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The aim of the current study was to analyze and compare oxygen uptake (VO_2) and heart rate (HR) in different water exercises. Eight postmenopausal women participated in a set of 4 sessions in water. Eight different exercises were randomly coupled for the 4 sessions. Each exercise was executed at a rate of 60 beats/min for 4 min with rest intervals of 30 min. A repeated-measures ANOVA and Bonferroni's post hoc test were used to test for statistical differences at $\alpha < .05$. Significant differences were seen in HR and VO_2 between some pairs of the 8 exercises. These results suggest that water-exercise classes should be prescribed based on percentages of maximal HR or VO_2, not on a fixed cadence, because different exercises correspond to different percentages of maximal effort.

Key Words: aquatic exercise, heart rate, oxygen uptake

The use of physical exercises in aquatic environments is expanding widely. The physiological responses to aquatic exercises, such as those performed on aquatic cycle ergometers (Christie et al., 1990; Connely et al., 1990), with deep-water running (DeMaere & Ruby, 1997; Nakanishi, Kimura, & Yoko, 1999), shallow-water walking or on an underwater treadmill (Hall, McDonald, Maddison, & O'Hare, 1998; Shono, Fujishima, Hotta, Ogaki, & Masumoto, 2001), and, more recently, through water exercises (Alberton, Coertjens, Figueiredo, & Kruel, 2005; Benelli, Ditroilo, & DeVito, 2004; Cassady & Nielsen, 1992; Johnson, Stromme, Adamczyk, & Tennoe, 1977; Kruel, 2000), have been analyzed and compared with exercises performed on land. Furthermore, other studies show that, in the long term, such exercises can provide numerous benefits, for example, increased strength (Pöyhönen et al., 2002; Takeshima et al., 2002), increased flexibility (Alves, Mota, Costa, & Alves, 2004; Takeshima et al., 2002), and improved cardiorespiratory conditioning (Alves et al.; Avellini, Shapiro, & Pandolf, 1983).

In addition to these benefits, there is less impact on the lower limbs when exercises are performed in an aquatic environment (Barella, Stolf, & Duarte, 2006;

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Kruel, 2000; Miyoshi, Shirota, Yamamoto, Nakazawa, & Akai, 2004). They are suitable for people who could not endure equivalent exercises on land, such as individuals with obesity, arthritis, low back pain, or other orthopedic dysfunctions (Cassady & Nielsen, 1992). Water exercise is an activity widely used for the purpose of recreation, improving or maintaining fitness, or preventing or recovering from muscle damage (Frangolias & Rhodes, 1995).

Nevertheless, contradictory results have been reported for some of the physiological responses observed with water exercises, especially in studies comparing exercises done in water with those done on land. Cassady and Nielsen (1992) found higher oxygen-uptake (VO_2) values in water-based exercises, whereas higher heart-rate (HR) values were found in response to land exercises. Johnson et al. (1977) observed higher HR and VO_2 values in aquatic activities. Kruel (2000) found lower HR and VO_2 values when the exercises were executed with the participants immersed up to the shoulders than when they did same exercises on land. Benelli et al. (2004) obtained similar responses, reporting lower HR and lactate concentrations with water immersion.

The lower HR in water can be explained by the action of hydrostatic pressure on the submerged body, which stimulates peripheral baroreceptors, which help redistribute blood from the lower limbs to the torso (Watenpaugh, Pump, Bie, & Norsk, 2000). There are no consistently defined advantages in VO_2 behavior, however, when exercises are performed and compared between water and land, because the higher or lower energy expenditure depends on the type and cadence of the exercise (Alberton et al., 2005).

When different water exercises were compared, Cassady and Nielsen (1992) found higher VO_2 values for lower limbs than for upper limbs when the same cadence was used. This confirms the results of Johnson et al. (1977), who also found higher VO_2 values in lower limb water exercise than in upper limb water exercise done at the same cadence. These authors suggest that the lower limbs represent a greater muscle mass and longer levers to lift against the hydrodynamic friction created by the water. Kruel (2000) found no significant differences in HR and VO_2 values for the five water exercises they analyzed, which were done at moderate levels of perceived exertion. Similarly, Alberton et al. (2005) found equivalent VO_2 values between three water exercises they analyzed, which were done at different cadences, also demonstrating that different exercises can be performed in water with the same energetic cost.

This variation in HR and VO_2 values was considered in establishing the aim of the current study, which was to analyze the HR and VO_2 responses of postmenopausal women performing different water exercises at the same cadence.

