



Published in final edited form as:

Obstet Gynecol. 2012 March ; 119(3): 603–610. doi:10.1097/AOG.0b013e31824760b5.

Exercise During Pregnancy: Fetal Responses to Current Public Health Guidelines

Linda M. Szymanski, MD, PhD and Andrew J. Satin, MD

Department of Gynecology and Obstetrics, Division of Maternal-Fetal Medicine, Johns Hopkins University School of Medicine, Johns Hopkins Bayview Medical Center, Baltimore, MD (Dr. Szymanski, Dr. Satin)

Linda M. Szymanski: lszymanski@jhmi.edu

Abstract

Objective—To evaluate acute fetal responses to individually-prescribed exercise according to existing guidelines (US Department of Health and Human Services) in active and inactive pregnant women.

Methods—Forty-five healthy pregnant women (15 Non-Exercisers, 15 Regularly Active, 15 Highly Active) were tested between 28-0/7 to 32-6/7 weeks. After a treadmill test to volitional fatigue, target heart rates were calculated for two subsequent 30-minute treadmill sessions: 1) moderate intensity (40-59% heart rate reserve), and 2) vigorous intensity (60-84%). All women performed the moderate test; only active women performed the vigorous test. Fetal well-being measures included umbilical artery Dopplers, fetal heart tracing and rate, and biophysical profile. Measures were obtained at rest and immediately postexercise.

Results—Groups were similar in age, body mass index, and gestational age. Maternal resting heart rate in the Highly Active group (61.6 ± 7.2 bpm) was significantly lower than the Non-Exercise (79.0 ± 11.6 and Regularly Active (71.9 ± 7.4) groups, $P < 0.001$. Treadmill time was longer in Highly Active (22.3 ± 2.9 min) than Regularly Active (16.6 ± 3.4) and Non-Exercise (12.1 ± 3.6) groups, $P < 0.001$, reflecting higher fitness. With moderate exercise, all umbilical artery Doppler indices were similar pre-exercise and postexercise among groups. With vigorous exercise, Dopplers were similar in Regularly and Highly Active women, with statistically significant decreases postexercise ($P < 0.05$). The group \times time interaction was not significant. Postexercise fetal heart tracings met criteria for reactivity within 20 minutes after all tests. Biophysical profile scores were reassuring.

Conclusion—This study supports existing guidelines indicating pregnant women may begin or maintain an exercise program at moderate (inactive) or vigorous (active) intensities.

Introduction

Specific evidence-based recommendations on exercise during pregnancy are lacking. The majority of pregnant women seek exercise information from commercial books, magazines, and friends rather than their provider (1). Obstetricians are hesitant to advise sedentary women to initiate exercise during pregnancy, and nearly half counsel exercisers to reduce activity (2). Many obstetricians continue to recommend limiting maternal heart rate to less

Corresponding Author: Linda M. Szymanski, MD, PhD, Department of Gynecology and Obstetrics, Division of Maternal-Fetal Medicine, Johns Hopkins Bayview Medical Center, 4940 Eastern Avenue, Room 121, Baltimore, MD 21224, Phone: (410) 550-0336; Fax: (410) 550-0196.

Financial Disclosure: The authors did not report any potential conflicts of interest.

than 140 beats per minute (3), a restriction removed from the American College of Obstetricians and Gynecologists (ACOG) guidelines in 1994 (4).

Existing recommendations for physical activity during pregnancy have been extrapolated from the physical activity and public health literature. The first public health guidelines (5) were subsequently adopted by ACOG (6). Updated public health recommendations provide specific definitions of moderate and vigorous intensity (7). In 2008, the U.S. Department of Health and Human Services (HHS) issued comprehensive guidelines on physical activity (8,9) and pregnant women are addressed. First, healthy women (non-exercisers and moderate exercisers) should begin or continue moderate-intensity aerobic activity during pregnancy, accumulating at least 150 minutes per week. Since vigorous-intensity exercise has not been carefully studied, these women are not advised to start vigorous exercise. Second, women who currently exercise vigorously may continue their exercise, provided they remain healthy (8).

Despite recommendations for pregnant women to be active (6,8), the majority are not meeting guidelines (10-12) and physical activity consistently decreases during pregnancy (10,12-14). We speculate that obstetricians have not encouraged exercise in pregnancy in part due to a paucity of data on fetal safety. This lack of counseling may deprive women of the overall health benefits of exercise and pregnancy-specific benefits, such as a decreased risk of gestational diabetes (6,8,15-17).

