as ≥60% of heart rate reserve (HRR) [preferably] or ≥65% of VO\textsubscript{2} reserve (VO\textsubscript{2R}).
\end{itemize}
who started labour spontaneously. Aerobic capacity was measured in these women (bodyweight = 77±9 kg) at 35–37 weeks of gestation. Duration of labour was defined as the time between 3 cm cervical dilation with regular uterine contractions and delivery. The mean aerobic capacity was 2.1 ± 0.3 LO2/min and duration of labour 583 ± 317 minutes. The potential determinants of the duration of labour, identified by a Pearson correlation were tested in a multivariate model. They concluded that increased aerobic fitness was associated with shorter labour in nulliparous women who started labour spontaneously. Other earlier research confirms Kardel’s study. Clapp[44] found that his well trained groups who exercised during pregnancy had a significant shorter first stage of labour by 118 minutes than a group who had stopped exercising before the end of the first trimester. Beckmann and Beckmann[45] found that nulliparous women who exercised regularly before becoming pregnant also had a significantly shorter labour (first and second stages) by ~8 hours in total compared with a non-exercising control group.

The minimal threshold for independent living requires an aerobic capacity of approximately 15 (women) to 18 (men) mLO2/kg/min,[46,47] which is four to five metabolic equivalent tasks (METs) [a value of one MET = resting VO2, or ~3.5 mLO2/kg/min]. Thankfully, only about 1% of women of childbearing age are at or below this minimum threshold.[48] Normal weight pregnant women in the second and third trimester (pre-pregnancy BMI = 23 kg/m²) have an aerobic capacity that ranges from 1.4 to 2.6 LO2/min, which equals about 27–39 mLO2/kg/min.[49-53] Unfit, overweight (pre-pregnancy BMI = 25.0 to 29.9 kg/m²) or obese pregnant women (pre-pregnancy BMI ≥30 kg/m²) who are unaccustomed to exercise have a low aerobic capacity relative to bodyweight (18–22 mLO2/kg/min).[50,54] Endurance-trained pregnant athletes have an aerobic capacity reported to be around 50 mLO2/kg/min.[55,56] Aerobic capacity in LO2/min remains quite stable between the second and third trimester; however, the aerobic capacity measured in mLO2/kg/min may decrease by 10% by the third trimester due to maternal weight gain.[52]

One way to incorporate vigorous exercise is the use of interval training, which incorporates brief intense bouts of exercise (>80% of VO2 reserve [VO2R]) with periods of rest. This has been found to be time efficient while improving oxidative capacity in skeletal muscle to the same extent as traditional low-intensity continuous exercise.[57,58] Interval training has been shown to be safe and more effective in improving peak VO2 and left ventricular function in patients with coronary artery disease than the traditional method of continuous moderate exercise.[59-61] In 75-year-old subjects, which included overweight women with stable post-infarction heart failure, 12 weeks of interval training increased aerobic capacity by 46%, several heart function parameters by 20–30% and improved their quality of life.[61] These changes were significantly greater compared with 12 weeks of regular continuous training.[61]

A major consideration is that if elderly overweight women with heart failure and/or coronary artery disease can successfully perform interval training, then this type of research should be implemented in pregnancy to establish the extent to which type of exercise periodic intense exercise is feasible, safe and results in appropriate exercise adherence. Interval training during pregnancy is an exciting new possibility. However, until further studies are performed, it is our opinion that pregnant women should build up to continuous, steady-state aerobic exercise of about ≥65% of aerobic capacity (vigorou exercise), which is ~60% of heart rate reserve (HRR) or ~70–75% of maximum heart rate (HRmax).[62] This recommendation is within the range of the recommendations from the Society of Obstetricians and Gynecologists of Canada (SOGC)/Canadian Society for Exercise Physiology.[63]

