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Effects of two deep water training programs on cardiorespiratory and muscular strength responses in older adults

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ABSTRACT

This study aimed to investigate the effects of two deep water training programs on cardiorespiratory and muscular strength responses in older adults. Thirty-four older adults men were placed into two groups: deep water endurance training (ET; n = 16; 66 ± 4 years) and deep water strength prior to endurance training (concurrent training: CT; n = 18; 64 ± 4 years). The training period lasted 12 weeks, with three sessions a week. The resting heart rate and the oxygen uptake at peak (VO_{2peak}) and at the second ventilatory threshold (VO_{2VT2}) were evaluated during a maximal incremental test on a cycle ergometer before and after training. In addition, maximal dynamic strength (one repetition maximum test — 1RM) and local muscular resistance (maximum repetitions at 60% 1RM) of the knee extensors and flexors were evaluated. After the training period, the heart rate at rest decreased significantly, while the VO_{2peak} and VO_{2VT2} showed significant increases in both groups ($p < 0.05$). Only the VO_{2VT2} resulted in significantly greater values for the ET compared to the CT group after the training ($p < 0.05$). In addition, after training, there was a significant increase in the maximal dynamic strength of the knee extensors and the local muscular endurance of the knee extensors and flexors, with no difference between the groups ($p > 0.05$). In summary, the two training programs were effective at producing significant improvements in cardiorespiratory and muscular strength responses in older adult men. However, deep water endurance training at high intensities provides increased cardiorespiratory responses compared to CT and results in similar muscular strength responses.

1. Introduction

Advancing age is associated with a progressive decline in maximal oxygen uptake. At approximately 60 years of age, this decline causes a reduction in the ability to perform normal activities comfortably, which affects the quality of life and independence of older adults (Fukuoka et al., 2002; Fleg et al., 2005; Weiss et al., 2006; Manini and Pahor, 2009). Moreover, the aging process is associated with a reduction in muscle mass, strength and muscle power. These deleterious effects on the skeletal musculature also lead to difficulties performing activities of daily living and can lead to falls and injuries (Frontera et al., 1991; Janssen et al., 2000; Mitchell et al., 2012; Smee et al., 2012). These modifications during aging are increased when accompanied by sedentary life habits. Thus, exercise is a tool that may prevent and/or delay this process, which is due to advancing age.

In this context, the scientific literature has demonstrated that concurrent training seems to be ideal for older adults because it works to increase both muscle strength and endurance (Sillanpää et al., 2008, 2009; Karavirta et al., 2011; Cadore et al., 2010, 2011a, 2011b, 2012a, 2012b; Ferrari et al., 2013). Regarding endurance training, the interval model has been suggested for older adults because it has resulted in more significant improvements in cardiorespiratory capacity compared with continuous training on dry land (Whitehurst, 2012; Stockwell et al., 2012). Furthermore, exercises in water have been highly recommended for this population (Takeshima et al., 2002; Tsourlou et al., 2006; Lord et al., 2006; Broman et al., 2006; Kang et al., 2007; Kaneda et al., 2008; Colado et al., 2009a; Graef et al., 2010; Colado et al., 2012; Fisken et al., 2014a, 2014b) due to its characteristics of low joint impact (Alberton et al., 2013a), lower sympathetic activation and reduced catecholamine levels, with a consequent reduction in heart rate (HR) (Coruzzi et al., 1984; Epstein, 1992; Pendergast and Lundgren, 2009). Among aquatic exercises, deep water running has gained prominence in the scientific literature. Deep water running is performed with the aid of a floatation vest, which serves to keep the body in an upright position and helps to prevent contact between the feet and the bottom

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of the pool, thus eliminating any impact. This characteristic allows practitioners to perform interval aerobic exercise at high loads with a reduced risk of injury (Dowzer and Reilly, 1998). Thus, it appears that the use of a concurrent training program in water can be a very effective strategy for older adults.

