

Exercise in Pregnancy



Vanessa H. Gregg, MD*, James E. Ferguson II, MD, MBA

KEYWORDS

• Exercise • Pregnancy • Maternal outcomes • Fetal outcomes

KEY POINTS

- Regular exercise is recommended for healthy pregnant women.
- Even those who have not been physically active can start a new exercise program gradually during pregnancy.
- Regular exercise during pregnancy promotes overall wellness and helps maintain appropriate gestational weight gain and appropriate fetal weight gain. Exercise in pregnancy may also reduce hypertensive disorders of pregnancy and gestational diabetes, and may be associated with shorter first stage of labor and decreased risk for cesarean section.
- Elite athletes can continue to be highly active, but some modifications may be needed during pregnancy.

INTRODUCTION

Regular exercise confers significant benefits for health and wellness. National guidelines from the US Department of Health and Human Services (HHS) and the American College of Obstetrics and Gynecology (ACOG) advise that all healthy pregnant women should engage routinely in exercise, after consultation with a care provider.^{1,2} Exercise is safe and beneficial for most pregnant women and their fetuses, within parameters as described by expert consensus as summarized by the ACOG Committee Opinion and other expert guidance.

EXPERT GUIDELINES AND RECOMMENDATIONS REGARDING EXERCISE DURING PREGNANCY

American College of Sports Medicine Position Stand on Exercise

The American College of Sports Medicine's Position Stand on Exercise points out that regular exercise has numerous benefits for physical and mental health. "The scientific evidence demonstrating the beneficial effects of exercise is indisputable, and the

Conflict of Interest and Financial Disclosure Statements: The authors report no conflict of interest.

Department of Obstetrics and Gynecology, University of Virginia School of Medicine, Charlottesville, VA, USA

* Corresponding author. 2955 Ivy Road, Suite 304, Charlottesville, VA 22903.

E-mail address: Vanessa.Gregg@virginia.edu

Clin Sports Med 36 (2017) 741–752

<http://dx.doi.org/10.1016/j.csm.2017.05.005>

0278-5919/17/© 2017 Elsevier Inc. All rights reserved.

sportsmed.theclinics.com

benefits of exercise far outweigh the risks in most adults.”³ The American College of Sports Medicine advises continuing an existing exercise program or initiation of a regular exercise program during pregnancy.⁴

US Department of Health and Human Services Physical Activity Guidelines

The 2008 physical activity guidelines from HHS offer specific guidance for exercise in pregnancy:

- “Healthy women who are not already highly active or doing vigorous-intensity aerobic activity should get at least 150 minutes of moderate-intensity aerobic activity per week during pregnancy and the postpartum period. Preferably, this activity should be spread throughout the week.”
- “Pregnant women who habitually engage in vigorous-intensity aerobic activity or are highly active can continue physical activity during pregnancy and the postpartum period, provided that they remain healthy and discuss with their health care provider how and when activity should be adjusted over time.”

American College of Obstetrics and Gynecology Committee Opinion #650

The ACOG Committee Opinion #650 states that¹:

- Physical activity in pregnancy has minimal risks and has been shown to benefit most women, although some modification to exercise routines may be necessary because of normal anatomic and physiologic changes and fetal requirements.
- Women with uncomplicated pregnancies should be encouraged to engage in aerobic and strength-conditioning exercises before, during and after pregnancy.

BENEFITS OF EXERCISE DURING PREGNANCY

There are numerous health benefits associated with exercise during pregnancy. The available literature is variable in what it explores and the strength of the findings. This article reviews the current available evidence regarding exercise and the maintenance of healthy weight gain, decreasing gestational hypertension, reducing maternal back pain during pregnancy, shortening the duration of labor, and reducing the risk for cesarean section.