This research aims to address gaps in existing data by evaluating fetal well-being in response to exercise using standard tests obstetricians find relevant in determining the health of a fetus. The primary objective was to evaluate acute fetal responses to the amount of exercise currently recommended by the HHS. Specifically, individually prescribed exercise sessions included: 1) moderate-intensity exercise in currently inactive and active women; and 2) vigorous-intensity exercise in currently active women.

Methods

Subjects

Healthy, pregnant women, with accurate dating (last menstrual period confirmed by first or second trimester ultrasound), currently receiving routine prenatal care were eligible for inclusion in the study. All women had low-risk pregnancies and no contraindications to exercise (6). Exclusion criteria included multiple gestation, body mass index (BMI) over 35, smoking, history of preterm delivery before 34 weeks, cervical insufficiency or cerclage in place, vaginal bleeding, placenta previa, any chronic medical condition (including pregestational diabetes or chronic hypertension), gestational diabetes or hypertension, or a fetus with known structural or chromosomal abnormalities, or growth restriction. Participants were volunteers and constituted a convenience sample. They were recruited primarily from Johns Hopkins-affiliated obstetric clinics. Recruitment flyers were posted in all clinics and the ultrasound unit and eligibility was confirmed by the investigators. Testing was performed between 28-0/7 and 32-6/7 weeks gestational age. This gestational age was chosen since the utility of fetal well-being tests, particularly umbilical artery Doppler measurements, is unclear before 28 weeks (18).

Women were classified according to self-reported physical activity into 3 groups. The *Non-Exercise* group did not perform regular physical activity (greater than 20 minutes per session for more than 3 times per week) the 6 months prior to pregnancy or during pregnancy. Two *Exercise* groups included women who were physically active at moderate to vigorous intensities before pregnancy and continued exercising during pregnancy. The *Regularly Active* group described their exercise as mild to moderate (typically walking) and exercised

more than 20 minutes per session 3 or more days per week. The *Highly Active* group described their activity as vigorous and exercised more than 4 days per week. Most were runners prior to pregnancy and many continued running during pregnancy. The Johns Hopkins University School of Medicine Institutional Review Board approved the protocol and all participants provided written informed consent.

Exercise Tests

All testing was performed in the Fetal Assessment Center in proximity to Labor and Delivery at Johns Hopkins Bayview Medical Center. Women in the Exercise groups reported for 3 visits; Non-Exercisers reported for 2 visits. All tests were performed within a 2-week period:

1. “Peak” exercise test: On the first visit, all women underwent a progressive treadmill test to volitional fatigue according to a modified Balke protocol (19). After a 2-minute warm-up at 3.0 mph and 0% grade, the speed was maintained at 3.0 mph and the incline increased 2% every 2 minutes. After the incline reached 12%, it remained at this level and speed was increased 0.2 mph every 2 minutes. Volitional fatigue was defined as the voluntary limit beyond which a participant no longer desired to continue the prescribed protocol. Treadmill time was recorded in minutes, excluding the warm-up. Peak oxygen consumption was estimated using a validated predication equation for pregnant women (19). The peak test provided the data necessary to prescribe target heart rate ranges for the subsequent moderate- and vigorous-intensity exercise sessions.
2. Moderate-intensity session: All women returned to perform a 30-minute exercise session at moderate-intensity on the treadmill (40-59% of aerobic capacity reserve) (9). Target heart rates were calculated by the heart rate reserve method using the resting and peak maternal heart rates obtained during the peak test. Each participant controlled the treadmill speed and grade to achieve their individualized target heart rate. Once they reached their target rate, they exercised for 30 minutes and adjusted speed and grade to maintain their heart rate in the target range.
3. Vigorous-intensity exercise session: Only women in the Exercise groups returned for the vigorous-intensity session, which was conducted in the same manner as the moderate-intensity session. The target heart rate was calculated using the vigorous-intensity range of 60-84% of heart rate reserve (9).

During all exercise tests, maternal ECG was continuously recorded. Rating of Perceived Exertion (RPE) using the 0 to 10 point scale (20) was obtained at the end of the peak test and during the middle of the submaximal exercise tests.

Fetal Well-Being

Fetal well-being measures included umbilical artery Doppler indices, fetal heart tracing, fetal heart rate (FHR), and biophysical profile (BPP). The primary outcome measure for fetal well-being was the umbilical artery Doppler systolic/diastolic (S/D) ratio. This variable was chosen as our primary outcome variable since it can be precisely measured and reproduced. Additionally, a number of existing studies have used this as a primary outcome variable, thus providing us with the appropriate data to perform a power analysis.

