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Effect of Walking in Water for 6 Weeks on Respiratory Muscle Strength

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Abstract

***Purpose:** The purpose of this study was to compare the effect on inspiratory and expiratory muscle strength (PImax and PEmax respectively) of walking in water with that of walking on land.*

***Participants and Methods:** Eighteen healthy males were randomly divided into the walking in water group (WG: 9 people) and the walking on land group (LG: 9 people). The LG walked on level ground and the WG walked in a pool filled to the depth 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 minutes 4 times a week over 6 weeks.*

***Results:** In both groups, PImax increased significantly after 6 weeks compared with pre-exercise value, but no significant difference was observed between the two groups. PEmax increased significantly after 4 weeks compared with the pre-exercise value only in the WG, and its value was significantly higher than that of the LG.*

***Conclusion:** We demonstrated that 6 weeks of walking on land and in water at 60% of the predicted maximum heart rate enhances PImax, but PEmax is enhanced only in the aquatic environment.*

Keywords: *Walking in water – Walking on land- Respiratory muscle strength-Healthy males.*

Introduction

Muscle fatigue involved in inspiration, such as with the diaphragm muscle, external intercostal muscles, or parasternal intercostal muscles, induces a shortness of breath resulting in impaired exercise tolerance[1, 2)]. Consequently, those regressions of the physical function could lead to lower physical activity. In addition, diminished respiratory muscle strength results in the reduced efficiency of coughing to remove airway secretions (phlegm), which increases the risk of atelectasis or pneumonia after surgery or prolonged bed rest.[3, 4)].

In Japan, pneumonia emerged as the third largest cause of death for the first time in 2011; more so than cerebrovascular diseases, reflecting an aging society[5)]. Therefore, the maintenance and enhancement of respiratory function, including respiratory muscle strength, are indispensable as a health promotion measure.

In recent years, aquatic exercise has been introduced at rehabilitation sites and at sports clubs as a means of health promotion[6, 7)]. Buoyancy in aquatic exercise lessens the load of one's weight, so even those who are obese[8)] or those with diseases in joints or lower back pain[9)] can safely do these exercises. It is also possible to add resistance using the viscosity and the pressure of water, which has been recognized as having the effect of limb muscle strengthening[10, 11)].

Breathing underwater requires great effort, primarily for the following two reasons: first, blood volume shifts into the chest cavity because of the increased venous return from the lower extremities; second, the inflexibility in the chest wall and diaphragm shift cranially because of hydrostatic pressure, resulting in restricted pulmonary compliance[12-14)]. Regarding the influence of water depth on respiratory function, the vital capacity (VC), forced expiratory volume during the first second (FEV1), and functional residual capacity (FRC) are apparently reduced by the hydrostatic pressure at water depths up to the clavicle or neck level[15-17)], and Andrade et al. reported that the maximum inspiratory muscle strength declines as the water depth increases [18)]. We too have confirmed the decrease in VC with the increased depth of water[19)].

Therefore, aquatic exercise, such as swimming or walking in water, is an ideal exercise for health promotion as it can add resistance training using water viscosity to aerobic exercise. In addition, the specific circumstance of resistance to chest expansion during the inspiratory phase may be useful in developing respiratory muscle strength. Previous studies reported that exercise in water for a duration of 8-10 weeks improved respiratory muscle strength and exercise tolerance in healthy individuals and patients with chronic obstructive pulmonary disease[20-22)]. However, we have founded that there was no difference in the influence on inspiratory muscle strength in aquatic and on-land exercises after testing for such for 8 weeks in healthy adults.[23)]. These facts suggest the need to consider the exercise style, exercise intensity, and water depth when promoting the enhancement of respiratory muscle strength in an aquatic environment. We hypothesized that the inspiratory muscle strength is enhanced more when walking in water than when walking on land because the inspiratory exercise is performed against water pressure. Similarly, the expiratory muscle strength would be enhanced when compared to walking on land because the abdominal muscle groups work to fix the trunk against water pressure.

Therefore, the purpose of this study was to compare the influence on respiratory muscle strength of walking in water to that of walking on land.