Improve or Maintain Fitness

A 2006 Cochrane Review (updated 2010) evaluated 14 controlled trials of exercise in pregnancy. Pregnant women who exercised at least two to three times per week seemed to improve or maintain their fitness level. There was not sufficient data to draw more specific conclusions about maternal and infant benefits or risks.⁵

A more recent small, randomized trial of sedentary pregnant women evaluated a supervised aerobic training program involving 45- to 60-minute exercise activities at moderate intensity, 4 days per week. Results showed increased aerobic fitness and strength in the exercise group compared with control subjects, with no significant difference in pregnancy outcomes.⁶

Maintain Healthy Weight Gain

A 2006 Cochrane Review (updated 2015) evaluated randomized controlled trials of diet and exercise interventions and their effects on gestational weight gain. Women who received exercise interventions were more likely to have low gestational weight gain than control subjects.⁷ A meta-analysis of randomized trials of structured

exercise programs in pregnancy showed similar findings of reduced maternal weight gain with structured exercise programs.⁸

Decrease Gestational Hypertension

A 2006 review of studies evaluating prescribed moderate-intensity aerobic exercise compared with maintenance of normal activity during pregnancy found no significant difference in the development of preeclampsia between the exercise group and the nonexercising group.⁹ A Cochrane review of diet and exercise interventions during pregnancy found no difference in the development of preeclampsia when comparing women who exercised with those who did not. However, in that review, women who participated in an exercise program during pregnancy were less likely to have hypertension during pregnancy.⁷

Another dose-response meta-analysis of observational studies evaluating physical activity and risk of preeclampsia found that increasing levels of physical activity before and during pregnancy were inversely associated with the development of preeclampsia. The more women exercised before and during their pregnancies, the less likely they were to develop preeclampsia.¹⁰ There is mixed-quality evidence from which to draw conclusions, but there is a possible association between exercising and a decreased risk of hypertensive disorders of pregnancy.

Reduce Back Pain

A survey of 950 pregnant women (84% response rate) showed that low back pain is a common complaint in pregnancy, with 68.5% of respondents reporting low back pain during their pregnancies.¹¹ A review of randomized controlled trials of interventions to reduce back pain in pregnancy found that any land-based exercise was associated with a significant reduction in back pain and improvement in functional disability.¹²

Shorten Labor

A recent randomized controlled trial conducted in Spain evaluated a prescribed physical conditioning program and its effects on outcomes. The investigators found a significant reduction in the first stage of labor among women who followed a prescribed exercise program compared with the control group.¹³

Reduce Risk of Cesarean Section

Women who participated in structured physical exercise programs were less likely to require cesarean delivery than women who did not participate in such programs.^{1,6,8,14}

MATERNAL PHYSIOLOGY OF PREGNANCY

It is clear that exercise during pregnancy is associated with numerous salutary outcomes. However, before exercise is prescribed, it is important that providers understand physiologic changes associated with pregnancy, and those associated with exercise in pregnancy.

Cardiovascular and Pulmonary Adaptations

There are many physiologic changes that occur during pregnancy. There are significant cardiovascular changes, including a significant increase in blood volume, heart rate, and cardiac output, and a decrease in systemic vascular resistance. In healthy pregnancies, blood pressure decreases, beginning in early pregnancy, with a nadir in mid-pregnancy. Heart rate and blood pressure typically normalize quickly in the postpartum period in the absence of superimposed complications.¹⁵ Pulmonary

changes include increased oxygen consumption and minute ventilation, and decreased functional residual capacity and oxygen reserve.^{16,17} **Table 1** summarizes the cardiovascular and pulmonary adaptations that occur during normal pregnancy.

Glucose Metabolism

Maternal physiologic changes in carbohydrate metabolism during pregnancy serve to ensure a constant supply of glucose to the fetus to sustain growth. Glucose crosses the placenta to the fetus by means of facilitated diffusion, a process by which the glucose is diffused across cell membranes by carrier proteins. Consequently in the fasting state maternal fasting glucose levels are decreased by 15% to 20% compared with those in nonpregnant women.¹⁹ The lowered glucose levels are associated with decreases in plasma insulin, producing an “accelerated and exaggerated response to starvation.”¹⁹ Feeding produces hyperglycemia, an increase in serum insulin levels, and hypertriglyceridemia. There is also a diminished response to insulin caused by human placental lactogen and other hormones.

