Ilana Finkelstein[1]
Paulo André Poli de Figueiredo[2]
Cristine Lima Alberton[3]
Roberta Bgeginski[4]
Ricardo Stein[5]
Luiz Fernando Martins Kruel[6]

Cardiorespiratory responses during and after water exercise in pregnant and non-pregnant women

Respostas cardiorrespiratórias durante e após exercício aquático em gestantes e não gestantes

Artigo original

Keywords
Pregnancy
Blood pressure
Oxygen consumption
Exercise
Physical exertion

Palavras-chave
Gravidez
Pressão arterial
Consumo de oxigênio
Exercício
Esforço físico

Abstract

PURPOSE: to compare the blood pressure and oxygen consumption ($\dot{V}O_2$) responses between pregnant and non-pregnant women, during cycle ergometer exercise on land and in water. **METHODS**: ten pregnant (27 to 29 weeks of gestation) and ten non-pregnant women were enrolled. Two cardiopulmonary tests were performed on a cycle ergometer (water and land) at the heart rate corresponding to $\dot{V}O_2$, over a period of 30 minutes each. Exercise measurements consisted of recording blood pressure every five minutes, and heart rate and $\dot{V}O_2$ every 20 seconds. Two-way ANOVA was used and α=0.05 (SPSS 17.0). **RESULTS**: there was no difference in cardiovascular responses between pregnant and non-pregnant women during the exercise. The Pregnant Group demonstrated significant differences in systolic (131.6±8.2; 142.6±11.3 mmHg), diastolic (64.8±5.9; 74.5±5.3 mmHg), and mean blood pressure (87.0±4.1; 97.2±5.7 mmHg), during water and land exercise, respectively. The Non-pregnant women Group also had a significantly lower systolic (130.5±8.4; 135.9±8.7 mmHg), diastolic (67.4±5.7; 69.0±10.1 mmHg), and mean blood pressure (88.4±4.8; 91.3±7.8 mmHg) during water exercise compared to the land one. There were no significant differences in $\dot{V}O_2$ values between water and land exercises or between pregnant and non-pregnant women. After the first five-minute recovery period, both blood pressure and $\dot{V}O_2$ were similar to pre-exercise values. **CONCLUSION**: for pregnant women with 27 to 29 weeks of gestation, water exercise at the heart rate corresponding to $\dot{V}O_2$ is physiologically appropriate. These women also present a lower blood pressure response to exercise in water than on land.

Resumo

OBJETIVO: comparar as respostas da pressão arterial e do consumo de oxigênio ($\dot{V}O_2$) no exercício em bicicleta ergométrica, realizado na terra e na água, por gestantes e não gestantes. **MÉTODOS**: dez gestantes (entre 27 e 29 semanas) e dez não gestantes realizaram dois testes em cicloergômetro (um na água e um na terra), na frequência cardíaca correspondente ao primeiro limiar ventilatório ($\dot{V}O_{2LV}$), com duração de 30 minutos cada. A pressão arterial foi aferida a cada cinco minutos durante o exercício e a frequência cardíaca e o $\dot{V}O_2$ a cada 20 segundos. Foi utilizada a análise de variância *two-way* e α=0,05 (SPSS 17.0). **RESULTADOS**: não houve diferença nas respostas cardiovasculares entre gestantes e não gestantes durante o exercício. O Grupo Gestante apresentou valores significativamente mais baixos de pressão arterial sistólica (131,6±8,2; 142,6±11,3 mmHg), diastólica (64,8±5,9; 74,5±5,3 mmHg) e média estimada (87,0±4,1; 97,2±5,7 mmHg), no exercício aquático comparado ao terrestre, respectivamente. O Grupo Não gestante também apresentou valores de pressão arterial sistólica (130,5±8,4; 135,9±8,7 mmHg), diastólica (67,4±5,7; 69,0±10,1 mmHg) e média (88,4±4,8; 91,3±7,8 mmHg) mais baixos no exercício na água do que na terra, respectivamente. Os valores de $\dot{V}O_2$ absoluto não apresentaram diferenças significativas, durante o exercício entre gestantes e não gestantes, como também nos meios aquáticos e terrestres. Após cinco minutos de repouso pós-exercício, tanto a pressão arterial quanto o $\dot{V}O_2$ já apresentavam valores semelhantes aos de repouso pré-exercício. **CONCLUSÃO**: para gestantes entre 27 e 29 semanas de gestação, a escolha pelo exercício aquático realizado na frequência cardíaca correspondente ao $\dot{V}O_{2LV}$ é fisiologicamente adequada. Essas mulheres também apresentam um comportamento de pressão arterial mais baixo na água comparado ao meio terrestre.

