Aerobic Exercise and Submaximal Functional Capacity in Overweight Pregnant Women

A Randomized Trial

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Objective: To evaluate the effects of aerobic training on submaximal cardiorespiratory capacity in overweight pregnant women.

Methods: We conducted a randomized clinical trial in a referral center prenatal clinic during the period 2000–2002. Of 132 overweight (body mass index 26–31 kg/m^2) but otherwise healthy volunteers, at 20 years of age or older, with gestational age of 20 weeks or less, and without diabetes or hypertension, 92 consented to participate and were randomized. Intervention consisted of 3 one-hour aerobic exercise sessions per week; the control group received weekly relaxation and focus group discussions. The main outcome measure was submaximal exercise capacity evaluated by oxygen uptake at the anaerobic (first ventilatory) threshold during cardiopulmonary treadmill testing 12 weeks after randomization.

Results: Oxygen uptake at the anaerobic threshold increased 18% (15.9 ± 2.6 to 18.1 ± 3.1 mL · min^{-1} · kg^{-1}) in the exercise group but decreased 16% (16.9 ± 3.0 to 15.8 ± 2.6 mL · min^{-1} · kg^{-1}) among the control group. Oxygen consumption at the anaerobic threshold, adjusted through analysis of covariance for baseline oxygen uptake, was 2.68 (95% confidence interval 1.23 to 4.12) mL · min^{-1} · kg^{-1} greater in the exercise group. Women in the exercise group were approximately 5 times more likely than those in the control group to have regular or good cardiorespiratory capacity (12/38 versus 2/38; relative risk 5.2, 95% confidence interval 1.2 to 22.0, number needed to treat 5).

Conclusion: Aerobic training in overweight pregnant women substantially increases submaximal exercise capacity, overcoming the otherwise negative effects of pregnancy in this regard. Additional studies are required to evaluate its effect on major clinical outcomes.
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Level of Evidence: I

See related editorial on page 216.

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Pregnancy is a period when anatomic, physiologic, hormonal, and emotional adjustments occur to permit necessary maternal and fetal adaptations to a rapidly changing internal milieu. For example, maternal weight, cardiac output, and energy expenditure at rest all increase. During exercise, pregnant women have an increased cardiac output, heart rate, and stroke volume.[1]

Recent studies suggest benefits of physical exercise during pregnancy in terms of decreased back pain and optimized fetal and maternal well-being.[2–4]

Nevertheless, physicians do not recommend physical activity for most women, especially if sedentary, during pregnancy.[5] This is due, in part, to the lack of well-designed studies evaluating the benefits and risks of the practice of physical activity during pregnancy. Thus, we investigated the effects of a supervised, gymnasium-style, physical activity program of aerobic exercise on submaximal cardiorespiratory capacity in overweight pregnant women.

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MATERIALS AND METHODS

Healthy, nonsmoking pregnant women, aged 20 years or more, of gestational age less than 20 weeks, having a body mass index (BMI) between 26 and 31 kg/m^2 (corresponding to a prepregnancy BMI of 25–30 kg/m^2)[6] were invited to participate in this randomized clinical trial conducted in Porto Alegre, Brazil. The participants were recruited at public health clinics or through announcements placed in local newspapers. Between March 2000 and March 2002, 224 pregnant women responded to the invitation.

Eligible women underwent a run-in period of 1 week, during which they completed a physical activity questionnaire (an adaptation of the Modifiable Physical Activity Questionnaire, designed to detect common activities of the participants, irrespective of pregnancy),[7] had ultrasonic documentation of gestational age, and attended 2 introductory physical activity classes. Reported physical activity was quantified using METs (metabolic equivalents, one MET being the resting metabolic rate obtained during quiet sitting). Women were asked to report all activity during work, including domestic labors, and leisure-time or sports-related physical activities. Each activity's metabolic equivalent[8] was multiplied by the habitual time expended performing that activity. These values were then totaled across all activities and expressed in MET-hours/week.

Eligibility criteria included compliance to the run-in period protocol and absence of hypertension and diabetes mellitus, as well as of conditions considered to contraindicate exercise, such as preterm labor, an incompetent cervix, high-order multiple gestation ($\geq$ triplets), and uncontrolled thyroid disease. Patients, once certified by the study interviewers as having completed evaluation and as eligible, gave written consent to participate and were randomized following a blocked sequence generated from a random number table by a statistician not participating in other aspects of the study. The study coordinator implemented this randomization by using numbered, opaque envelopes. The study's protocol was previously approved by the ethics committee of the Hospital de Clínicas de Porto Alegre.