Broadly speaking, the literature has already shown evidence of cardiorespiratory improvement in older adults using training programs based on deep water running, including decreased resting heart rates (HR_{rest}) and increased peak oxygen uptake (VO_{2peak}) values (Broman et al., 2006). Many studies in the literature have shown improvements in muscle strength in different populations performing strength training in shallow water (Pöyhönen et al., 2002; Colado et al., 2009a; Graef et al., 2010; Souza et al., 2010; Colado et al., 2012). In addition, some studies have investigated the effects of concurrent training in an aquatic environment (Taunton et al., 1996; Takeshima et al., 2002; Tsourlou et al., 2006; Meredith-Jones et al., 2009; Pinto et al., 2014). However, the great majority of these studies were conducted in shallow water and with older women. Only one study was conducted in deep water, and in that study, the authors demonstrated that aquatic resistance training combined with deep water running (concurrent training) could increase aerobic capacity and the muscle strength of the upper and lower limbs in adult and obese women (Meredith-Jones et al., 2009). However, none of the above-mentioned studies were developed using older men, and results obtained in shallow water cannot be directly applied to modalities in deep water. This may be explained by the fact that these modalities, particularly those activities aimed at maximum velocity, such as strength exercises, have distinct characteristics. For example, the lack of contact of the feet with the bottom of the pool in deep water exercises promotes greater instability and, consequently, lower body control.

Furthermore, deep water running is a cyclical feature that involves a large muscle mass working against the drag forces of the water, another important characteristic that differentiates this type of exercise from those performed in shallow water, such as water aerobics. The resistance of the water (i.e., drag force) is maximized when the deep water running is performed in horizontal displacement and at a higher velocity (Kanitz et al., 2010). Therefore, the execution of this modality at a high velocity increases the resistance to displacement of the body, which characterizes it as a muscular resistance exercise that can stimulate gains in neuromuscular parameters, especially in older adults, possibly because the older population undergoes a large window of training that provides a faster response to exercise stimuli (Fleck and Kraemer, 1997). Thus, it is speculated that deep water running has both cardiorespiratory and neuromuscular benefits, similar to those of concurrent training.

Due to these characteristics, the aim of this study was to evaluate the effects of two training programs in deep water – concurrent training (aquatic resistance training combined with deep water running) and endurance training (only deep water running) – on cardiorespiratory responses and muscle strength in older adults. We hypothesized that both groups would present increases in muscle strength and improved cardiorespiratory responses, with greater increases in strength in the concurrent training group compared to the endurance training group.

2. Methods

2.1. Experimental design and approach to the problem

To understand the effects of 12 weeks of deep water training on the maximal dynamic strength and local muscular resistance of the lower limbs, as well as on cardiorespiratory fitness, both groups performed different types of training models. One group performed training that combined aquatic resistance exercises with deep water running, and the other group performed only deep water running. A control group was not tested because the aim of the present study was to compare two models of training and because the efficacy of water-based exercises on both muscle strength and cardiorespiratory fitness has been well documented in the literature (Pöyhönen et al., 2002; Kruel et al., 2005; Broman et al., 2006; Meredith-Jones et al., 2009; Colado et al., 2009a, 2009b; Graef et al., 2010; Souza et al., 2010; Colado et al., 2012; Pinto et al., 2014). However, the maximal dynamic strength of the knee extensors and flexors and the oxygen uptake in the second ventilatory threshold (VT2) were evaluated twice before the start of training (weeks −4 and 0, which served as the control period) to test the stability and reliability of the main outcomes. The post-training measurements began 72 h after the last training session, and the participants completed all of the evaluations within one week, with an interval of 48 h between the tests. Different tests were conducted on different days to prevent fatigue. Testing was overseen by the same investigator, who was blinded to the training group of the participants, and was conducted on the same equipment, with identical participant/equipment positioning, at the same time of day. Furthermore, the ambient temperature was kept constant, between 22 and 24 °C, during all tests on dry land; for the maximal deep water running test, the water temperature was maintained at 30 °C.

