Fetal Responses to Maternal Strength Conditioning Exercises in Late Gestation

Nicole D. Avery, Kimberley D. Stocking, Joan E. Tranmer, Gregory A.L. Davies, and Larry A. Wolfe

Catalogue Data

Key words: pregnancy, resistance exercise, fetal heart rate, maternal cardiovascular responses
Mots-clés: grossesse, exercices de force, fréquence cardiaque du fœtus, ajustements cardiovasculaires maternels

Abstract/Résumé
Cardiovascular responses to strength conditioning exercises were examined in 12 healthy pregnant women and their unborn fetuses during the third trimester. A group of 12 healthy nonpregnant women of similar ages, parity, body height, and pre-pregnant body mass was also studied. Maternal heart rate and blood pressure and fetal heart rate (FHR) responses were measured in both the supine (30° tilt) and seated postures during handgrip (HG), single-leg extension (SL), and double-leg extension (DL) exercise. Subjects performed 3 sets of 10 reps at 50, 70, and 90% of their 10-repetition maximum (10-RM) for each exercise in both postures. Pregnant subjects exhibited higher heart rates but similar blood pressure responses to control subjects under all experimental conditions. Significant increases were observed for the frequency of FHR accelerations (0.10 to 0.27/min) from rest to DL in the sitting posture at 90% RM. Moderate fetal bradycardia was observed occasionally in the tilted supine posture at rest and both during (SL, DL) and following (HG, SL, DL) exercise, suggesting that this posture should be avoided in late gestation. The results support the safety of moderate strength conditioning exercises in healthy pregnancy.

Douce femmes enceintes et en bonne santé participent à une étude dont l’objectif est d’analyser leurs ajustements cardio-vasculaires et ceux de leur fœtus à des exercices de force. Un groupe témoin de 12 femmes non enceintes mais de même âge, parité, masse

The authors are with the School of Physical & Health Education, Dept. of Physiology, and Dept. of Obstetrics & Gynaecology, Queen’s University. Request reprints from Larry A. Wolfe, School of Physical & Health Educ., Queen’s University, Kingston, Ontario K7L 3N6.
corporée (avant la grossesse), et taille corporelle participe aussi à l'étude. La fréquence cardiaque et la pression sanguine de la mère en plus de la fréquence cardiaque du fœtus (FHR) sont mesurées, en position inclinée à 30° et en position assise, au cours d'exercices de préhension (HG), d'extension unilatérale (SL) et bilatérale (DL) du genou. Dans chacune des postures, les sujets exécutent trois séries de dix répétitions à 50, 70, et 90% de leur capacité à 10 RM. Comparativement au groupe témoin, les femmes enceintes présentent une fréquence cardiaque plus élevée mais une pression sanguine semblable dans chacune des conditions expérimentales. Du repos à la position assise pour des exercices DL à 90% de 10-RM, l'augmentation de FHR est significative (de 0,10 à 0,27/min). Tant au repos couché qu'au cours des exercices SL et DL et après les exercices HG, SL, et DL, on observe une bradycardie modérée chez le fœtus; il y aurait donc lieu d'éviter cette posture en fin de grossesse. Nos observations indiquent que les exercices modérés de force ne sont pas contre-indiqués chez les femmes enceintes en bonne santé.

Introduction

The safety of high intensity muscular exertion during late gestation has long been a subject of concern (Green et al., 1988; Nesler et al., 1988; Work, 1989). Both conventional wisdom and traditional medical advice have been for pregnant women to avoid activities that involve heavy lifting or straining and which have a static or isometric exercise component. However, conditioning exercises that involve high resistance or static muscular effort have been recommended by medical authorities to promote good posture, prevent gestational low back pain and diastasis recti, and to strengthen the pelvic floor during pregnancy (American College of Obstetricians and Gynecologists [ACOG], 1985). The use of weight-training to maintain muscular fitness during gestation is also considered safe by various authorities (ACOG, 1985; Shangold, 1989; Work, 1989).