The intervention consisted of an unblinded program of supervised physical exercise of 60 minutes duration, performed 3 times per week. Each session consisted of 5–10 minutes of warm up, 30 minutes of heart rate–monitored aerobic activity, 10–15 minutes of exercise involving upper and lower limbs, and 10 minutes of stretching and relaxation. Aerobic activities were always performed between 50% and 60% of the maximum predicted heart rate, never exceeding 140 beats per minute (bpm). The exercises followed the recommendations concerning physical activity practice during pregnancy according to the American College of Sport Medicine,[9] and The American College of Obstetricians and Gynecologists (ACOG).[10] Aerobic exercises included walking, pedaling a bicycle ergometer, and aerobic gymnastics. Upper extremity resistance exercises were performed with handheld dumbbells (up to 1 kg), rods, and tennis balls. For the legs, body weight resistance exercises such as squats and lunges were performed.

The control group participated in once-weekly sessions that included relaxation (respiratory exercises and light stretching but no aerobic or weight-resistance exercises) and focus group discussions concerning maternity. Control participants were neither encouraged to exercise nor discouraged from exercising.

Participants underwent 2 submaximal cardiopulmonary tests, one immediately after randomization and the second approximately 12 weeks later. The same cardiologist, blinded to treatment allocation, performed both tests. The submaximal test was chosen because of the limited documentation of the safety of maximal exercise testing in pregnancy, especially when the fetus is not monitored.[11,12] Subjects walked on a motor-driven treadmill (Inbramed TK 10,200, Porto Alegre, Brazil), with an initial speed of 1.5 mph and no inclination, with continuous increments in speed and inclination, following a ramp protocol. The test was stopped at least 30 seconds after the identification of the anaerobic threshold. Blood pressure was measured at least every 3 minutes with a standard arm sphygmomanometer, a 12-lead electrocardiogram was continuously monitored (Micromed-Biotecnologia, Brasília, Brazil), and respiratory gases were analyzed by a previously validated commercial system (Total Energy Expenditure Measurements 100, Aerosport, Ann Arbor, MI).[13]

The main submaximal functional capacity outcome was the oxygen uptake at the anaerobic threshold. This parameter demarcates the upper limit of exercise intensities that can be accomplished almost entirely aerobically,[14] is an indicator of level of fitness, and is considered appropriate for monitoring the effects of aerobic exercise training.[15] The anaerobic threshold was determined by review of the gas exchange curves by 2 cardiologists working independently and blinded to treatment allocation as the point at which the ventilatory equivalent for oxygen increased systematically without an increment in the ventilatory equivalent for carbon dioxide. Sample size calculations demonstrated that, to find a statistically significant difference in oxygen consumption of 5 mL $\cdot$ min^{-1} $\cdot$ kg^{-1} assuming a standard deviation of 2.5 mL $\cdot$ min^{-1} $\cdot$ kg^{-1}, for an α value of 0.05 and power of 80%,

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a minimum of 26 pregnant women would need to complete the study.

Secondary outcome variables included respiratory exchange ratio, carbon dioxide output, and heart rate at the anaerobic threshold. Resting heart rate was also considered an outcome. Physical conditioning of the women was categorized on the basis of oxygen uptake at the anaerobic threshold (VO_2 AT) as: low (9 $mL \cdot min^{-1} \cdot kg^{-1} < VO_2\ AT \leq 20\ mL \cdot min^{-1} \cdot kg^{-1}$); medium ($20\ mL \cdot min^{-1} \cdot kg^{-1} < VO_2\ AT \leq 22\ mL \cdot min^{-1} \cdot kg^{-1}$); or good ($22\ mL \cdot min^{-1} \cdot kg^{-1} < VO_2$ AT).[16]

Low birth weight was defined as weight less than 2,500 g and *prematurity* as a gestational age at birth of less than 37 weeks.[17] *Small for the gestational age* was defined as birth weight less than the 10th percentile for gestational age, using norms from the Brazilian Gestational Diabetes Study to define percentiles.[18] The Apgar scores at 1 and 5 minutes were used to characterize newborn vitality.