All testing was performed in the afternoon, starting between 3:30 and 7:30 pm. Women were instructed not to eat or drink anything except water for 1 hour prior to arrival. Upon arriving to the Fetal Assessment Center, women laid in a semi-recumbent position with a leftward tilt. Electrodes were placed to obtain a maternal 3-lead ECG and a fetal heart tracing was obtained (Corometrics 120 Maternal/Fetal Monitor). A minimum of 20 minutes

was recorded. Blood pressure, using an automated sphygmomanometer on the left arm, and maternal resting heart rate were obtained after a minimum of 15 minutes of rest. Ultrasound was then performed. The same researcher (LMS), an obstetrician trained in maternal-fetal medicine, performed all ultrasounds. After obtaining resting ultrasound data (umbilical artery Doppler indices), the participant performed the exercise session. Immediately after the exercise test, they returned to the semi-recumbent position with a leftward tilt. Ultrasound was performed to obtain Doppler measures, followed by the BPP. After the BPP was completed and time to completion recorded, another fetal heart tracing was obtained.

Ultrasound

Ultrasound was performed using a Phillips IU22 ultrasound system. Umbilical artery flow velocity waveforms were obtained using color Doppler imaging in a free loop of umbilical cord. Several time points, each containing a minimum of 3 sequential uniform waveforms, were obtained and stored.

Analysis of Doppler Waveforms

Built-in software calculated the S/D ratio, resistance index, and pulsatility index. Mean values were calculated for each frame and averaged over the several time-points obtained. The FHR was calculated from umbilical Doppler data. The immediate-post-exercise FHR was determined from the first Doppler measure obtained.

Delivery Data

Gestational age at delivery, mode of delivery, birth weight, and Apgar scores were obtained from delivery records.

Statistical Analyses

Sample size was calculated to achieve 80% power at the 0.05 level of significance. Two analyses were performed using umbilical artery Doppler data. First, data from an existing study evaluating S/D ratios at 32 weeks gestational age after exercise at 71% of estimated maximal heart rate (21) indicated 12 subjects per group would be sufficient. S/D ratios pre-exercise were 2.6 with a standard deviation of 0.33 and post-exercise were 2.22 with a standard deviation of 0.33. Second, reference data from umbilical artery Doppler S/D ratios (22) attempting to detect a change from the 50th percentile to the 75th percentile from 28-32 weeks indicated 11-13 per group, depending upon gestational age, would be sufficient. For example, at 32 weeks the S/D ratio at the 50th percentile is 2.67 and the 75th percentile is 3.11. To be conservative, a standard deviation of 0.4 was assumed.

Shapiro-Wilk tests were performed to evaluate for normality. Due to small sample sizes, the Kruskal-Wallis test was used to compare demographic and descriptive variables among the groups. The FHR was also analyzed using the Kruskal-Wallis test. Wilcoxon rank sum tests were then performed when a significant difference was found, using Bonferroni corrections for multiple comparisons. Differences in Doppler indices before and after the moderate and vigorous exercise sessions in the groups were analyzed using a mixed effects regression analysis examining main effects of activity group and time (pre-post), accounting for within subject correlation, and the group by time interaction. For Doppler variables that were not normally distributed, log transformations were utilized to normalize the distributions. Delivery data were analyzed by either the Kruskal-Wallis test or Fisher exact test (categorical variables). Statistical significance was reached at $P < 0.05$. Statistical analyses were performed using STATA 12.0 and SAS 9.2.

Results

Forty-five healthy pregnant women participated in the study from May 2010 to May 2011. Descriptive characteristics and responses to the peak exercise test are summarized in Table 1. There were no significant differences in age, race, parity, BMI, or gestational age among groups ($P>0.05$). As expected, there were significant group differences in maternal resting heart rate ($P<0.001$), with the lowest heart rate in the Highly Active women. Treadmill time and predicted VO_2 peak, indices of physical fitness, increased with increasing activity level and all groups were different from each other ($P<0.001$). There were no group differences in RPE ($P>0.05$), which was 8 or higher in all groups (7 = “very hard”), indicating excellent effort.

The umbilical artery S/D ratio was the only variable not normally distributed. Therefore, log transformations were performed for statistical analysis. The non-transformed means and standard deviations are reported.

Moderate-Intensity Exercise

Descriptive data for the moderate-intensity exercise session (40-59% heart rate reserve) are shown in Table 2. There were no differences among groups ($P>0.05$). Actual average intensity of the exercise was similar among groups, ranging from 51.1% to 51.9%, confirming the women worked at a moderate-intensity. One participant in the Non-Exercise group stopped the session 3.5 minutes early secondary to increased contractions. The contractions subsided and fetal measures were all reassuring.

