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Original Article

The Effects of Aquatic Exercise on Pulmonary Function in Patients with Spinal Cord Injury

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Abstract. [Purpose] The purpose of this study was to determine the effects of aquatic exercise on pulmonary function of patients with spinal cord injury. [Subjects] The subjects were randomly allocated to an aqua group (n=10) and a land group (n=10). [Methods] Both groups trained for 60 minutes, 3 times a week for 8 weeks. Pulmonary function was assessed by measuring the forced vital capacity (FVC), forced expiratory flow rate (FER), force expiratory volume at one second (FEV_1) and force expiratory volume at one second/forced vital capacity (FEV_1/FVC). [Results] Following the intervention, the aqua group showed significant changes in FVC, FER, FEV_1, and FEV_1/FVC. The land group showed only significant differences FER. [Conclusion] The results of this study suggest the effects on the aqua group were significantly higher than those on the land group in patients with spinal cord injury.

Key words: Spinal cord injury, Aqua, Pulmonary function

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INTRODUCTION

Spinal cord injuries (SCIs) are most often traumatic and caused by lateral bending, dislocation, rotation, axial loading, and hyperflexion or hyperextension of the cord or cauda equine. Motor vehicle accidents are the most common cause of SCIs, while other causes include falls, work-related accidents, sports injuries, and penetrations such as stab or gunshot wounds[1)]. Persons with SCIs have a high lifetime risk of serious debilitating and costly medical conditions such as pressure ulcers, urinary tract infections, pain, spasticity, and respiratory[2)].

In normal subjects, breathing occurs primarily through the use of the intercostal muscles and the diaphragm[3)]. However, when this condition is disrupted by an SCI, control of respiratory muscles (intercostal muscles) innervated below the injury level is compromised, leading to respiratory muscle dysfunction and pulmonary complications[4)]. The weakening of the expiratory muscles may also cause a restrictive lung disease, which is accompanied by lung volume reduction, including lung capacity. At the same time, the weakening of inspiratory muscle strength reduces ventilation[5)]. These conditions are among the leading causes of death in patients with SCIs[6)].

From the perspectives of physics and physiology, aquatic environments are beneficial in the management of a variety of musculoskeletal, neurological, and cardiopulmonary pathologies[7)] due to the advantages of hydrostatic forces (buoyancy) and drag resistances unique to the water medium[8)]. Aquatic exercises have advantages when full weight bearing ambulation is not possible or contraindicated, such as for those who are severely obese, arthritic, have balance limitations, or are in the early stages of rehabilitation when joint range of motion should be actively progressed[9)].

Masumoto et al.[10)] reported that walking in water elicits higher muscles activities, higher cardiorespiratory responses, and increased perceived exertion levels in older adults than walking on dry land at the same speed. Jung et al.[11)] studied the application of additional weights to the affected leg to reduce the limb circumduction during aquatic treadmill walking in people poststroke. Baena-Beato et al.[12)] reported that an aquatic therapy program decreased levels of back pain and disability, increased quality of life, and improved health-related fitness in adults with chronic low back pain. Alberton et al.[13)] reported that in water, cardiorespiratory responses to stationary running exercise are higher on land in healthy women.

Although there have been many recent studies in aquatic environments, few studies on pulmonary function in patients with spinal cord injury have been reported. Therefore, the purpose of this study was to examine the effects of aquatic exercise on pulmonary function in patients with spinal cord injury.

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SUBJECTS AND METHODS

The subjects of this study were 20 patients with spinal cord injury. The subjects were provided with a full explanation of the experimental procedure, and all provided their written consent signifying voluntary participation. This study was approved by the Sahmyook University Human Studies Committee (SYUIRB2013-037). The subjects were inpatients at O hospital in Pohang city which is located in the north Kyungsangbuk-do in Korea, diagnosed with an American Spinal Injury Association (ASIA) grade B, C, or D spinal cord injury at the levels of C8 to L5. There were no significant differences in the injury levels and ASIA grades between the groups in this study. The subjects were randomly divided into an aqua group (10 subjects) and a land group (10 subjects); exercise programs were performed in 60-minute sessions three times per week, over a period of 8 weeks. The general characteristics of the aqua group and land group are shown in Table 1.

The training programs used in this study was applied after modifying and supplementing the obstacle course used by Boswell-Ruys et al[14]. The training programs were as follows. (1) Warming-up included range of motion exercises and breathing exercises (10 minutes). (2) The main exercises were upper extremity exercises for function including weight bearing to the left and right with the arms spread out (90 degree angle) while sitting, moving forward and backward with the hands clasped together while sitting, and moving a heavy ball (sensory-therapy ball) forward and backward and left or right (40 minutes). (3) Cooling down included range of motion exercise for flexibility and breathing exercises (10 minutes).

Pulmonary function was measured using a CardioTouch 3000s (BIONET, Tustin, CA, USA) in a sitting position. The forced vital capacity (FVC), forced expiratory flow rate (FER), force expiratory volume at one second (FEV$_1$) and forced expiratory volume at one second/forced vital capacity (FEV$_1$/FVC) were measured. The subjects received sufficient education regarding the instrument's use before measurement.

SPSS version 12.0 was used for all statistical analyses. The dependent variables were the pulmonary function parameters. The general characteristics of the subjects and variables followed a normal distribution. The paired t-test was used to determine whether there were changes in pulmonary function between before and after the training. The independent t-test was used for analysis of changes in dependent variables between groups. Results were considered significant at $p<0.05$.

