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Original Article

The Effect of Underwater Gait Training on Balance Ability of Stroke Patients

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Abstract. [Purpose] The purpose of this study was to investigate the effects of underwater treadmill gait training on the balance ability of stroke patients. [Subjects] Twenty-two patients with stroke were randomly assigned to an underwater treadmill group (n =11) or a control group (n =11). [Methods] Both groups received general rehabilitation for 30 min per session, 5 times per week, over a 4-week period. The underwater treadmill group received additional underwater gait training for 30 min per session, 5 times per week, over the same 4-week period. Static and dynamic balances were evaluated before and after the intervention. [Results] The means of static and dynamic balance ability increased significantly in both groups, but there was no significant difference between the two groups. [Conclusion] Compared to the general rehabilitation program, underwater treadmill gait training was not more effective at improving the balance ability of stroke patients than land-based training.

Key words: Stroke, Gait, Stability

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INTRODUCTION

Balance is the ability to move without falling down or maintain posture, and includes the static stability to maintain a given position with minimum fluctuation, and the dynamic stability to move from a given position without a loss of balance[1)]. Because stroke patients have difficulty in controlling their movements due to muscle weakness, abnormal muscle tone and abnormal movement patterns, their movement amounts are reduced[2)], and their body sway increases approximately 2-fold compared to the static standing posture of normal subjects; their stability limits are also decreased[3–5)]. If body sway increases in a static posture, the weight is loaded asymmetrically on both lower extremities and the ability to move the center of gravity toward the paralytic side is decreased[4)]. The bias of the weight has a direct influence on instability of gait, and decreases gait speed and increases the risk of falls; approximately 25% of stroke patients will be injured in a fall[6)]. Stroke patients use an abnormal postural control strategy due to their inability to control posture and the asymmetry of balance during task performance[7)]. Therefore, the focus of functional recovery for stroke patients should be balance ability and the improvement of functional movements[8)].

Underwater exercises can easily enhance muscular strength and muscular endurance, as well as extend the range of motion, and improve the equilibrium capacity and cardiovascular ability by reducing body weight through buoyancy[9, 10)]. In addition, because it is possible to more stably perform exercises underwater than out-of-water, underwater exercises can provide larger benefits by improving mental stability and self-confidence in training[11)]. Improvement of exercise capacity and stability can enhance the quality of life[12)]. Underwater exercises for the elderly help improve their cognitive function, psychological stability, and postural stability, which could prevent falls[13–15)]. In recent years, in the rehabilitation of stroke patients, underwater exercises have been used for gait training[13)]. Underwater, it is possible to perform gait with less difficulty with supporting body weight. Underwater gait training, which is underwater gait combined with a treadmill compels patients to walk at a regular speed, and it may could have the same effect as treadmill training on the ground[9, 16)].

The most important thing in the rehabilitation of the disabled suffering from central nervous system damage is to enable them to move by themselves, and to conduct reeducation of functional movements through repetitive motor learning. Rehabilitation exercises in the water have been studied in recent years to improve the range of abnormal joint motions, or the degree of muscular strain and functional movements, using a range of natural water and active movements, in contrast with exercises on the ground.

Underwater treadmill gait training combines treadmill training with underwater gait to encourage subjects to walk rhythmically at a constant speed[17)], and it can achieve the same outcomes as treadmill training on the ground[15, 16)]. Underwater treadmill gait training resulted in significant

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improvements in the stance phase of the lower extremity on the affected side, weight support, and psychological stability compared to out-of-water treadmill gait training, and it was suggested that underwater treadmill gait training is more effective at helping stroke patients to recover their ability to walk than out-of-water treadmill gait training[18]. Also, underwater treadmill gait, which places a load on the paralyzed ankle of hemiplegic patients, provides stability in the stance phase by reducing hip flexion and hip abduction can improve and the support rate of the lower extremities and the dynamic equilibrium capacity[17].

The effects of underwater gait training on patients with stroke have been reported mostly for comprehensive underwater exercise programs. There are few experimental studies focusing on underwater treadmill gait training as a balance promotion exercise alone. Therefore, this study examined the impact of on hemiplegic stroke patients' balance of underwater treadmill gait training to provide basic clinical data for underwater treadmill gait training.

SUBJECTS AND METHODS

Forty stroke patients at more than six months and less than two years since stroke onset who were admitted to a rehabilitation hospital in Incheon were enrolled in this study. The subjects included those who could move at least 10 m with the help of an assistive instrument or a person. Those who had cardiovascular disease, such as cardiac failure or arrhythmia, those who were receiving medical treatment that would have affected their abilities, those with a pulse rate of more than 100 beats per minute at rest or a systolic blood pressure of more than 180 mmHg or a relaxation blood pressure of more than 110 mmHg, and those who could not understand verbal instructions due to serious perception impairment, cognitive impairment, or communication disability etc. or could not use the evaluation equipment were excluded. This study was conducted after receiving approval from the Ethics Committee of Sahmyook University. All subjects were provided with information regarding the process, study purpose, and all agreed in writing to participate in the study[19, 20]. A total of 22 patients from the 40 enrolled subjects were selected as subjects for this study. The 18 exclusions included 10 who could not walk independently, five with cognitive disabilities, and three who declined to participate in the experiment.