In nonpregnant subjects, static exercise evokes the “pressor response.” This includes moderate increases in heart rate and cardiac output, no significant change in stroke volume or peripheral vascular resistance, and substantial increases in both systolic and diastolic blood pressure (Asmussen, 1981; Perez-Gonzalez, 1981; Rowell and O’Leary, 1990). There is a direct linear relationship between the magnitude of the pressor response and the intensity of muscular contractions (Perez-Gonzalez, 1981), as well as the size of the active muscle mass (Lewis et al., 1985). Arterial blood pressure changes may be further augmented if the women employs the Valsalva maneuver, which can decrease blood flow to internal organs (R. Artal, cited in Work, 1989). This may cause a temporary reduction in uterine blood flow and fetal hypoxia if this maneuver is performed during static exercise in pregnancy.

Other theoretical risks of resistance exercise during pregnancy include excessive maternal blood pressure (Shangold, 1989), induction of premature labour (Durak et al., 1990), and transient fetal hypoxia (Parer, 1989). An increase in sympathetic neural activity and level of circulating plasma catecholamines during high resistance exercise could reduce blood flow and oxygen supply to the uterus, causing mild transient fetal hypoxia reflected by fetal heart rate decelerations, or bradycardia (Parer, 1989).

Only a few studies have examined the safety of strength conditioning exercises for the fetus and the mother (Hall and Kaufmann, 1987; Lotgering et al.,
1992; Nesler et al., 1988). Thus there is no reliable basis for advising pregnant women on the safety of such activity. Existing studies have reported stable fetal heart rate (FHR) patterns during isometric and isotonic exercises (Marsal et al., 1979; Ruissen et al., 1990; Webb et al., 1991), whereas others have reported transient FHR changes including changes in FHR baseline, and reduced variability or reactivity during exercise performed in the supine posture (Green et al., 1988; Nesler et al., 1988).

The purpose of this study was to examine the effects of variations in maternal posture as well as increasing exercise intensity and muscle mass on maternal and fetal cardiovascular responses to strength conditioning exercises. The following hypotheses were tested: (a) that strength conditioning exercises would not alter FHR baseline or periodic features; (b) that maternal heart rate would be elevated at rest and throughout the exercise tests compared to nonpregnant controls; (c) that increasing maternal muscle mass would augment maternal and fetal cardiovascular responses to exercise; (d) that increasing maternal exercise intensity would augment maternal and fetal cardiovascular responses; and (e) that tilted supine posture would induce different maternal and fetal cardiovascular responses compared to the sitting posture.

**Methods**

**SUBJECTS AND STUDY DESIGN**

Pregnant subjects were 12 healthy women in late gestation (gestational age at study entry 31 ± 1 wk). The results were compared to those of a control group of 12 healthy nonpregnant women with similar physical and demographic characteristics. Subjects were recruited by media advertisements, prenatal fitness classes, and antenatal clinics at Kingston General Hospital. All pregnant subjects were non-smokers who were screened medically for contraindications to exercise (ACOG, 1985) and were not taking any medications or consuming alcoholic beverages during their pregnancy. A health and lifestyle questionnaire (Fitness and Amateur Sport Canada, 1986) confirmed that none of the subjects were currently involved in a strength training program and had not been involved in such programs prior to the study. A meal was consumed 2 hrs prior to exercise testing and caffeine was avoided on the day of testing. All subjects completed and signed an informed consent form. The protocol and consent form were approved by an institutional human ethics committee.

There were three visits to the Queen’s University Clinical Exercise Physiology Laboratory, including maximal exercise testing and two submaximal exercise tests. The tests were spaced approximately one week apart.

**EXERCISE TESTING**

The first visit at 31 ± 1 wk gestation involved familiarization with equipment and determination of the 1-repetition maximum (1-RM) and 10-rep maximum (10-RM) in the sitting posture for three resistance exercises: handgrip (HG) using a Stoelting dynamometer, and single-leg (SL) and double-leg extension (DL) using a Universal Gym apparatus. The 10-RM was determined starting with the weight corresponding to 80% of 1-RM followed by the Delorme method of trial and error
(Delorme and Watkins, 1948). After the 1-RM and 10-RM were determined, the women practiced proper lifting technique with 3 sets of 10 reps at 5 kg of resistance for SL and DL, and at minimal force during HG. A 2-min rest was taken between sets. Body height, body mass, and the sum of 5 skinfolds (Fitness and Amateur Sport Canada, 1986) were also measured during this visit.