2.2. Participants

Thirty-five healthy older men (mean ± SD: 65.2 ± 3.8 years), who had not been engaged in any regular or systematic training program in the previous three months, volunteered for the study after signing an informed consent form. The participants volunteered for the present investigation following announcements in a widely read local newspaper. The participants were informed about the study and the possible risks and discomfort related to the procedures and were randomized by the investigators to two groups (by picking an envelope with predefined group numbers): deep-water endurance training (ET; $n = 16$) or concurrent training (CT; $n = 18$). The study was conducted according to the Declaration of Helsinki and was approved by the research Ethics Committee at the Federal University of Rio Grande do Sul.

The exclusion criteria included any history of neuromuscular, metabolic or hormonal diseases. The participants were not taking any medication that could influence their hormonal or neuromuscular metabolism and were advised to maintain their normal dietary intake throughout the study. Medical evaluations were performed using clinical anamnesis and effort electrocardiograph tests to ensure the suitability of the participants for the testing procedure.

2.3. Physical characteristics

Body mass and height were measured using an Asimed analog scale (resolution of 0.1 kg) and Asimed stadiometer (resolution of 1 mm), respectively. Body composition was assessed using the skinfold technique. A seven-site skinfold equation was used to estimate body density (Jackson and Pollock, 1978), and body fat was subsequently calculated using the Siri equation (Siri, 1993).

2.4. Maximal dynamic strength

Maximal dynamic strength was assessed using the one-repetition maximum (1RM) test on the unilateral knee extension and flexion using an exercise machine (Word-Esculptor, Porto Alegre, Brazil). One week prior to the test day, the participants were familiarized with all procedures in two sessions. On the test day, the participants warmed up on a cycle ergometer for 5 min, and each participant's maximal load was determined, with no more than five attempts and a 4-min recovery between attempts. The performance time for each contraction (concentric and eccentric) was 1.5 s and was controlled by an electronic metronome (Quarts, CA, USA).

2.5. Dynamic muscular resistance

Dynamic muscular resistance (DMR) was assessed during the knee flexion and extension exercises using a load corresponding to 60% of the 1RM. In these tests, the individual had to perform a maximum number of repetitions; the performance time for each contraction (concentric and eccentric) was 1.5 s. In the post-training evaluation, the same absolute load of the first evaluation was used.

2.6. Resting heart rate

The HR_{rest} was collected every 10 s for 1 min after the participants had been seated for 15 min in a noise-free environment with the upper body relaxed. A Polar HR monitor was used (model FS1™, Shanghai, China).

2.7. Peak oxygen uptake and second ventilatory threshold

The participants performed an incremental test using a cycle ergometer (Cateye Ergociser, Osaka, Japan) to determine the peak oxygen consumption (VO_{2peak}) and the second ventilatory threshold (VO_{2VT2}). They initially cycled at 0.5 kg·m, which was progressively increased by 0.4 kg·m every 2 min, while maintaining a cadence of 65–70 rpm, until exhaustion. The test was halted when the participants were no longer able to maintain a cadence of over 65 rpm. All incremental tests were conducted in the presence of a physician. Expired gas was analyzed using a VO2000 gas analyzer (MedGraphics, Ann Arbor, USA). The second ventilatory threshold (VT2) was determined using the ventilation curve corresponding to the point of exponential increase in the ventilation in relation to the load. In addition, to confirm the data, VT2 was determined using the CO_2 ventilatory equivalent (Wasserman et al., 1973). Three experienced, independent physiologists determined the corresponding points. The maximum VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$) that was obtained close to exhaustion was considered the VO_{2peak}. The maximum test was considered valid if at least two of the following three listed criteria were met: (1) the maximum HR predicted by age was reached (220 − age); (2) continuing to cycle at a minimum velocity of 65 rpm was impossible; and (3) a Rating of Perceived Exertion (RER) greater that 1.1 was obtained (Bell et al., 1997, 2000).

2.8. Maximal deep water running test

The aim of this test was to determine the HR corresponding to the anaerobic threshold (HR_{AT}) for subsequent training prescription. First, the participants performed eight deep water running familiarization sessions over four weeks. During each familiarization session, the correct deep water running technique, using a floatation vest, was demonstrated. The deep water running technique involved maintaining a near-vertical position, with the head kept above water, alternately flexing the shoulders, and continually flexing the elbows at approximately 90°. In addition, leg movements were standardized and made to simulate land running (Michaud et al., 1995).