Correspondência:
Ilana Finkelstein
Escola de Educação Física da UFRGS
Rua Felizardo 350 – LAPEX sala 208 – Jardim Botânico
CEP: 90690-200
Porto Alegre (RS), Brasil

Recebido
10/18/2011
Aceito com modificações
11/21/2011

Study carried out at Laboratório de Pesquisa do Exercício da Escola de Educação Física e Divisão de Cardiologia do Hospital de Clínicas de Porto Alegre of Universidade Federal do Rio Grande do Sul – UFRGS – Porto Alegre (RS), Brazil.
[1] Master's degree in Human Movement Sciences by Escola de Educação Física of Universidade Federal do Rio Grande do Sul – UFRGS – Porto Alegre (RS), Brazil.
[2] Master's degree in Human Movement Sciences by Escola de Educação Física of Universidade Federal do Rio Grande do Sul – UFRGS – Porto Alegre (RS), Brazil.
[3] Postdoctorate degree by Programa de Pós-graduação em Ciências do Movimento Humano of Universidade Federal do Rio Grande do Sul – UFRGS – Porto Alegre (RS), Brazil.
[4] Physical Educator and Master's Degree in Human Movemente Sciences by Escola de Educação Física of Universidade Federal do Rio Grande do Sul – UFRGS – Porto Alegre (RS), Brazil.
[5] Professor of Programa de Pós-graduação em Cardiologia e Ciências Cardiovasculares do Hospital de Clínicas de Porto Alegre of Universidade Federal do Rio Grande do Sul – UFRGS – Porto Alegre (RS), Brazil.
[6] Adjunct Professor of Exercise Physiology at Escola de Educação Física da Universidade Federal do Rio Grande do Sul – UFRGS – Porto Alegre (RS), Brazil.
Interest conflicts: none.

Introduction

Aerobic exercise has been prescribed in pregnancy, both for active and inactive women, and it should be part of a global physical conditioning program[1-5]. Literature is scant regarding the modality, intensity, frequency, and duration of maternal exercise, even though there is evidence pointing that water exercise might be very adequate for pregnant women[4,6]. When people do exercise, different physiological adaptations occur: modification in the body temperature, increase in the circulating cathecholamines, redistribution of the blood flow, alterations in ventilation, in cardiac output and in the renal blood flow[7]. Moreover, as these individuals get into the water, they suffer the effects of immersion, such as: thermoregulation[8], flotation[6,9], and redistribution of blood flow[10], which generate deep physiological modifications.

The influence of regular aerobic exercise on the acute and chronic behavior of blood pressure (BP) during pregnancy, both for normotensive and hypertensive pregnant women, is not clear[11-13]. Similarly, it has not been well established if the medium (water or land) in which the exercise is done may affect hemodynamic responses in a different way during pregnancy, both in the acute and in chronic setting.

Regarding oxygen consumption ($\dot{V}O_2$), there is disagreement whether the mediums (water or land) and the pregnant state may result in different behaviors, when compared with the non-pregnant state[14-16]. Such fact is relevant and may affect, directly, the exercise prescription during pregnancy.

This study aimed to compare the behavior of BP and $\dot{V}O_2$ during exercises done on a cycle ergometer, performed at the heart rate (HR) of the first ventilatory threshold ($\dot{V}O_{2VT1}$) and in the first 30 minutes following the exercise, on land and in water, in pregnant and non-pregnant women.

Methods

Subjects

The sample was composed of 20 women (established by sample calculation for a significance of 0.05, p=80% and correlation of 0.8), ten pregnant women, who participated in a directed program of water gymnastics, and ten active non-pregnant women, volunteers, and students in the university. The following inclusion criteria were used: to be at a gestational age between 27 and 30 weeks, present familiarity with the water medium, be nonsmokers and have a medical authorization to be submitted to the exercise tests. Besides similar inclusion criteria, individuals of the Non-pregnant Group were selected according to age and a body mass index (BMI) similar to the pre-pregnancy one of the Pregnant Group. All of them provided an informed consent form, which was previously approved by the Ethics in Research Committee of the Federal University of Rio Grande do Sul (registered under number 2005449).

