The effects of maternal exercise on fetal heart rate and movement patterns

M.A.M. Manders, G.J.B. Sonder, E.J.H. Mulder, G.H.A. Visser*

Department of Obstetrics and Gynaecology, University Hospital, Heidelberglaan 100, 3584 CX, Utrecht, The Netherlands

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Abstract

The aim of this study was to investigate the effects of maternal exercise on fetal movement and heart rate patterns. Twelve healthy women at 29–32 weeks of pregnancy performed a (sub)maximal bicycle exercise test, reaching 53–99% (median 82%) of their maximal increase in heart rate (MIHR). Fetal heart rate (FHR) and its variation and fetal body and breathing movements were recorded for 1 h before and after the exercise and also on a control day. After exercise, FHR was higher for 30 min and FHR variation reduced for 20 min as compared with pre-exercise levels ($P < 0.01$). Fetal body movements were reduced for the first 5 min following exercise ($P < 0.05$). In two cases, fetal bradycardia was observed (at 89 and 99% MIHR) followed by a considerable reduction in FHR variation and absence of body and breathing movements for 20 min. In the other 10 fetuses fetal breathing activity was increased for the first 5 min after exercise ($P < 0.05$). FHR (and to a lesser extent breathing movements) increased with increasing level of maternal exercise, but decreased when the % MIHR exceeded approximately 90%. Body movements were negatively correlated with the % MIHR ($P < 0.05$). In conclusion, moderate to heavy maternal exercise clearly affects the human fetus with signs of transient fetal impairment after heavy exercise. © 1997 Elsevier Science Ireland Ltd.

Keywords: Maternal exercise; Fetal body movements; Fetal breathing movements; Fetal heart rate

*Corresponding author. Tel.: +31 30 2506426; fax: +31 30 2541900.

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1. Introduction

Maternal exercise is associated with reduced blood flow in the main uterine artery, both in animals and man [1–3]. Fetal heart rate (FHR) responses to maternal exercise have been found to vary from none to an increased or decreased rate. The effects on basal FHR seem to depend on the level and type of exercise with, in general, no change or a slight increase during or after light exercise [4–8], a progressive increase during moderate exercise [4,9–12] and a slight increase or decrease during or after strenuous exercise [4,13,14]. Data on FHR variation and fetal body and breathing movements are only known for light exercise [5–8,15]. After such exercise, FHR variation and body movements were unaltered, whereas fetal breathing activity remained the same [8,15] or increased [5,6]. However, in none of these studies the fetal variables were assessed simultaneously.

The aim of the present study was to investigate the effects of maternal exercise on basal FHR, FHR variation and fetal body and breathing movements, and to relate fetal responses to the level of exercise performed.

2. Subjects and methods

Twelve healthy pregnant women between 29 and 32 weeks of gestation (median 30 week) participated in this study. Their median age was 29 years, range 20–36 years. None of the women was a conditioned athlete. All pregnancies were uncomplicated and resulted in life births at term with birth weights between the 20th and 95th centile, corrected for gestational age, parity and sex (six fetuses were female and six male).

Experimental and control sessions were carried out on 2 consecutive days in a counterbalanced order, between 18.00 and 22.00 h (start about 1 h after the evening meal). Each session consisted of two 1-h recordings of maternal heart rate (MHR), FHR and fetal movements, separated by either a 30-min break (control day) or a 30-min period of exercise (experimental day). The exercise was performed on a bicycle-ergometer. The initial load was 50 W which was increased by 25 W every 5 min until the woman decided herself that she exercised maximally. This maximal load was continued for 5 min. The room temperature was kept constant at 25°C. Cooling of the subjects was attempted with the use of a ventilator.

MHR was monitored continuously before, during and after the exercise (or break) using surface electrodes and was recorded on one channel of a fetal cardiotocograph (Hewlett Packard 8040A). The mean MHR in the hour preceding exercise (HR_{Rest}) and the maximal heart rate reached during exercise (HR_{Exercise}) were used to calculate the percentage of maximal increase in heart rate (% MIHR) applying the formula:

\[ \%\text{MIHR} = 100\times(\text{HR}_{\text{Exercise}} - \text{HR}_{\text{Rest}})/(\text{APMHR} - \text{HR}_{\text{Rest}}). \]

APMHR is the age predicted maximal heart rate which is assumed to equal (220-maternal age) bpm [16]. As oxygen uptake (VO_2) and maternal heart rate are linearly correlated during exercise, the % MIHR is more or less comparable with the percentage maximal increase in VO_2 during exercise [16].
FHR was monitored by means of Doppler ultrasound. The signal was fed into a computer running the Sonicaid 8000 FHR analysis program for calculation of the basal heart rate (bpm) and heart rate variation (mean minute range; in ms) [17]. Fetal body and breathing movements were visualized using a real-time ultrasound scanner (Aloka, Model SSD 256; probe 3.5 MHz) and recorded on videotape for off-line analysis. Monitoring the fetal activity and heart rate was impossible during maternal exercise.

