

Comparison of respiratory muscle strength in individuals performing continuous and noncontinuous walking exercises in water after the 6-week program

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This study aimed to compare respiratory muscle strength in individuals performing continuous and noncontinuous walking exercises in water after the 6-week program. Twenty-nine healthy men were randomly divided into a continuous group (CG, n=14) and a noncontinuous group (NG, n=15). Firstly, both groups executed the 6-week program which set them to walk for 30 min, 4 times per week, over 6 weeks in a pool with the adjusted intensity that their walking speed increased the heart rate to 60% of the predicted maximum. After the 6-week program, participants in the CG continued the water-walking program for 4 weeks while those in the NG discontinued the water-walking program. In both groups, respiratory muscle strength evaluated by maximum inspiratory pressure (P_Imax) and maximum expiratory pressure (P_Emax) increased significantly after the 6-week program compared with pre-exercise val-

ue. Compared to the value after the 6-week program, P_Emax increased significantly in the CG after 10 weeks ($P < 0.05$), but the P_Imax showed no significant change. Compared to the value after the 6-week program, after 10 weeks, in the NG, P_Emax decreased significantly, with a considerable decrease after 9 and 10 weeks compared to the CG ($P < 0.05$). The P_Imax in the NG significantly decreased after 10 weeks from the value observed after the 6-week program. We demonstrated that 6 weeks of walking in water at 60% of the predicted maximum heart rate enhances P_Imax and P_Emax, and that P_Imax and P_Emax decrease in 4 weeks without a water-walking program.


Keywords: Walking in water, Respiratory muscle strength, Healthy males

INTRODUCTION

As a part of health enhancement plans, aquatic exercise has recently been introduced to rehabilitation and sports clubs (Ide et al., 2005; Jung et al., 2014; Wilcock et al., 2006). Aquatic exercise can reduce the self-weight load, which enables those with obesity (Sheldahl, 1986), joint diseases (Chi et al., 2011), or lumbago (Iranoust et al., 2015) to perform the exercise safely. In addition, it is known that water viscosity and pressure can be used as exercise loads contributing to the enhancement of extremity muscle strength (Craig and Ware, 1967; Ha et al., 2018; Lee et al., 2015).

Breathing underwater requires great effort mainly for the following two reasons: first, the blood volume shifts into the chest

cavity because of the increased venous return from the lower extremities; second, inflexibility of the chest wall and diaphragm shifts toward the cranial side because of the hydrostatic pressure, resulting in restricted pulmonary compliance (Craig and Ware, 1967; Craig et al., 1975; de Souto et al., 2012; McNamara et al., 2013). Regarding the effect of the water depth on the respiratory function, the pulmonary vital capacity (VC), forced expiratory volume in 1 sec (FEV₁), and functional residual capacity decrease during water immersion at the clavicular or cervical level (Agostoni et al., 1966; Buono, 1983; Leith and Mead, 1967; Prefaut et al., 1976). Furthermore, de Andrade et al. (2014) reported that the decrease in the maximum inspiratory muscle strength during water immersion was greater when the water level was at the clav-

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icle than at the xiphoid process because of the higher water pressure at the clavicular level. We also suggested that forced respiration during upright water immersion up to the clavicular level resulted in greater inspiratory muscle fatigue than at shallower depths (Yamashina et al., 2016a).

Therefore, aquatic exercise, such as swimming or walking in water, is ideal for health promotion, which can incorporate resistance training when considering water viscosity during aerobic exercise. In fact, we reported that greater inspiratory and expiratory muscle fatigue was induced by walking in water than walking on land at the same exercise intensity in healthy young men (Yamashina et al., 2016b). In addition, we demonstrated that 6 weeks of walking on land and in water at 60% of the predicted maximum heart rate enhances respiratory muscle strength (Yamashina et al., 2018).

However, the duration of respiratory muscle strengthening after walking in water has not been studied. Therefore, the purpose of this study was to compare respiratory muscle strength in continuous and noncontinuous groups after walking in water for 6 weeks.

MATERIALS AND METHODS

Compliance with ethical standards

The present study was approved by the Institutional Review Board of Aino University (approval number: Aino2016-002). The present study also conformed to the standard set by the Declaration of Helsinki.