3. Increasing Weekly Physical Activity Energy Expenditure is an Important Goal for Pregnant Women

Increasing weekly physical activity energy expenditure has been found to reduce the incidence of the metabolic syndrome,[64] GDM[23] and systemic inflammation,[65] while delaying ageing[66] and disability.[67] The risks of coronary heart
disease and cardiovascular disease also decrease linearly in association with increasing physical activity energy expenditure.\cite{68} Johnson and colleagues\cite{64} studied the effects of three different 6-month exercise programmes on components of the metabolic syndrome: low amount/moderate intensity (equivalent to jogging 19 km/wk at 40–55% of aerobic capacity), low amount/high intensity (equivalent to jogging 19 km/wk at 65–80% of aerobic capacity) or high amount/vigorous intensity (equivalent to jogging 32 km/wk at 65–80% aerobic capacity). These investigators showed that the high-amount/vigorous-intensity group had improvement in the highest number of metabolic variables, compared with the other two groups and a control group.\cite{64} This makes sense because insulin resistance is negatively related to caloric expenditure from a single bout of exercise (figure 1). From this study, the dose-response of energy expenditure in reducing the risk factors for metabolic syndrome were uncovered.\cite{64}

Reduced risk of GDM and pre-eclampsia is seen when women exercise between 3 months and 1 year before or during pregnancy.\cite{1,25,27,70,71} During pregnancy, exercise programmes lasting at least several weeks\cite{72} is the best way to reduce the fasting blood glucose level and to blunt the glycaemic response following a meal, whereas, single bouts of exercise provided the fewest benefits.\cite{73,74} Zhang and co-workers\cite{25} conducted a prospective cohort study to assess whether the amount, type and intensity of pregravid physical activity are associated with GDM risk. The relative risks (RRs) of GDM decreased with total pregravid weekly physical activity (figure 2), such that 16 MET hours per week showed a 17% reduction in GDM risk, and 56 MET hours per week showed a ~30% reduction in GDM risk, compared with subjects who did not exercise. If the amount of pregravid weekly vigorous physical activity (figure 2) increased (vigorous exercise intensity ≥6 METs or ≥21 mLO₂/kg/min), the RR for GDM also decreased by 20% and 25% if 6 and 15 MET hours per week of vigorous physical activity is performed, respectively. Rudra et al.\cite{27} demonstrated that those who exercised strenuously up to maximal exertion using the Borg rating of perceived exertion (RPE) scale in the year before pregnancy, showed a 43% decrease in the risk for GDM. Also, those that performed ≥30 MET hours per week of energy expenditure from physical activity in the year before pregnancy had a 50% decrease in the risk of GDM, compared with only a 34% decrease in GDM if the exercise expenditure was <14.9 MET hours per week.\cite{27} Dempsey et al.\cite{1}

![Fig. 1. Exercise-induced changes in (a) homeostasis model assessment of insulin resistance as a function of total energy expenditure during exercise; and (b) subjects who expended <900 or >900 (kcal) during the exercise bout. The data demonstrate that whole body insulin sensitivity from a single bout of exercise is improved only when the total energy expenditure is >900 kcal per session. Reproduced from Magkos et al.\cite{69} with permission from Portland Press Ltd. * p<0.05 compared with resting state.](image_url)
demonstrated that pregravid women who exercised ≥21.1 MET hours per week during the year before pregnancy reduced GDM risk by 74%, while women who were pregnant and expended ≥28 MET hours per week per week during pregnancy reduced GDM risk by 33% (figure 3). However, due to the large confidence intervals for the reduction in RR for GDM during pregnancy in the group that exercised ≥28 MET hours per week compared with no exercise (RR = 0.67; 95% CI 0.31, 1.43), statistical significance was not reached. Nonetheless, this does not negate the findings of how exercise during pregnancy can reduce GDM risk. Therefore, it is our opinion that there is a potential benefit for the adoption and continuation of an active lifestyle for women of reproductive age that is of vigorous intensity prior to and during pregnancy.

To obtain energy expenditure in MET hours per week, one multiplies the number of METs required for the activity by the number of hours per day multiplied by the total number of days per week performing the activity. For example, 5 METs × 0.95 hours per day × 6 days per week = 28.5 MET hours per week. Second, to convert MET hours per week into kcal/wk of energy expenditure, one multiplies 28.5 MET hours per week by the resting metabolic rate of 3.5 mLO$_2$/kg/min and by 60 min/h to get 5985 mLO$_2$/kg/wk. Now, the bodyweight is needed. For this example, the bodyweight of an individual is 58.7 kg, therefore, 5985 mLO$_2$/kg/wk × 58.7 kg = 351319.5 mLO$_2$/wk or 351.2 L0$_2$/wk consumed in total for physical activity. Since 5 kcal are yielded for every L of oxygen consumed, then 351.2 L0$_2$/wk × 5 kcal/L = 1756.6 kcal/wk.