Fetal breathing movements were regarded to be continuously present if the interval between consecutive breaths was < 6 s. For fetal body movements an interval of 1 s was considered. The incidence of fetal movements was expressed as a percentage per 10 min of observation time. Heart rate data were also analyzed per 10 min epochs.

The data are presented as medians and ranges. Significance of results was determined with Friedman’s two-way analysis of variance by ranks (α = 0.01) or the Wilcoxon signed rank test.

3. Results

The exercise level reached during cycling varied between 53 and 99% MIHR (median 82%). The median duration of exercise was 20 min, range 15–30 min. Recording was restarted within 1.5 to 4.2 min (median 2.2 min) after cycling was stopped.

The courses of FHR and its variation and of fetal body and breathing movements on the 2 days of the study are presented in Fig. 1 and Fig. 2, respectively. No significant trends were obtained on the control day, except for breathing movements (Fig. 2B; \( F_r = 27.9; P < 0.005 \)). On the exercise day, significant trends were found for FHR (Fig. 1A; \( F_r = 53.0; P < 0.001 \)), FHR variation (Fig. 1B; \( F_r = 28.7; P < 0.005 \)) and fetal breathing (Fig. 2B; \( F_r = 29.2; P < 0.002 \)). After maternal exercise, basal FHR was significantly increased for 30 min (Fig. 1A) and FHR variation was significantly lower for 20 min (Fig. 1B) as compared with the last 10 min epoch before cycling (\( P < 0.01 \) for all differences). When compared with the corresponding epochs on the control day, significant differences were found for the first 40 and 15 min, respectively (\( P < 0.05 \); Wilcoxon test).

After exercise the incidence of fetal body movements was reduced, but this appeared also to be the case during the corresponding period on the control day (Fig. 2A). When analyzed in detail, a significantly lower incidence of body movements was found for the first 5 min following exercise only (Fig. 3A; \( P < 0.05 \), Wilcoxon test). For fetal breathing movements no significant differences were found between the control and post-exercise values (Fig. 2B).

Despite the general and considerable increase in FHR following exercise (Fig. 1A), there were two fetuses who showed bradycardia immediately after maternal exercise. In the one fetus this bradycardia was followed after 5 min by a slight tachycardia and in the other fetus normal basal heart rate was also reached after about 5 min (Fig. 4). In both fetuses, FHR variation was greatly reduced for about 20 min following the exercise and fetal breathing and body movements were absent for this time period.
Fig. 1. Course of (A) fetal heart rate and (B) its variation during the first and second hours of observation on the control (○) and experimental days (●). The vertical line at t = 0 min represents the 30-min break (control day) or period of maternal exercise (experimental day). *P < 0.01, Friedman's analysis of variance.

(see example, Fig. 5). Because of the different responses found in these two fetuses as compared with the others, we analyzed fetal breathing movements again but excluding these two cases. Now, the incidence of fetal breathing was increased for the first 5 min after exercise as compared with the control day (Fig. 3B; P < 0.05, Wilcoxon test).

When the change in basal FHR between the last 10 min before exercise and the first 10 min epoch following exercise was plotted against the level of maternal
Fig. 2. Course of the incidences of (A) fetal body movements and (B) fetal breathing movements during the first and second hours of observation on the control (○) and experimental days (●). The vertical line at t = 0 min represents the 30-min break (control day) or period of maternal exercise (experimental day).

exercise, a parabolic relationship appeared with an increase in FHR in association with moderate levels of exercise and a decrease with further increasing levels of maternal exercise (Fig. 6; \( y = -0.048x^2 + 7.23x - 250.1; \ n = 12; \ r = 0.73 \)). Fetal bradycardia occurred at 89 and 99% MIHR. A similar parabolic curve was found for fetal breathing movements but the correlation was less evident (\( r = 0.27 \)). Fetal body movements during the first 10 min after the exercise showed a negative linear correlation with the level of maternal exercise (Fig. 7; \( r = 0.60; \ n = 12; P < 0.05 \)).
Fig. 3. Incidences of (A) fetal body movements and (B) fetal breathing movements during the first and second 5-min epochs after the break (open bars) and after maternal exercise (shaded bars). Presented are the medians and (interquartile) ranges (boxplots). Fetal body movements were reduced during the first 5 min after cycling \((n = 12)\), whereas breathing activity was increased during the same epoch \((n = 10)\). *\(p < 0.05\), Wilcoxon test.

No significant relationships were found between the % MIHR on the one hand and FHR variation or the change in heart rate variation during the first 10 min following exercise on the other hand.

Fig. 4. Course of fetal heart rate in 12 fetuses during the first 15 min after maternal exercise. Two fetuses initially showed bradycardia (solid lines) but basal heart rate normalized within 10 min.
Fig. 5. Compiled 90-min recording of one of two fetuses showing bradycardia after maternal exercise. It shows the FHR tracing and the occurrence of fetal body and breathing movements before and after maternal exercise (all periods 30 min), and the MHR tracing and the level of exercise performed before, during and after cycling. The maximal MHR reached during exercise was 191 bpm, at a work load of 150 W (99% MIHR). After exercise, FHR variation was considerably reduced for about 20 min and fetal activity was absent during this time.