The participants performed the test in the stationary position and were submerged in the water to shoulder level (T1 vertebrae). The test was performed with one end of a cable attached to the participant through the floatation vest and the other end fixed to the edge of the pool. The participants were then asked to maintain constant stride amplitude throughout the entire test and were assisted through visual feedback from the researcher. The protocol test was performed at an initial cadence of 85 beats per minute (bpm) for 3 min, with 15-bpm increases every 2 min until the participant reached maximum effort. The cadences used during the protocols were recorded by a digital metronome (MA-30, KORG, Japan) onto a CD and reproduced during the test using a CD player. The test was interrupted when the participant indicated exhaustion or could not maintain the pace marked by the cadence and stride length. The HR was collected every 10 s using a Polar Monitor (model FS1™), and the anaerobic threshold (AT) was determined based on the HR deflection point that was observed on the HR-by-intensity graph (Conconi et al., 1982). Previous studies demonstrated that the AT determined during the aquatic exercises using the HR deflection point was not significantly different from that obtained using the ventilatory method. Thus, the HR deflection point can be used as a simple and practical alternative for determining the AT during water-based exercises (Alberton et al., 2013b; Kruel et al., 2013).

2.9. Training programs

Participants in the study were trained on nonconsecutive days, three times per week for 12 weeks. The training sessions lasted 45 min; the first part of the session was used to warm up, and the end of the session was used to stretch the main active muscle groups that were used in the session. One group performed only deep water running corresponding to endurance training (ET). Another group (CT) performed aquatic resistance training combined with deep water running in the same session (CT), with resistance performed first and running performed second. Before the start of CT, the participants completed three familiarization sessions in the water to practice the resistance exercises at their perceived maximal exertion effort.

2.9.1. Endurance training (deep water running)

The endurance training program with deep water running was performed using the vest float and consisted of a period of 30-min interval training. The water temperature during training was maintained at 30 °C, and the training intensity was controlled using the HR_{AT}, as determined in a maximal deep water running test. During the first 4 weeks, the participants performed 6 bouts of 4 min at 85–90% of the HR_{AT} (weeks 1–4), with 1 min of active recovery at below 85% of the HR_{AT} between bouts. During weeks 5–8, the participants performed 6 bouts of 4 min at 90–95% of the HR_{AT}, with 1 min of active recovery at below 85% of the HR_{AT} between bouts. During the last 4 weeks, the participants performed 6 bouts of 4 min at 95–100% of the HR_{AT}, also with 1 min of active recovery at below 85% of HR_{AT} between bouts. The endurance training periodization is shown in Table 1.

2.9.2. Aquatic resistance training

Aquatic resistance training was performed prior to endurance training to avoid possible interference effects of the endurance session on the resistance session (Pinto et al., 2014). The participants performed each repetition at maximal effort and amplitude to achieve the greatest possible velocity of motion and, consequently, greater resistance. Verbal encouragement was provided by the same instructor during all resistance exercises. Analogous to the type of prescription used for traditional resistance exercises on land, in which maximal repetitions are required throughout the training session, the aquatic resistance exercises were always performed at maximal velocity to reach the maximal effort. Moreover, the sets included a 2-min period for each muscle group to rest; this interval seemed to be sufficient for recovery via the ATP-CP metabolic pathway, which is primarily involved in this type of training (Gastin, 2001). The resistance exercises included knee flexion and extension of the right leg, knee flexion and extension of the left leg and hip adduction and abduction. These exercises were chosen to stimulate different muscle groups of the lower limbs and aimed to improve the functionality of older adults. During weeks 1–4, the

Table 1
Endurance training (deep water running) periodization.