Musculoskeletal Changes

There are multiple physiologic changes in pregnancy that impact the musculoskeletal system. There is a variable increase in body mass, and the distribution of body mass changes with the growth of the uterus and fetus.²⁰ Relaxation of the peripheral joints is a normal physiologic process in pregnancy and has been confirmed in multiple studies, leading to increased joint laxity.²¹ There is usually progressive lordosis and a change in the center of gravity.²²

A three-dimensional gait analysis of 15 pregnant women in the third trimester of pregnancy showed alteration in several kinetic parameters, including increased use of hip abductor, hip extensor, and ankle plantar flexor muscle groups. These alterations are likely adaptive to compensate for the physiologic changes in the center of gravity and the increased lordosis of pregnancy.²⁰

Weight Gain in Pregnancy

The Institute of Medicine (IOM) has published and revised guidelines for recommended weight gain in pregnancy, which varies based on the prepregnancy body mass index. The IOM recommendations are summarized in **Table 2**. The goal of the guidelines is to define appropriate weight gain to promote normal infant birth weight, and to reduce postpartum weight retention.²³

A systematic literature review of birth outcomes associated with gestational weight gain confirmed that there was an association between appropriate gestational weight

Table 1 Cardiovascular and pulmonary adaptations in pregnancy			
Cardiovascular		Pulmonary	
Blood volume	Increased, can be 40%–45%	Oxygen consumption	Increased, 10%–20% at rest
Heart rate	Increased 10 bpm	Minute ventilation	Increased 40%–50%
Cardiac output	Increased	Functional residual capacity	Decreased
Systemic vascular resistance	Decreased systemic vascular resistance	Oxygen reserve	Decreased

Data from Refs.^{15–18}

Table 2
Institute of Medicine's recommended weight gain based on body mass index

Prepregnancy Weight	Body Mass Index	Recommended Weight Gain (lb)
Underweight	<18.5	28–40
Normal weight	18.5–24.9	25–35
Overweight	25–29.9	15–25
Obese	≥30	11–20

Data from Institute of Medicine, I.O.M.P.W.G. National Research Council Committee to Reexamine. 2009; and American College of Obstetricians and Gynecologists. ACOG committee opinion No. 548: weight gain during pregnancy. *Obstet Gynecol* 2013;121(1):210–2.

gain as defined by the IOM and the outcomes of having a normal-range birthweight baby with normal fetal growth. In addition, the same review found that gestational weight gain within the IOM guidelines was associated with less postpartum weight retention. This review further identified that there was strong evidence that excess gestational weight gain was associated with increased infant birthweight, whereas insufficient weight gain was associated with lower infant birth weight.²⁴

PHYSIOLOGIC CHANGES ASSOCIATED WITH EXERCISE DURING PREGNANCY

Maternal Cardiovascular Physiology Changes with Exercise

Research suggests that exercise performed during pregnancy can improve cardiovascular function in pregnant women without compromising fetal well-being.^{5,25–27} Heart rate variability is a measure of cardiac autonomic nervous system function, which is a measure of cardiovascular health. A recent study of healthy pregnant women assessed heart rate variability with exercise in pregnancy. The results showed that consistent maternal exercise throughout pregnancy was associated with lower maternal heart rate and increased heart rate variability, suggesting overall improved cardiac autonomic control.²⁸

Maternal Glucose Metabolism During Exercise

A study of glucose metabolism in pregnancy evaluated glucose homeostasis in the third trimester in response to exercise, compared with glucose homeostasis in a nonpregnant control group. Results showed that pregnant women had more rapid and extreme drops in blood glucose with exercise compared with nonpregnant control subjects. In addition, pregnant women had more significantly decreased insulin levels after exercise.²⁹

Fetal Physiology During Exercise

Just as maternal physiology is affected by exercise, so is fetal physiology. The fetal heart rate has been shown to increase as a result of maternal exercise, both during and soon after the exercise occurs.^{1,18,30} A research study evaluated exercise treadmill tests in pregnant women of varying fitness levels, with exercise intensities that were appropriate to the prepregnancy activity levels of the participants, based on HHS guidelines. Assessments of fetal well-being were made before and after the treadmill exercise sessions. The results indicated that maternal treadmill exercise was well-tolerated by the fetuses in this study.³¹ These results confirm that light-to-moderate-intensity exercise during pregnancy is well-tolerated by the fetus.