Method

Participants

The study sample comprised 8 voluntary postmenopausal women, with a mean age of 59.63 ± 4.69 years. They participated in water-exercise classes at the School of Physical Education at the Federal University of Rio Grande do Sul, Brazil. They had no known physical or mental illness and signed an informed-consent form containing all pertinent data. Each of them took part in five experimental sessions.

Several restrictions were imposed on the volunteers: no food 3-4 hr before the exercises and no stimulants (coffee, chocolate, or tea) or intense physical activity (>70% VO_{2max}) 12 hr before the exercises (Cooke, 1996).

Procedure

The first data-collection session took place at the university's exercise research laboratory. On that occasion, body mass and height were measured with a Filizola standard medical balance. Peak oxygen uptake (VO_{2peak}) was determined with a 10200 ATL Inbramed treadmill (Porto Alegre, Brazil). The test was conducted with a ramp protocol at 5-km/hr initial speed and slope of 1%. Subsequent speed increments, at 1-min intervals, were of 1 km/hr. The data were considered a good peak test if one of the following criteria was attained (Howley, Basset, & Welch, 1995): The HR_{max} was attained (estimated as 220 – age), VO_2 reached a plateau with the increase of treadmill speed, or respiratory-exchange ratio > 1.1.

During all sessions, respiratory gases were collected with a mixing-box-type portable Aerosport KB1-C gas analyzer (Ann Arbor, MI, USA). A pneumotach was used with a neoprene mask. Data were collected each 20 s. The power supply was a Hayama CH1220 switched source (Londrina, Brazil). HR measurements were obtained with a Polar T61 transmitter and a S610 wrist monitor (Kajaani, Finland).

Eight water exercises were randomly paired for the four sessions held at the university swimming center. The exercises, as shown in Figure 1, were

- Stationary running with arms pushing alternately to the front (SR-AP)
- Stationary running with horizontal shoulder flexion and extension (SR-FE)
- Frontal kick to 90° with arms pushing alternately to the front (FK-AP)
- Frontal kick to 90° with horizontal shoulder flexion and extension (FK-FE)
- Cross-country skiing with arms pushing alternately to the front (CCS-AP)
- Cross-country skiing with horizontal shoulder flexion and extension (CCS-FE)
- Jumping jacks with arms pushing alternately to the front (JJ-AP)
- Jumping jacks with horizontal shoulder flexion and extension (JJ-FE)

A rest was taken at the beginning of each session out of the water: The participants rested in a supine position for 10 min followed by 5 min in an upright standing position so that we could measure VO_2 and HR at rest. The mean value collected during the last 3 min in each position was used in the analysis.

Two exercises were performed in each test session, with a break of 30 min between bouts. Each exercise was performed for 4 min to obtain the VO_2 and HR values. An average of Minutes 3 and 4 was retained for analysis from this period, because these variables attain a steady state, for the intensity used in this study, in the third minute of exercise (Linnarsson, 1974). A Quartz Matrix MR-500 metronome marked the 60-beats/min cadence of the exercises, later recorded on a CD to facilitate sound amplification. The sound was reproduced by a Toshiba CD digital-audio set.

All participants performed with the water at the xiphoid-process level, with their arms submerged approximately from the elbow to the hand. The water was kept at the thermoneutral temperature of 32–33 °C (~90 °F; Christie et al., 1990;