Study protocol

Four cardiopulmonary submaximal tests on a cycle ergometer were carried out, with a minimal interval of 48 hours and a maximum of 72. The two first tests (one in the water and one on land) were performed with a progressive increment of load for the determination of the $\dot{V}O_{2VT1}$ in each medium. In the water test, two cycle ergometers were used. One, a Monark – Valburg/Sweden, remained outside the water. It was connected by a 6-meter strap to the other one, a Sculptor – RGS, Brazil, which remained in the water. In the land test, the individual cycled the Monark cycle ergometer. Evaluation started with weight and height measurements (Stadiometer and Filizola Scale). Then, the individual laid down in the left lateral decubitus position for ten minutes for measurement of $\dot{V}O_2$, HR, and BP.

The $\dot{V}O_2$ evaluation was performed through portable gas analyzer KB1-C (Aerosport Inc.-USA), and the software Aerograph (USA) was utilized. For BP measurements, a mercurial sphygmomanometer Baumanometer (W. A. Baum Co., New York) was used. And, for the HR measurement, we utilized a Polar model F1™ (Polar Electro Oy, Finland). Immediately, the subject remained sat for three minutes and all variables were collected again. These resting measurements in the sitting position were compared with postexercise values. After that, the individual sat on the bicycle and did a warm-up for one minute, cycling at the speed of 50 rotations per minute (rpm) without any load. Then, it was increased to the initial load, corresponding to 25 watts (W), and had increments of 25 W, every two minutes. The speed remained constant though. The test was interrupted as soon as the $\dot{V}O_{2VT1}$ was identified, through the analysis of the curve inflection point of the ventilatory equivalent for oxygen ($VE/\dot{V}O_2$). Women who presented $\dot{V}O_{2LV1}$ between 9 and 22 $mL.kg^{-1}.min^{-1}$ were included in the study[17].

Next, two more tests, one in each medium, were carried out (there was a draft to define the sequence of the tests), in a continuous (rectangular) way during 30 minutes, at the HR corresponding to the $\dot{V}O_{2VT1}$ found in the respective submaximal test. A 30-minute period was established in order to attempt the reproduction of aerobics activity timing, usually observed in fitness centers.

In the water tests, the depth of the immersion was close to the height of the xiphoid appendix and the mean temperature was 32.4±0.37° C.

The continuous tests, performed for 30 minutes, started with individual cycling for four minutes, without any load, at a speed of 50 rpm. The load was increased until the individual reached the HR corresponding to $\dot{V}O_{2VT1}$, according to what had been found in the progressive test in the corresponding medium. Exercise measurements consisted of recording BP every five minutes, and HR and $\dot{V}O_2$ every 20 seconds.

At the end of the 30-minute period, the test was interrupted without a cooling period, the individual was asked to leave the bicycle and to sit on a chair. Postexercise rest analysis was always carried out outside water. In the water tests, the individuals were dried up and had to wear a robe so that they would not feel cold. In the next 30 minutes, again, BP measurements were taken every five minutes, and HR and $\dot{V}O_2$, every 20 seconds.

Participants were aware of the fact that they could not participate in any other physical activity during the testing period, they could not ingest any food three hours before the tests, and caffeine 24 hours before each test.

Statistical analysis

Descriptive statistics and Shapiro Wilk's Test for normality were used. Uniformity of the means between the two groups was tested by the *t* test for independent measures. Identification of pre-exercise resting values, for each group, was done by the variance analysis (ANOVA) for repeated measurements in the four-day test. In order to verify whether the HR obtained in the progressive test was the same in the continuous ones, the paired *t* test was used. For the analysis of the dependent variables, during and after exercise, regression for the different moments of collections along the tests was used. As there was no significance of the coefficients of the regression models for the variables studied, it was possible to use a mean of these values, both for exercise and postexercise data. In order to compare the responses between the mediums (water and land), between the state (pregnant and non-pregnant), and the interaction between facts, ANOVA two-way was used. Finally, to compare the situations of pre-exercise and postexercise rest, in each group, the paired *t* test was used. The analyses described used a significance level of up to 5%. The statistical software package was SPSS 17.0.

Results

Table 1 shows the similarity between the two groups regarding age and height. There is a difference in the items that compared body mass and BMI between pregnant and non-pregnant women.

Behavior of BP during exercise

Figure 1 shows a different behavior of BP during exercise in water and on land, depicting the significant effect of the medium (systolic BP, p=0.008; diastolic BP, p=0.016; mean BP, p=0.001). It is interesting to point out that in the results of the interaction between state and medium for the diastolic BP (p=0.077) and mean BP (p=0.054), a tendency was verified with BP presenting lower values during exercise in the water, probably potentized by the pregnant state (Figure 1).