The more vigorous the exercise, the less total time of exercise is required. For example, one can exercise 3 METs × 1.6 hours per day × 6 days per week = 28.8 MET hours per week; or one can exercise for less time at a higher intensity to achieve the same expenditure (e.g. 5 METs × 0.95 hours per day × 6 days per week = 28.5 MET hours per week). For a 54 kg woman, 28.5 MET hours per week × 5 kcal/L × 58.7 kg = 351319.5 mLO$_2$/wk × 5 kcal/L = 1756.6 kcal/wk.

Fig. 2. Relative risks (RRs) of gestational diabetes mellitus (GDM) according to total physical activity (solid line) and vigorous activity (dotted line) measured in metabolic equivalent task (MET) hours per week, continuous, prior to pregnancy. RRs are adjusted for age, race/ethnicity, cigarette smoking status (never, past or current), family history of diabetes in a first-degree relative (yes, no), parity (0, 1, 2, ≥3), alcohol intake (0.0, 0.1–5.0, 5.1–15.0 or >15.0 g/day), dietary factors (in quintiles of total energy, cereal fibre, glycaemic load and total fat) and body mass index before the pregnancy. The error bars illustrate the approximate 95% CI [28].
Updated Exercise Guidelines in Pregnancy

4. Potential Risks of Exercise in Pregnancy

4.1 Cardiac Risks of Exercise

With regard to the frequency with which myocardial infarction is triggered by exertion, it is important to distinguish absolute from RR. The absolute risk of a 50-year-old non-smoking, non-diabetic individual having a myocardial infarction during a given 1-hour period, is approximately 1 in 1 million (0.0001%). If an individual is habitually sedentary, but engaged in heavy physical exertion (>6 METs) during that hour, the risk would increase 100-fold over the baseline value, but the absolute risk during that hour still would be only 1 in 10 000 (0.01%). The research has shown that a single episode of vigorous physical exertion can increase the short-term risk of myocardial infarction. The paradox, however, is that increased frequencies of vigorous exercise at >6 METs is associated with a reduction in the long-term risk of coronary events. Individuals who exercise regularly not only have a lower baseline risk of myocardial infarction, they also have a lower RR that an infarction will be triggered by heavy physical exertion. There is no reason to suggest that the maternal cardiac risk of exercise would be different during pregnancy.

The number of sudden cardiac arrests or other cardiac events in the general population is one event per 565 000 hours of exercise. For individuals with known heart disease, it is one event per 59 142 hours. The absolute risk of sudden death during any episode of vigorous exercise equals about one death per 1.51 million episodes of exertion. Thus, the risk of exercise in triggering cardiac events is very small. Compare the risk of triggering sudden cardiac events (which is about 0.01%) with the CDCs death rate for accidental deaths (unintentional injuries), which is about 0.04%. As such, the risk of death from unintentional injuries in the US is higher than the risk of triggering cardiac events from exercise; therefore, the risks must be placed in perspective to a real-world context. The US death rate of all causes (accidents, homicides, suicides, diseases, cancer, infection, dying of old age, etc.) is about 0.8%, so when compared with the risk of exercise, these other issues provide more risk to human health than a vigorous exercise session in sedentary pregnant women.

