



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.

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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; Fiske 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 flotation 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; Kruegel 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 $\pm$ SD: 65.2 $\pm$ 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 pre-defined 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).

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