During the second laboratory visit, at 32 ± 1 wk gestation, 3 sets of 10 reps at 50, 70, and 90% of 10-RM were undertaken for each exercise test: HG, SL, and DL. Sitting or tilted supine (upper body tilted 30° up from supine) posture was assigned randomly during the first submaximal testing session. The other posture was used on the next visit, at 33 ± 1 wk gestation. During both testing days, the HG, SL, and DL exercises were performed. Since there were 6 possible combinations of exercises, 2 subjects in both the pregnant and nonpregnant groups performed each combination. Subjects were assigned randomly to these combinations. There was a 2-min rest between sets and a 20-min rest between exercises.

Maternal heart rate was monitored continuously by a Polar heart rate monitor every 5 min of the 20-min rest periods, at 0:30 and 1:30 min during the 2-min rest period between sets, and at peak exercise during a static hold at full extension (approx. 10 sec) on the 10th repetition. Maternal blood pressure was measured by auscultation at the same time periods as for maternal heart rate. FHR was recorded continuously throughout the exercise protocol using a Doppler ultrasound cardiotocograph (Hewlett-Packard Model 8041-A) by an obstetric resident.

FHR patterns were analyzed to quantify baseline features and periodic features using an established protocol (Webb et al., 1994; Wolfe et al., 1994) in accordance with the measurement criteria of Parer (1989). Baseline features include FHR baseline and long-term variability. A normal FHR baseline is between 120–160 bpm and it decreases with increasing gestational age. Tachycardia was defined as FHR >160 bpm sustained for ≥120 sec. Conversely, bradycardia was defined as FHR <120 bpm sustained for ≥120 sec. Long-term variability was considered normal between 5–25 bpm. Periodic features include accelerations defined as FHR >15 bpm from baseline for 15–120 sec, and decelerations defined as FHR <15 bpm from baseline for 15–120 sec. Accelerations are associated with fetal movement and well-being whereas decelerations are associated with mild hypoxia (Parer, 1989).

PREGNANCY OUTCOME

Pregnancy outcome data were collected from medical records by qualified medical personnel at delivery. Variables included infant gender, gestational age at delivery, number of premature births, number of postmature births, infant birth weight, Apgar scores (1 min and 5 min), labour complications, and use of analgesic medications.

STATISTICAL ANALYSIS

The physical characteristics and muscular strength of both groups upon entry into the study were compared using unpaired Student t-statistics. The maternal cardiovascular variables were analyzed within and between the nonpregnant control group, using a four-way ANOVA (posture × muscle mass × set × time) with repeated measures on all four factors. Modified Bonferroni t-statistics were performed when significant F-ratios were obtained from the analysis of variance (Keppel, 1982).
Between-group comparisons employed ANOVA to determine whether pregnancy affected heart rate and systolic and diastolic blood pressure responses. The two groups were compared for each exercise and posture in the analysis of variance. The mean cardiovascular responses for each exercise (HG, SL, and DL) were pooled and are an average of the preexercise, exercise (Sets 1–3), and recovery values (0:30 and 1:30 min) for each posture. This pooling of responses was also used for within-group comparisons.

Exercise effects on FHR were analyzed using a three-way ANOVA (muscle mass × posture × time) with repeated measures on all three factors. Tukey (HSD) post hoc comparisons were employed when significant F-ratios were obtained from the ANOVA. Interobserver reliability and reproducibility of FHR recordings were evaluated by comparing the data from the independent analysis of 12 FHR tracings by two investigators (K.D.S., J.E.T.). Interobserver reliability of FHR analyses was tested using the Pearson product-moment correlation coefficient (r), and reproducibility was examined using paired Student t-statistics. Variables examined included FHR baseline, and variability and frequency of accelerations and deceleration before, during, and after HG, SL, and DL exercise. The results of all statistical tests were considered significant at \( p \leq 0.05 \).

**Results**

**SUBJECTS**

Fourteen women in the third trimester of pregnancy and 12 nonpregnant women volunteered to participate in the study. Two members from the pregnant group were unable to complete the study due to medical complications unrelated to exercise participation. As a result, 12 women in the third trimester of pregnancy and 12 nonpregnant women completed the exercise testing sessions.