4.2 Risk of Regular Exercise Training Resulting in Small for Gestational Age Infants and Increased Risk of Preterm Birth

Small for gestational age (SGA), which is a birthweight that is in the 10th percentile or below for the gestational age of the infant, is usually a consequence of compromised intrauterine development, and is considered a risk of perinatal morbidity and mortality. Regardless of whether a woman is sedentary or an endurance athlete, exercise during the first two trimesters has not been shown to affect birthweight. However, female endurance athletes who exercise vigorously (>6 x per week, >1 hour per session for 10 weeks, >50% of age predicted HR max) into the third trimester, produce infants that are on average 212 g (95% CI 149, 276) smaller than active...
controls (≥3× per week, 30 minutes per session for 10 weeks, >50% of age-predicted HR_{max}), and 437 g (95% CI 268, 606) smaller than sedentary controls. Nonetheless, a 200–400 g decrease in mean birthweight is not clinically meaningful for two reasons. First, this difference in weight is less than the 500 g difference between the 50th percentile and 10th percentile in recent published tables. Second, SGA is an anthropometric characteristic that does not necessarily have adverse health implications, and is therefore commonly used (but not necessarily appropriately) as a proxy for the pathological outcomes believed to be associated with an inadequate rate of fetal growth (i.e. the majority of SGA births are small for no demonstrative reason; an aetiology is not found in >50% of cases of SGA). Third, more recent data published in 2010 with a larger sample size suggests no real clinically meaningful difference in birthweight of infants born to women who exercise during pregnancy for >5 hours per week compared with pregnant women who do not exercise. In this study of ~80 000 infants, it was found that women who exercised during pregnancy had a decreased risk of having a SGA child or a large for gestational age child (birthweight greater than the 90th percentile for gestational age). These data suggest that women who exercise >5 hours per week have smaller infants by only 11 g than those of non-exercisers; therefore, differences may not be clinically meaningful.

As a corollary, SGA-identified fetuses may not tolerate the mild diversion of cardiac output from the uterus to the skeletal muscles during exercise. Therefore, there is a slight chance of post-exercise bradycardia. This has occurred previously in a subsequently diagnosed growth-restricted fetus. While there are many SGA fetuses who are not growth restricted, the clinician does not know which is which until after birth. As such, caution is advised against exercise in the growth-restricted fetus.

In terms of preterm births, exercise during pregnancy actually reduces the risk of complications. Using data of over 85 000 births, >5 hours a week of exercise during pregnancy reduced the risk of preterm birth by 18% (RR 0.81; 95% CI 0.64, 1.04). When calculating energy expenditure, pregnant women who exercised 10–15 MET hours per week (715–1071 kcal/wk for a 68 kg woman) experienced a 17% reduction in the risk of preterm births (RR 0.83; 95% CI 0.71, 0.96), and those who exercise for more than 15 MET hours per week (>1071 kcal/wk for a 68 kg woman) experienced a 12% reduction (RR 0.88; 95% CI 0.78, 1.00) in preterm births.

4.3 Risks of Exercise Resulting in an Abnormal Fetal Heart Rate (HR) Response

A misconception about exercise in pregnancy is that fetal health may be compromised because uterine blood flow can decrease progressively with exercise intensity and duration (by up to ~20%). However, several compensatory mechanisms act to preserve fetal VO_{2} even during exhaustive exercise. In sheep, the increased haemoglobin concentration from pregnancy maintains total oxygen delivery to the uterus and, with increased uterine oxygen extraction, VO_{2} remains unaltered. In humans, the measurement of fetal umbilical and maternal uterine pulsatility index (PI), which is the best non-invasive technique to assess changes in resistance to blood flow in those areas, was assessed in pregnant women (third trimester) immediately after strenuous exercise above the anaerobic threshold. Compared with rest, there were modest changes in the right uterine PI without changes in umbilical artery PI or left uterine PI in pregnant women 2 minutes post-exercise. However, by 5 minutes post-exercise, right uterine PI returned to baseline values. Therefore, sheep and human data imply that limited strenuous exercise above the anaerobic threshold has minimal effects on total uterine and umbilical oxygen delivery and VO_{2}.

Fetal heart rate (FHR) monitoring has been widely used to monitor fetal well-being before and after exercise. The earlier studies demonstrating fetal bradycardia (FHR <110 beats/minute for 10 seconds) during exercise have been dismissed as representing motion artifact. FHR is increased by about 20 beats/minute within 30 seconds of strenuous exercise stoppage. By 10 minutes post-exercise, FHR is 0–10 beats/minute.
higher, compared with pre-exercise after a bicycle test to maximal or near maximal exertion.\cite{87,98,99} This suggests that brief intense exercise does not cause fetal distress. Furthermore, regular exercise training does not alter the fetal response.\cite{100} More recently, researchers have demonstrated that FHR response to strenuous maternal exercise is not a predictor of fetal distress since the incidence did not vary with the level of fitness, maternal BMI or fetal weight.\cite{98}