EXERCISE PRESCRIPTION

Pregnant women are often more receptive than their nonpregnant counterparts to life-style modification and health counseling. Exercise is encouraged for pregnant women; however, physicians must evaluate each individual pregnant woman before prescribing her optimal exercise regimen.

The HHS guidelines recommend that pregnant women should work with their care providers to tailor their exercise programs appropriately based on their prepregnancy fitness levels and any complications in the pregnancies. Women who are starting a new exercise program should increase their physical activity gradually over time.²

The ACOG Committee Opinion recommends that the pregnant patient should have a medical evaluation to ensure that it is safe for her to pursue an exercise program during her pregnancy. ACOG provides specific guidance regarding activities to encourage, and those to avoid, during pregnancy. In a prior guideline, ACOG had recommended limiting the maximum heart rate to 140 beats per minute during exercise in pregnancy. However, that limitation is no longer included in the updated guideline, published in 2015. Rather, ACOG now recommends the use of perceived exertion as a self-guide to limiting exertion during exercise.^{1,32,33}

It must be remembered that prescriptions for exercise during pregnancy may impact two individuals and thus maternal and fetal well-being must be considered.

Recommended Exercise Types: American College of Obstetrics and Gynecology Committee Opinion

ACOG has provided specific guidance on exercise activities that are considered safe in pregnancy. These activities are recommended for healthy women who are cleared for exercise in pregnancy. Walking, swimming, stationery cycling, and low-impact aerobics are all preferred forms of exercise in pregnancy. Yoga and pilates are considered safe, if care is taken to avoid positions that could cause hypotension. Running, jogging, and strength-training are considered safe but should be discussed first with an obstetric care provider. Racquet sports may be acceptable, although activities with an increased risk of abrupt loss of balance and falls should be avoided.¹

Exercises to Avoid in Pregnancy: American College of Obstetrics and Gynecology Committee Opinion

Contact sports should be avoided because of the risk of trauma. In addition, activities with a significant risk of falls or trauma should be avoided, including skiing, water skiing, surfing, off-road cycling, horseback riding, and gymnastics. Scuba diving, sky diving and hot yoga are not recommended in pregnancy.¹ **Box 1** summarizes the relative contraindications to aerobic exercise in pregnancy, as recommended by ACOG, and **Box 2** summarizes the absolute contraindications. Individual recommendations should be made with the advice of an obstetric care provider.

LIMITATIONS AND CONTRAINDICATIONS TO EXERCISE DURING PREGNANCY

Pregnant women should be careful to maintain adequate nutrition and hydration with exercise.^{1,29} Although it is unlikely that body core temperatures would exceed 39°C, the Royal College of Obstetricians and Gynaecologists recommends limiting exposure during exercise to temperatures exceeding 90°F and keeping hydrotherapy pool temperatures less than or equal to 95°F.³⁴ Because of anatomic and physiologic changes associated with pregnancy, there is increased risk of hypotension with exercise. In particular, activities that require flat supine positioning can increase this risk, and

Box 1**Relative contraindications to aerobic exercise during pregnancy**

- Anemia
- Unevaluated maternal cardiac arrhythmia
- Chronic bronchitis
- Poorly controlled type 1 diabetes
- Extreme morbid obesity
- Extreme underweight (body mass index <12)
- History of extremely sedentary lifestyle
- Intrauterine growth restriction in current pregnancy
- Poorly controlled hypertension
- Orthopedic limitations
- Poorly controlled seizure disorder
- Poorly controlled hyperthyroidism
- Heavy smoker

Reprinted with permission from Physical activity and exercise during pregnancy and the postpartum period. Committee Opinion No.650. American College of Obstetricians and Gynecologists. *Obstet Gynecol* 2015;126:e135–42.

therefore should be avoided. Increased musculoskeletal discomforts or injuries could be a complication of exercise in pregnancy because of increased laxity and altered center of gravity, and care should be taken to avoid activities that increase the risk of musculoskeletal injuries.^{6,20,35} ACOG provides specific warning signs for discontinuation of exercise during pregnancy, as summarized in **Box 3**.

