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Strenuous Exercise During Pregnancy: Is There a Limit?

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Abstract

Objective—To evaluate fetal responses to strenuous exercise in physically active and inactive women.

Study Design—45 healthy women (15 Non-Exercisers, 15 Regularly Active, 15 Highly Active) underwent a peak treadmill test at 28-0/7 to 32-6/7 weeks. Fetal well-being [umbilical artery Dopplers, fetal heart tracing/rate, biophysical profile (BPP)] was evaluated pre and post-exercise. Uterine artery Dopplers were also obtained.

Results—Umbilical and uterine artery Doppler indices were similar among activity groups and did not change with exercise (P>.05). BPP and fetal heart tracings were reassuring in all groups. However, subgroup analyses showed transient post-exercise fetal heart rate decelerations and elevated umbilical and uterine artery Doppler indices in 5 Highly Active women. Following this, BPP and fetal heart tracings were reassuring.

Conclusions—Overall fetal well-being is reassuring after short-duration, strenuous exercise in both active and inactive pregnant women. A subset of Highly Active women experienced transient fetal heart rate decelerations and Doppler changes immediately after exercise. Athletes may push beyond a threshold intensity at which fetal well-being may be compromised. However, potential impact on neonatal outcomes is unknown.

Keywords

Exercise; Fetal-well being; Pregnancy; Umbilical artery Doppler; Uterine artery Doppler

INTRODUCTION

Existing guidelines for exercise during pregnancy do not adequately address “vigorous” or “strenuous” exercise.[1,2] According to the American College of Obstetricians and Gynecologists (ACOG), information on strenuous exercise is scarce and women who engage in such activities require close medical supervision.[2] In the *2008 Physical Activity*

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Guidelines for Americans, the U.S. Department of Health and Human Services (HHS) emphasizes that vigorous-intensity aerobic activity during pregnancy has not been studied carefully and women who have not been exercising prior to pregnancy should not begin vigorous exercise.[1]

One of the difficulties in evaluating existing research on exercise during pregnancy is that "strenuous" and "vigorous" are inconsistently defined. In the recent HHS guidelines, vigorous intensity is defined in absolute terms as 6.0 metabolic equivalents (METs) or, in relative terms, as 60–84% of aerobic capacity reserve (or heart rate reserve).[1] Exercise over this intensity level in pregnant women is not addressed, and there is no defined upper limit of safety. The dilemma facing providers was appropriately summarized by Pivarnik: "It is difficult for clinicians to counsel athletes adequately on safe levels of training during pregnancy. Any clinician who chooses not to follow the ACOG guidelines assumes some level of additional risk". [3] As a result of a lack of data, guidelines for vigorous or strenuous exercise are vague.

Thus, there is insufficient data to counsel pregnant women on strenuous exercise, particularly athletes who wish to continue training during pregnancy. When athletes turn to their provider for advice, they are unable to receive evidence-based responses. To further highlight the need for more information, a recent small study reported fetal well-being may be compromised during strenuous exercise in elite athletes.[4] Thus, the primary purpose of this study was to evaluate fetal responses to high intensity, i.e., "strenuous", exercise in active and inactive pregnant women.

MATERIALS AND METHODS

The current study is part of a larger investigation of exercise during pregnancy and results regarding fetal responses to current exercise recommendations for moderate and vigorous intensity exercise have been published.[5] The present study includes unpublished data on fetal well-being and uterine artery Doppler data in response to strenuous exercise.

Participants included healthy women with low-risk, accurately dated (last menstrual period confirmed by first or second trimester ultrasound) pregnancies. 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, placenta previa, any chronic medical condition, gestational diabetes or hypertension, or a fetus with known structural or chromosomal abnormalities, or growth restriction. Testing was performed between 28-0/7 and 32-6/7 weeks gestation. This gestational age range was chosen because fetal well-being tests, particularly umbilical artery Doppler measurements, are generally more informative after 28 weeks.