Behavior of $\dot{V}O_2$ during exercise

The $\dot{V}O_2$ behavior during the 30-minute exercise phase presented in Figure 2 suggests that both the pregnant state (pregnant women = 0.7±0.1 $L\cdot min^{-1}$; non-pregnant women =0.7±0.1 $L\cdot min^{-1}$), and the medium, in which the exercise was done (water medium = 0.7±0.1 $L\cdot min^{-1}$; land medium 0.7±0.1 $L\cdot min^{-1}$), did not interfere in the behavior of this variable. The interaction between the factors, state (p=0.786), and medium (p=0.424), was not significant either.

Behavior of the BP during the postexercise period

The present study resulted in the return of the BP to pre-exercise values, in the first measurement; measured five minutes after the exercise had been interrupted. Figure 3 shows the behavior of systolic, diastolic, and mean BP. There was no difference in the mean of these variables after water and land exercises. Both returned quickly to pre-exercise values.

Behavior of $\dot{V}O_2$ in the postexercise period

$\dot{V}O_2$ did not differ between groups (pregnant women = 0.2±0.05 $L\cdot min^{-1}$; non-pregnant women = 0.2±0.05 $L\cdot min^{-1}$) in the 30 minutes following

Table 1. Characterization of the sample: means±standard deviation values of the variables: age (years), height (m), body mass (kg), current body mass index (kg/m²), pre-pregnancy mass (kg), pre-pregnancy body mass index (kg/m²), pre-pregnancy/current non-pregnant body mass index (kg/m²), total weight gain (kg), weight gain during tests (kg), and initial gestational age (weeks)

Variables	Pregnant women (n=10) Mean±SD	Non-pregnant women (n=10) Mean±SD	Significant
Age (years)	31.9±3.1	32.3±2.8	0.77
Height (m)	1.6±0.1	1.6±0.1	0.72
Body mass (kg)	65.5±6.4	58.2±6.3	0.01*
Current BMI (kg/m²)	24.9±1.9	21.8±1.7	0.00*
Pre-pregnancy mass (kg)	57.0 ± 6.8		
Pre-pregnancy BMI (kg/m²)	21.6 ± 2.1		
Pre-pregnancy/current BMI (kg/m²)	21.6±2.1	21.8±1.7	0.83
Total weight gain (kg)	8.5±1.7		
Weight gained during tests (kg)	0.6±0.5		
Initial gestational age (weeks)	27.7±0.5		

SD: standard deviation; BMI: body mass index; significant difference between groups: *α<0.05.

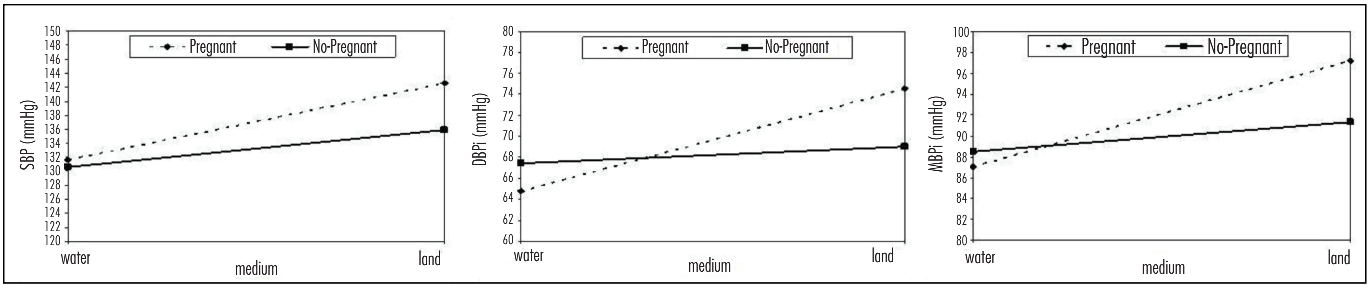

Figure 1. Behavior of the systolic blood pressure (SBP, A), diastolic blood pressure (DBP, B), and mean blood pressure (MBP, C) expressed by the mean, in water and land exercise, done by pregnant and non-pregnant women.