### 5. Developing New Exercise Guidelines in Pregnancy

In 2003, the SOGC published guidelines that were somewhat more specific than the ACOG guidelines. The SOGC suggested that pregnant women should perform 15 minutes of continuous aerobic exercise 3 days per week, with progression to 30 minutes sessions four times per week in previously sedentary women.\cite{63} For most pregnant women, the intensity of exercise is recommended to be 12–14 (out of 20) on the Borg RPE scale.\cite{63} RPE is the perceived, subjective, overall effort of exertion and fatigue from 6 (no exertion) to 20 (maximal exertion). A rating of 6 = no exertion at all, 7–8 = extremely light, 9–10 = very light, 11–12 = light, 13–14 = somewhat hard, 15–16 = hard, 17–18 = very hard, 19 = extremely hard and 20 = maximal exertion. This scale scores the total, overall exertion and fatigue level of exercise. The more exertion, the less total time of exercise is required to reach the recommended weekly physical activity expenditure goal.

Basal resting heart rate (HR) is increased by 10–15 beats/minute in pregnancy.\cite{101,102,103} In turn, HR\textsubscript{max} is blunted by 10–15 beats/minute, compared with the predicted HR\textsubscript{max} of 220 minus age\textsuperscript{50,54,103} (although not always\textsuperscript{102}), the HRR is lowered. Thus, the target HR zones are modified in the SOCG guidelines. For example, the target HR zone for a non-obese pregnant woman 20–29 years of age is 135–150 beats per minute, 130–145 for a woman 30–39 years-of-age and 125–140 for a woman ≥40 years of age.\cite{63} This equates to 71–79% of predicted HR\textsubscript{max} for the 20–39 years-of-age group combined. Nonetheless, developing an HR zone generalizable to pregnant populations may not be appropriate because of the individual variation of resting HR, and the large standard deviation of predicting HR\textsubscript{max} from age (HR\textsubscript{max} = 220 minus age), which is ±10–12 beats/minute.\cite{104}

To identify the optimal HR for a given intensity in a given individual, the HRR method was developed by Karvonen.\cite{105} The HRR method essentially uses the difference between HR\textsubscript{max} and resting HR (in which both should be measured directly and not predicted). The ‘reserve’ available is the difference between measured HR\textsubscript{max} and measured resting HR. Then, a given intensity is provided, and the correct exercise prescription HR can be determined from the following formula:

\[
\text{Prescription HR} = \%\text{intensity} \times (\text{HR}_{\text{max}} \text{that is measured from an aerobic capacity test} - \text{resting HR obtained from 5 minutes of sitting upright on a chair}) + \text{resting HR}.
\]

HR zones are published for pregnant overweight or obese women.\cite{54} However, since the minimum intensity for improving aerobic fitness was updated in 2002,\cite{106} the HR zones provided for sedentary, overweight and pregnant women begin at an exercise intensity of 101 beats/minute, which is too low.\cite{54} According to Swain and Franklin,\cite{106} those individuals classified as having low initial fitness (VO\textsubscript{2max} < 40 mL/kg/min), based on a graded exercise test to maximum, will show improvements in aerobic capacity only if the training intensity is ≥30% VO\textsubscript{2R}.\textsuperscript{3} For those with higher aerobic capacities (VO\textsubscript{2max} > 40 mL/kg/min), the minimal training intensity has to be ≥45% VO\textsubscript{2R}.\textsuperscript{106} The percentage of HRR (%HRR) is equal to the percentage of VO\textsubscript{2R} (%VO\textsubscript{2R}) unless the woman is overweight, sedentary and pregnant. In overweight, sedentary pregnant women, %VO\textsubscript{2R} is slightly higher by about 5% compared with %HRR, until 70% VO\textsubscript{2R} after which %VO\textsubscript{2R} and %HRR are about equal.\cite{54}

Prescribing exercise intensity based on %HRR provides the most accurate training prescription, especially when the patient’s resting and HR\textsubscript{max} is

\[
\text{Prescription VO}_2 = \%\text{intensity} \times (\text{VO}_{2\text{max}} - \text{resting VO}_2) + \text{resting VO}_2.
\]
Table II. Updated aerobic exercise recommendations during pregnancya