Materials and Methods

We recruited the volunteers, healthy males aged between 20 and 29 years. Participants who had 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 (BMI) ≥ 30 kg/m^2), or habit of smoking were excluded. The eligible applicants who met the inclusion criteria participated in the study after familiarizing themselves with the experimental protocol, such as the measurement method and load of walking on land or in water described below. This study was approved by AINO University Research Ethics Committee (Aino 2016-002), and also conformed to the standard set by the Declaration of Helsinki, and written informed consent was obtained from all participants prior to the experiment.

Eighteen healthy adult males were randomly divided into the walking in water group (WG: 9 people) and the walking on land group (LG: 9 people). One week before starting the walking program, the weight, height, and respiratory function were measured to confirm that there were no problems with respiratory functions. We measured respiratory muscle strength by evaluation of maximum inspiratory and expiratory pressure (PImax, and PEmax, respectively) on land while seated. These were used as the pre-exercise values. PImax and PEmax were evaluated using a sthenometer attached to the spirometer (AAM337, Minato, Osaka, Japan) according to the method by Black and Hyatt[24)] and were considered the surrogate indices of inspiratory and expiratory muscle strength, respectively.

For the walking program, the LG walked on level ground and the WG walked in a pool filled up to the depth 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 minutes 4 times per week over 6 weeks. The breathing rate for each minute before and immediately after the end of each walk was measured and recorded. The respiratory muscle strength was measured on land in a sitting position every 2 weeks. A wrist-type pulsometer (ForeAthlete 235J, Garmin, USA) was used for the measurement of the heart rate. T-shirts, shorts and ordinary sports shoes were worn when walking on land and trouser-type swimsuit (without upper parts) and underwater shoes were used for underwater walks.

All statistical analyses were performed using Stat View statistical software package (Ver5.0, SAS, Cary, NC, USA). Data were expressed as mean ± standard deviation (SD) unless otherwise indicated. The effects of walking in water and on land, and changes in the respiratory muscle strength were examined by two-way (trial × time) ANOVA with repeated measurements. In the case of significant time and trial effect, subsequent post-hoc multiple pairwise comparisons (Tukey method) were performed. Statistical significance was defined by a value of $p < 0.05$.

Results

The mean values of height, weight, and respiratory functions of the participants were shown in Table 1. All participants who participated in this study completed the walking program for 6 weeks. In both groups, PImax increased significantly after 6 weeks ($p < 0.05$) compared with pre-exercise value, but no significant difference was observed between the two groups. PEmax increased significantly after 4 and 6 weeks compared with the pre-exercise value only in the WG, and its value was significantly higher than that of LG.

The breathing rate increased significantly in both groups after walking compared to before walking, but there was no significant difference between them (Before walking in water: 14.8 ± 1.9, Before walking on land: 15.5 ± 1.4, After walking in water: 25.4 ± 2.0, After walking on land: 24.8 ± 3.4 times/min; $p < 0.05$ for Before walking in water vs After walking in water, $p < 0.05$ for Before walking on land vs After walking on land).

Table 1. *The physical characteristics of the participants*

	Land Group			Water Group		
Number	9			9		
Age (years)	24.1	±	1.6	23.8	±	2.5
Weight (kg)	66.0	±	5.5	63.5	±	4.8
Height (cm)	170	±	7	168	±	4
%VC (%)	92.9	±	7.5	94.4	±	8.4
FEV1 (%)	87.9	±	3.6	89.6	±	2.7

Values are means ± SD.

Abbreviations: %VC. % vital capacity, FEV1: forced expiratory volume during the first second

Table 2. *Changes in PImax and PEmax following walking on land and in water*

Group	changes (cmH_2O)	pre-exercise			2 weeks			4weeks			6 weeks		
Land Group	PImax	89.0	±	13.1	90.1	±	12.5	93.0	±	12.4	100.1	±	12.6^{*}
	PEmax	86.1	±	10.8	86.8	±	10.7	88.0	±	12.1	90.1	±	12.3
Water Group	PImax	87.1	±	8.3	87.3	±	8.5	90.6	±	10.5	99.6	±	9.4^{*}
	PEmax	89.6	±	6.0	88.8	±	7.5	101.0	±	$7.0^{*\#}$	104.8	±	$5.4^{*\#}$

*Values are means ±SD. *$p < 0.05$ vs. pre-exercise, $^{\#}p < 0.05$ vs. land group.*

Abbreviations: PImax. maximum inspiratory pressure, PEmax. maximum expiratory pressure.