FETAL OUTCOMES WITH MATERNAL EXERCISE DURING PREGNANCY

Pregnant women can be reassured that maternal exercise in pregnancy is generally well-tolerated by the fetus.^{1,31}

Box 2**Absolute contraindications to aerobic exercise during pregnancy**

- Hemodynamically significant heart disease
- Restrictive lung disease
- Incompetent cervix or cerclage
- Multiple gestation at risk of premature labor
- Persistent second- or third-trimester bleeding
- Placenta previa after 26 weeks of gestation
- Premature labor during the current pregnancy
- Ruptured membranes
- Preeclampsia or pregnancy-induced hypertension
- Severe anemia

Reprinted with permission from Physical activity and exercise during pregnancy and the postpartum period. Committee Opinion No.650. American College of Obstetricians and Gynecologists. *Obstet Gynecol* 2015;126:e135–42.

Box 3**Warning signs to discontinue exercise while pregnant**

- Vaginal bleeding
- Regular painful contractions
- Amniotic fluid leakage
- Dyspnea before exertion
- Dizziness
- Headache
- Chest pain
- Muscle weakness affecting balance
- Calf pain or swelling

Reprinted with permission from Physical activity and exercise during pregnancy and the postpartum period. Committee Opinion No.650. American College of Obstetricians and Gynecologists. *Obstet Gynecol* 2015;126:e135–42.

Effects of Maternal Exercise on Fetal Growth and Birthweight

Some studies have suggested that exercise during pregnancy does not significantly alter birthweight. A meta-analysis found that mean birthweight for infants born to mothers who exercised was similar to those born to control, nonexercising mothers. However, the researchers found that women who continued vigorous exercise in the third trimester delivered infants who weighed 200 to 400 g less than the infants of their nonexercising counterparts.³⁶

A more recent meta-analysis reviewed randomized controlled trials in pregnant women comparing a supervised exercise intervention with a group receiving usual prenatal care. In this group of 36 trials, pregnant women who exercised were less likely to have a large-for-gestational-age newborn, with no change in the likelihood of having a small-for-gestational-age newborn. In this study, mean weight gain in pregnancy was less among those who participated in the exercise protocol than among those who did not.³⁷ Thus, the best evidence available suggests that prescribed moderate-intensity exercise during pregnancy does not adversely affect infant weight at birth.

Maternal Exercise and Preterm Birth

A recent meta-analysis of randomized clinical trials of exercise programs during pregnancy evaluated studies of aerobic exercise for 35 to 90 minutes, performed three to four times weekly, found that there was no significant difference in the rate of preterm birth for women who exercised compared with those who did not. The mean gestational age at delivery was similar among those prescribed an exercise program and those who were not. There were no significant differences in low birthweight babies or in mean infant weight at delivery.³⁸ This analysis confirms that among sedentary women with a normal, singleton pregnancy, moderate-intensity exercise does not seem to increase the risk of preterm birth or earlier delivery. This review also confirmed previous findings that moderate-intensity exercise does not adversely affect infant birthweight.