The FHR and umbilical artery Doppler data, before and immediately after the moderate-intensity exercise session, in all groups, are shown in Table 3. The FHR was similar among groups ($P=0.26$) and increased with exercise. This increase reached statistical significance in the Regularly Active group only ($P=0.01$). The mean umbilical artery S/D ratios are between the 25th and 50th percentiles according to reference data (22). No differences were seen in any umbilical artery Doppler indices among groups or with exercise ($P>0.05$).

All participants in both Exercise groups achieved BPP scores of 8 out of 8 within 30 minutes after the exercise session. Fourteen of 15 subjects in the Non-Exercise group achieved BPP scores of 8 out of 8 within 30 minutes; one subject achieved a score of 8 out of 8 after 30 minutes and 23 seconds. The fetal heart tracings after the exercise sessions met criteria for reactivity within 20 minutes and were reassuring in all participants (23).

Vigorous-Intensity Exercise

Descriptive data for the vigorous-intensity exercise session (60-84% heart rate reserve) in the two Exercise groups were similar and are shown in Table 4. Six participants were unable to perform the vigorous session secondary to scheduling constraints ($n=4$) or illness ($n=2$); thus 24 participants (13 Highly Active and 11 Regularly Active) completed the session. The actual average intensity of the exercise session was 71.8 and 73.8% in the Regularly and Highly Active women, respectively, confirming vigorous-intensity exercise.

The FHR and umbilical artery Doppler indices during the vigorous exercise session are shown in Table 5. The FHR remained in the normal range and was not different between the two groups ($P=0.50$). There was a significant increase post-exercise in both groups ($P=0.001$). There were no significant group differences in umbilical artery indices; however, the main effect for time was significant for all indices ($P<0.05$). The group by time interaction was not significant for any Doppler variable ($P>0.05$).

All participants in the Regularly Active group and 12 of 13 participants in the Highly Active group achieved BPP scores of 8 out of 8 within 30 minutes; one participant in the Highly Active group achieved a score of 8 out of 8 at 33 minutes and 49 seconds. The fetal heart tracings after the exercise sessions met criteria for reactivity within 20 minutes and were reassuring in all participants (23).

Umbilical artery Doppler measures on average were obtained by 1:07 minutes post-exercise.

Delivery Data

None of the delivery variables differed among the groups. All participants delivered at term, except one Highly Active woman delivered at 36-6/7 weeks and one Non-Exerciser delivered at 36-1/7 weeks (preterm labor). Both of these babies were discharged home with their mother on postpartum day number 2. Mean gestational age at delivery was 39.7 ± 1.3 , 39.6 ± 1.1 , and 39.2 ± 1.3 weeks for Non-Exercisers, Regularly, and Highly Active groups, respectively. Birth weight was similar among the three groups ($P=0.10$). For the Non-Exercisers, birth weight ranged from 2,875 – 4,451 grams, with a mean of $3,460 \pm 427$ and a median of 3,390 grams. Birth weight for the Regularly Active ranged from 2,890 – 4,700 grams, with a mean of $3,408 \pm 426$ and a median of 3,302 grams; birth weight for the Highly Active ranged from 2,665 – 3,590 grams, with a mean of $3,167 \pm 299$ and a median of 3,215 grams. One participant in the Highly Active group delivered a small for gestational age baby (2,690 grams at 39-3/7 weeks, <10th percentile) (24). Two participants delivered large for gestational age babies (>90th percentile), one Regularly Active (4,700 grams at 39-5/7 weeks), and one Non-Exerciser (4,451 grams at 41-0/7 weeks). Apgar scores were not different among the groups ($P>0.05$) and all 5-minute Apgar scores were greater than 7.

Discussion

The *Physical Activity Guidelines for Americans* (8) recommend that pregnant women who are not already highly active get at least 150 minutes of moderate-intensity aerobic activity per week during pregnancy. Participating in vigorous-intensity exercise is not recommended for previously inactive women or women who engage in only moderate-intensity exercise. Women who are currently vigorously active may continue this level of activity during pregnancy according to the guidelines.

This investigation assessed the effects of the current physical activity guidelines for pregnant women (6,8) on fetal well-being. The recommended intensities were implemented using an exercise mode and duration that are typical and practical. We chose 30-minute sessions as a feasible approach to achieve the recommended 150 minutes weekly, i.e., 5 sessions lasting 30 minutes. In addition, this is the prescription recommended in the updated public health guidelines (7). In accordance with the HHS guidelines (8,9), moderate intensity was defined as 40-59% of heart rate reserve and vigorous intensity was defined as 60-84%.