Weeks	Volume × Intensity	Total time
1–4	6x (4 min 85–90% HR_{AT} + 1 min < 85% HR_{AT})	30 min
5–8	6x (4 min 90–95% HR_{AT} + 1 min < 85% HR_{AT})	30 min
9–12	6x (4 min 95–100% HR_{AT} + 1 min < 85% HR_{AT})	30 min

HR_{AT}: heart rate at anaerobic threshold.

participants performed 2 sets for 20 s, with an interval of 1 min 20 s between each set; during weeks 5–8, the participants performed 3 sets for 20 s, with the same time interval between sets; and during the last weeks, the participants performed 4 sets for 15 s, with an interval of 1 min 30 s between each set. It is important to highlight that the duration of the sets was shortened from week 8 to week 9 to increase the load during the resistance exercises because it is possible to achieve greater movement velocities during a shorter stimulus time. Furthermore, the rest between sets was passive, meaning the participant did not perform any exercise and just held on to the edge of swimming pool for stability. The aquatic resistance training periodization is shown in Table 2.

2.10. Statistical analysis

The SPSS statistical software package was used to analyze all of the data. Normal distribution and homogeneity parameters were checked using the Shapiro–Wilk and Levene tests, respectively. The results are reported as the means ± SDs. Statistical comparisons with the control period (from week −4 to week 0) were performed using Student's paired t-test. The training-related effects were assessed using two-way analysis of variance (ANOVA) with repeated measures (group × time), and the sample size was calculated using G POWER software (version 3.0.1), which determined that a minimal sample of 16 participants was necessary. The retrospective statistical power provided by SPSS after analysis was equal to or greater than 0.998 for all variables in which a significant time effect was observed and was 0.874 for the significant time vs. group interaction. Significance was accepted when the alpha level was 5%.

3. Results

During the control period (between week −4 and week 0), no significant differences were observed in VO_{2VT2} (10.7 ± 2.5 vs. 11.6 ± 2 $ml \cdot kg^{-1} \cdot min^{-1}$), knee extension 1RM ($49.9 \pm 9.6$ vs. 51.1 ± 9.2 kg) or knee flexion 1RM (19.7 ± 4.3 vs. 20.5 ± 5.9 kg). These results demonstrate that the main variables of the study did not change over time; therefore, the changes in these variables after the intervention period may be attributed to the type of training that was conducted. There were no differences between the groups in terms of body mass, height, age or body fat percentage prior to training (Table 3). No significant differences were observed in training compliance between the ET and CT groups (32.5 ± 1.4 vs. 32.4 ± 2.6 sessions, respectively; $p = 0.381$).

At baseline, there were no differences between groups in the VO_{2peak} or VO_{2VT2} values. After training, significant decreases in HR_{rest} (ET: −9%; CT: −4%; $p = 0.052$) and significant increases in VO_{2peak} (ET: 41%; CT: 17%; $p < 0.001$) and VO_{2VT2} (ET: 35%; CT: 7%; $p < 0.001$) were observed in both groups. In addition, there was a significant time vs. group interaction for VO_{2VT2} ($p = 0.003$) (Table 4). Therefore, the main factors were tested again using T tests (Fig. 1), which showed that both groups presented a significant increase from pre- to post-training and that the ET had higher values compared to the CT group in the post-training situation.

Table 2
Strength training periodization.

Week	Sets	Volume × Exercise	IBS	Total time
1–4	2×	20 s knee flexion and extension right 20 s knee flexion and extension left 20 s hip adduction and abduction (right and left together)	1 min 20 s	3 min 20 s
5–8	3×	20 s knee flexion and extension right 20 s knee flexion and extension left 20 s hip adduction and abduction (right and left together)	1 min 20 s	5 min 40 s
9–12	4×	15 s knee flexion and extension right 15 s knee flexion and extension left 15 s hip adduction and abduction (right and left together)	1 min 30 s	7 min 45 s

IBS: interval between sets; s, seconds; min, minutes.

Table 3
Baseline characteristics.

Variables	Endurance training (n = 16)		Concurrent training (n = 18)		p
	Mean	±SD	Mean	±SD	
Age (years)	66	±4.06	64.37	±3.61	0.239
Height (m)	1.71	±0.05	1.70	±0.08	0.630
Body mass (kg)	78.46	±11.57	83.23	±14.54	0.622
Body fat percentage (%)	15.33	±5.36	17.25	±5.62	0.348

Mean ± SD.