Women were classified into one of 3 groups according to self-reported physical activity during the 6 months prior to and continuing into pregnancy: 1) *Non-Exercisers* did not perform regular physical activity (defined as greater than 20 minutes per session for more than 3 times per week); 2) *Regularly Active* described their activity as mild to moderate for at least 20 minutes per session 3 or more days per week; 3) *Highly Active* were predominantly runners who described their activity as vigorous more than 4 days per week. The Johns Hopkins University School of Medicine Institutional Review Board approved the protocol and all participants provided written informed consent.

All women underwent a peak treadmill test to volitional fatigue according to a modified Balke protocol.[6] In the current study, this is defined as "strenuous" exercise. After a warm-up at 3.0 mph and 0% grade, treadmill speed was maintained at 3.0 mph and incline increased 2% every 2 minutes. After the incline reached 12%, it remained at this level and speed increased 0.2 mph every 2 minutes. Volitional fatigue was defined as the limit beyond which a participant no longer desired to continue the protocol. Treadmill time was recorded in minutes, excluding warm-up. Exercise capacity, which can be quantified by measuring oxygen consumption at maximal exercise (i.e., VO2 max), is considered the best measure of cardiovascular fitness. Since not measured in this study, VO2 peak was estimated using a validated prediction equation for pregnant women and is expressed as ml of oxygen used per kg of body weight per minute.[6]

Maternal ECG was continuously recorded. Peak heart rate achieved during the test was recorded. Percent of predicted maximum heart rate achieved was calculated using the typical equation for estimating maximum heart rate (220-age). Rating of Perceived Exertion (RPE) using the 0 to 10 point scale[7] was obtained at the end of the test. This scale has been validated as an effective means to monitor exercise intensity.[8]

Fetal well-being measures obtained at rest and immediately after exercise included umbilical artery Doppler, fetal heart tracing, fetal heart rate (FHR), and biophysical profile (BPP). Uterine artery Doppler measures evaluated maternal blood flow. 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 and a fetal heart tracing was recorded. Fetal heart tracings were evaluated for "reactivity" according to established criteria for gestational age and were classified by the three-tier interpretation system.[9] Blood pressure and maternal resting heart rate were taken after 15 minutes of rest. After resting umbilical and uterine artery Doppler measures were obtained, participants performed the exercise test. Immediately post-exercise, they returned to the semi-recumbent position with a leftward tilt. Ultrasound was performed to acquire umbilical and uterine artery Doppler measures, followed by BPP and then fetal heart tracing.

Ultrasound was performed by one researcher (LMS), an obstetrician trained in maternal-fetal medicine, using a Phillips IU22 ultrasound system. Umbilical artery flow velocity waveforms were assessed using color Doppler imaging in a free loop of umbilical cord. Three to 5 time-points, each containing a minimum of 3 sequential uniform waveforms, were recorded. Uterine artery Doppler measures were obtained from the maternal right side. Color flow Doppler was used to assist in identifying the uterine artery at the point of crossover with the (external) iliac artery and velocimetry measurements were obtained approximately 1 cm distal to the crossover before branching of the uterine artery. The angle of insonation was always less than 50 degrees. Again, 3 to 5 time-points, each containing 2–3 sequential uniform waveforms, were recorded for later analysis. Built-in software calculated the systolic to diastolic (S/D) ratio, resistance index (RI), and pulsatility index (PI). Mean values were calculated for each frame and averaged over several time-points. FHR was calculated from umbilical Doppler data. The immediate-post-exercise FHR was determined from the first Doppler measure.

Gestational age at delivery, mode of delivery, birth weight, and Apgar scores were obtained from delivery records and have been previously reported.[5]

Sample size was calculated to achieve 80% power at the 0.05 level of significance using umbilical artery S/D ratios, our primary outcome measure for fetal well-being. This variable was chosen since it can be precisely measured and reproduced and has been used as a primary outcome variable in existing studies, providing data to perform a power analysis. Two analyses were performed. First, existing data[10] measuring umbilical artery S/D ratios after exercise in pregnant women at 32 weeks indicated an N of 12 per group would be sufficient. Second, reference data[11] attempting to detect a change from the 50th percentile to the 75th percentile, indicated an N of 11–13 per group, depending upon gestational age, would be sufficient. These percentiles were chosen to allow detection of smaller differences among groups. Although a change from the 50th to 90th percentile would likely be more clinically significant, this would have significantly decreased the N.