<table>
<thead>
<tr>
<th>Gestational age (wk)</th>
<th>%HRR</th>
<th>%( \text{VO}^{\text{2R}} )</th>
<th>RPE</th>
<th>Total target exercise energy expenditure (MET h/wk)</th>
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<td>Previously sedentary and/or overweight/obese pregnant women unaccustomed to exercisea</td>
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<td>45</td>
<td>50</td>
<td>13–14</td>
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<tr>
<td>Previously healthy and/or physically active pregnant womena</td>
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<td>27–40</td>
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<td>55</td>
<td>14–15</td>
<td>16</td>
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</table>

a See table III for the estimated converted total amount of energy expenditure from physical activity in kcal/wk. The Borg RPE scale is from 6 (no exertion) to 20 (maximal exertion). Some of the suggested programme shown in this table for exercise intensity is based on the American College of Sports Medicine and elsewhere. The target goal for the amount of physical activity per wk expended during pregnancy is based on the study by Dempsey et al. which shows a 33% risk reduction in GDM in women who exercise ≥28 MET h/wk during pregnancy. The complications are listed in table V. These recommendations are for individuals without medical and obstetrical complications.

GDM = gestational diabetes mellitus; MET = metabolic equivalent task; RPE = rating of perceived exertion; %HRR = percentage of heart rate reserve; %\( \text{VO}^{\text{2R}} \) = oxygen consumption reserve.

known (table II). The actual target HRs, which have been listed elsewhere, are not provided in table II because each pregnant woman will have a different resting and HR\(_{\text{max}}\). Let us consider an exercise HR for a sedentary overweight pregnant woman with GDM. At the beginning of the programme, the intensity would be ~35–39% HRR. If her resting HR is 90 beats/min (after sitting upright in a chair for 5 minutes), and measured HR\(_{\text{max}}\) (measured from a graded exercise test to volitional exhaustion) [\( \text{VO}^{\text{2max}} \) test] is 185 beats/minute, then 39% HRR = 0.39 • (185–90) + 90 = 127 beats/minute. A HR of 127 beats/minute would be her prescription HR.

Pregnant women can monitor their HR during pregnancy using a simple HR monitor (e.g. Polar FS1), which is relatively inexpensive. For those women who are not willing or able to purchase one, then pulse rates can be monitored from their wrists at intervals or the Borg RPE scale can be used (see table II). An additional consideration is that the definition of moderate intensity classified as physical activity requiring 3–6 METs (10.5–21 mLO2/kg/min), and vigorous activity classified as ≥6 METs (>21 mLO2/kg/min) is circumspect, because the definition of moderate and vigorous should be based on each individual’s own aerobic capacity. For example, some pregnant women have an aerobic capacity that approaches 46 mLO2/kg/min, which is 13 METs or 13-fold greater than the resting metabolic rate. An activity level of 7 METs would be moderate rather than vigorous intensity for them, as they would only be exercising at ~53% of \( \text{VO}^{\text{2max}} \). On the other hand, an unfit, sedentary, overweight pregnant woman may have an aerobic capacity of only 21 mLO2/kg/min or 6 METs. An activity level of 6 METs would not be moderate for her, as she would be exercising at 100% of \( \text{VO}^{\text{2max}} \). Therefore, the terms ‘moderate’ and ‘vigorous’ are relative, depending on the fitness level of the pregnant woman. That is why exercise intensity based on %HRR and the Borg RPE scale are the best ways to prescribe exercise intensity in all individuals, including pregnant women with GDM, and for those who are sedentary or overweight.

Given that obstetricians and gynecologists may wish to simplify exercise prescription by eliminating the use of HRR and its calculations,
we understand the practicality of using the Borg RPE scale for exercise intensity, so we have added the scale in table II. Based on the woman's weight prior to pregnancy, the amount of weekly physical activity energy expenditure in kcal/week during pregnancy is provided in table III. However, we also recognize that calculating the energy expenditure from exercise in a pregnant woman in kcal/week may not be user friendly for the patient or physician, so an estimated total time of exercise is also reported in table III (see footnotes). Muscle strengthening guidelines are reported in table IV for women who wish to supplement their aerobic exercise training periodically.

Several physical activity questionnaires are suitable for obtaining an estimate of weekly energy expenditure during pregnancy. We suggest the use of a questionnaire that estimates previous energy expenditure, such as the 7-day physical activity recall,[107-109] the Kaiser Physical Activity Survey in Women[111,112] or the Pregnancy Physical Activity Questionnaire.[113] These questionnaires can be completed in a structured 15-20-minute interview. Nonetheless, for simplicity, we provide an estimated number of hours of physical activity needed per week based on two different modes of exercise that would allow a pregnant woman to achieve the target energy expenditure (this is listed in table III in the footnotes).

