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Acute breathing patterns in healthy and heart disease participants during cycling at different levels of immersion

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ABSTRACT

We aimed to determine the effect of aquatic cycling and different levels of immersion on respiratory responses in healthy and heart disease (HD) volunteers. Thirty-four age matched volunteers, 21 HD and 13 healthy controls (HC) took part in this study. The ventilatory pattern, phase 1 V_E and steady-state ventilatory responses to progressive exercise from 40 to peak rpm, were measured while participants exercised on a water stationary bike (WSB) at different levels of immersion. No effect of immersion was observed on steady-state respiratory responses in the HD group, but immersion reduced V_E phase 1 by ~79% at pedaling cadences of 40, 50 and 60 rpm. In conclusion, immersion at hips and xiphoid process blunted the fast drive to breathe in the HD group. This transient effect on the respiratory response to immersed exercise cannot be considered a contraindication for exercise in HD individuals.

1. Introduction

Exercise is an important part of cardiac rehabilitation contributing to improved longevity and quality of life. However, only 12% of older patients with heart disease (HD) participate in cardiac rehabilitation programs (Forman et al., 2011). Training in water, such as pool base exercise programs, has the potential to make exercise more attractive to individuals that are limited by their medical and/or physical condition on land. However, the quantification of the effort intensity in water has been challenging in traditional activities such as running and calisthenics with different levels of immersion. (Hall et al., 1998; Nakanishi et al., 1999; Shono et al., 2000). Specifically the physical characteristics of individuals influencing the resistance provided by water, together with either the use of arms and/or the loss of balance, make it more difficult to accurately estimate exercise intensity applied.

In recent years, the challenges posed by the quantification of aquatic exercise have been addressed by a new training modality—water stationary bicycle (WSB)—that makes exercise intensity quantification possible through external power output (Garzon et al., 2014a,b; Leone et al., 2014). Although several studies have assessed the physiological responses to cycling in water (Brechat et al., 1999; Chen et al., 1996; Christie et al., 1990; Connelly et al., 1990; Costill, 1971; Dressendorfer et al., 1976; Sheldahl et al., 1987, 1984), very few have reported on patients affected by heart disease (HD) (Hanna et al., 1993; McMurray, 1988). The viscosity and buoyancy of the water contribute to the reduction of body weight and the hydrostatic pressure causes a cephalad fluid shift. This epiphenomenon has been shown to increase cardiac output and appears to be beneficial during water immersed exercise (Brechat et al., 2013; Garzon et al., 2014a,b). Little is known, however, about the effect of the hydrostatic pressure exerted on the thorax of HD patients, which could be detrimental to their breathing pattern. In fact, the increase in the intrathoracic blood volume caused by the cephalad shift in blood volume packs the pulmonary capillaries and competes for air space in the lungs resulting in a reduction of 30 to 50% of the static and dynamic lung compliance, respectively (Taylor and Morrison, 1993).

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Previous studies in healthy individuals show that during immersed exercise the hydrostatic pressure that acts against both the anterior abdominal and chest wall at the xiphoid process can cause a reduction in both the inspiratory capacity and the expiratory reserve volume (de Andrade et al., 2016). Modifying these two components of the respiratory system may affect the breathing pattern to exercise in both healthy and HD patients. Also, it is well established that minute ventilation (V_E) increases rapidly in response to exercise – phase 1 V_E response. Phase 1 V_E response is typically out of proportion to the metabolic requirements and has been associated with proprioception of limb movement, more specifically to leg movement frequency during walking, running or cycling. Recently, Phase 1 V_E (the fast increase to breathe) has been shown proportional to the cadence on an ergocycle on dryland (Duffin, 2013). However, the effect of water immersion on Phase 1 V_E response remains unknown, in particular in patients suffering from HD. Thus, the purpose of this study was to investigate the effect of different levels of immersion during cycling on the respiratory responses to exercise in both healthy and heart disease individuals. We hypothesized that different levels of immersion (either the hips or the xiphoid process) affect the ventilatory pattern similarly in both HD patients and healthy individuals during a progressive exercise on a WSB.