Shapiro-Wilk tests were performed to evaluate for normality. One-way analysis of variance (ANOVA) was used to compare descriptive variables among groups. Bonferroni post-hoc analyses were used to probe significant differences among groups. Differences in FHR and Doppler indices before and after the exercise tests in the 3 groups were analyzed using a two-way (group × time) ANOVA with repeated measures. Post-hoc comparisons evaluated significant differences using Bonferroni's method to correct for multiple comparisons. Subgroup analyses evaluated potential differences between those in the Highly Active group who experienced post-exercise fetal heart rate decelerations to those in the Highly Active who did not. Because of the small sample sizes, Kruskal-Wallis test was used to compare descriptive variables. Secondary to the unbalanced design in the subgroup analyses, FHR and Doppler indices were analyzed using a mixed effects regression analysis examining main effects of activity group and time (pre-post), accounting for within subject correlation, and group by time interaction. Delivery data were analyzed by either one-way ANOVA or Chi-square (categorical variables). Statistical significance was reached at P<.05. Statistical analyses were performed using STATA 12.1.

RESULTS

Forty-five healthy pregnant women, divided into 3 groups by physical activity level, participated. Subject characteristics have been previously reported.[5] Briefly, groups were similar in age, BMI, and gestational age (P>.05). Mean ages for the Non-Exercisers, Regularly Active, and Highly Active were 32.9, 34.3, and 32.9 years, respectively. All women were normal weight pre-pregnancy. Gestational age at the time of testing was 30.7±1.1, 30.2±0.9, and 30.3±1.0 weeks for Non-Exercisers, Regularly, and Highly Active, respectively. As expected, maternal resting heart rate (P<.001) was lower in the Highly Active (61.6±7.2) compared with Non-Exercise (79.0±11.6) and Regularly Active (71.9±7.4) groups (P<.001). Maternal heart rate at peak exercise (Non-Exercisers: 163.0±18.8; Regularly Active: 163.3±8.9; Highly Active: 172.4±11.7) and percent of predicted maximum heart rate achieved (Non-Exercisers: 87±10.8; Regularly Active: 87.9±4.8; Highly Active: 92.1±5.7) were similar (P>.05). Predictably, treadmill time in minutes (Non-Exercisers: 12.1±3.6; Regularly Active: 16.6±3.4; Highly Active: 22.3±2.9) and predicted VO2 peak in ml/kg/min (Non-Exercisers: 21.3±2.5; Regularly Active: 23.8±2.2; Highly Active: 27.7±1.4) increased with increasing activity status (P<.001). RPE was similar among the groups (Non-Exercisers: 8.0±1.6; Regularly Active: 8.3±1.3; Highly Active: 9.1±0.6).

All variables were normally distributed, except uterine artery S/D ratio and PI. These data were then analyzed using log transformations, which normalized the distributions. Nontransformed means and standard deviations are reported.

FHR and Doppler indices pre and post-exercise by activity group are shown in Table 1. There were significant group differences in FHR (P=.017) and a statistically significant group by time interaction (P=.033), indicating the groups responded differently to the exercise. Planned comparisons revealed no group differences between FHR at rest; however, post-exercise FHR in the Highly Active was lower than the other groups (P<.05). Further evaluation of the data indicated post-exercise FHRs for the Highly Active included 5 subjects with post-exercise fetal heart rate decelerations. When reanalyzed excluding these 5 subjects, the mean post-exercise FHR in the Highly Active group was 149.3±10.6 and there were no group differences (P=.714). Additionally, post-exercise FHR increased (P<.001), and the group by time interaction was no longer significant (P=.553), suggesting FHR responses were similar in the three groups.