To minimize selection bias, the 22 selected subjects were randomly assigned to the underwater treadmill group (11 subjects) or the control group (11 subjects). Subjects' general characteristics, static balance ability, and dynamic balance ability were examined prior to the intervention. The two groups participated in a 30-min general rehabilitation program which was conducted by a physical therapist, 5 times per week. Underwater treadmill training was conducted for 30 min twice a week for the underwater treadmill group. In addition, warm-up and cool-down exercises were carried out for five minutes at the start and end of each workout at the end of the 4-week intervention, the subjects' static balance and dynamic balance were evaluated again. Subjects were excluded from the analysis if their participation rate was less than 80%. In the underwater treadmill group, one patient was discharged for personal reasons, and 10 subjects received the post-test. In the control group, one was injured in an accident caused by a fall, and 10 subjects received the post-test. Therefore, the study sample comprised 10 people in the underwater treadmill group and 10 people in the control group.

The general rehabilitation program was composed of motor exercise (ME), functional electrical stimulation (FES), and occupational therapy (OT). The motor exercises were performed five times a week, once per day, for 30 minutes. The motor exercises consisted of postural control, gait training, and balance training. The program was conducted taking into consideration patients' levels for development of the central nervous system. Muscular strength training was carried out using the apparatus for 30 minutes. FES was applied to the upper and lower extremities for 15 minutes each. OT was performed for activities of daily living as upper extremity training, five times per week, once a day for 30 minutes each time[21].

The underwater treadmill gait program began with a warm-up in the water for 5 minutes to establish psychological stability and prevent accidents. The main exercise was carried out for 30 minutes. At the end of the main exercise, cool-down exercises were carried out for 5 minutes including stretching to relax muscle tension and recover muscle fatigue. Training was performed twice a week for four weeks. The initial speed of the underwater treadmill training was set at 36% of each subject's ground gait speed[22]. The speed was increased in increments of by 0.1 m/s, to maintain comfort and good gait patterns, to the maximum ability of the subjects. The training speed of the next day began at the maximum speed of the previous day[23], and the speed was lowered when the alignment of the trunk and limbs was abnormal or the gait was unbalanced due to the treadmill speed being faster than a subject's ability to comfortably perform gait. Training was performed twice a week for 30 minutes over a four-week period, and the subjects wore water shoes to prevent slipping on the treadmill foothold. The pool water temperature for the gait training was 34°C, and the water depth was adjusted to each the patient's xiphoid[17].

In this study, the Hydrophysio-Focus (Hydrophysio, USA, 2009) was used as the underwater treadmill gait training tool. Hydrophysio-Focus allows easy adjustment of the water depth (0–1,280 mm) to each individual's height through a touch-screen control panel, and provides hydrokinetic exercise in an environment in which a subject can jump or walk on the underwater treadmill (3,500 × 1,400 × 2,100 mm). The gait speed (0.1–8 km/h) can be adjusted to match a subject's ability.

In this study, the Balance System SD (Biodex, USA, 2009) was used to evaluate the static balance and dynamic balance. Static balance and dynamic balance were analyzed. The Balance System SD consists of a platform and display device, and 12 strain gauges within the platform measure the equilibrium angle of the platform. The platform can slope up to 20° in all directions, and the mean angle of the slope indicates the stability of static balance.

Static balance is measured by limiting the platform movement to within 5°, whereas platform movement is unlimited in dynamic balance tests. Balance is scored as anteroposterior, mediolateral and total balance, and the mean slope angle of the platform is calculated; higher scores indicate lower stability.

The intra-rater reliability of this test is r = 0.80, and the inter-rater reliability is r = 0.40[24–26]. The static balance was measured using the postural stability test of the Balance System SD test methods. The postural stability test assesses total posture sway. Subjects stood with their feet shoulder-width apart on the platform (restricted to 5° movement) and adjusted their balance aiming to keep the cursor within the target displayed on the screen. The test lasts for 30 seconds and was measured three times with 10-second rest intervals. The average value of the measurements of anteroposterior postural sway, and the mediolateral postural sway of each leg were calculated[24, 26].

The dynamic balance was measured using the fall risk test of the Balance System SD test methods. Subjects stood with their feet shoulder-width apart on the freely-pivoting platform and adjusted their balance aiming to keep the cursor within the target displayed on the screen. The data was collected for 30 seconds, three times, with 10-second rest intervals between measurements.

All statistical analyses of this study were performed using SPSS 17.0. The data were normally distributed. We compared the exercise effect between before and after the intervention in each group using the paired t-test. The independent t-test was performed to examine the differences between the groups. A p value < 0.05 was considered significant.