RESULTS

Differences in pulmonary function after the interventions are shown in Table 2. The aqua group showed significant differences in FVC (p=0.001), FER (p=0.010), FEV1 (p=0.019), and FEV1/FVC (p=0.001). The land group showed only significant differences in FER (p=0.037). There were significant differences in FVC (p=0.031) and FEV1 (p=0.038) between the two groups after the interventions, but there were no differences in FER (p=0.238) and FEV1/FVC (p=0.243).

DISCUSSION

This aim of this study was to evaluate the effect of water-based functional exercise on pulmonary function in SCI patients. Respiratory complications are the most common cause of morbidity and mortality in SCI[15], and Lisa[16] reported that lung disease can contribute to cardiac dysfunction in several ways. Lung disease invariably threatens oxygen transport by its effects on respiratory mechanics and ventilation-perfusion matching. To compensate, the heart attempts to increase cardiac work. Overall, ventilation and oxygen transport are less efficient. Hypoxemia secondary to inadequate ventilation-perfusion matching may predispose the patient to cardiac dysrhythmias. Possessing an understanding of these topics is assumed to be of great importance for clinicians involved in the care rehabilitation of

Table 1. Characteristics of the participants (n=20)

		Aqua group (n=10)	Land group (n=10)
Gender (%)	Male	7 (70.0)	5 (50.0)
	Female	3 (30.0)	5 (50.0)
Age (y)		42.1 (10.6)	51.1 (8.7)
Height (cm)		170.0 (10.5)	163.1 (9.1)
Weight (kg)		64.2 (11.2)	59.2 (12.1)
Time since onset (months)		8.5 (3.9)	8.4 (3.4)

n (%) or mean (SD)

Table 2. Comparison of pulmonary function within groups and between groups (n=20)

Parameters	Values				Change values	
	Aqua group (n=10)		Land group (n=10)		Aqua group (n=10)	Land group (n=10)
	Before	After	Before	After	Before-after	Before-after
FVC(L)	2.5 (0.7)	4.3 (1.4) **	3.0 (0.9)	3.4 (1.4)	−1.8 (1.3)	−0.31 (1.6) *
FER (L/sec)	80.5 (15.5)	90.5 (17.0) *	85.2 (18.0)	90.6 (18.0) *	−10.0 (9.7)	−5.4 (7.0)
FEV1 (L)	2.1 (0.9)	3.2 (1.2) *	2.7 (1.0)	2.9 (1.0)	−1.1 (1.2)	−0.21 (0.3) *
FEV1/FVC (%)	89.3 (3.8)	93.0 (3.6) **	88.3 (4.6)	90.4 (3.2)	−3.7 (2.3)	−2.1 (3.4)

Values are means (SD). FVC, forced vital capacity; FER, forced expiratory flow rate; FEV1, force expiratory volume at one second;FEV1/FVC, forced expiratory volume at one second/forced vital capacity. *$p<0.05$, **$p<0.01$.

patients with a spinal cord injury, as well as for researchers in the field, especially when armed with knowledge that pulmonary complications remain a major cause of morbidity and mortality in this population[4]. The present study shows that FVC, FEV_1, FEV_1/FVC, and FEF improved in both groups ($p<0.05$). However, FER improved in the land group ($p<0.05$), and there was also a significant between-group difference in FVC and FEV_1/FVC ($p<0.05$).

Estenne et al.[17] reported that progressive resistance training improves expiration of ventilator function in people with SCI. Roth et al.[18] reported implications for breathing exercise in treatment of patients with an SCI that may reduce respiratory morbidity and improve outcome. Walker et al.[19] reported a combination of incentive spirometry and arm ergometry improves vital capacity (VC) and increases the maximum volume of expired air during exercise. Mclachaian et al.[20] reported an increase in FVC and FEV_1 throughout the training period and that the absence of a change before or after training suggests that passive abdominal FES training can be used for respiratory rehabilitation in SCI. Soyupek et al.[21] reported that body weight supported treadmill training significantly improves cardiopulmonary functions in patients with an incomplete SCI. It is also that such advanced research coincides with the results of this study showing that the functional training applied both in water and on land has a significant effect on improvement of FVC, FEV_1, FEV_1/FVC, and FEF, which is considered to support the reliability and suitability of the intervention program. It is also considered that future intervention programs for patients need to include training that can cope with daily danger and complex environments like functional training. Stevens and Morgan[22] reported that while an underwater treadmill training program meaningfully improved motor function by improving stability during transfers to walking, Leal et al. reported that water immersion training significantly improved VC in SCI. Also Gass et al.[23] reported that aquatic training improved VO_2. Such an advanced research coincides with the results of this study finding that referred to hydrostatic pressure and is the second property of water. The degree of hydrostatic pressure that is exerted upon the tissue depends on two factors, the density of the fluid and the depth of immersion. When the fluid density increases, so does the hydrostatic pressure. When an individual who is standing or sitting is immersed in water to the shoulder level, the hydrostatic pressure exerted will assist the VC while at the same time resisting inspiratory capacity. This effect will result in strengthening of the diaphragm and intercostal muscles. Training in water can be largely applied to many patients, as it can be easily applied to patients with various illnesses in every age group, and the impact on the joints can be largely reduced by the buoyancy of water in the case of functional training in water. In our study, although measurements of pulmonary function showed that FVC, FEV_1, FEV_1/FVC, and FEF were improved in both the groups, the error decreased more in the aquatic exercise group than in the land exercise group. Therefore, we assume that aquatic exercise therapy is more effective than land exercise therapy, even though land exercise therapy is also effective.

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