Umbilical artery indices were similar among the 3 activity groups and changed minimally with exercise (P<.05). The main effect for time was significant for umbilical artery RI only; however, the interaction was not significant and planned comparisons showed no differences between pre and post-exercise values for any group. Uterine artery indices were also similar among groups and did not change with exercise (P>.05). BPP scores were 8/8 within 30 minutes in 44/45 subjects. Time to 8/8 score was 32:57 in one Highly Active participant. Fetal heart tracings were Category I and met criteria for reactivity in all participants post-exercise.

Five women experienced transient fetal heart rate decelerations immediately post-exercise, ranging in duration from 2:08 to 3:12 minutes (average 2:37). These 5 women were all in the Highly Active group. Table 2 displays subgroup analyses comparing the Highly Active women with fetal heart rate decelerations (n=5) to Highly Active women without decelerations (n=10). Subgroups did not differ in gestational age, treadmill time, maternal peak heart rate (which ranged from 162–192 and 152–184 beats per minute in those with and without fetal heart rate decelerations, respectively) or percent of predicted maximum maternal heart rate (P>.05). FHR, umbilical and uterine artery indices were normally distributed. In addition to the significant differences in FHR between subgroups, umbilical and uterine artery Doppler indices were different. The significant subgroup by time interactions in Dopplers reflect different responses to the strenuous exercise by the subgroups. All participants in the fetal heart rate deceleration group scored 8/8 on the BPP within 30 minutes. In the Highly Active subjects without decelerations, one participant reached 8/8 in 32:57 minutes; all others were 8/8 within 30 minutes. All fetal heart tracings were Category I and met criteria for reactivity post-exercise.

COMMENT

There are two primary findings from this study. First, overall fetal well-being was reassuring after strenuous exercise in both exercisers and non-exercisers. Second, a small subset of highly active women demonstrated transient fetal heart rate decelerations and alterations in umbilical and uterine artery Dopplers immediately post-exercise.

With strenuous exercise, all participants, regardless of activity status, reported perceived exertion ratings consistent with strenuous exercise and peak maternal heart rates were similar. Umbilical artery S/D ratio, a common measure used to evaluate fetal well-being, fell within the 25th to 50th percentile for gestational age according to reference values[11] and did not significantly change with exercise. Similarly, uterine artery Doppler measures, a reflection of maternal blood flow, were near the 50th percentile for gestational age according to reference intervals[12] and did not significantly change with strenuous exercise. Furthermore, fetal heart tracings were classified as Category I and met established criteria for reactivity after exercise in all women and BPPs were reassuring. Although one participant's time to a BPP of 8/8 was 32:57, this is not likely clinically significant.

An intriguing finding in this study is the transient fetal heart rate decelerations experienced by a subset of participants. Interestingly, each woman who experienced an immediate post-exercise fetal heart rate deceleration was in the Highly Active group. The subgroup numbers are small; thus, the data must be interpreted cautiously. It is also important to note that these decelerations were of short duration (mean 2:37 minutes), not technically meeting the definition of a bradycardia, defined as lasting 10 minutes or more.[9] However, in addition to the fetal heart rate decelerations, changes were also seen in umbilical and uterine artery parameters. In the Highly Active women with fetal heart rate decelerations, umbilical artery S/D ratio increased with exercise, which is a different and potentially more concerning response. Additionally, uterine artery PI increased to the 90th percentile according to reference data.[12] This may indicate a brief relative reduction in maternal blood flow to the uterus in some women immediately after strenuous exercise. This brief alteration in resistance indices did not appear to affect overall fetal-well being, as all scored 8/8 BPPs shortly after exercise and all fetal heart tracings were reactive. Importantly, we recently reported no fetal heart rate decelerations or untoward fetal responses after vigorous exercise, defined as 60–84% of heart rate reserve,[5] suggesting this response may only occur with exercise intensity over the "vigorous" threshold.