Intention-to-treat analyses were performed by using a repeated measures analysis of variance[19] initially and then analysis of covariance to adjust for the baseline value of the outcome in question.[20] Because maternal age, gestational age, and maternal weight at the moments of examination varied somewhat between groups despite randomization, they were also included as covariates in the latter models.

Chi-squared testing was used to evaluate the intervention effect on cardiorespiratory conditioning, when the latter was characterized in categorical form. Group differences in low birth weight, gestational

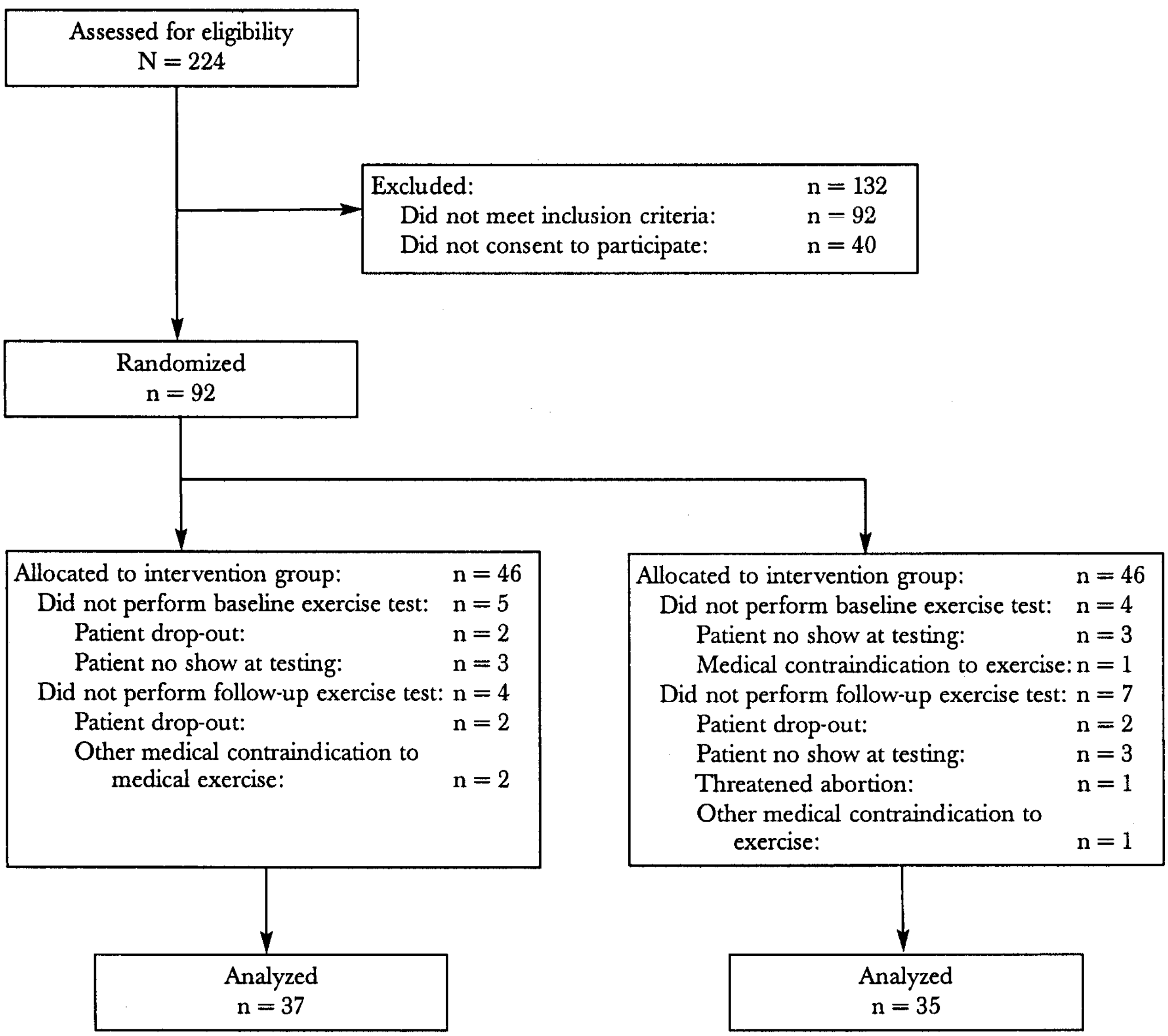

Fig. 1. Flow of participants through the trial.
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Table 1. Exercise and Control Group Characteristics at Baseline