The pregnant group and nonpregnant control group had similar mean values (± SE) for age, parity, pre-pregnancy body mass, body height, and sum-of-5 skinfolds, as follows:

<table>
<thead>
<tr>
<th></th>
<th>Pregnant group</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>29 ± 1</td>
<td>29 ± 2</td>
</tr>
<tr>
<td>Parity (#)</td>
<td>0.9 ± 0.3</td>
<td>0.5 ± 0.3</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>166 ± 2</td>
<td>165 ± 1</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>70 ± 3</td>
<td>62 ± 2*</td>
</tr>
<tr>
<td>Sum-of-5 skinfolds</td>
<td>88 ± 8</td>
<td>81 ± 7</td>
</tr>
<tr>
<td>Pre-pregn. body mass (kg)</td>
<td>58 ± 2</td>
<td>na</td>
</tr>
</tbody>
</table>

*Significant differ., \( p < 0.05 \)

As expected, the pregnant group had a significantly greater mean body mass than the control group (70 ± 3 vs. 62 ± 2 kg). Age ranged from 23 to 39 years in the pregnant group and 22 to 40 in the nonpregnant control group.

There were no significant differences in strength between groups in the HG and SL exercise in the 1-RM and 10-RM. However, the nonpregnant control group achieved a significantly higher resistance at 1-RM during the DL, 37 ± 3 kg compared to 34 ± 2 kg for the pregnant group. The mean resistances achieved in the pregnant group were 14, 20, and 25 kg at 50, 70, and 90% of 10-RM, compared to 15, 21, and 26 kg in the control group.
MATERNAL RESPONSES

Heart rate was significantly higher in the pregnant group at baseline compared to the nonpregnant group in both the sitting and tilted supine postures (Figure 1). Heart rate values were higher during each exercise for the pregnant group. Heart rate values were also significantly higher in the SL than the HG, and higher in the DL than the HG exercise. Only the control group had a significant increase in heart rate from SL to DL. There was no postural effect on heart rate response for the pregnant group. The control group had significantly higher heart rates during the sitting posture than the tilted supine posture.

Blood pressure responses were similar in both groups. There were no significant differences in systolic (Figure 2a) or diastolic (Figure 2b) BP responses between groups for posture or muscle mass. For both groups, systolic and diastolic blood pressures were higher with increasing muscle mass (DL>SL>HG).

FETAL RESPONSES

There were no significant main effects for maternal posture, muscle mass, and time before, during, and after exercise for FHR baseline and frequency of FHR decelerations. The number of decelerations during and after tilted supine exercise was greater than for sitting exercise, but this effect did not reach significance. As shown in Table 1, FHR accelerations increased significantly during the DL exercise in the sitting posture from preexercise baseline (0.10 to 0.27/min). Similar trends were noted in the HG and SL exercises (both postures) and DL tilted supine without significance. An overall significant time difference was noted for FHR variability, which was found to increase significantly during the HG exercise in the supine posture (10 ± 1 bpm) from preexercise (6.9 ± 1 bpm) values.

The number of exercise-induced deviations of FHR (bradycardia or tachycardia) from normal baseline before, during, and after maternal resistance exercises was low (Table 2). One fetus had transient, borderline bradycardia (120 bpm for 3 min) in the tilted supine posture prior to exercise. However, a normal fetal tracing was obtained prior to exercise testing. This fetus had a heart rate of approximately 120 bpm during HG exercise, 115 bpm during SL exercise, and 115 bpm during DL exercise in the tilted supine posture.

Excellent agreement was found for the reliability and reproducibility of the independent analysis of 12 FHR data sets by two observers (K.D.S., J.E.T.). No significant differences were observed before, during, or after exercise between mean values for FHR baseline, variability, or frequency of accelerations or decelerations. Reliability coefficients were also high and ranged from 0.97 to 1.00 for FHR baseline, from 0.70 to 0.91 for FHR variability, and from 0.92 to 1.00 for accelerations and decelerations.