Our results are similar to a recently published study evaluating fetal well-being after strenuous exercise between 23–29 weeks gestation in Olympic-level athletes.[4] In 2 of the 6 athletes, fetal "bradycardias" were noted when maternal heart rate exceeded 90% of maximum. Additionally, elevated umbilical artery PI was seen in these 2 women. Uterine artery Doppler studies determined overall flow was less than 50% of the initial value in these women. Their fetuses recovered quickly with no signs of sustained bradycardia or elevated Dopplers in the following 10 minutes. The overall conclusions by the authors were that fetal well-being may be compromised when exercise intensity exceeds 90% of maximum maternal heart rate and that uterine artery blood flow was reduced 25–60% during intensive exercise. However, similar to the current study, they recognize the sample size is small and results should be interpreted with caution. It is difficult to compare our findings to Salveson et al.[4] in terms of percent of predicted maximum maternal heart rate achieved during exercise. Because they did not report maternal heart rate data, we are unable to determine how percent of maximum heart rate achieved was calculated. Using standard prediction equations in the present study, all Highly Active participants achieved over 90% of predicted maximum heart rate. Although those with fetal heart rate decelerations achieved a slightly higher percentage (95.9 vs 90.3), this was not statistically significant. Importantly, the sample sizes are small, making it difficult to draw conclusions. Additionally, the accuracy of predicting maximum heart rate in pregnant women is unclear as existing literature indicates conflicting results with most studies reporting no change in maternal maximum heart rate with pregnancy[13] while others suggest an attenuation.[14]

In the present study, the mean peak maternal heart rates achieved by all activity groups were significantly greater than 140 beats per minute, the threshold heart rate many providers advise women not to exceed during exercise.[15] Notably, ACOG removed this restriction from their exercise recommendations in 1994.[16] More data are needed before we are able to provide evidence-based threshold heart rates for exercising women.

A strength of our study is that a variety of fetal well-being tests were performed, all of which were reassuring in all women after strenuous exercise. Additionally, we evaluated both exercisers and non-exercisers, which is important since exercise recommendations differ depending upon a woman's activity status.[1,2]

An obvious limitation to this study is that the fetal well-being measures were not evaluated during exercise. Monitoring fetal heart rate during exercise is technically difficult and previous early investigations that reported fetal bradycardias during exercise[17] likely reported artifact from exercise movement.[18,19] We believe the immediate post-exercise results are a good representation of fetal well-being. It is often hypothesized that maternal hypoxemia contributes to fetal bradycardia. We did not measure maternal oxygenation status or lactate with exercise. However, if the fetus was hypoxic during the exercise, post-exercise measures would likely be nonreassuring. We did not see any nonreassuring fetal responses to exercise and the decelerations were all transient. Moreover, Salveson et al.[4] did not find differences in lactate levels between the exercisers with and without fetal bradycardias. It has also been speculated that fetal bradycardias with maternal exercise[20,21] may be related to maternal catecholamine release, leading to a reduction in uterine blood flow. Importantly, in these studies, similar to the current study, the brief "bradycardic" episodes appeared to be well-tolerated by the fetuses.

Another limitation to the present study is that it only involves healthy women of normal weight prior to pregnancy. Responses may be different in obese women and women with medical complications, such as hypertension or diabetes. We also only evaluated responses to strenuous exercise at one time-point in the third trimester. Responses could differ at different gestational ages. Additionally, this study was not powered to evaluate neonatal outcomes. However, all delivery data was reassuring and all deliveries were uncomplicated. All delivered at term, with the exception of two participants, one non-exerciser (36-1/7 weeks) and one highly active participant (36-6/7 weeks). Both of these neonates were discharged home on day two with their mothers.

In conclusion, overall fetal well-being is reassuring after short-duration, strenuous exercise in both active and inactive pregnant women. However, a subset of highly active women experienced transient fetal heart rate decelerations and alterations in umbilical and uterine artery Dopplers immediately after exercise. Although all of the fetuses subsequently showed reassuring fetal testing responses and the decelerations were short in duration, further research is needed on exercise in pregnant athletes to determine if an upper limit of exercise exists that, if exceeded, places their fetus at risk. Pregnant athletes, particularly elite athletes, may benefit from individualized exercise prescriptions as they may push themselves beyond a threshold where measures of fetal well-being may be compromised. However, the clinical significance of a transient "bradycardia" is unclear. Whether or not this translates into adverse neonatal outcomes is not known. No available neonatal data suggests adverse outcomes.