A recent Norwegian study evaluated 188 children whose mothers had participated in a structured exercise program during their pregnancies compared with a control group whose mothers had not participated in an exercise program during their pregnancies. Assessments of cognitive, language, and motor skills were undertaken at 18 months of age. Results indicated that there were no adverse neurodevelopmental effects on the children whose mothers had participated in exercise during pregnancy.³⁹

OTHER CONSIDERATIONS

High Performance Exercise During Pregnancy

Serena Williams, a professional tennis athlete, recently won the Australian Open professional tennis tournament during her first trimester of pregnancy, garnering a great deal of public interest. The HHS and ACOG guidelines for exercise in pregnancy state that it is safe and reasonable for pregnant women who are already participating in vigorous-intensity aerobic activity to continue to be highly active during pregnancy, in conjunction with advice from their care providers.^{1,2}

Pregnant elite athletes need provider supervision to ensure safe progression of exercise during pregnancy. Physiologic changes associated with pregnancy may necessitate alteration in training routines. High-performing athletes may need additional nutritional support to ensure adequate pregnancy weight gain.⁴⁰

Providing advice to elite athletes during pregnancy is challenging for providers because there is no uniform agreement on what defines an “elite athlete.” Moreover, it is difficult in practical terms to define and measure degree of exertion during exercise, and there are few studies (typically only with small numbers of patients) on which to draw conclusions when advising patients. A reasonable definition is an athlete who trains year round at a high level. Training is likely to be at least 5 days per week, averaging close to 2 hours per day and meet or exceed 6 metabolic equivalents level used to describe vigorous physical activity.⁴¹

In a study of high-performing pregnant athletes, six Olympic-level pregnant women were studied at 23 to 29 weeks of gestation on a treadmill exercise activity at approximately 60% to 90% of maximal oxygen consumption. Fetal heart rate was within the normal range as long as the mother exercised less than 90% of maximal maternal heart rate. In some instances when maternal heart rate exceeded 90% of maximal, there was a simultaneous reduction in uterine volume blood flow to less than 50% of the initial value and fetal heart rate decelerations. Overall, however, all fetuses did well. It was concluded that exercise at less than 90% of maximal maternal heart rate may be regarded as a safety zone for elite athletes.⁴²

In a subsequent similar study, it was likewise found that the fetuses of a subset of highly active pregnant women (whose conditioning was less than that of an elite athlete) had transient heart rate decelerations following strenuous exercise. These changes were often accompanied by increased resistance in the umbilical and uterine artery Doppler parameters and did not occur when the maternal heart rate was less than or equal to 84% of maximal.^{31,32} Although the clinical significance of the transient fetal decelerations and increased vascular impedance is unknown, a conservative course might target strenuous exercise in pregnancy to achieve maternal heart rates less than or equal to 84% of maximum.

Specific counseling to elite athletes regarding exercise during pregnancy should include advice regarding limitations to maximum exertion, precautions to minimize risk of injury, and vigilance for potential indicators of overexertion. **Table 3** provides examples of specific guidelines for elite athletes regarding exercise during pregnancy.

Postpartum Exercise

Regular exercise during pregnancy can help to achieve recommended gestational weight gain. Adherence to recommended guidelines for weight gain in pregnancy can help to reduce postpartum weight retention.²⁴ Investigators have observed that women tend to have decreased exercise participation after giving birth, and sedentary lifestyles for these women can contribute to the development of obesity and

Table 3	
Risks of exercise in pregnancy for the elite athlete	
Risks	Guidelines
Maternal	
Musculoskeletal injuries	With evidence of joint and ligament laxity, individualize and modify training
Cardiovascular complications	Be vigilant of warning signs, including palpitations and tachycardia at rest or any signs of orthostatic hypotension
Threatened abortion or premature labor	Stop training
Hypoglycemia	Prevent hypoglycemia by following proper nutritional guidelines
Fetal	
Fetal distress	Be alert to fetal movements or activity; in the presence of any complication, stop training and resume only after medical clearance
Intrauterine growth restriction	Stop training
Fetal malformations	Avoid hyperthermia and dehydration immediately after conception and for weeks thereafter
Fetal injuries	Avoid sports with a high probability of blunt trauma after 16–20 wk of gestation

Reprinted with permission from Artal R, Hopkins S. Exercise. Clin Update Womens Health Care 2013;XII(2):1–105.

associated metabolic disorders.^{43,44} Regular exercise should be encouraged in the postpartum period, as soon as it is deemed medically safe to participate in such exercise.¹