Fig. 6. Relationship between the change in basal fetal heart rate (last 10-min epoch before vs. first 10-min epoch after exercise) and the level of maternal exercise.
4. Discussion

This study suffers from the same methodological problem as many in its kind, as monitoring the fetus was impossible during maternal exercise. However, monitoring was resumed immediately after the exercise. The importance of the observations on the control day is well illustrated by the progressive decrease in fetal breathing movements which occurred during both the control and experimental sessions. This decrease can be explained by the elapsed time period following the maternal meal and by the concomitant fall in maternal blood glucose concentration [18]. We have no solid explanation for the initial low incidence of body movements after the break on the control day. The only option is that it occurred by chance, since after the break 6 out of the 12 fetuses had a low FHR variation pattern, indicative of quiet sleep or coincidence 1F, in contrast to only 3 out of 12 immediately before the break. FHR variation was also slightly lower after cycling (Fig. 1B), indicating that the low incidence of body movements was realistic and not due to poor observation of the fetus.

The data clearly show that moderate to heavy levels of maternal exercise (> 60% MIHR) affect the fetus during the early third trimester of pregnancy. The results are summarized in Table 1. The only change which has to be relativated is that of the reduction in FHR variation. Fetal heart rate and its variation are negatively correlated, and the reduction in the latter may therefore be explained, at least in part, by the increased FHR [19]. Hypoxaemia, on the other hand, may also have negatively affected FHR variation, especially in the two fetuses showing bradycardia following exercise (see below). The data regarding basal FHR and breathing movements indicate that the fetal response depends on the level of exercise, with an increase in
Table 1
Effects of moderate (60–90% MIHR) and heavy (>90% MIHR) levels of maternal exercise on various fetal variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>60–90</th>
<th>&gt;90</th>
</tr>
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<tbody>
<tr>
<td>Basal fetal heart rate</td>
<td>↑</td>
<td>↓</td>
</tr>
<tr>
<td>Fetal heart rate variation</td>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Fetal body movements</td>
<td>↓ (?)</td>
<td>↓</td>
</tr>
<tr>
<td>Fetal breathing movements</td>
<td>↑</td>
<td>↓</td>
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</tbody>
</table>

both immediately after moderate exercise and a decrease or arrest after heavy exercise. Fetal body movements progressively decrease with increasing level of maternal exercise, showing reduced values (<5% of recording time) above 80% MIHR (Fig. 7).

Clapp et al. [20] recently described a linear increase in delta FHR with an increasing level of exercise from 35 to 85% of maximal maternal capacity. This is in line with the present findings. Data on maximal maternal exercise during pregnancy are scarce. However, our findings are in agreement with those of Artal et al. [4], who found a smaller increase in FHR following heavy exercise than following moderate exercise.

Fetal bradycardia following (heavy) exercise has mainly been found beyond 34 weeks of gestation when oxygen demand is largest [13,14,21]. Our study shows that it may also occur earlier in the third trimester. The temporary decrease in FHR variation following bradycardia in the absence of both body and breathing movements suggests that the bradycardia was an expression of fetal hypoxaemia. Similar effects have been found in growth-retarded fetuses following late FHR decelerations [22]. These changes partly resemble a transition from an active sleep state into a quiet sleep state [23]. However, fetal sleep states have not fully developed at 30 weeks of gestation and breathing continues during quiet sleep (with an identical or somewhat lower incidence) [24,25].

The fetal responses may be due to decreased uterine artery blood flow, increased fetal temperature, an increase in catecholamines or to a combination of these. During treadmill running maternal core temperature has been found to rise till 39°C [26]. In the human, the content of maternal catecholamines, noradrenaline in particular, rises during exercise [27]. The parabolic relationship between delta FHR and the level of exercise may be explained by a stimulatory effect through one factor (temperature?) or a combination of these changes. This effect is overruled at high levels of exercise by fetal hypoxaemia. The temporarily increased breathing incidence as found by others [5,6] and by us in the women who had moderately exercised, may also be explained by an increase in CO₂ (high metabolic rate during hyperthermia, decreased exchange over the placenta?). The decrease in fetal breathing following heavy exercise is likely to be due to fetal hypoxaemia [22].

Effects of maternal exercise may also depend on the kind of exercise. Following a light degree of exercise (e.g. <60% MIHR or <60% VO₂ maximum) an increase in
FHR has been observed with running [7,8] but not with cycling [5,6]. Swimming might be one of the most advisable sports, as body temperature is more likely to remain stable and plasma volume expands with immersion. Indeed, during maternal exercise in water at 60% VO_{2} maximum, no changes have been found in maternal body temperature and FHR [28].

We conclude from this study that moderate to heavy levels of maternal exercise during the early third trimester have clear effects on the human fetus. The kind of effect depends on the level of exercise. Heavy exercise must be discouraged as it may lead to a temporary impairment of the fetal condition. The advise given in Williams’ textbook of Obstetrics, published in 1903 [29], “to advise her to take as much outdoor exercise as possible, . . . a safe rule being to instruct her to desist while still feeling that she could do more . . .”, still seems to be appropriate.

References