Discussion

We found that walking at this exercise intensity level is effective for improving inspiratory muscle strength regardless of land and aquatic walking environments, but the aquatic environment was better in improving the expiratory muscle strength.

In general, in the aquatic environment, the hydrostatic pressure on the abdominal wall causes the diaphragm to be lifted and to pressurize the lungs, and the hydraulic pressure applied to the chest wall causes a lowering of the compliance of the thorax[25, 26)]. Kurabayasi et al. reported that the chest circumference decreased significantly by 0.5 cm due to water pressure at neck-level water when compared to before entering the water [27)]. Furthermore, it is said that the vital capacity and the respiratory muscle strength decrease as the water depth becomes deeper than the umbilical level[18)]. Based on these facts, we hypothesized that the inhibitory muscular strength is increased in the aquatic environment as compared with the land environment because of the load added by the water pressure while enlarging the thorax during inspiration.

In fact, at the depth of the fourth intercostal space, it seems that the water pressure is applied to the thorax rather than on the land, but it was possible to consider that the load was not enough to raise the inspiratory muscle strength in water compared to on land. However, inspiration muscular strength has increased by walking both in water and on land. This is likely due to the increased breathing rate from walking that added a load on the inspiratory muscles, which led to the increased inspiratory muscle strength after 6 weeks.

Increased strength in expiratory muscles was, however, detected only in the walking in water group. Previous studies have reported that the abdominal muscular tonus is crucial for stabilization of the body trunk to maintain a standing posture during underwater walking[28], and expiratory muscle fatigue was induced by underwater walking more than by land walking [29]. These reports show that load is added to the abdominal muscle groups when walking in water. Therefore, the abdominal muscle groups were continually working against water pressure during walking in the water to fix the trunk, which might have strengthened the expiratory muscles after 4 weeks of exercise.

There are several limitations to this research. We have not measured the tidal volume during walking in water and on land. Although we confirmed that the respiratory rate increased after walking, the tidal volume may also have increased. Since an increased tidal volume is an element of added load on the inspiratory muscles, it would be important to measure this in the future. Moreover, in this study, the walking speed was adjusted to 60% of the predicted maximum heart rate, but whether the same effect can be obtained at other loads should also be studied in the future.

In summary, we demonstrated that 6 weeks of walking at 60% of the predicted maximum heart rate enhances inspiratory muscle strength regardless of land and aquatic environments, but expiratory muscle strength is enhanced only in the aquatic environment. 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.

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References

[1] Sasaki M, Kurosawa H, Kohzuki M. Effects of Inspiratory and Expiratory Muscle Training in Normal Subjects. J Jpn Phys Ther Assoc 2005; 8 (1): 29-37.

[2] Smith K, Cook D, Guyatt GH, Madhavan J, Oxman AD. Respiratory muscle training in chronic airflow limitation: a meta-analysis. Am Rev Respir Dis 1992; 145 (3): 533-539.

[3] McCool FD. Global physiology and pathophysiology of cough: ACCP evidence-based clinical practice guidelines. Chest 2006; 129 (1): 48S-53S.

[4] Kulnik ST, Rafferty GF, Birring SS, Moxham J, Kalra L. A pilot study of respiratory muscle training to improve cough effectiveness and reduce the incidence of pneumonia in acute stroke: study protocol for a randomized controlled trial. Trials 2014; 15.

[5] Janssens JP, Krause KH. Pneumonia in the very old. Lancet Infect Dis 2004; 4 (2): 112-124.

[6] Jung JH, Lee JY, Chung EJ, Kim K.The effect of obstacle training in water on static balance of chronic stroke patients. J phys Ther Sci 2014; 26: 437-440.

[7] Wilcock IM, Cronin JB, Hing WA. Physiological response to water immersion: A method for sport recovery? Sports Med 2006; 36 (9) :747-765.

[8] Sheldahl LM. Special ergometric techniques and weight-reduction. Med Sci Sport Exerc 1986; 18 (1): 25-30.

[9] Irandoust K, Taheri M. The effects of aquatic exercise on body composition and nonspecific low back pain in elderly males. J phys Ther Sci 2015; 27: 433-435.

[10] Chi D, Back Y, Park G, Ju S, Jang HJ. The effect of aquatic exercise on peak torque and stability of knee joints of elderly women. J phys Ther Sci 2011; 23: 871-873.