Our major finding is that exercise according to the current HHS guidelines was well tolerated by both the mother and the fetus, as indicated by a variety of commonly used tests of fetal well-being. During moderate-intensity exercise, umbilical artery S/D ratios were within the normal range and did not significantly change with exercise. During vigorous-intensity exercise, all umbilical artery indices showed decreases post-exercise. Although statistically significant, this decrease is likely not clinically significant. A decrease in umbilical artery S/D after exercise has been reported in other studies on healthy pregnant women (21). We speculate that post-exercise decreased vascular resistance results in increased blood flow to the fetus. If the fetus was hypoxic, one would expect vasoconstriction in placental

circulation, resulting in an increased vascular resistance, and elevations in Doppler indices. Thus, this change with exercise is likely a reassuring finding.

In the HHS Advisory Committee report (9) it is noted that approximately 600 studies were published between 1985 and 1994 indicating exercise during pregnancy causes “no harm,” and many studies have reported no negative effects on several pregnancy outcomes, including rate of preterm delivery, birth weight, and mode of delivery (16,25). However, fewer data are available on fetal responses to exercise and this study provides evidence that acute fetal well-being is not negatively affected when exercising according to recommendations.

In the recent HHS recommendations for the general population, various methods of gauging exercise intensity are provided in addition to target heart rates. Perceived exertion scales are one suggested method. RPE scales have been validated as a clear, concise, and effective means to regulate exercise intensity in a number of populations (26). Two scales are generally used, the original 6-20 scale and the category RPE scale, ranging from 0 to 10, with numbers anchored by verbal expressions that are simple and understandable (20). According to the HHS guidelines, a 5 to 6 on the category RPE scale reflects moderate intensity and a 7 to 8 reflects vigorous intensity. However, this may not be appropriate for pregnant women. In the present study, RPE scores during both moderate and vigorous exercise sessions were lower than these recommendations. During moderate exercise, all women, regardless of activity status, provided similar numbers (mean 2.5 to 2.7). Similarly, during vigorous exercise, mean RPE ranged from 3.8 to 4.2. This finding is in agreement with existing data (27,28) and is concerning since pregnant women may not perceive when the exercise intensity is high. Thus, if using RPE to gauge intensity, they may exercise significantly more intensely than the guidelines intend. More data are needed to evaluate the use of RPE for exercise intensity monitoring in pregnant women.

There are several strengths of the current study. First, the existing guidelines for exercise during pregnancy were evaluated in a practical manner. Walking is one of the easiest and most accessible forms of exercise; therefore, these findings are applicable to most healthy pregnant women. Second, women were classified according to activity level and tested accordingly. This is important since providers appear to provide different recommendations to women depending on their pre-pregnancy activity levels. Third, women underwent a peak exercise test to more accurately prescribe the recommended intensity ranges. Fourth, a variety of fetal well-being tests were performed to provide an overall assessment of fetal status.

This study was limited in that it was not powered to address neonatal outcomes. However, we did collect delivery data and all women delivered healthy infants. Although two women delivered between 36 and 37 weeks, the deliveries were uncomplicated and both babies were discharged from the hospital 2 days after delivery.

Additionally, this study only evaluated fetal responses to a single exercise session between 28 and 32-6/7 weeks gestation. It is possible that responses are different at different gestational ages. Our results also only apply to exercise performed in the currently prescribed intensity ranges and may not apply to very strenuous exercise. Furthermore, these findings only address healthy women, without pregnancy complications. Other populations and various gestational ages need to be studied. For example, all of the women in our study had normal pre-pregnancy BMIs. Pre-pregnancy BMI and excess gestational weight gain have both increased over the years in women of childbearing age, placing these women at higher risk for pregnancy complications (29). Among other interventions, increasing

physical activity is likely an important intervention and more data on safety of exercise in this subgroup of pregnant women are needed.

We also acknowledge that a limitation in this investigation, and other studies on exercise during pregnancy, is that fetal well-being measures were assessed immediately post-exercise rather than during exercise as it is technologically difficult to evaluate the fetus during exercise. Many studies have limited their exercise to stationary cycle ergometry as an exercise mode in an effort to improve fetal monitoring; however, this has also proven technologically difficult. We chose walking/jogging as it is a very practical and popular mode of exercise for pregnant women. If the fetus was hypoxic during the exercise session, we would expect the fetal-well being measures to be non-reassuring after exercise. We found no untoward fetal responses to the individually prescribed exercise in our study population.