PREGNANCY OUTCOME

The incidence of labour complications in this study was low (Table 3). One woman required a Caesarian section and another had meconium staining of amniotic fluid. Six women required medication; one required an analgesic, five required anaesthetics, and two received oxytocic drugs during labour. Each stage of labour (1–3) and the total duration of labour was significantly longer for the primiparous
Figure 1. Maternal heart rate with increasing muscle mass. Results (mean ± SE) are from 90% of 10-RM. Pregnant subjects (□) had significantly higher heart rates under all conditions. DL and SL heart rates were > HG in both groups for both postures. DL heart rate was > SL only in the control group, and sitting heart rate was > supine only in the control group (■).
Figure 2a. Maternal systolic blood pressure with increasing muscle mass. Results (mean ± SE) from 90% of 10-RM. Responses of pregnant (■) and control (□) groups were similar. There was no effect of posture within groups. Systolic BP increased with increasing muscle mass in both groups.
Figure 2b. Maternal diastolic blood pressure with increasing muscle mass. Results (mean ± SE) from 90% of 10-RM. Responses of pregnant (○) and control (■) groups were similar. There was no effect of posture within groups. Diastolic BP increased with increasing muscle mass in both groups.
Table 1  Fetal HR Patterns (M ± SE) During Maternal Double-Leg Extension

<table>
<thead>
<tr>
<th>Variable</th>
<th>Position</th>
<th>Preexerc. (20 min)</th>
<th>Exercise (Sets 1–3)</th>
<th>Postexerc. (0–10 min)</th>
<th>Postexerc. (10–20 min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FHR baseline</td>
<td>Sitting</td>
<td>140 ± 3</td>
<td>140 ± 2</td>
<td>137 ± 3</td>
<td>138 ± 3</td>
</tr>
<tr>
<td>(bpm)</td>
<td>Supine</td>
<td>137 ± 2</td>
<td>139 ± 3</td>
<td>139 ± 3</td>
<td>139 ± 2</td>
</tr>
<tr>
<td>FHR variability</td>
<td>Sitting</td>
<td>6 ± 1</td>
<td>7 ± 1</td>
<td>7 ± 1</td>
<td>7 ± 1</td>
</tr>
<tr>
<td>(bpm)</td>
<td>Supine</td>
<td>7 ± 1</td>
<td>7 ± 1</td>
<td>6 ± 1</td>
<td>7 ± 1</td>
</tr>
<tr>
<td>Accelerations</td>
<td>Sitting</td>
<td>0.10 ± 0</td>
<td>0.27 ± 0*</td>
<td>0.18 ± 0</td>
<td>0.22 ± 0</td>
</tr>
<tr>
<td>(#/min)</td>
<td>Supine</td>
<td>0.12 ± 0</td>
<td>0.20 ± 0</td>
<td>0.16 ± 0</td>
<td>0.22 ± 0</td>
</tr>
<tr>
<td>Decelerations</td>
<td>Sitting</td>
<td>0</td>
<td>0</td>
<td>0.01 ± 0</td>
<td>0.01 ± 0</td>
</tr>
<tr>
<td>(#/min)</td>
<td>Supine</td>
<td>0</td>
<td>0.03 ± 0</td>
<td>0.02 ± 0</td>
<td>0.01 ± 0</td>
</tr>
</tbody>
</table>

*Significant differ. (p < 0.05) between preexercise and DL exercise in sitting position. No significant differ. (p < 0.05) between postures nor for muscle mass.

Table 2  Deviations From Normal Fetal HR Baseline Before, During, and After Maternal Resistance Exercise

<table>
<thead>
<tr>
<th>Posture</th>
<th>Moderate bradycardia</th>
<th>Moderate tachycardia</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>During</td>
</tr>
<tr>
<td>Rest</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>(sitting)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(supine)</td>
<td>1/12 (8%)</td>
<td></td>
</tr>
<tr>
<td>Hand grip</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>(sitting)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(supine)</td>
<td>none</td>
<td>1/12 (8%)</td>
</tr>
<tr>
<td>Single-leg exten.</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>(sitting)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(supine)</td>
<td>1/12 (8%)</td>
<td>1/12 (8%)</td>
</tr>
<tr>
<td>Double-leg exten.</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>(sitting)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(supine)</td>
<td>1/12 (8%)</td>
<td>2/12 (17%)</td>
</tr>
</tbody>
</table>