[11] Lee DG, Jeong SK, Kim YD. Effects of underwater treadmill walking training on the peak torque of the knee in hemiplegic patients. J phys Ther Sci 2015; 27: 2871-2873.

[12] Bondi KR, Young JM, Bennett RM, Bradley ME. Closing volumes in man immersed to neck in water. J Appl Physiol 1976; 40 (5): 736-740.

[13] Craig AB, Dvorak M. Expiratory reserve volume and vital capacity and residual volume of lungs during immersion in water. J Appl Physiol 1975; 38 (1): 5-9.

[14] Craig AB, Ware DE. Effect of immersion in water on vital capacity and residual volume lungs. J Appl Physiol 1967; 23 (4): 423-425.

[15] Agostoni E, Gurtner G, Torri G, Rahn H. Respiratory mechanics during submersion and negative-pressure breathing. J Appl Physiol 1966; 21 (1): 251-258.

[16] Leith DE, Mead J. Mechanisms determining residual volume of the lungs in normal subjects. J Appl Physiol 1967; 23 (2): 221-227.

[17] Prefaut C, Lupih E, Anthonisen NR. Human lung mechanics during water immersion. J Appl Physiol 1976; 40 (3): 320-323.

[18] de Andrade AD, Junior JC, Lins de Barros Melo TL, Rattes Lima CS, Brandão DC, de Melo Barcelar J. Influence of different levels of immersion in water on the pulmonary function and respiratory muscle pressure in healthy individuals: observational study. Physiother Res Int 2014; 19 (3): 140-146.

[19] Yamashina Y, Yokoyama H, Naghavi N, Hirasawa Y, Takeda R, Ota A, Imai D, Miyagawa T, Okazaki K. Forced respiration during the deeper water immersion causes the greater inspiratory muscle fatigue in healthy young men. J Phys Ther Sci 2016; 28: 412-418.

[20] Ide MR, Belini MA, Caromano FA. Effects of an aquatic versus non-aquatic respiratory exercise program on the respiratory muscle strength in healthy aged persons. Clinics 2005; 60 (2): 151-158.

[21] McNamara RJ, McKeough ZJ, McKenzie DK, Alison JA. Water-based exercise in COPD with physical comorbidities: a randomised controlled trial. Eur Respir J 2013; 41 (6): 1284-1291.

[22] de Souto Araujo ZT, de Miranda Silva Nogueira PA, Cabral EE, de Paula Dos Santos L, da Silva IS, Ferreira GM.. Effectiveness of low-intensity aquatic exercise on COPD: a randomized clinical trial. Respir Med 2012; 106 (11): 1535-1543.

[23] Yamashina Y, Aoyama H, Hori H, Morita E, Sakagami N, Hirayama T, Tabira K. The influence of inspiratory muscle training in water for eight weeks on respiratory muscle strength. AINO J 2016; 15: 29-33.

[24] Black LF, Hyatt RE. Maximal respiratory pressures: normal values and relationship to age and sex. Am Rev Respir Dis 1969; 99: 696-702

[25] Dahlback GO, Jonsson E, Liner MH. Influence of hydrostatic compression of the chest and intrathoracic blood pooling on static lung mechanics during head-out immersion. Undersea Biomed Res 1978; 5 (1): 71-85.

[26] Buono MJ. Effect of central vascular engorgement and immersion on various lung volumes. J Appl Physiol 1983; 54 (4): 1094-1096.

[27] Kurabayashi H TK, Kubota K, Tamura J. Analysis of the Circumferences of Chest, Abdomen, Thigh and Calf during Head-out Water Immersion. The Japanese Society of Balneology, Climatology and Physical Medicine 2001; 64(4): 199-202.

[28] Kaneda K, Sato D, Wakabayashi H, Nomura T. EMG activity of hip and trunk muscles during deep-water running. J Electromyogr Kinesiol 2009; 19 (6): 1064-1070.

[29] Yamashina Y, Yokoyama H, Naghavi N, Hirasawa Y, Tkeda R, Ota A, Imai D, Miyagawa T, Okazaki K. Treadmill walking in water induces greater respiratory muscle fatigue than treadmill walking on land in healthy young men. J physiol Sci, 2016; 66 (3): 257-264.

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