In conclusion, providers should feel more reassured that pregnant women can exercise during pregnancy when following existing exercise recommendations (6,8). We are highly encouraged that in our study population, existing exercise recommendations were well-tolerated by women and their babies. Importantly, we did not identify any adverse acute fetal responses to current exercise recommendations. It is our hope that this investigation will justify the initiation of larger trials to address the safety of exercise in pregnancy. The potential public health benefits of exercise are too great for obstetricians to miss the opportunity to effectively counsel pregnant women about this important health-enhancing behavior.

Acknowledgments

The authors thank Kathryn A. Carson, Sc.M. for assisting with the statistical analysis. She is supported by the Johns Hopkins Institute for Clinical and Translational Research grant number UL1RR025005 from the National Institutes of Health/National Center for Research Resources.

Dr. Szymanski was supported on a grant from the National Institutes of Health Clinical Loan Repayment Program (National Institute of Child Health and Human Development).

References

1. Clarke PE, Gross H. Women's behaviour, beliefs and information sources about physical exercise in pregnancy. *Midwifery*. 2004; 20:133–41. [PubMed: 15177856]
2. Entin PL, Munhall KM. Recommendations regarding exercise during pregnancy made by private/small group practice obstetricians in the USA. *J Sports Sci Med*. 2006; 5:449–58.
3. Bauer PW, Broman CL, Pivarnik JM. Exercise and pregnancy knowledge among healthcare providers. *J Womens Health (Larchmt)*. 2010; 19:335–41. [PubMed: 20113144]
4. American College of Obstetricians and Gynecologists. Exercise during pregnancy and the postpartum period. ACOG Technical Bulletin Number 189. *Int J Gynaecol Obstet*. 1994; 45:65–70. [PubMed: 7913067]
5. Pate RR, Pratt M, Blair SN, Haskell WL, Macera CA, Bouchard C, et al. Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *JAMA*. 1995; 273:402–7. [PubMed: 7823386]
6. American College of Obstetricians and Gynecologists. Exercise during pregnancy and the postpartum period. ACOG Committee Opinion No 267. *Obstet Gynecol*. 2002; 99:171–3. [PubMed: 11777528]
7. Haskell WL, Lee I. Physical activity and public health. Updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Circulation*. 2007; 116:1081–93. [PubMed: 17671237]
8. U.S. Department of Health and Human Services. 2008 Physical Activity Guidelines for Americans. Department of Health and Human Services; Washington, DC: 2008.