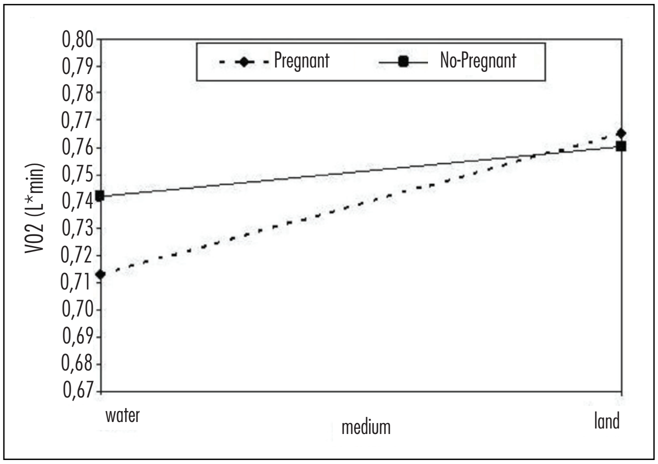

Figure 2. Behavior of absolute oxygen consumption (V̇02) expressed by the mean in land and water exercise, done by pregnant and non-pregnant women.

the exercise. The medium in which the exercise was done (water = 0.2±0.04 L.min^{-1}; land = 0.2±0.06 L.min^{-1}) and the interaction between the factors (state; p=0.660 and medium; p=0.482) were not significant either. $\dot{V}O_2$ values were similar to those of the pre-exercise period.

Discussion

BP behavior

Studies demonstrated that BP was lower in water exercises[17-18]. This results are in accordance with the present findings, in which pregnant women have lower systolic (131±8 mmHg), diastolic (66±6 mmHg), and mean BP (88±4 mmHg) in water exercise compared with land exercise (systolic BP: 139±10 mmHg; diastolic BP: 72±8 mmHg; mean BP: 94±7 mmHg). These data provided by our laboratory seem to be important and relate to the potentialization of BP behavior during water exercise, modified by the pregnant state. A possible reason for the decrease in the BP, during immersion, may be related to the increase of cardiac preload[19], which is closely linked to the increase of central BP during immersion[20]. The increase of central blood volume and cardiac output causes a greater renal blood flow[21], mainly because of the plasmatic rennin decrease. Consequently, there is an increment in concentration of the atrial natriuretic peptide[22], which contributes to the lowering effect of the BP during immersion. Another possible explanation for the decrease of BP in the water medium is the water temperature (32.4±0.37° C), which may promote vasodilatation and a systemic decrease in arterial resistance[23].

Most studies, which evaluated the response of BP during land exercise, have not found any difference when comparing pregnant and non-pregnant women[24-26]. An interesting aspect to be observed is the duration of the physical activity. In our experimental design, we exercised both groups for 30 minutes, always at the same intensity, differently from other studies[24-27] that presented shorter exercise duration (10 to 15 minutes). It is important to mention that in our study in the first ten minutes of continuous exercise, a similar systolic BP response between pregnant and non-pregnant women was elicited. However, after the first ten minutes, a tendency of increase in systolic BP in pregnant women on land exercise was verified as time went by (coefficients obtained in the regression analysis of positive coefficient of 2.4 and significance of 0.07 in the pregnant women; in the non-pregnant women, it was negative, between -1.04 and 0.2, respectively), as can be seen in Figure 4. This fact may be explained by the theory that gradual increases in the stroke volume and in cardiac output also cause a gradual increase in systolic BP, along continuous land exercise, in pregnant women. This behavior would be different in water by the probable influence of the length of immersion[28].

The present study has a practical application that extrapolates the crude statistical analyses "per se". With the aim of amplifying the safety margin of pregnant women, when they do exercises, water exercise, done at the intensity of $\dot{V}O_{2VT1}$, causes a BP lower than the correspondent land exercise. It seems to be a relevant aspect concerning exercise prescription during pregnancy.