Subjects

We recruited healthy men without exercise habits aged between 20 and 29 years. Subjects with a phobia of water, a history of respiratory or cardiovascular disease, hypertension (resting systolic blood pressure [BP] ≥ 140 mmHg and/or diastolic BP ≥ 90 mmHg), diabetes, obesity (body mass index ≥ 30 kg/m²), or a habit of smoking were excluded. Twenty-five eligible applicants met the inclusion criteria and participated in the study.

Informed consent

Written informed consent was obtained from all subjects prior to the initiation of the present study.

Experimental protocol

Effects of the 6-week walking in water program on respiratory muscles

The subjects were randomly divided into two groups, i.e., the

Table 1. The physical characteristics of the participants

Characteristic	Continuous group (n=14)	Noncontinuous group (n=15)
Age (yr)	26.5±2.3	25.8±2.7
Weight (kg)	66.8±6.3	65.9±5.6
Height (cm)	169.4±5.1	166.5±4.1
%VC (%)	91.4±6.1	89.6±7.4
FEV ₁ (%)	87.1±3.8	90.7±5.2

Values are presented as mean ± standard deviation.

%VC, % vital capacity; FEV₁, forced expiratory volume in 1 sec.

continuous group (CG, n=14) and noncontinuous group (NG, n=15) (Table 1). One week before starting the walking program, each individual's weight, height, and respiratory function were measured to confirm that there were no problems with respiratory function.

We used these measured respiratory functions as the pre-exercise values. The maximum inspiratory pressure (PI_{max}) and maximum expiratory pressure (PE_{max}) in the oral cavity were evaluated using a sphenometer attached to the spirometer (AAM337, Minato, Osaka, Japan) according to the method by Black and Hyatt (1969) and were considered as the surrogate indices of inspiratory and expiratory muscle strength, respectively.

For the walking program, both groups walked in a pool filled to the level of the fourth intercostal space or above. The exercise intensity was adjusted so that the walking speed raised the heart rate to 60% of the predicted maximum in both groups, and walking continued for 30 min 4 times per week over 6 weeks. A wrist-type pulsometer (ForeAthlete 235J, Garmin, Kansas City, MO, USA) was used for the heart rate measurement. Trouser-type swimsuits (without upper parts) and underwater shoes were used for underwater walks. PI_{max} and PE_{max} were remeasured on land in a sitting position after 6 weeks.

Effects on respiratory muscles with/without the continuation of walking in water

After the 6-week walking in water program, the CG continued a program another for 4 weeks and the NG was restricted from any exercises except for daily activities. We measured PI_{max} and PE_{max} weekly for 4 weeks, after the 6-week walking in water program. Using the data gathered after the 6-week walking in water program as baseline values, the following formula was used to calculate the percentage of change in the respiratory muscles.

$$\text{Rate of change (\%)} = \frac{[(\text{measured value}) - (\text{baseline value})]}{(\text{baseline value})} \times 100$$

Table 2. Respiratory muscle strength in the continuous and noncontinuous groups pre- and postexercise

Variable	Continuous group	Noncontinuous group
Plmax (cmH ₂ O)		
Pre-exercise	105.9±10.1	110.1±8.1
After walking in water for 6 weeks	115.1±7.6*	117.8±8.9*
PEmax (cmH ₂ O)		
Pre-exercise	107.5±8.4	103.3±6.9
After walking in water for 6 weeks	116.8±11.6*	111.3±9.7*

Values are presented as mean ± standard deviation.

Plmax, maximal inspiratory pressure; PEmax, maximal expiratory pressure.

**P*<0.05 vs. pre-exercise.

Statistical analysis

All statistical analyses were performed using Stat View (SAS Institute Inc., Cary, NC, USA), and all values were presented as mean ± standard deviation. The physical characteristics and the pre-exercise respiratory muscle strength and after the 6-week walking in water program between both groups were performed using the unpaired *t*-test. The pre- and postexercise respiratory muscle strength were compared using the paired *t*-test. The duration of respiratory muscle strengthening after the 6-week walking in water program was examined by two-way (group × time) analysis of variance with repeated measurements. In cases where significant group and time effects were detected, subsequent *post hoc* multiple pairwise comparisons (Bonferroni method) were performed. Statistical significance was defined by a value of *P* < 0.05.

RESULTS

Effects of the 6-week walking in water program on respiratory muscles

In the CG and the NG, Plmax and PEmax increased significantly after the 6-week program compared with the pre-exercise value, and no significant difference was observed between the two groups (Table 2).