REFERENCES

1. ACOG committee opinion No. 650: physical activity and exercise during pregnancy and the postpartum period. *Obstet Gynecol* 2015;126(6):e135–42.
2. US Department of Health and Human Services. Physical activity guidelines advisory committee report 2008:A1-H14. Washington, DC: U.S. Department of Health and Human Services; 2008.
3. Garber CE, Blissmer B, Deschenes MR, et al. 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(7):1334–59.
4. American College of Sports Medicine. ACSM's guidelines for exercise testing and prescription. In: American College of Sports Medicine, editor. ACSM's guidelines for exercise testing and prescription. 9th edition. Philadelphia: Wolters Kluwer/ Lippincott Williams & Wilkins Health; 2014.
5. Kramer MS, McDonald SW. Aerobic exercise for women during pregnancy. *Cochrane Database Syst Rev* 2006;(3):CD000180.
6. Price BB, Amini SB, Kappeler K. Exercise in pregnancy: effect on fitness and obstetric outcomes. A randomized trial. *Med Sci Sports Exerc* 2012;44(12):2263–9.

7. Muktabhant B, Lawrie TA, Lumbiganon P, et al. Diet or exercise, or both, for preventing excessive weight gain in pregnancy. *Cochrane Database Syst Rev* 2015;(6):CD007145.
8. Domenjoz I, Kayser B, Boulvain M. Effect of physical activity during pregnancy on mode of delivery. *Am J Obstet Gynecol* 2014;211(4):401.e1-11.
9. Meher S, Duley L. Exercise or other physical activity for preventing pre-eclampsia and its complications. *Cochrane Database Syst Rev* 2006;(2):CD005942.
10. Aune D, Saugstad OD, Henriksen T, et al. Physical activity and the risk of pre-eclampsia: a systematic review and meta-analysis. *Epidemiology* 2014;25(3):331–43.
11. Wang SM, Dezinno P, Maranets I, et al. Low back pain during pregnancy: prevalence, risk factors, and outcomes. *Obstet Gynecol* 2004;104(1):65–70.
12. Liddle SD, Pennick V. Interventions for preventing and treating low-back and pelvic pain during pregnancy. *Cochrane Database Syst Rev* 2015;(9):CD001139.
13. Perales M, Santos-Lozano A, Ruiz JR, et al. Benefits of aerobic or resistance training during pregnancy on maternal health and perinatal outcomes: a systematic review. *Early Hum Dev* 2016;94:43–8.
14. Barakat R, Pelaez M, Lopez C, et al. Exercise during pregnancy reduces the rate of cesarean and instrumental deliveries: results of a randomized controlled trial. *J Matern Fetal Neonatal Med* 2012;25(11):2372–6.
15. Mahendru AA, Everett TR, Wilkinson IB, et al. Maternal cardiovascular changes from pre-pregnancy to very early pregnancy. *J Hypertens* 2012;30(11):2168–72.
16. Artal R, Wiswell R, Romem Y, et al. Pulmonary responses to exercise in pregnancy. *Am J Obstet Gynecol* 1986;154(2):378–83.
17. Hegewald MJ, Crapo RO. Respiratory physiology in pregnancy. *Clin Chest Med* 2011;32(1):1–13, vii.
18. Artal R, Rutherford S, Romem Y, et al. Fetal heart rate responses to maternal exercise. *Am J Obstet Gynecol* 1986;155(4):729–33.
19. Barclay M. Physiology of pregnancy. *Global Library of Women's Medicine* 2009. Available at: http://www.glowm.com/section_view/item/103#16901. Accessed March 14, 2017.
20. Foti T, Davids JR, Bagley A. A biomechanical analysis of gait during pregnancy. *J Bone Joint Surg Am* 2000;82(5):625–32.
21. Marnach ML, Ramin KD, Ramsey PS, et al. Characterization of the relationship between joint laxity and maternal hormones in pregnancy. *Obstet Gynecol* 2003;101(2):331–5.
22. Williams Obstetrics LK, Cunningham F, Bloom SL, et al, editors. *Maternal physiology*. New York: McGraw-Hill; 2013.
23. Institute of Medicine. *Weight gain during pregnancy: reexamining the guidelines*. Washington, DC: National Academies Press; 2009.
24. Siega-Riz AM, Viswanathan M, Moos MK, et al. A systematic review of outcomes of maternal weight gain according to the Institute of Medicine recommendations: birthweight, fetal growth, and postpartum weight retention. *Am J Obstet Gynecol* 2009;201(4):339.e1-14.
25. Prather H, Spitznagle T, Hunt D. Benefits of exercise during pregnancy. *PM R* 2012;4(11):845–50 [quiz: 850].
26. Kalisiak B, Spitznagle T. What effect does an exercise program for healthy pregnant women have on the mother, fetus, and child? *PM R* 2009;1(3):261–6.
27. Davies GA, Wolfe LA, Mottola MF, et al. Joint SOGC/CSEP clinical practice guideline: exercise in pregnancy and the postpartum period. *Can J Appl Physiol* 2003;28(3):330–41.