9. Physical Activity Guidelines Advisory Committee. Physical Activity Guidelines Advisory Committee Report, 2008. Washington, DC: U.S. Department of Health and Human Services; 2008.
10. Borodulin KM, Evenson KR, Wen F, Herring AH, Benson AM. Physical activity patterns during pregnancy. *Med Sci Sports Exerc.* 2008; 40:1901–8. [PubMed: 18845974]
11. Evenson KR, Savitz DA, Huston SL. Leisure-time physical activity among pregnant women in the US. *Paediatr Perinat Epidemiol.* 2004; 18:400–7. [PubMed: 15535815]
12. Gaston A, Cramp A. Exercise during pregnancy: A review of patterns and determinants. *J Sci Med Sport.* 2011; 14:299–305. [PubMed: 21420359]
13. Ning Y, Williams MA, Dempsey JC, Sorensen TK, Frederick IO, Luthy DA. Correlates of recreational physical activity in early pregnancy. *J Matern Fetal Neonatal Med.* 2003; 13:385–93. [PubMed: 12962263]
14. Poudevigne MS, O'Connor PJ. A review of physical activity patterns in pregnant women and their relationship to psychological health. *Sports Med.* 2006; 36:19–38. [PubMed: 16445309]
15. Clapp JF. Long-term outcome after exercising throughout pregnancy: fitness and cardiovascular risk. *Am J Obstet Gynecol.* 2008; 199:489.e1–6. [PubMed: 18667190]
16. Hegaard HK, Pedersen BK, Nielsen BB, Damm P. Leisure time physical activity during pregnancy and impact on gestational diabetes mellitus, pre-eclampsia, preterm delivery and birth weight: a review. *Acta Obstet Gynecol Scand.* 2007; 86:1290–6. [PubMed: 17851805]
17. Dempsey JC, Sorensen TK, Williams MA, Lee IM, Miller RS, Dashow EE, Luthy DA. Prospective study of gestational diabetes mellitus risk in relation to maternal recreational physical activity before and during pregnancy. *Am J Epidemiol.* 2004; 159:663–70. [PubMed: 15033644]
18. Maulik D, Mundy D, Heitmann E, Maulik D. Evidence-based approach to umbilical artery Doppler fetal surveillance in high-risk pregnancies: an update. *Clin Obstet Gynecol.* 2010; 53:869–78. [PubMed: 21048454]
19. Mottola MF, Davenport MH, Brun CR, Inglis SD, Charlesworth S, Sopper MM. VO₂peak prediction and exercise prescription for pregnant women. *Med Sci Sports Exerc.* 2006; 38:1389–95. [PubMed: 16888450]
20. Borg GA. Psychophysical bases of perceived exertion. *Med Sci Sports Exerc.* 1982; 14:377–81. [PubMed: 7154893]
21. Rafla NM, Beazely JM. The effect of maternal exercise on fetal umbilical artery waveforms. *Eur J Obstet Gynecol Reprod Biol.* 1991; 40:119–22. [PubMed: 2070949]
22. Acharya G, Wilsgaard T, Berntsen GK, Maltau JM, Kiserud T. Reference ranges for serial measurements of umbilical artery Doppler indices in the second half of pregnancy. *Am J Obstet Gynecol.* 2005; 192:937–44. [PubMed: 15746695]
23. Macones GA, Hankins GD, Spong CY, Hauth J, Moore T. The 2008 National Institute of Child Health and Human Development workshop report on electronic fetal monitoring: update on definitions, interpretation, and research guidelines. *Obstet Gynecol.* 2008; 112:661–6. [PubMed: 18757666]
24. Alexander GR, Himes JH, Kaufman RB, Mor J, Kogan M. A United States national reference for fetal growth. *Obstet Gynecol.* 1996; 87:163–8. [PubMed: 8559516]
25. Morris SN, Johnson NR. Exercise during pregnancy: a critical appraisal of the literature. *J Reprod Med.* 2005; 50:181–8. [PubMed: 15841930]
26. Russell WD. On the current status of rated perceived exertion. *Percept Mot Skills.* 1997; 84:799–808. [PubMed: 9172185]
27. Wolfe LA, Ohtake PJ, Mottola MF, McGrath MJ. Physiological interactions between pregnancy and aerobic exercise. *Exerc Sport Sci Rev.* 1989; 17:295–351. [PubMed: 2676551]
28. O'Neill ME, Cooper KA, Mills CM, Boyce ES, Hunyor SN. Accuracy of Borg's ratings of perceived exertion in the prediction of heart rates during pregnancy. *Br J Sports Med.* 1992; 26:121–4. [PubMed: 1623357]
29. IOM (Institute of Medicine) and NRC (National Research Council). *Weight Gain During Pregnancy: Reexamining the Guidelines.* Washington, DC: The National Academies Press; 2009.

Table 1

Baseline Maternal Demographic and Descriptive Variables

Variable	Non-Exercisers (n=15)	Regularly Active (n=15)	Highly Active (n=15)	P
Age (y)	32.9 ± 5.8	34.3 ± 2.5	32.9 ± 4.0	.47
Race				.54
White	10	13	13	
African American	1	1	1	
Asian	4	0	1	
Hispanic	0	1	0	
Nulliparous	9	7	13	.07
Body mass index (kg/m ² ; prepregnancy)	24.2 ± 4.2	22.9 ± 2.8	22.3 ± 2.4	.35
Body mass index (kg/m ² ; at testing)	27.6 ± 3.6	27.2 ± 2.8	25.9 ± 2.2	.40
Gestational age (wks)	30.7 ± 1.1	30.2 ± 0.9	30.3 ± 1.0	.40
Resting systolic blood pressure (mm Hg)	103 ± 9.7	107 ± 9.5	108.3 ± 7.0	.25
Resting diastolic blood pressure (mm Hg)	60.2 ± 7.1	63.5 ± 8.9	67.4 ± 6.9	.04
Maternal resting heart rate (bpm)	79.0 ± 11.6	71.9 ± 7.4	61.6 ± 7.2	<.001*
Maternal peak heart rate (bpm)	163.0 ± 18.8	163.3 ± 8.9	172.4 ± 11.7	.12
Treadmill time (minutes)	12.1 ± 3.6	16.6 ± 3.4	22.3 ± 2.9	<.001†
Predicted VO ₂ peak (ml/kg/min)	21.3 ± 2.5	23.8 ± 2.2	27.7 ± 1.4	<.001†
Rating of perceived exertion (peak)	8.0 ± 1.6	8.3 ± 1.3	9.1 ± 0.6	.21

Data are mean ± SD or n.

* Highly Active different from other groups; No difference between Non-Exercisers and Regularly Active.

† All groups different from each other.