### 5.1 Exercise Testing to Determine Maximum HR (Peak HR and Aerobic Capacity)

Individualizing an exercise programme for pregnant women involves medical screening with the use of a physical activity readiness questionnaire for pregnancy,[114] an estimation of previous physical activity level and developing a programme specific to the woman's situation. Informing the patient about limitations, contraindications and warning signs should also be performed (table V).[6] On the basis of numerous studies, exercise testing to maximum exercise capacity in pregnant women is safe for both the mother and the fetus.[43,87,92,98,99,103,115,116] Therefore, before an exercise programme is given to a woman, a graded exercise test using a cycle ergometer or treadmill would be an ideal scenario to obtain

<table>
<thead>
<tr>
<th>Weight of woman at the start of pregnancy (kg)</th>
<th>Minimum energy expenditure of 16 MET h/wk</th>
<th>Target energy expenditure of 28 MET h/wk</th>
</tr>
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<tbody>
<tr>
<td>45.2</td>
<td>759</td>
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<td>49.7</td>
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</table>

a For every 4.5 kg increase in bodyweight, the weekly energy expenditure increases by about 76 kcal for the minimum required 16 MET h/wk category and 133 kcal/wk for the target 28 MET h/wk category. The minimum and target energy expenditure is based on recent data by Dempsey et al.[1] and Zhang et al.[10] To estimate the total weekly physical activity energy expenditure from vigorous exercise, a questionnaire such as the 7-day physical activity recall can be used.[107-109] However, for simplicity, the required number of h/wk of exercise is estimated here. This is based on two different modes of physical activity. As one can see, the more vigorous the exercise, the less total time of exercise is required per wk.

b Light = approximately 6.4 h/wk walking (2.0 mph, 2.5 METs); vigorous = approximately 2.7 h/wk bicycling on a stationary bike (6-7 METs).

c Light = approximately 11.2 h/wk walking (2.0 mph, 2.5 METs); vigorous = approximately 4.7 h/wk bicycling on a stationary bike (6-7 METs).

MET(s) = metabolic equivalent task(s); mph = miles per hour.
Table IV. Muscle strengthening exercise guidelines during pregnancy

For pregnant women aged 18-45 y, 8-10 muscular strength exercises can be performed over one to two sessions per wk (non-consecutive days). One aerobic training session can be replaced by a muscle strengthening session in the weight room or at home.

**Use lighter weights, more reps**

Heavy weights may overload joints already loosened by increased levels of the hormone relaxin during pregnancy. Thus, perhaps it would be wise to use lighter weights and do more repetitions instead. For example, if one usually performs leg presses with 15.8 kg for 8-12 reps, try 9.0 kg for 15-20 reps. Or, if one typically performs a chest press with 6.8 kg for 8-12 reps, try 3.6 kg for 15-20 reps.

**Avoid walking lunges**

These may raise the risk of injury to connective tissue in the pelvic area.

**Watch the free weights**

One should be careful with free weights as free weights may involve the risk of hitting the abdomen. Women can use resistance bands instead, which offer different amounts of resistance and varied ways to do weight training and should pose minimal risk to the stomach.

**Try not to lift while flat on your back.**

In the second and third trimester, lying on your back may cause the uterus to compress a major vein, the inferior vena cava into which blood from the pregnant uterus flows. This increased pressure can be transmitted to the placenta, to compromise fetal blood flow in the gas exchange area, thereby limiting oxygen supply to the infant. An easy modification is to tilt the bench to an incline.

**Try to avoid the valsalva manoeuver**

This manoeuver, which involves forcefully exhaling without actually releasing air, can result in a rapid increase in blood pressure and intra-abdominal pressure, and may decrease oxygen flow to the fetus. However, on rare occasions, the uterus can be displaced against the inferior vena cava, which can result in a decrease in blood pressure. Thus, a decrease in blood pressure can also occur with the valsalva manoeuver, but this is uncommon.

**Listen to your body**

The most important rule is to pay attention to what is going on physically. If you feel muscle strain or excessive fatigue, modify the moves and/or reduce the frequency of the workouts. Pregnancy is not the time to perform heavy weightlifting but muscle strengthening according to these guidelines will burn calories and increase the resting metabolic rate.