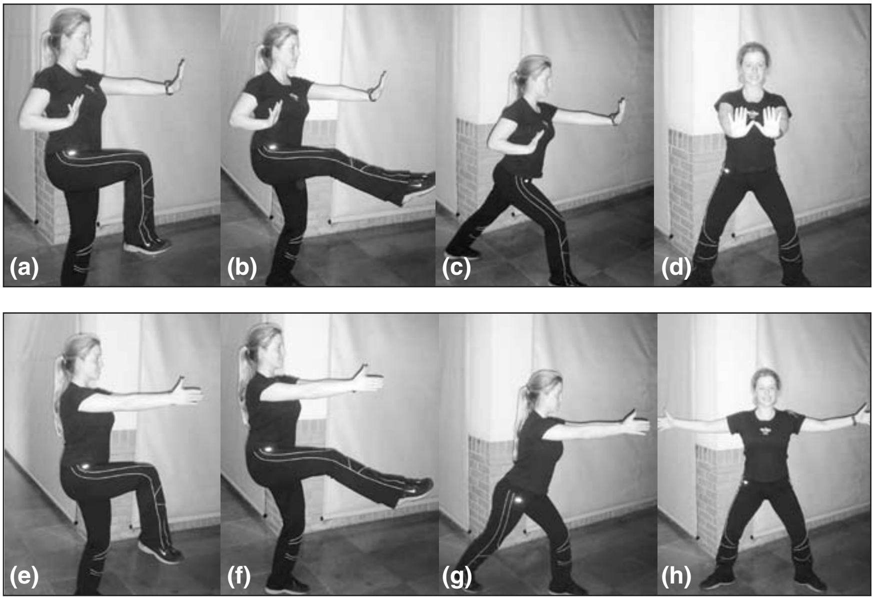

Figure 1 — (a) Stationary running with arms pushing alternately to the front. (b) Frontal kick to 90° with arms pushing alternately to the front. (c) Cross-country skiing with arms pushing alternately to the front. (d) Jumping jacks with arms pushing alternately to the front. (e) Stationary running with horizontal shoulder flexion and extension. (f) Frontal kick to 90° with horizontal shoulder flexion and extension. (g) Cross-country skiing with horizontal shoulder flexion and extension. (h) Jumping jacks with horizontal shoulder flexion and extension.

Connely et al., 1990), as verified by means of an Incoterm alcohol thermometer accurate to 1 °C. Mean atmospheric pressure was 758.3 ± 2 mmHg, monitored with a Sunto barometer.

Statistical Analysis

Descriptive statistics were used for initial data analysis, and the results are presented as $M \pm SD$. Normality was tested using the Shapiro–Wilk test. All parameters were analyzed using repeated-measures ANOVA, with the Bonferroni correction for post hoc comparison tests. SPSS version 11.0 was used to calculate all statistical comparisons, and the level of significance was set at $\alpha < .05$, with a statistical power of 80%.

Results

The main purpose of this study was to analyze the cardiorespiratory responses of postmenopausal women to eight different water exercises. The demographic characteristics of the sample of 8 women are presented in Table 1. The results of the

Table 1 Participants' Demographic Characteristics

Variables	*M*	*SD*
Age (years)	59.63	4.69
Height (cm)	156.63	4.70
Body mass (kg)	64.08	10.04
Body-mass index (kg/m^2)	26.13	4.12
Resting peak oxygen uptake ($ml \cdot kg^{-1} \cdot min^{-1}$)	22.00	4.63

Table 2 Resting Oxygen Uptake (VO_2) and Heart Rate in Supine and Standing Positions Over the 4 Days of the Experiment

		VO_2 ($mL \cdot kg^{-1} \cdot min^{-1}$)				Heart Rate (beats/min)			
Position	Day	*M*	*SD*	*F*	α	*M*	*SD*	*F*	α
Supine	1	3.27	0.47	0.434	.738	70.80	9.55	0.829	.532
	2	3.23	0.97			71.76	11.41		
	3	3.02	0.70			71.25	8.99		
	4	3.25	0.73			73.51	9.55		
Standing	1	4.01	0.92	2.606	.164	80.40	11.45	0.283	.836
	2	4.05	0.80			82.23	11.75		
	3	3.53	0.70			83.33	5.03		
	4	3.93	0.87			83.92	12.45		

tests of normality for HR and VO_2 values justified the use of parametric statistics in the subsequent analyses.

The rest values for HR and VO_2 are shown in Table 2. No statistically significant differences in resting values were observed over the 4 days of the experiment, in either the supine or standing positions.

The results for VO_2 and HR are shown in Figures 2 and 3, respectively, and they indicate that water exercises, when performed at the same cadence (in the present study maintained at 60 beats/min and controlled by a metronome), elicit different physiological responses.

The highest VO_2 values were found during the FK-FE (16.48 ± 3.49 $mL \cdot kg^{-1} \cdot min^{-1}$) and the lowest values in JJ-AP (8.22 ± 1.66 $mL \cdot kg^{-1} \cdot min^{-1}$) for the cadence used. For VO_2 responses, five subgroups were observed, one for each letter. Subgroup A, for example, is composed of the FK-FE, FK-AP, SR-FE, and CCS-FE. Different exercises in the same subgroup had no significant differences in VO_2 values, but different subgroups, with different letters, were significantly different.

As was found with the results for VO_2, the highest values for HR were seen in the FK-FE condition (135.94 ± 10.45 beats/min), and the lowest, in the JJ-AP (97.04 ± 11.92 beats/min). For HR, however, there were only three subgroups of similar exercises.