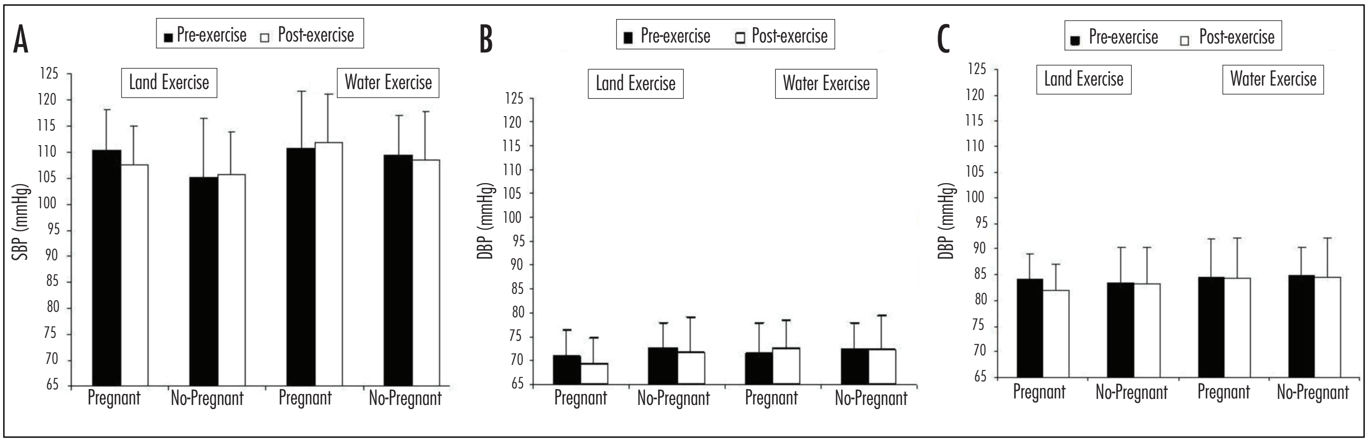

Figure 3. Comparison of the means of systolic blood pressure (SBP, A), diastolic blood pressure (DBP, B), and mean blood pressure (MBP, C) between rest (on land) in the pre and postexercise done in the water and on land with pregnant and non-pregnant women.

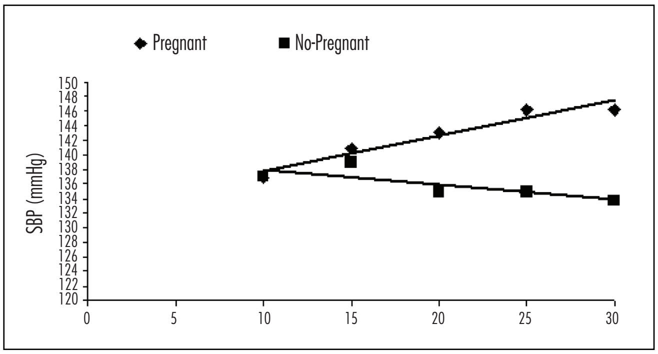

Figure 4. Tendency line of the means of systolic blood pressure at five moments, during water exercise in the pregnant and non-pregnant groups.

$\dot{V}O_2$ behavior

Corroborating with the present study, several authors[25-27,29-30] did not find significant differences in the behavior of $\dot{V}O_2$ in pregnant women exercising on a cycle ergometer, in submaximal intensities on land, when compared to non-pregnant state. Significant differences in $\dot{V}O_2$ at the maximum equivalent load between pregnant (GA: 28±0.3 weeks) and non-pregnant women were reported in the literature[31]. McMurray et al.[15] and Spinnewijn et al.[16] concluded that the $\dot{V}O_2$ peak during pregnancy was lower in water exercise than the one observed on land. The difference observed among the mentioned studies and ours might be attributed to different intensity and modality of exercise, which might have influenced the results. Some studies mentioned above compared swimming with exercising on a bicycle, whereas ours used the same modality for both mediums[32].

Behavior of the BP in the postexercise

Results found in this study are in agreement with some authors[33] that evaluated pregnant women in the 37th week of pregnancy, during 12 minutes of exercise on a cycle ergometer on land, and who verified that after 15 minutes of rest, the BP presented values similar to the pre-exercise ones. Divergent results were showed by Hartmann et al.[34], who verified a decrease in BP after water exercise. The mechanisms that resulted in distinct behaviors[34] or similar (present study) of BP after exercise done in water and land mediums, between pregnant women, are not clear yet. Nevertheless, it seems that the immersion in water by pregnant women with preeclampsia has little therapeutic effect. The lowering of BP is limited to a short period of time, and it does not have an effect, that is, endothelium-dependent vasodilatation[35].

Behavior of $\dot{V}O_2$ in the postexercise period

The intensity of exercise might reduce or prolong the $\dot{V}O_2$ kinetic during recovery[36]. The authors also observed that in the lying position the excess of postexercise $\dot{V}O_2$ prolongs as in comparison to the sitting position. It is probable that these two factors have contributed to the results presented in this study (there was no difference in $\dot{V}O_2$ at rest in the pre and postexercise resting periods in pregnant and non-pregnant women). Both the sitting position adopted in our protocol during the recovery period and in the low intensity of the exercise performed might have influenced the behavior of the postexercise $\dot{V}O_2$.