**HR\text{max} and current fitness.** However, access to this type of testing is limited by the number of exercise physiologists, adequate equipment and/or patient finances; as a result, exercise testing is impractical for a majority of pregnant women. As such, HR\text{max} can be estimated by the formula 220 minus age; subsequently, the programme outlined in table II using %HRR would be appropriate. Should HR not be measured or recorded during exercise, the Borg RPE scale could be a substitute for determining exercise intensity.

Exercises that stimulate large muscle groups such as stationary cycling, swimming, walking or jogging are recommended. A standard stationary bicycle can substitute for one that is recumbent. A pregnant woman who has just finished exercise should be aware of uterine contractions. Women should be informed that stimulation of the uterus (i.e. as it moves inside the body from exercise) will cause contractions or tightening. Women should seek medical advice when these contractions become increasingly painful and do not dissipate within a reasonable time frame after exercise.

When monitoring fetal movements pre-, during or post-exercise, the National Institute for Health and Clinical Excellence recommends that health professionals should no longer suggest the routine counting of fetal movements in the second half of a woman’s pregnancy. Nevertheless, pregnant women should continue to be aware of fetal movements throughout the day. Less than ten fetal movements in 12 hours is an indication that further investigation at a hospital is warranted.

**6. Conclusions**

The updated 2007 ACSM and AHA recommendations are used to help establish new guidelines for pregnancy, in the absence of medical or obstetric complications. These recommendations are based on recent findings that suggest increasing the amount of physical activity expenditure to at least 16 MET hours per week. To achieve the minimum expenditure of 16 MET hours per week, one could walk at 3.2 km per hour for 6.4 hours per week (2.5 METS, light intensity), or preferably exercise on a stationary bicycle for 2.7 hours per week (6.0-7.0 METS, more vigorous intensity). Incorporating vigorous exercise at about 60% HRR, obtained from the pregnant woman’s own resting and HR\text{max} will provide the best health outcome. Use of these new aerobic exercise and muscle strengthening guidelines for pregnancy (tables II, III, IV), which...
Table V. Absolute and relative contraindications to aerobic exercise during pregnancy as well as warning signs to terminate exercise while pregnant (reproduced from the ACOG Committee opinion,[6] with permission from the American College of Obstetricians and Gynecologists)

**Absolute contraindications**
- Haemodynamically significant heart disease
- Restrictive lung disease
- Incompetent cervix/cervical incompetence
- Multiple gestation at risk for premature labour
- Persistent second or third trimester bleeding
- Placenta previa after 26-wk gestation
- Premature labour during the current pregnancy
- Ruptured membranes
- Pre-eclampsia/pregnancy-induced hypertension

**Relative contraindications**
- Severe anaemia
- Unlevated maternal cardiac arrhythmia
- Chronic bronchitis
- Poorly controlled type 1 diabetes mellitus
- Extreme morbid obesity
- Extremely underweight (body mass index <12)
- History of extremely sedentary lifestyle
- Intrauterine growth restriction in current pregnancy
- Poorly controlled hypertension
- Orthopaedic limitations
- Poorly controlled seizure disorder
- Poorly controlled hyperthyroidism
- Heavy smoker

**Warning signs to terminate exercise while pregnant**
- Vaginal bleeding
- Dyspnoea prior to exertion
- Dizziness
- Headache
- Chest pain
- Muscle weakness
- Calf pain or swelling (need to rule out thrombophlebitis)
- Preterm labour
- Decreased fetal movement
- Amniotic fluid leakage

are specific, safe for both mother and fetus and which incorporate the emerging research findings over the last decade, may result in a cohort of pregnant women with increased fitness and health, and infants with an enlarged prospect for a healthy and productive life.

**Acknowledgements**

Gerald S. Zavorsky, PhD, holds a Certified Strength and Conditioning Specialist® credential from the National Strength and Conditioning Association™ and a Certified Exercise Physiologist® credential from the Canadian Society for Exercise Physiology. Lawrence D. Longo is an obstetrician-gynecologist with extensive expertise in exercise and pregnancy in both animal and human models.

No sources of funding were used to assist in the preparation of the article. The authors have no conflicts of interests to declare that are directly relevant to the content of this article.

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