Characteristic	Control (n = 35) Mean	Control (n = 35) SD	Exercise (n = 37) Mean	Exercise (n = 37) SD
Weight (kg)	71.2	7.4	71.5	7.9
Height (m)	1.61	0.07	1.60	0.07
BMI (kg/m^2)*	27.5	2.1	28.0	2.1
Gestational age (wk)*	18.4	3.9	17.5	3.3
Age (y)	28.6	5.9	26.0	3.4
Habitual physical activity (MET-h/week)	114	62.4	140	88.6

SD, standard deviation; BMI, body mass index; MET-h, metabolic equivalent hours.
* Determined at the time of the first cardiopulmonary testing.

size, and prematurity were tested using the Fisher exact test. Differences in birth weight were tested with the *t* test and differences in Apgar scores with the Mann-Whitney test. All analyses were performed using SAS 8.0 (SAS Institute, Cary, NC).

RESULTS

The flux of participants through stages of the study protocol is described in Figure 1. Of these participants, 92 were found to be ineligible (none of these were excluded due to a condition contraindicating exercise), and 40, although eligible, opted not to participate in the study. The remaining 92 pregnant women were randomized. Of these, 72 performed both cardiopulmonary tests. Of those not completing both tests, 16 underwent only the first test and 4 only the second. Reasons for noncompletion are displayed in Figure 1. Difficulty in performing or dissatisfaction with the exercises did not appear to be reasons for noncompletion. Distance to the clinic and hot summer weather, on the other hand, did appear to have contributed.

As seen in Table 1, both groups were in general alike, although women in the intervention group were somewhat younger (26 versus 28 years of age) and were randomized somewhat earlier in their pregnancies. Average reported habitual physical activity at baseline was somewhat higher, although not significantly so, in the exercise (140 ± 88.6 MET-hours/week) than in the control group (114 ± 62.4 MET-hours/week).

On average, those allocated to exercise participated, from enrollment to delivery, in 28 (standard deviation ± 14.9) physical activity sessions (40% of those offered), whereas those allocated to the control group participated in 11 (± 5.5) sessions (50% of those offered).

Figure 2 shows individual patient responses with respect to the main outcome: oxygen consumption at the anaerobic threshold. Oxygen consumption improved for most patients in the exercise group, increasing, as shown by repeated measures analysis, on average, 2.35 mL · min^{-1} · kg^{-1} with the intervention ($P < .001$). Consumption declined for most women in the control group, decreasing, on average, 1.15 mL · min^{-1} · kg^{-1} ($P = .02$). Table 2 shows the crude values and adjusted differences of cardiopulmonary testing for this and several other outcomes. The adjusted oxygen uptake (VO_2) at the anaerobic threshold was 2.68 (95% confidence interval [CI] 1.23 to 4.12) mL · min^{-1} · kg^{-1} higher after intervention in the exercise group ($P < .001$). Similarly, ventilation at the anaerobic threshold increased 18% in the exercise group but decreased 16% in the control group, resulting in an adjusted difference of 4.11 (95% CI 0.64 to 7.59) L/min. Adjusted CO_2 production at the anaerobic threshold at 12 weeks was also 1.81 (95% CI 0.49 to 3.14) mL · min^{-1} · kg^{-1} higher ($P = .008$) in the exercise group. Although not statistically significant, heart rate at anaerobic threshold increased from 144 (± 12) to 150 (± 16) bpm in the exercise group, but was stable at around 144 (± 15) bpm in the control group, producing a final adjusted difference of 4.8 bpm (95% CI –2.0 to 11.7; $P = .16$). The respiratory exchange ratio at the anaerobic threshold was similar in both groups ($P = .41$). Although women in the

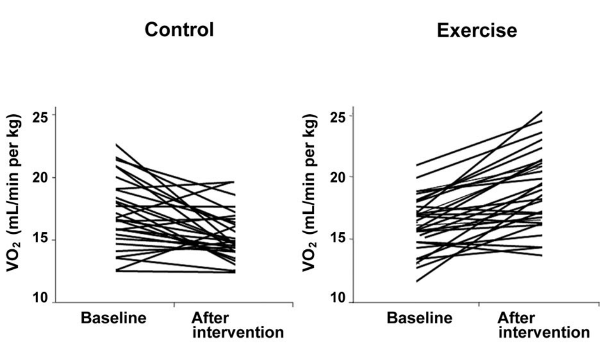

Fig. 2. Individual values of oxygen uptake at the anaerobic threshold (VO_2) before and after intervention in the control and exercise groups ($P = .002$ for both). Each line shows the change between the pre- and postintervention values for a given patient.