Effects on respiratory muscles with/without the continuation of walking in water

Compared to the value after the 6-week program, the CG showed a significant increase in PEmax after 10 weeks (*P* < 0.05), but the Plmax did not show any significant change in the CG. Compared to the value after the 6-week program, the NG showed a significant decrease in PEmax after 10 weeks, and also showed a considerable decrease after 9 and 10 weeks when compared to the CG (*P* < 0.05). The Plmax in the NG showed a significant decrease af-

Table 3. Comparison of respiratory muscle strength in the continuous and noncontinuous groups after 6-week program

Rate of change (%)	7 Weeks	8 Weeks	9 Weeks	10 Weeks
Plmax				
Continuous group	0.3±2.0	1.4±2.5	0.8±2.2	1.9±1.8 [#]
Noncontinuous group	-0.9±1.5	-0.4±1.3	-1.2±1.4	-2.6±0.6*
PEmax				
Continuous group	0.4±2.1	1.1±1.8	2.7±2.6 [#]	3.6±2.4* [#]
Noncontinuous group	0.1±2.0	-0.1±3.0	-2.3±3.8	-3.2±4.5*

Values are presented as mean ± standard deviation.

Plmax, maximal inspiratory pressure; PEmax, maximal expiratory pressure.

**P*<0.05 vs. baseline. [#]*P*<0.05 vs. noncontinuous group.

ter 10 weeks when compared to the baseline value and the CG (Table 3).

DISCUSSION

We found that walking in water for 6 weeks at this exercise intensity level was effective to improve inspiratory and expiratory muscle strength and that respiratory strengths decrease in 4 weeks when ceasing walking in water. In general, in the aquatic environment, the hydrostatic pressure on the abdominal wall causes the diaphragm to lift and to pressurize the lungs, and the hydraulic pressure applied to the chest wall causes a lowering of the compliance of the thorax (Bondi et al., 1996; Buono, 1983; Dahlbäck et al., 1978). It is reported that the chest circumference decreased significantly by about 0.8 cm due to water pressure when it was clavicle-level when compared to before entering the water (Yamashina et al., 2016a). Furthermore, it is reported that the VC and respiratory muscle strength decrease as the water level deepens than the umbilical level (de Andrade et al., 2014). Therefore, it is thought that inspiratory muscle strength increased in the aquatic environment because of the increased load from the water pressure as it enlarges the thorax during inspiration.

PEmax also increased after 6-week program. Previous studies have reported that the abdominal muscular tonus is crucial for stabilizing the trunk to maintain a standing posture while walking in water (Kaneda et al., 2009), and expiratory muscle fatigue was induced by underwater walking more than by land walking (Yamashina et al., 2016b). These reports show that load is added to the abdominal muscle groups when walking in water. Therefore, the abdominal muscles were continually working against water pressure while walking in the water to fix the trunk, which might have strengthened the expiratory muscles after 6-week program.

Regarding the influence of continuous water walking on respiratory muscle strength, PEmax in the CG showed a significant increase in the 10th week compared to the baseline at the 6th week. When walking in water, it is necessary to work the abdominal muscles, which are expiratory muscles, and to fix the trunk to move forward while resisting water pressure, so it is thought that PEmax increased even after 10 weeks in the CG compared with the value after the 6-week water program. However, PImax in CG showed no significant change. It has been suggested that walking in water for 6 weeks or more can maintain inspiratory muscle strength but may not provide enough load to increase inspiratory muscle strength. On the other hand, in the NG, PImax and PEmax decreased in 4 weeks after the 6-week program. It is suggested that the continuation of exercise is important to maintain and improve respiratory muscle strength.

There are several limitations to this research. We did not measure the tidal volume while walking in water. Since an increased tidal volume is an element of added load on the inspiratory muscles, it is important to measure this in the future. Moreover, in this study, the walking speed was adjusted to 60% of the predicted maximal heart rate, but whether the same effect can be obtained at other loads should also be investigated in the future.

In summary, we demonstrated that 6 weeks of walking in water at 60% of the predicted maximum heart rate enhances inspiratory and expiratory muscle strength, and that respiratory strength decreases in 4 weeks after ceasing a water-walking program. Further studies are needed to develop an exercise regimen that can be utilized in the field of sport or clinical settings that makes the most of the characteristics of submersion and aquatic exercise.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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