Note: Values are frequencies. Before = # within 20-min window; During = # during exercise sets 1–3; After = # within 20-min window.
Table 3  Neonatal Characteristics ($M \pm SE$)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pregnant group ($n = 12$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infant gender</td>
<td></td>
</tr>
<tr>
<td># girls</td>
<td>6</td>
</tr>
<tr>
<td># boys</td>
<td>6</td>
</tr>
<tr>
<td>Gestational age (weeks)</td>
<td>$40.0 \pm 1.4$ (38 – 42)</td>
</tr>
<tr>
<td># Premature births (%) (&lt;37 weeks)</td>
<td>0</td>
</tr>
<tr>
<td># Postmature births (%) (&gt;42 weeks)</td>
<td>0</td>
</tr>
<tr>
<td>Infant birth weight (g)</td>
<td>$3439 \pm 412$ (2595 – 4280)</td>
</tr>
<tr>
<td>Apgar score (1 min)</td>
<td>$8 \pm 0.7$ (7 – 9)</td>
</tr>
<tr>
<td># &lt; 7 at 5 min</td>
<td>0</td>
</tr>
<tr>
<td>Apgar score (5 min)</td>
<td>$9.3 \pm 0.5$ (9 – 10)</td>
</tr>
<tr>
<td># &lt; 7 at 5 min</td>
<td>0</td>
</tr>
</tbody>
</table>

subjects ($613 \pm 499$ min; $56 \pm 46$ min; $8 \pm 5$ min) than for the multiparous subjects ($364 \pm 164$ min; $23 \pm 18$ min, $3 \pm 1$ min). Six women delivered girls and six delivered boys. The gestational age of the women was $40 \pm 1.4$ weeks. One woman delivered a $2,595$-g infant earlier than 38 weeks, while none delivered after 42 weeks gestation. Mean infant birth weight was $3,439 \pm 412$ g and within the normal range for this population (Arbuckle et al., 1993). Apgar scores at 1 min ($8 \pm 0.7$) and 5 min ($9 \pm 0.5$) were not clinically relevant.

**Discussion**

The purposes of this study were to provide basic information on the effects of human pregnancy on maternal cardiovascular responses to strength conditioning exercises, to investigate fetal responses to strength conditioning exercises in late gestation, and to test the hypothesis that maternal and fetal responses are altered by maternal posture, exercising muscle mass, or increasing exercise intensity.

As originally hypothesized, pregnant women had significantly higher heart rates at rest and during each exercise (HG, SL, DL) test. Heart rate increased with increasing muscle mass (DL>SL>HG) in the nonpregnant group, with heart rate
increases from HG to SL and HG to DL in the pregnant group. Earlier studies of maximal isometric exercise have reported linear relationships between heart rate and force production during pregnancy (Lotgering et al., 1992). In the present study, however, heart rate did not increase significantly from SL to DL, suggesting a blunted heart rate response to higher intensity exercise during pregnancy. This finding is consistent with dynamic exercise studies which have reported a blunted heart rate response to maximal exercise (Lotgering et al., 1991). Plasma norepinephrine levels are also blunted in the third trimester compared to nonpregnant controls during exercise (Bonen et al., 1992).

Heart rate and blood pressure did not change significantly as a result of postural changes in the pregnant group. However, heart rate was significantly higher in the sitting posture than during tilted supine in the nonpregnant group. Therefore, the HR response during pregnancy appears to be altered in response to postural changes. Altered cardiac vagal modulation via baroreflex stimulation at rest (left lateral and sitting postures) appears to be blunted in late gestation compared to nonpregnant controls (Amara and Wolfe, 1997). Blunted cardiac vagal modulation may be one mechanism responsible for the altered HR response.

Blood pressure responses both at rest and during resistance exercise did not differ from those in the nonpregnant state and were comparable to results reported previously (Barron et al., 1986; Lotgering et al., 1992; Webb et al., 1991). It appears that healthy pregnant women do not exhibit hypertensive responses to strength conditioning exercises in the third trimester.

The most important concern over the safety of strenuous exercise during pregnancy has been the possibility that uterine blood flow may be reduced in order to increase the perfusion of exercising maternal skeletal muscle (Wolfe et al., 1994). If redistribution of maternal cardiac output results in significant fetal hypoxia, then fetal deceleratory responses may be observed. Fetal bradycardia appears as a normal protective reflex and is accompanied by fetal hypertension and blood flow redistribution favouring vital organs as well as a reduced metabolic rate (Parer, 1989). Lesser degrees of fetal hypoxia may result in transient FHR decelerations. Finally, Clapp et al. (1993) also hypothesized that mild hypoxia during exercise may be associated with moderate increases in FHR baseline.