It is important to mention some limitations of this study. First, the HR was chosen as a variable to control the intensity, due to its better practical application of the results in the locations where pregnant women perform exercises. However, it might have been interesting to know which was the mean load used on the bicycle during the tests. This datum was obtained when the exercise was done on land. In the water, however, it was not possible to assess the load used in this medium. Second, the data found in this study do not enable us to extrapolate the results found for all the gestational period, as the tests were carried out in a single period of the pregnancy. As a relatively small "n" was tested, the sample was as homogeneous as possible.

In conclusion, pregnant women, at the beginning of the last trimester of pregnancy, presented cardiovascular responses similar to the non-pregnant during exercise, when performed at the intensity corresponding to the $\dot{V}O_{2VT}$. The choice of water exercise, done under these conditions, seems advisable as the pregnant women could take part in a cardiovascular conditioning program, presenting a lower BP behavior in comparison to that observed on land.

As a practical application, the present data enabled the assumption that the behavior of $\dot{V}O_2$ in submaximal activities, such as those elicited in this study, when performed by a sample with a low to moderate physical conditioning, is not changed during pregnancy, when $\dot{V}O_2$ is expressed in absolute values. Therefore, exercise prescription can be based on tests carried out before pregnancy or even with the use of formulas for the estimation of the HR for training, similarly to what was applied to non-pregnant women, making the training intensity control easier in fitness centers. Also, and importantly, the medium did not influence the behavior of $\dot{V}O_2$. Such fact shows that water exercise is able to promote cardiovascular alterations in the same magnitude as of land exercises.

Referências

1. Artal R, O'Toole M. Guidelines of the American College of Obstetricians and Gynecologists for exercise during pregnancy and postpartum period. Br J Sports Med. 2003;37(1):6-12.
2. Wolfe LA, Davies GA; School of Physical and Health Education, Department of Obstetrics and Gynaecology and Physiology, Queen's University, Kingston, Ontario, Canada. Canadian guidelines for exercise in pregnancy. Clin Obstet Gynecol. 2003;46(2):488-95.
3. Santos IA, Stein R, Fuchs SC, Duncan BB, Ribeiro JP, Kroeff LR, et al. Aerobic exercise and submaximal functional capacity in overweight pregnant women: a randomized trial. Obstet Gynecol. 2005;106(2):243-9.
4. Pivarnik JM, Mudd L. Oh baby! Exercise during pregnancy and postpartum period. ACSM's Health Fitness J. 2009;13(3):8-13.
5. Gaston A, Cramp A. Exercise during pregnancy: a review of patterns and determinants. J Sci Med Sport. 2011;14(4): 299-305.
6. Katz VL. Exercise in the water during pregnancy. Clin Obstet Gynecol. 2003;46(2):432-41.
7. Clapp JF 3rd. Exercise during pregnancy. A clinical update. Clin Sports Med. 2000;19(2):273-86.
8. Soultanakis-Aligianni HN. Thermoregulation during exercise in pregnancy. Clin Obstet Gynecol. 2003;46(2):442-55.
9. Finkelstein I, Alberton CL, Figueiredo PAP, Garcia DR, Tartaruga LAP, Kruel LFM. Comportamento da freqüência cardíaca, pressão arterial e peso hidrostático de gestantes em diferentes profundidades de imersão. Rev Bras Ginecol Obstet. 2004;26(9):685-90.
10. Arborelius M Jr, Ballidin UI, Lilja B, Lundgren CE. Hemodynamic changes in man during immersion with the head above water. Aerosp Med. 1972;43(6):592-8.
11. Sorensen TK, Williams MA, Lee IM, Dashow EE, Thompson ML, Luthy DA. Recreational physical activity during pregnancy and risk of preeclampsia. Hypertension. 2003;41(6):1273-80.
12. Weissgerber TL, Wolfe LA, Davies GA. The role of regular physical activity in preeclampsia prevention. Med Sci Sports Exerc. 2004;36(12):2024-31.
13. Finkelstein I, Bgeginski R, Tartaruga MP, Alberton CL, Kruel LFM. Comportamento da freqüência cardíaca e da pressão arterial, ao longo da gestação, com treinamento no meio líquido. Rev Bras Med Esporte. 2006;12(6):376-80.
14. McMurray RG, Katz VL, Berry MJ, Cefalo RC. Cardiovascular responses of pregnant women during aerobic exercise in water: a longitudinal study. Int J Sports Med. 1988;9(6):443-7.
15. McMurray RG, Hackney AC, Katz VL, Gall M, Watson WJ. Pregnancy-induced changes in the maximal physiological responses during swimming. J Appl Physiol. 1991;71(4):1454-9.
16. Spinnewijn WE, Wallenburg HC, Struijk PC, Lotgering FK. Peak ventilatory responses during cycling and swimming in pregnant and nonpregnant women. J Appl Physiol. 1996;81(2):738-42.
17. Barros Neto TL, César MC, Tambeiro VL. Avaliação da aptidão física cardiorrespiratória. In: Ghorayeb N, Barros Neto TL, editores. O exercício: preparação fisiológica, avaliação médica, aspectos especiais e preventivos. São Paulo: Atheneu; 1999. p. 15-34.
18. McMurray RG, Katz VL, Meyer-Goodwin WE, Cefalo RC Thermoregulation of pregnant woman during aerobic exercise on land and in the water. Am J Perinat. 1993;10(2):178-82.
19. Park KS, Choi JK, Park YS. Cardiovascular regulation during water immersion. Appl Human Sci. 1999;18(6):233-41.
20. Gabrielsen A, Johansen LB, Norsk P. Central cardiovascular pressures during graded water immersion in humans. J Appl Physiol. 1993;75(2):581-5.
21. Kent T, Gregor J, Deardorff L, Katz V. Edema of pregnancy: a comparison of water aerobics and static immersion. Obstet Gynecol. 1999;94(5 pt 1):726-9.
22. Asai M, Saegusa S, Yamada A, Suzuki M, Nogushi M, Niwa S, et al. Effect of exercise in water on maternal blood circulation. Nippon Sanka Fujinka Gakkai Zasshi. 1994;46(2):109-14.
23. Srámek P, Simecková M, Janský L, Savlíková J, Vybíral S. Human physiological responses to immersion into water of different temperatures. Eur J Appl Physiol. 2000;81(5):436-42.
24. Van Doorn MB, Lotgering FK, Struijk PC, Pool J, Wallenburg HC. Maternal and fetal cardiovascular responses to strenuous bicycle exercise. Am J Obstet Gynecol. 1992;166(3):854-9.
25. Pivarnik JM, Ayres NA, Mauer MB, Cotton DB, Kirshon B, Dildy GA. Effects of maternal aerobic fitness on cardiorespiratory responses to exercise. Med Sci Sports Exerc. 1993;25(9):993-8.
26. Avery ND, Wolfe LA, Amara GA, Davies GA, McGrath MJ. Effects of human pregnancy on cardiac autonomic function above and below the ventilatory threshold. J Appl Physiol. 2001;90(1):321-8.