At baseline, there were no differences between groups in the knee extension and flexion 1RM and DMR. However, after training, there were significant increases in knee extension 1RM (ET: 10%; CT: 6%; $p < 0.001$), knee extension DMR (ET: 8%; CT: 18%; $p < 0.001$) and knee flexion DMR (ET: 18%; CT: 18%; $p < 0.001$) of both groups, with no differences between groups. In addition, after training, there was no difference in the knee flexion 1RM of both groups (Table 4).

4. Discussion

The main findings of this study were the increased maximal dynamic strength of the knee extensors and DMR of the knee flexors and extensors in both groups. These findings partly contradict our hypothesis. We hypothesized that both groups would show increases in muscle strength but that more substantial increases would be achieved with CT. Regarding the cardiorespiratory responses, both groups showed significantly increased VO_{2peak} and VO_{2VT2} but decreased HR_{rest}. Nevertheless, ET resulted in greater increases in VO_{2VT2} compared with CT, which contradicts our hypothesis that both groups would have similar improvements in cardiorespiratory responses.

Aquatic resistance training has been widely investigated in recent years (Pöyhönen et al., 2002; Kruel et al., 2005; Colado et al., 2009a, 2009b; Graef et al., 2010; Souza et al., 2010; Colado et al., 2012), as have the effects of concurrent training in this environment (Takeshima et al., 2002; Tsourlou et al., 2006; Meredith-Jones et al., 2009; Pinto et al., 2014). However, most of these studies were conducted using specific exercises in shallow water (Pöyhönen et al., 2002; Takeshima et al., 2002; Alves et al., 2004; Kruel et al., 2005; Tsourlou et al., 2006; Colado et al., 2009a, 2009b; Graef et al., 2010; Souza et al., 2010; Ambrosini et al., 2010; Colado et al., 2012; Pinto et al., 2014). Ambrosini et al. (2010) observed increases in the maximal dynamic strength of the lower limbs between 34 and 42%, which were greater than the findings of the present study (6–10% for knee extensors strength). In that study, sedentary women who performed resistance training in shallow water for 12 weeks (two sessions per week) were evaluated. Therefore, it is possible that the lack of contact of the feet with the bottom of the pool may have interfered with the resistance training that was conducted in deep water, which may have caused greater instability and possibly reduced the maximal velocity of motion, resulting in lower overload and, consequently, lower strength gains compared with studies that were conducted in shallow water. This instability has already been described in the literature for exercises in deep water. According to Moening et al. (1993), deep water exercises are considered open kinetic chain exercises, which result in greater instability compared with closed kinetic chain exercises such as walking/running in shallow water.

Moreover, the results demonstrated that endurance training using deep water running seemed to generate stimuli for increased strength of the same magnitude as concurrent training in deep water in older

Table 4
Cardiovascular and neuromuscular parameters before and after training: endurance (ET) and concurrent training (CT).

	Endurance training (n = 16)		Concurrent training (n = 18)	
	Pre-training	Post-training	Pre-training	Post-training
HR_{rest} (bpm)	70 ± 10	64 ± 7[*]	77 ± 11[†]	74 ± 11[*]
VO_{2peak} ($ml \cdot kg^{-1} \cdot min^{-1}$)	16.97 ± 3.76	23.93 ± 5.38[*]	18.51 ± 3.37	21.69 ± 3.02[*]
VO_{2VT2} ($ml \cdot kg^{-1} \cdot min^{-1}$)	14.36 ± 3.36	19.39 ± 4.13[*]	15.35 ± 2.43	16.45 ± 2.82[*#]
KF 1RM (kg)	21.00 ± 5.84	21.46 ± 5.36	18.94 ± 3.89	19.50 ± 4.62
KE 1RM (kg)	52.61 ± 6.44	57.85 ± 8.60[*]	51.47 ± 10.6	54.65 ± 12.80[*]
KF DMR (number of repetitions)	11 ± 1	13 ± 2[*]	11 ± 1	13 ± 1[*]
KE DMR (number of repetitions)	12 ± 1	13 ± 2[*]	11 ± 2	13 ± 2[*]

Mean ± SD; HR_{rest}, Resting heart rate; VO_{2peak}, peak oxygen uptake; VO_{2VT2}, oxygen uptake in the second ventilatory threshold; KF, knee flexion; KE, knee extension; 1RM, maximal dynamic strength; DMR, dynamic muscular resistance.