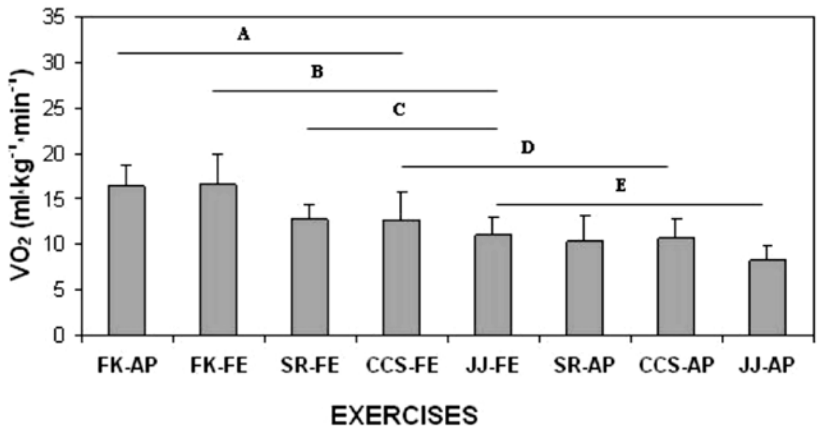

Figure 2 — Oxygen uptake. *Note*. FK-AP = frontal kick to 90° with arms pushing alternately to the front; FK-FE = frontal kick to 90° with horizontal shoulder flexion and extension; SR-FE = stationary running with horizontal shoulder flexion and extension; CCS-FE = cross-country skiing with horizontal shoulder flexion and extension; JJ-FE = jumping jacks with horizontal shoulder flexion and extension; SR-AP = stationary running with arms pushing alternately to the front; CCS-AP = cross-country skiing with arms pushing alternately to the front; JJ-AP = jumping jacks with arms pushing alternately to the front. Different letters indicate the presence of significant differences between exercises (α < .05).

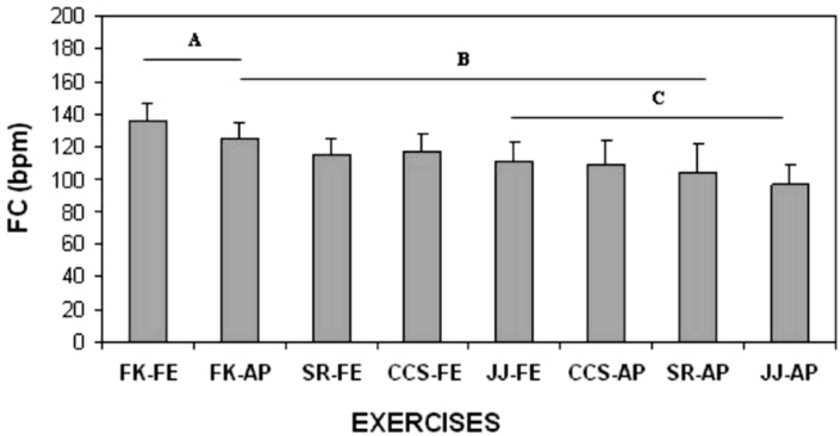

Figure 3 — Heart rate. *Note.* FK-FE indicates frontal kick to 90° with horizontal shoulder flexion and extension; FK-AP = frontal kick to 90° with arms pushing alternately to the front; SR-FE = stationary running with horizontal shoulder flexion and extension; CCS-FE = cross-country skiing with horizontal shoulder flexion and extension; JJ-FE = jumping jacks with horizontal shoulder flexion and extension; CCS-AP = cross-country skiing with arms pushing alternately to the front; SR-AP = stationary running with arms pushing alternately to the front; JJ-AP = jumping jacks with arms pushing alternately to the front. Different letters indicate the presence of significant differences between exercises (α < .05).

Discussion

The resting values for HR and VO_2 confirm that each day the participants started the exercises with equivalent HR and VO_2 values. Thus, the changes in these values that occurred during the exercises can be attributed to the efforts made and physiological responses to the exercises.

The results of the present study indicate that cardiorespiratory responses seem to be modified by the exercises chosen, because different exercises demand different levels of physiological effort. The statistically significant differences in VO_2 and HR values between some of the different exercises might be related to the muscle mass and range of motion of the lower and upper limb segments and to their projected areas responsible for the water resistance and the energy spent to overcome it.