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Table 2. Cardiorespiratory Status and Change in Exercise and Control Groups in the 72 Women Who Completed Study Protocol

Variable	Group	Baseline	After Intervention	Difference (95% CI)*	P†
HR_R (bpm)	Exercise	88.1 ± 9.5	89.5 ± 10.7	0.82	
	Control	86.8 ± 12.2	88.6 ± 11.7	(−4.75 to 6.40)	.77
HR_{AT} (bpm)	Exercise	144 ± 12	150 ± 14.5	4.83	
	Control	143.7 ± 15.8	143.7 ± 15.8	(−2.03 to 11.7)	.16
$VO_{2\ AT}$ ($mL \cdot min^{-1} \cdot kg^{-1}$)	Exercise	15.9 ± 2.6	18.1 ± 3.1	2.68	
	Control	16.9 ± 2.9	15.8 ± 2.6	(1.23 to 4.12)	< .002
$VCO_{2\ AT}$ ($mL \cdot min^{-1} \cdot kg^{-1}$)	Exercise	13.1 ± 2.3	15.5 ± 2.8	1.81	
	Control	14.1 ± 2.9	13.7 ± 2.5	(0.49 to 3.14)	< .008
$V_{\ddot{E}\ AT}$ (L/min)	Exercise	27.0 ± 6.1	34.3 ± 8.5	4.11	
	Control	28.9 ± 7.6	30.1 ± 7.1	(0.64 to 7.59)	.02
R_{AT}	Exercise	0.83 ± 0.1	0.86 ± 0.07	−0.03	
	Control	0.83 ± 0,09	0.87 ± 0.09	(−0.07 to 0.01)	.143
Weight (kg)	Exercise	71.5 ± 7.9	77.2 ± 9.1	−0.52	
	Control	71.3 ± 7.4	77.6 ± 8.3	(−2.53 to 1.49)	.605

CI, confidence interval; HR_R, resting heart rate; bpm, beats per minute; HR_{AT}, heart rate at the anaerobic threshold; $VO_{2\ AT}$, oxygen consumption at the anaerobic threshold; $VCO_{2\ AT}$, carbon dioxide production at the anaerobic threshold; $V_{E\ AT}$, ventilation of the anaerobic threshold; R_{AT}, respiratory exchange ratio at the anaerobic threshold.
* Difference between exercise and control groups after intervention, adjusted in covariance analysis for baseline values of gestational age and age and weight at both exams.
† *P* value of the difference.

exercise group gained approximately 0.5 kg less over the 12 weeks, this difference was not statistically significant ($P = .62$). Table 3 presents the classification of physical capacity before and after the intervention. At final testing, pregnant women allocated to the aerobic exercise program were approximately 5 times more likely to be classified as having a good or medium physical capacity than those in the control group (relative risk 5.2, 95% CI 1.2 to 22.0).

In the subgroup of pregnant women characterized as presenting low cardiorespiratory conditioning at the first cardiopulmonary testing, the intervention increased adjusted oxygen consumption by 2.51 (95% CI 1.18 to 3.85) $mL \cdot min^{-1} \cdot kg^{-1}$, $P < .001$. Among these pregnant women, the percentage with good or medium capacity at the final test was similarly larger in the exercise group (32% versus 5%, $P = .004$).

Table 3. Cardiorespiratory Capacity Based on Oxygen Consumption Values (VO_2) at the Anaerobic Threshold in Exercise Test Evaluation at Baseline and After Intervention

	Baseline		After Intervention†	
Capacity*	Exercise	Control	Exercise	Control
Low	35 (95)	29 (83)	27 (72)	36 (95)
Regular	2 (5)	4 (12)	7 (18)	1 (3)
Good	0 (0)	2 (6)	4 (10)	1 (3)

Data are presented as n (%).
* Categorized at the anaerobic threshold as low ($9\ mL \cdot min^{-1} \cdot kg^{-1} < VO_2 \leq 20\ mL \cdot min^{-1} \cdot kg^{-1}$), regular ($20\ mL \cdot min^{-1} \cdot kg^{-1} < VO_2 \leq 22\ mL \cdot min^{-1} \cdot kg^{-1}$), or good ($22\ mL \cdot min^{-1} \cdot kg^{-1} < VO_2$).
† After-intervention exercise test evaluation was performed after approximately 12 weeks of intervention.