27. Sady SP, Carpenter MW, Thompson PD, Sady MA, Haydon B, Coustan DR. Cardiovascular response to cycle exercise during and after pregnancy. J Appl Physiol. 1989;66(1):336-41.
28. Ayres CE, Mauad-Filho F, Ferreira AC, Gomes UA, Pinheiro Filho LS. Modificações no índice de líquido amniótico estimado pela ultra-sonografia em gestantes submetidas à imersão subtotal em água. Rev Bras Ginecol Obstet. 2001;23(2):101-5.
29. Heenan AP, Wolfe LA, Davies GA, McGrath MJ. Effects of human pregnancy on fluid regulation responses to short-term exercise. J Appl Physiol. 2003;95(6):2321-7.
30. Treuth MS, Butte NF, Puyau M. Pregnancy-related changes in physical activity, fitness, and strength. Med Sci Sports Exerc. 2005;37(5):832-7.
31. Jensen D, Webb KA, Wolfe LA, O´Donnell DE. Effects of human pregnancy and advancing gestation on respiratory discomfort during exercise. Respir Physiol Neurobiol. 2007;156(1):85-93.
32. Carpenter MW, Sady SP, Sady MA, Haydon B, Coustan DR, Thompson PD. Effect of maternal weight gain during pregnancy on exercise performance. J Appl Physiol. 1990;68(3):1173-6.
33. Jovanovic L, Kessler A, Peterson CM. Human maternal and fetal response to graded exercise. J Appl Physiol. 1985;58(5):1719-22.
34. Hartmann S, Kolble N, Rake A, Bung P, Huch A, Huch R. Aqua-fit during pregnancy: maternal and fetal hemodynamic responses during rest, immersion and exercise. Geburtshilfe Frauenheilkunde. 2001;61(12):977-82.
35. Elvan-Taspinar A, Franx A, Delprat CC, Bruinse HW, Koomans HA. Water immersion in preeclampsia. Am J Obstet Gynecol. 2006;195(6):1590-5.
36. Short KR, Sedlock DA. Excess postexercise oxygen consumption and recovery rate in trained and untrained subjects. J Appl Physiol. 1997;83(1):153-9.