Our results support the hypothesis that FHR baseline is not altered significantly and remains normal (120–140 bpm) during and after maternal strength conditioning exercises. We did not find bradycardia or more frequent decelerations in the sitting posture; however, there was a low frequency of FHR decelerations and occasional incidences of moderate bradycardia (FHR 100–120 bpm). The low incidence of these responses during and after conditioning exercises may indicate a smaller degree of blood flow redistribution than during high-intensity dynamic exercise. This may indicate compensatory mechanisms that protect oxygen availability to the fetus. These compensatory mechanisms include an increase in arteriovenous oxygen extraction and exercise-induced hemoconcentration which enhances maternal hematocrit (Hohimer et al., 1984; Lotgering et al., 1983a, 1983b). FHR baseline and long-term variability during strength conditioning exercises were unchanged and consistent with the literature (Hall and Kaufmann, 1987; Marsal et al., 1979; Nesler et al., 1988; Ruissen et al., 1990; Webb et al., 1991). These findings indicate that the fetuses did not experience hypoxia and their well-being was not compromised.
Approximately 10–15% of maternal catecholamines may cross the placenta and reach the fetus, thereby increasing FHR (Cohen et al., 1982; Copher and Huber, 1967). The fetus may also release catecholamines in response to reduced uterine blood flow and decreased fetal perfusion which may occur during maternal exercise (Clapp et al., 1993; Parer, 1989). Maternal catecholamine concentrations have been shown to increase during maximal static HG exercise in pregnant women; however, the percent change from rest is significantly lower than during dynamic exercise (Barron et al., 1986; Nisell et al., 1985).

Unless exercise is prolonged and results in lower blood glucose levels, moderate exercise has little or no effect on circulating catecholamines (Keul et al., 1978). Catecholamine concentrations may increase during resistance exercise, but perhaps not enough to alter FHR due to the short exercise phase and rest periods between sets. FHR did not respond differently in response to varying maternal exercising muscle mass or intensity, suggesting that maternal strength conditioning exercise is well tolerated by the fetus in the third trimester. A nonsignificant increase in FHR decelerations in the tilted supine posture may indicate a decreased fetal tolerance in this posture. Therefore, pregnant women who experience an increase in heart rate and a decrease in pulse pressure in the supine posture may be more susceptible to supine hypotensive syndrome and resulting FHR decelerations (Kinsella and Lohmann, 1994) as a result of aortocaval obstruction of blood flow by the gravid uterus.

Fetal well-being during the study was also supported by FHR accelerations, frequently associated with fetal activity (Lee et al., 1975). These results are consistent with the findings of Webb et al. (1991), who reported that FHR accelerations were significantly increased immediately following maternal static HG exercise in the sitting position (30% MVC to fatigue). Therefore it appears that maternal strength conditioning exercises are associated with fetal arousal and activity and may be useful for promoting fetal wakefulness prior to medical evaluations of fetal reactivity.

In conclusion, pregnant women have higher heart rates at rest and in response to strength conditioning exercises with similar BP responses compared to the nonpregnant state. Heart rate and BP responses to strength conditioning exercises are significantly affected by increasing muscle mass in the pregnant and nonpregnant state. The effects of change in posture on heart rate may be less evident in the pregnant state. Changes in FHR baseline in response to maternal strength conditioning exercises are small and usually insignificant; however, fetal wakefulness may be increased. FHR deceleratory responses may be more common in the tilted supine posture at rest and in response to strength conditioning exercises. Therefore, maternal strength conditioning does not compromise maternal or fetal well-being during healthy pregnancies in the third trimester when performed in a controlled environment with increased rest periods between sets. However, in late gestation, strength conditioning exercises in the tilted supine posture should be avoided.

References


**Acknowledgments**

This study was supported by the Ontario Ministry of Culture, Tourism and Recreation and the Ontario Thoracic Society (Block Term Grant).

*Received October 28, 1998; accepted in final form March 22, 1999.*