Kruel (2000) analyzed the VO_2 and HR responses to five water exercises performed in an aquatic environment at two distinct water depths, the shoulder and the navel. The cadence was varied from 57 to 86 beats/min to correspond to moderate perceived exertion, using the Borg perceived-exertion scale. No significant differences were found for either dependent variable between the five exercises at the different execution depths.

Alberton et al. (2005) also analyzed the behavior of VO_2 during three water exercises performed at three fixed cadences (80, 100, and 120 beats/min). For each cadence, no significant differences were found in VO_2 values gathered during the three exercises. It is important to stress that only three exercises were tested in that study and that, if the present study analyzed only the first three exercises shown in Figure 2, no significant differences for VO_2 would be found. No study was found in the literature that analyzed more than five exercises together. It is therefore valuable that the current study analyzed eight exercises with similar and dissimilar intensities.

The increase in VO_2 between different water exercises seems to be caused by the involvement of the muscle groups. The highest VO_2 values were elicited by FK-FE and FK-AP, exercises with biarticular movements of the lower limbs involving large muscle masses. The other exercises also depend on the muscle groupings involved. Exercises with wider arm movements (SR-FE, CCS-FE, and JJ-FE) require higher VO_2 than the others (SR-AP, CCS-AP, and JJ-AP), excluding the biggest grouping of the lower limbs. These results confirm the data from Johnson et al. (1977) and Cassady and Nielsen (1992), who found higher VO_2 values for lower limb exercises than for upper limb exercises. For those authors, the greater size of the muscles of the lower limbs was responsible for the higher VO_2 values.

The projected area of resistance and the range of motion also seem to influence VO_2 values. Alberton et al. (2005) report that it is possible to increase VO_2 by increasing water resistance. Therefore, a great resistance ($R = 0.5 \times \rho \times A \times v^2 \times \text{Cd}$) can be achieved by performing exercises in water, because the density of water is greater than that of air (ρ) at greater velocity (v^2) and the largest possible projected area (A; Pöyhönen, Keskinen, Hautala, & Mälkiä, 2000). The different exercises included in the present study use different projected areas, thus requiring different degrees of effort. For instance, FK-FE elicited the highest VO_2 values, because the greater movement amplitude of the legs and arms with the full projected area for these limbs resulted in a high water resistance. As seen in Figure 2, the projected area seemed to be related to the increase in VO_2.

Angular speed also might be important, because different speeds probably were required for shoulder articulation and for the lower limb articulations. For instance, FK-AP and JJ-AP use the same arm movements and have the same projected area for the leg segment, although the range of motion of the leg is much wider for FK-AP than for JJ-AP. Even with the same cadence, these two exercises probably provided different angular speeds, and greater resistance is offered by water in the FK-AP exercise. This is shown by the statistically significant difference in cardiorespiratory responses.

The patterns of VO_2 responses were very similar to those of HR in all eight exercises, but they were not identical. A linear relation between VO_2 and HR has been observed in exercises using only lower limbs, such as running and bike riding (Franklin, Hodgson, & Buskirk, 1980; Londeree & Ames, 1976), but not in exercises using both upper and lower limbs, such as dance and step training (Olson, Williford, Blessing, & Greathouse, 1991; Parker, Hurley, Hanlon, & Vaccaro, 1989; Rupp, Johnson, Rupp, & Granata, 1992; Williford, Blessing, Olson, & Smith, 1989). For the aquatic environment, Eckerson and Anderson (1992) analyzed HR and VO_2 in the course of a water-exercise session, using arm and leg movements, and observed that there was no simple relationship between them. Parker et al. (1989) suggest that such differences can be explained by the increase in sympathetic production with activities using the upper limbs in high movements.

Conclusion

We can conclude that, for the cadence used in this study, different VO_2 and HR values are found for different exercises in aquatic environments. These results occur because, for a fixed cadence, different exercises involve different muscle masses, as well as different projected areas. The larger muscle groups of lower limbs, together with their large projected areas, are the main factors responsible for the higher VO_2 values because they require greater effort. Furthermore, even when performed at a fixed cadence, different ranges of motion of the articulations involved could affect the resistance to the movement.

These results indicate that water exercise should be prescribed on the basis of rating of perceived exertion or percentage of maximal VO_2 or HR, obtained in maximal tests performed in water, not on the basis of cadence or musical-rhythm rates, because the different exercises included in the current study, although performed at the same fixed cadence, involved different effort intensities.

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