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REFERENCES

1. U.S. Department of Health and Human Services. 2008 Physical Activity Guidelines for Americans. Washington, DC: Department of Health and Human Services; 2008.
2. American College of Obstetricians and Gynecologists. Exercise during pregnancy and the postpartum period. ACOG Committee Opinion No. 267. Obstet Gynecol. 2002; 99:171–173. [PubMed: 11777528]
3. Pivarnik JM, Perkins CD, Moyerbrailean T. Athletes and pregnancy. Clin Obstet Gynecol. 2003; 46:403–414. [PubMed: 12808390]
4. Salvesen KA, Hem E, Sundgot-Borgen J. Fetal wellbeing may be compromised during strenuous exercise among pregnant elite athletes. Br J Sports Med. 2012; 46:279–283. [PubMed: 21393257]
5. Szymanski LM, Satin AJ. Exercise during pregnancy: Fetal responses to current public health guidelines. Obstet Gynecol. 2012; 119:603–610. [PubMed: 22314872]
6. 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; 38:1389–1395. [PubMed: 16888450]
7. Borg GA. Psychophysical bases of perceived exertion. Med Sci Sports Exerc. 1982; 14:377–381. [PubMed: 7154893]

8. Russell WD. On the current status of rated perceived exertion. Percept Mot Skills. 1997; 84:799–808. [PubMed: 9172185]
9. 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; 112:661–666. [PubMed: 18757666]
10. Rafla NM, Beazely JM. The effect of maternal exercise on fetal umbilical artery waveforms. Eur J Obstet Gynecol Reprod Biol. 1991; 40:119–122. [PubMed: 2070949]
11. 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; 192:937–944. [PubMed: 15746695]
12. Flo K, Wilsgaard T, Acharya G. A new non-invasive method for measuring uterine vascular resistance and its relationship to uterine artery Doppler indices: a longitudinal study. Ultrasound Obstet Gynecol. 2011; 37:538–542. [PubMed: 21154788]
13. McMurray RG, Mottola MF, Wolfe LA, Artal R, Millar L, Pivarnik JM. Recent advances in understanding maternal and fetal responses to exercise. Med Sci Sports Exerc. 1993; 25:1305–1321. [PubMed: 8107536]
14. Wolfe LA, Mottola MF. Aerobic exercise in pregnancy: an update. Can J Appl Physiol. 1993; 18:119–147. [PubMed: 8513287]
15. Bauer PW, Broman CL, Pivarnik JM. Exercise and pregnancy knowledge among healthcare providers. J Womens Health (Larchmt). 2010; 19:335–341. [PubMed: 20113144]
16. American College of Obstetricians and Gynecologists. Exercise during pregnancy and the postpartum period. ACOG Technical Bulletin No. 189. February 1994. Int J Gynaecol Obstet. 1994; 45:65–70. [PubMed: 7913067]
17. Jovanovic L, Kessler A, Peterson CM. Human maternal and fetal response to graded exercise. J Appl Physiol. 1985; 58:1719–1722. [PubMed: 3888949]
18. Clapp JF, Little KD, Capeless EL. Fetal heart rate response to sustained recreational exercise. Am J Obstet Gynecol. 1993; 168:198–206. [PubMed: 8420327]
19. Paolone AM, Shangold M, Paul D, Minnitti J, Weiner S. Fetal heart rate measurement during maternal exercise--avoidance of artifact. Med Sci Sports Exerc. 1987; 19:605–609. [PubMed: 3323767]
20. Artal R, Romem Y, Paul RH, Wiswell R. Fetal bradycardia induced by maternal exercise. Lancet. 1984; 2:258–260. [PubMed: 6146811]
21. Artal R, Rutherford S, Romem Y, Kammula RK, Dorey FJ, Wiswell RA. Fetal heart rate responses to maternal exercise. Am J Obstet Gynecol. 1986; 155:729–733. [PubMed: 3766626]