[*] Significant difference from the pre-training values ($p < 0.05$).

[†] Significant difference from the endurance training group ($p < 0.05$).

[#] Significant time vs. group interaction ($p < 0.05$).

adults because no significant differences were observed between the groups in terms of the neuromuscular responses post-training. Some authors have shown that there may be small increases in the strength of the lower limbs due to endurance training performed using a cycle ergometer on land (Van Zan and Bouillon, 2007; Cadore et al., 2011b) or treadmill running in water (Greene et al., 2009). The density of water is an important feature of the aquatic environment that may generate increased muscle strength because movement in water provides a resistance 900 times greater than that in air (McGinnis, 2005). Therefore, we believe that to overcome the drag force imposed by water, greater recruitment of motor units with higher excitation thresholds must be activated. This type of motor unit was responsible for the greater strength output that might have resulted in increased muscle strength in the ET group (Cadore et al., 2011b), especially in the last mesocycle of training, in which the intensity corresponded to the HR_{AT}.

In addition, we believe that interference with the strength gains may have occurred due to the performance of strength training before aerobic training because strength training may have generated a residual metabolic fatigue that interfered with the strength gains from aerobic training. Due to this fatigue, participants likely performed with lower aerobic training velocities to achieve the target HR, thereby decreasing the drag and, consequently, decreasing the stimulus to increase muscle strength.

Moreover, in the present study, the DMR of the knee flexors and extensors increased similarly in both groups. These increases can be explained by the specificity of the training modality because deep water running is an exercise that involves high resistance during its performance compared to other endurance modalities. Additionally, the participants performed the training exercises at a high velocity. This increased velocity affects the drag force, as shown in the following equation: $R = 0.5\ \rho\ A\ v^2\ Cd$, where ρ is the fluid density, A is the projected area, v is the velocity of motion, and Cd is the drag coefficient (Alexander, 1977). Thus, the increased velocity maximizes the strength necessary to overcome the resistance imposed by the water, which may result in a significant effect on the dynamic muscle resistance of the lower limbs.

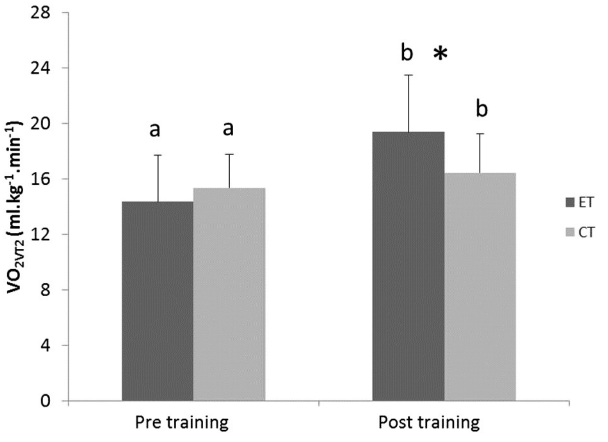

Fig. 1. Mean ± SD of the oxygen uptake at the second ventilatory threshold (VO_{2VT2}) of the endurance training (ET) and concurrent training (CT) groups, pre- and post-training. Different letters represent significant differences between pre- and post-training ($p < 0.05$). *Significant difference between training groups ($p < 0.05$).

The reduction in the HR_{rest} due to endurance training has already been documented in the literature; however, the mechanisms responsible for this change remain unclear. It has been proposed that endurance training increases the parasympathetic activity and decreases the sympathetic activity of the heart (Levy et al., 1998; Carter et al., 2003). This result is consistent with the study by Broman et al. (2006), who conducted high-intensity interval training using deep water running with older women (69 ± 4 years) and observed a significant reduction in HR_{rest}, from 79 ± 8 to 72 ± 8 bpm (8%).