Table 2
Maternal Parameters During Moderate-Intensity Exercise Sessions

Variable	Non-Exercisers (n=15)	Regularly Active (n=15)	Highly Active (n=15)	P
Gestational age (wks)				.16
Mean \pm standard deviation	31.7 \pm 0.8	31.1 \pm 1.2	31.1 \pm 0.9	
Median (range)	32.1 (30.1 – 32.9)	31.1 (29.4 – 32.9)	31.0 (29.4 – 32.4)	
Average maternal heart rate (bpm)				.64
Mean \pm standard deviation	121.7 \pm 11.9	119.2 \pm 7.0	118.7 \pm 9.2	
Median (range)	126 (104 – 139)	123 (104 – 128)	117 (107 – 138)	
Percent of heart-rate reserve				.83
Mean \pm standard deviation	51.2 \pm 2.9	51.9 \pm 2.9	51.1 \pm 3.4	
Median (range)	51 (47 – 56)	52 (48 – 57)	52 (43 – 55)	
Rating of perceived exertion				.72
Mean \pm standard deviation	2.7 \pm 1.4	2.5 \pm 0.6	2.6 \pm 0.5	
Median (range)	3.0 (1.0 – 6.0)	2.3 (1.5 – 4.0)	2.8 (2.0 – 3.3)	

Table 3

Fetal Parameters During Moderate-Intensity Exercise Sessions

Variable		Non-Exercisers (n=15)	Regularly Active (n=15)	Highly Active (n=15)
Fetal heart rate (bpm)	Pre	142.3 ± 6.9	135.4 ± 7.7	138.9 ± 9.6
	Post	149.5 ± 9.5	146.5 ± 10.8*	146.9 ± 7.3
<u>Umbilical artery</u>				
Systolic to diastolic ratio	Pre	2.54 ± .33	2.63 ± .30	2.62 ± .23
	Post	2.57 ± .31	2.67 ± .44	2.58 ± .34
Resistance Index	Pre	.60 ± .05	.61 ± .04	.61 ± .05
	Post	.60 ± .05	.61 ± .06	.61 ± .05
Pulsatility Index	Pre	.85 ± .10	.88 ± .09	.88 ± .07
	Post	.87 ± .09	.89 ± .12	.87 ± .10

bpm, beats per minute

* Pre-exercise and Postexercise difference ($P=0.01$).

P-values for umbilical artery Doppler indices (group, time, interaction): Systolic to diastolic ratio: 0.70, 0.86, 0.61; Resistance Index: 0.75, 0.52, 0.84; Pulsatility Index: 0.70, 0.89, 0.58.

Table 4
Maternal Parameters During Vigorous-Intensity Exercise Sessions

Variable	Regularly Active (n=11)	Highly Active (n=13)	P
Gestational age (wks)			.43
Mean \pm standard deviation	31.6 \pm .9	31.4 \pm .9	
Median (range)	31.7 (30.1 – 32.9)	31.4 (30.0 – 32.9)	
Average maternal heart rate (bpm)			.43
Mean \pm standard deviation	138.4 \pm 7.0	142.2 \pm 9.1	
Median (range)	142 (123 – 145)	140 (128 – 156)	
Percent of heart-rate reserve			.62
Mean \pm standard deviation	72.1 \pm 3.4	73.5 \pm 5.7	
Median (range)	73.0 (66 – 77)	73.0 (65 – 83)	
Rating of perceived exertion			.54
Mean \pm standard deviation	4.2 \pm 1.3	3.8 \pm .7	
Median (range)	3.6 (3.0 – 7.0)	4 (2.8 – 4.7)	

Table 5

Fetal Parameters During Vigorous-Intensity Exercise Session

Variable	Regularly Active (n=11)		Highly Active (n=13)	
Fetal heart rate (bpm)	Pre	133.5 ± 7.4	137.2 ± 9.9	
	Post	153.1 ± 8.8*	156.8 ± 10.7*	
<u>Umbilical artery</u>				
Systolic to diastolic ratio	Pre	2.71 ± .45	2.51 ± .20	
	Post [†]	2.46 ± .39	2.5 ± .27	
Resistance Index	Pre	.62 ± .05	.60 ± .03	
	Post [†]	.58 ± .06	.59 ± .05	
Pulsatility Index	Pre	.90 ± .11	.85 ± .07	
	Post [†]	.83 ± .13	.82 ± .09	

bpm, beats per minute.

* Pre-exercise and postexercise difference ($P=0.001$)[†] Significant main effect for "time" ($P<0.05$)

P values for umbilical artery Doppler indices (group, time, interaction): Systolic to diastolic ratio: 0.47, 0.02, 0.16; Resistance Index: 0.56, 0.02, 0.21; Pulsatility Index: 0.48, 0.02, 0.22.