Exercise sessions during pregnancy were not associated with low birth weight, this outcome being present in 4.9% and 3% in the exercise and control groups, respectively ($P = .61$), nor with a decreased average birth weight: 3,363 (± 504) g versus 3,368 (± 518) g, $P = .97$. Significant differences did not occur in the frequency of prematurity (exercise 4.9% versus control 2.4%; $P = .62$). Median Apgar scores were 9 (range 3–10) versus 9 (range 2–10), $P = .88$, at 1 minute, and 10 (range 9–10) versus 9 (range 8–10), $P = .15$, at 5 minutes, for exercise and control groups, respectively. No spontaneous abortions occurred during the study. The clinical diagnosis of a threatened abortion was established in one woman in the control group. Consistent with the fact that the study was not powered to investigate many relevant clinical outcomes, no statistically significant differences were found for cesarean delivery rate, hypertension/preeclampsia, and gestational diabetes (data not shown).

DISCUSSION

In this randomized clinical trial, 12 weeks of aerobic physical training in pregnancy promoted cardiorespiratory conditioning, as indicated by a significantly higher VO_2 at the anaerobic threshold in the exercise group. Although the sample size was not adequate for a thorough evaluation of potential adverse clinical outcomes, no significant difference in such outcomes was observed.

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Several previous studies have investigated the question of the effect of physical activity during pregnancy. However, as noted by Kramer in a recent meta-analysis,[21] no trials were of high methodologic quality, and most were quite small. Many were presented only in abstract form. Our results are consistent with those found by Collings et al,[22] who investigated in a partially randomized trial the effect of training in 12 exercising pregnant women and 8 controls during 7–19 weeks. In that study, cardiorespiratory conditioning, as measured by VO_{2max}, presented an absolute increment of 18% in the exercise group and a nonsignificant decrease of 4% in the control group. South-Paul et al[23] demonstrated an increase in several parameters of aerobic capacity on maximal exercise testing in a trial of 23 women with a poorly described randomization technique. Marquez-Sterling et al[2] reported notably longer exercise duration on a graded submaximal exercise test in a randomized study of 20 women with 25% dropout.

No previous studies have used the anaerobic threshold as the endpoint in submaximal exercise testing. We feel that our study shows that this method is quite applicable to evaluate this issue, especially as it obviates the need to perform fetal monitoring.

The resting heart rate tends to increase progressively during pregnancy, because of the decrease in vascular resistance.[24–26] Further studies are necessary to elucidate whether an increase in the heart rate at the anaerobic threshold is an aspect of physical conditioning in pregnancy.

We believe these results can be confidently generalized to most modern day, sedentary or near sedentary, overweight pregnant women who would undertake a similar exercise program during pregnancy. Certainly, there is nothing in our population that particularly distinguishes them in this regard. One would expect, however, that a lower compliance with the exercise regimen in clinical practice settings with a lesser intensity of intervention would result in a decreased degree of conditioning.

It is important to mention limitations to our study. First, we investigated exercise capacity, and as such, we cannot directly extrapolate these results to the question of potential benefit that might logically be expected of the exercise program in terms of more important clinical outcomes. In this regard, randomized trials with power to detect clinically meaningful differences in end points such as excessive gestational weight gain, gestational diabetes, preeclampsia, and macrosomia should be performed. Second, study subject attrition during the follow-up was relatively high. However, we believe that this attrition, given the statistical significance of our findings, rather than casting doubt on the internal validity of the study, mostly emphasizes the difficulty in encouraging pregnant women to participate in exercise training.

In conclusion, this randomized clinical trial shows that aerobic training, when performed by overweight and predominantly sedentary women, significantly improves submaximal exercise capacity, reducing the negative effects of pregnancy upon aerobic capacity. Although the sample size was too small to evaluate many clinically relevant outcomes, none of the findings suggest that the exercise program increased risk to the mother or newborn. Whether the achieved difference in exercise capacity would result in improvements in more important clinical outcomes, such as gestational diabetes for the mother and future health for the neonate, requires further study.

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