2. Methods

2.1. Participants

Thirty-four men and women participated in this study. The heart disease group (HD) was composed of 21 patients (19 men and 2 women), 14 affected by coronary heart disease (CHD) and 7 with congestive heart failure (CHF) with a mean age of 64.7 ± 7.4 years. The HD group included stable patients for at least three months, non-smokers, with either a past myocardial infarction, a history of coronary disease documented by angiography, angioplasty or by nuclear imaging testing, or CHF. Only 2 participants were taking a single medication, all others were on a combined therapy. Even though many participants were taking β-adrenergic blocking agents, this medication exerts its primary influence during exercise on the cardiovascular system, without any discernible effect on respiration (Agostoni et al., 2010; Sheldahl et al., 1984). The etiology of all CHF participants was ischemic of origin, the mean ejection fraction (EF) was 36.5% and two participants had an internal pacemaker defibrillator. The control group was composed of 13 healthy, age- matched participants (5 men and 8 women). The healthy control (HC) participants recruited for this study were non-smokers, without any known cardiovascular or pulmonary disease. Apparently healthy participants with high blood pressure that was controlled with medication with a dose that was unchanged for the past three months were accepted. In addition, a preliminary analysis indicated that there was no significant difference between CHD and CHF patients, and between both women and men, thus, it was agreed to pool the data for further analysis to form two groups, respectively, the HD (CHD and CHF) group and the HC group.

Participants from both groups did not have previous experience of underwater pedaling. This study was approved by the Ethics Committee of the University of Québec in Montréal (UQAM). Before testing, each participant was informed of the objective of the study, the testing procedures and provided their written informed consent to participate in the study. All HD participants obtained consent from their treating physicians in order to participate, according to the American College of Sports Medicine (ACSM) guidelines (ACSM, 2006). The baseline characteristics of participants are presented in Table 1.

Table 1
Participant characteristics.

	HD(n = 21)	Healthy(n = 13)	*p*
Age (years)	64.7 (7.8)	61.0 (6.3)	0.142
Height (m)	1.71 (0.1)	1.69 (0.1)	0.510
Weight (kg)	83.2 (16.2)	78.6 (15.3)	0.419
BMI	28.2 (4.4)	27.6 (5.5)	0.724
HRpeak (bpm)	119 (23)	131 (17)	0.098
VO_2peak (ml/kg/min)	18.6 (4.9)	23.7 (6.4)*	0.012
EF (%) in CHF	36.5 (10.3)		
Medical treatment (n)			
ACE-inhibitors	14	2	
β-blockers	18	1	
ARA	5	2	
CCB	8		

Means ± (S.D.). HRpeak and VO_2peak represent the highest values reached by each participant at calf immersion (land analog); BMI: body mass index; ACE: angiotensin converting enzyme; ARA: angiotensin receptor blocker; CCB: calcium channel blocker; EF: ejection fraction; CHF, congestive heart failure; HD: subjects with heart disease; * $p \leq .05$ significant difference between groups.

2.2. Experimental conditions

Research activities were carried out in a pool at either UQAM or College Édouard Montpetit Sport Complexes at a water temperature of 29 °C, which is considered as a thermoneutral temperature during exercise (Sheldahl et al., 1984). All testing sessions were separated by at least 48 h.

2.3. Experimental procedure

Cycling in water was done on a water stationary bicycle (WSB, Hydrorider, Bologna, Italy) with the resistance offered by the four paddles on the pedaling mechanism set to maximum length, as described by (Leone et al., 2014). The WSB was then placed at the appropriate pool depth allowing the participants to be immersed to calf, hip or xiphoid process level. Immersion to the calf was intended to measure respiratory parameters without the contribution of hydrostatic pressure. All three tests were conducted with the same WSB. Therefore, testing at the calf level ensured that the pedaling mechanism was completely immersed in order to reproduce comparable experimental conditions.

Before immersion into the pool, each participant was fitted with a facial mask (Hans Rudolph, U.S.A.) so that no leaks were present. The calibrated turbine was then fitted to the mask and connected to the portable metabolic unit. The unit was attached to a 2-m pole that maintained the unit approximately 1 m above the water surface near the head of the participant. Once immersed, the participant sat on the WSB and resting ventilatory parameters where collected for three minutes. Afterwards, the participants were instructed to pedal. Pedalling cadence was measured with a pedal rpm meter (Cateye Echowell F2, Taiwan) and controlled voluntarily by the subject. The exercise protocol began at a pedal cadence of 40 rpm. Cadence was then increased every 2 min by 10 rpm until at least one of the following was obtained: 85% of calculated maximum heart rate, a score of 16 on the Borg scale or an inability to reach and maintain cadence (ACSM, 2006). The final stage reached was then defined as the peak value and did not represent maximum value. All breathing variables were averaged over the last 30 s of each 2 min stages. A more detailed analysis of the phase 1 V_E of hyperpnoea was calculated as the difference in V_E before cadence changed (average of last 10 s) and V_E 10 s after the cadence change for all different immersion levels (Duffin, 2013).