28. May LE, Knowlton J, Hanson J, et al. Effects of exercise during pregnancy on maternal heart rate and heart rate variability. *PM R* 2016;8(7):611–7.
29. Soultanakis HN, Artal R, Wiswell RA. Prolonged exercise in pregnancy: glucose homeostasis, ventilatory and cardiovascular responses. *Semin Perinatol* 1996;20(4):315–27.
30. Carpenter MW, Sady SP, Hoegsberg B, et al. Fetal heart rate response to maternal exertion. *JAMA* 1988;259(20):3006–9.
31. Szymanski LM, Satin AJ. Exercise during pregnancy: fetal responses to current public health guidelines. *Obstet Gynecol* 2012;119(3):603–10.
32. Szymanski LM, Satin AJ. Strenuous exercise during pregnancy: is there a limit? *Am J Obstet Gynecol* 2012;207(3):179.e1-6.
33. American College of Obstetrics and Gynecology. Exercise during pregnancy and the postpartum period. ACOG technical bulletin No. 189–February 1994. *Int J Gynaecol Obstet* 1994;45:65–70.
34. Royal College of Obstetricians and Gynecologists. Exercise in pregnancy. 2006. Available at: <http://www.nice.org.uk>. Accessed March 10, 2017.
35. Impact of physical activity during pregnancy and postpartum on chronic disease risk. *Med Sci Sports Exerc* 2006;38(5):989–1006.
36. Leet T, Flick L. Effect of exercise on birthweight. *Clin Obstet Gynecol* 2003;46(2):423–31.
37. Wiebe HW, Boulé NG, Chari R, et al. The effect of supervised prenatal exercise on fetal growth: a meta-analysis. *Obstet Gynecol* 2015;125(5):1185–94.
38. Di Mascio D, Magro-Malosso ER, Saccone G, et al. Exercise during pregnancy in normal-weight women and risk of preterm birth: a systematic review and meta-analysis of randomized controlled trials. *Am J Obstet Gynecol* 2016;215(5):561–71.
39. Hellenes OM, Vik T, Løhaugen GC, et al. Regular moderate exercise during pregnancy does not have an adverse effect on the neurodevelopment of the child. *Acta Paediatr* 2015;104(3):285–91.
40. Artal R, Hopkins S. Exercise. *Clin Update Womens Health Care* 2013;12:1.
41. Pivarnik JM, Szymanski LM, Conway MR. The elite athlete and strenuous exercise in pregnancy. *Clin Obstet Gynecol* 2016;59(3):613–9.
42. Salvesen KA, Hem E, Sundgot-Borgen J. Fetal wellbeing may be compromised during strenuous exercise among pregnant elite athletes. *Br J Sports Med* 2012;46(4):279–83.
43. Minig L, Trimble EL, Sarsotti C, et al. Building the evidence base for postoperative and postpartum advice. *Obstet Gynecol* 2009;114(4):892–900.
44. O'Toole ML, Sawicki MA, Artal R. Structured diet and physical activity prevent postpartum weight retention. *J Womens Health (Larchmt)* 2003;12(10):991–8.