Table 1

Fetal Heart Rate and Doppler Indices Pre and Post-Exercise in All Groups

Variable	Non-Exercisers (n=15)	Regularly Active (n=15)	Highly Active* (n=15)	*P*
Fetal Heart Rate (beats per minute)				Group: .017
Pre	141.8 ± 8.4	137.7 ± 6.5	138.9 ± 8.1	Time: .660
Post	148.5 ± 10.3	147.9 ± 16.2	126.8 ± 34.4	Interact: .033
Umbilical Artery S/D Ratio				Group: .330
Pre	2.58 ± .34	2.71 ± .38	2.69 ± .26	Time: .100
Post	2.51 ± .42	2.45 ± .28	2.70 ± .45	Interact: .232
Umbilical Artery RI				Group: .306
Pre	.60 ± .05	.62 ± .05	.62 ± .04	Time: .018
Post	.59 ± .06	.58 ± .05	.62 ± .05	Interact: .320
Umbilical Artery PI				Group: .236
Pre	.86 ± .11	.90 ± .10	.90 ± .07	Time: .074
Post	.83 ± .12	.83 ± .09	.91 ± .15	Interact: .208
Uterine Artery S/D Ratio				Group: .279
Pre	1.96 ± .48	1.91 ± .28	1.98 ± .32	Time: .518
Post	1.85 ± .25	1.95 ± .41	2.17 ± .50	Interact: .242
Uterine Artery RI				Group: .270
Pre	.46 ± .10	.47 ± .08	.48 ± .08	Time: .511
Post	.45 ± .07	.47 ± .09	.52 ± .09	Interact: .257
Uterine Artery PI				Group: .232
Pre	.61 ± .18	0.61 ± .13	.64 ± .14	Time: .457
Post	.59 ± .12	0.62 ±.16	.73 ± .22	Interact: .266

Data are mean ± Standard Deviation.

*Includes 5 subjects with bradycardias. S/D: Systolic to Diastolic ratio; RI: Resistance Index; PI: Pulsatility Index.

P values: Two-way ANOVA with repeated measures. Main effects for group and time (pre and post-exercise) and group by time interaction.

Table 2

Peak treadmill test results and pre and post exercise fetal heart rate and Doppler indices in Highly Active women with and without fetal heart rate decelerations

Variable	Highly Active - No Decelerations (n=10)	Highly Active - Decelerations (n=5)	*P*
Gestational Age (weeks)	30.2 ± .9	30.7 ± 1.2	.327
Treadmill time (minutes)	22.8 ± 2.9	21.2 ± 2.7	.178
Maternal peak heart rate	169.4 ± 10.6	178.4 ± 12.5	.391
Percent of predicted maternal max heart rate	90.3 ± 5.1	95.9 ± 5.3	.072
Fetal heart rate			Group: <.001
Pre	137 ± 6.5	142.8 ± 10.4	Time: <.001
Post	149.3 ± 10.6	81.8 ± 10.01	Interact: <.001
Umbilical Artery S/D Ratio			Group: .012
Pre	2.70 ± .25	2.67 ± .31	Time: .035
Post	2.46 ± .21	3.19 ± .41	Interact: <.001
Umbilical Artery RI			Group: .029
Pre	.63 ± .03	.62 ± .05	Time: .018
Post	.59 ± .03	.67 ± .05	Interact: .001
Umbilical Artery PI			Group: .026
Pre	.90 ± .07	.90 ± .10	Time: .065
Post	.83 ± .07	1.05 ± .15	Interact: .001
Uterine Artery S/D Ratio			Group: .180
Pre	1.97 ± .32	2.00 ± .36	Time: .876
Post	1.99 ± .32	2.55 ± .63	Interact: .018
Uterine Artery RI			Group: .240
Pre	.48 ± .07	.49 ± .09	Time: .829
Post	.48 ± .07	.59 ± .11	Interact: .029
Uterine Artery PI			Group: .189
Pre	.64 ± .13	0.64 ± .16	Time: .913
Post	.64 ± .13	0.89 ± .30	Interact: .027

Data are mean ± Standard Deviation. S/D: Systolic to Diastolic ratio; RI: Resistance Index; PI: Pulsatility Index.

P values: Mixed effects regression analysis. Include main effects for group and time (pre and post exercise) and group × time interaction.