Regarding the VO_{2peak} values, both groups showed a significant increase after the training period. These results also support the study by Broman et al. (2006), in which an increase in VO_{2peak} (10–11%) was observed in a maximal test using a cycle ergometer. The highest weekly frequency (three times vs. two times per week) and longer training (12 vs. 8 weeks) may explain the higher VO_{2peak} percentage values (17–41%) after training in the present study. In addition to the study by Broman et al. (2006), Meredith-Jones et al. (2009) observed a significant increase of 13% in the VO_{2peak} in a maximal test of deep water running after 12 weeks of circuit training, which involved alternation between deep water running and aquatic resistance exercises in obese women. In the present study, the group that performed deep water running and aquatic resistance exercises showed a gain in the VO_{2peak} (17%) that was similar to that in the study by Meredith-Jones et al. (2009). However, the group that performed only endurance training with deep water running showed an even greater percentage increase of 41% in the VO_{2peak}. The different percentage values between this study and other studies may be due to methodological differences such as the population that was studied and the different maximal tests and different training models that were used.

A study conducted by Myers et al. (2002) showed that every 1-MET improvement of the VO_{2peak} was associated with an 18% reduction in the number of cardiac events in older men. In the present study, the CT group showed an improvement of 1 MET in the VO_{2peak}. Thus, the participants in this group may have reduced their chances of cardiac events by 18%. The ET group showed an improvement of 2 METs, which indicates that participants in this group may have reduced their chances of cardiac events by up to 36%. These findings support the great clinical relevance of the effects of deep water training in the older population. In this context, according to the American College of Sports Medicine (1980), the participants of the ET group improved from a weak level of physical fitness (16–22 $ml \cdot kg \cdot min^{-1}$) to a regular level of physical fitness (23–30 $ml \cdot kg \cdot min^{-1}$), whereas the CT group remained at a low level, showing greater effects in favor of the ET group.

The VO_{2VT2} also increased in both groups after training, but the CT group showed a significantly lower increase compared with the ET group. This behavior has not been well described in the literature. Chtara et al. (2005) demonstrated that performing strength exercises on land before endurance training produces smaller increases in VO_{2peak}, whereas the reverse was observed in young people. The authors believe that the fatigue resulting from the strength exercises could influence the physiological effects of endurance training because the training was performed at a velocity corresponding to the VO_{2peak}. Pinto et al. (2014) evaluated the effect of the order of the exercises in concurrent training with water-based exercises and found no interference of aquatic resistance training on cardiorespiratory responses when performed prior to endurance training. However, the endurance training included three different exercises that emphasized different muscle groups and were performed without horizontal displacement. In the present study, endurance training was performed using deep water running; in this type of exercise, the main active muscle groups are the flexors and extensors of the hip and knees. Additionally, the exercise was performed with displacement, which increases the projected area and resistance to movement (Kanitz et al., 2010). These characteristics, combined with the previously performed strength training, may have caused localized fatigue in the motor units of the main muscles involved in the exercise. This fatigue may have impaired the performance of the endurance exercises, especially during the last mesocycle, when the participants were required to achieve a high training intensity (HR corresponding to 95–100% of the anaerobic threshold).

A possible limitation of the present study was the lack of controls for the velocity and number of repetitions performed during the 20-s and 15-s series of resistance exercises during the training. Another limitation of the study was the lack of cardiorespiratory assessments, such as maximal aerobic power, using a maximal test conducted in the water to observe the responses of these variables in the environment in which the exercise was performed. Furthermore, the evaluations of older adults that were performed via functional tests could identify other relevant aspects related to the training, especially for the CT group. Thus, we suggest that future studies assess cardiorespiratory adaptations due to aquatic training in both environments (water and land) and add functional tests to these assessments. Finally, the results of this study are limited to sedentary and healthy older men.

Based on the results of this study, we conclude that the two models of training in deep water – endurance and concurrent – produced improvements in cardiorespiratory parameters and the muscle strength of the lower limbs of older men. However, deep water running endurance training at intensities near the AT produced significant increases in the cardiorespiratory responses and provided similar increases in muscular strength compared to concurrent training in sedentary older men. These positive results indicate that a minimum of 135 min of training in deep water per week can effectively produce significant improvements in the cardiovascular and neuromuscular systems of older men.

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