RESULTS

Twenty subjects were enrolled in this study, and there were no significant differences in the general characteristics of the underwater treadmill group and the control group (Table 1). In addition, there were no significant differences in the static and dynamic balance abilities of the underwater treadmill group and control group. In static balance, both the underwater treadmill group and the control group showed significant decreases in anteroposterior, mediolateral and total postural sway after the interventions (p<0.05). The comparison of the pre- and post- test results of the two groups found no significant differences (Table 2). Both the underwater treadmill group and the control group showed a significant improvement in dynamic balance (p<0.05). A comparison of the pre- and post- test results of in the two groups, however, did not find significant difference (Table 3).

DISCUSSION

Static balance is the ability to maintain the center of gravity within the limits of stability, and dynamic balance is the ability to adjust the body posture to prevent falls while moving the body[27]. The balance is one of the first of the body functions to be restored in stroke patients[28].

In this study, the static and dynamic balance abilities of hemiplegic stroke patients were evaluated after underwater treadmill gait training for four weeks. To determine the changes after the intervention in their static balance ability, anteroposterior, mediolateral, and total postural sway on a fixed stable support surface were measured using balance measuring equipment (balance system SD, SD 950-304, Biodex, USA). Evaluation of total postural sway was performed on a moving stable support surface to determine the dynamic balance ability of anteroposterior postural sway.

After the interventions, the anteroposterior postural sway of static balance ability of the underwater treadmill group showed a significant difference, with a 41% decrease compared to pre- training (p<0.05), and the control group also showed a significant difference, with a 35% decrease (p<0.05). For the mediolateral postural sway, the underwater treadmill group showed a significant difference with a 31% decrease from pre- training (p<0.05), and the control group

Table 1. General characteristics

	Underwater treadmill group (n=10)	Control group (n=10)
Sex (M/F)	6/4	5/5
Affected side (R/L)	6/4	5/5
Age	61.8±12.0[a]	60.6±11.8
Height (cm)	170.0±9.3	163.1±11.2
Weight (kg)	67.5±8.9	63.8±8.4

[a] Mean±SD

Table 2. Changes in static balance ability

		Underwater treadmill group (n=10)	Control group (n=10)
Anteroposterior (°)	Before	2.8±1.2[a]	2.8±1.1
	After	1.7±0.9	1.8±0.9
	Difference	−1.1±1.2*	−1.0±1.2*
Mediolateral (°)	Before	2.9±1.2	2.9±2.0
	After	2.0±0.7	1.3±0.6
	Difference	−0.9±0.9*	−1.6±1.1*
Total (°)	Before	4.5±1.6	1.4±1.4
	After	3.1±1.1	3.2±1.0
	Difference	−1.4±1.4*	1.8±1.3**

[a] Mean±SD, *p<0.05, **p<0.01

Table 3. Change in dynamic balance ability

		Underwater treadmill group (n=10)	Control group (n=10)
Total	Before	3.7±1.7[a]	3.9±1.2
	After	2.6±0.9	3.0±1.2
	Difference	−1.1±1.2*	−0.9±1.2*

[a] Mean±SD, *p<0.05

also showed a significant difference with a 31% decrease ($p<0.05$). Regarding the overall postural sway, the underwater treadmill group showed a significant difference with a 32% decrease from the pre- and post-training ($p<0.05$). The control group also showed a significant difference with a 29% decrease ($p<0.01$). The post-intervention comparison of the two groups found no significant differences. These findings show that underwater treadmill gait training might not have a more significant than land-based training on the static balance ability of stroke patients. Although a direct comparison was difficult due to different subject characteristics, our results differ from those of previous studies, which have reported improvements in static balance ability after underwater gait training performed by patients with osteoarthritis of the lower limb[29)]. Giaquinto et al. reported that underwater gait training improved subjects' the ability to adjust their posture by increasing the information of proprioception and touch sensation, and improving the stability of static balance ability during standing with both feet, by reducing the angular velocity of the center of mass[30)]. However, stroke patients have abnormal motor and sensory nerves on the paralyzed side of the lower extremity, and the amount of information of proprioception and touch sensation from the water would have been insufficient to induce an improvement in their static balance.

Suomi et al. reported that the condition of a temperature-controlled water exercise may be a factor that helps to improve static balance ability[29)]. In this study, although our subjects were trained in a relaxed state in a temperature-controlled underwater training environment, the balance test after training was measured at a different temperature. Therefore, there was the possibility that the different temperatures of the environment, between training and test, affected the static balance ability of our subjects.

In this study, the overall postural sway of dynamic balance ability showed significant differences, with a 31% reduction in the underwater treadmill group ($p<0.05$), and a 42% reduction in the control group ($p<0.05$). However, the post-intervention comparison of the two groups found no significant differences between them.

Lund et al. reported that the results were statistically significant in 79 patients with osteoarthritis because the underwater gait training group showed a 3% increase in dynamic balance ability compared to a land-based gait training group, and between pre- and post-training ($p<0.05$)[31)]. Jung et al. found a significant increase in dynamic balance ability, due to an increase in weight bearing capacity, after underwater treadmill gait training for stroke patients. They loaded the paralyzed side ankle of the patients to reduce its buoyancy and to increase its weight bearing capacity in the stance phase ($p<0.05$). The increase in subjects' dynamic balance ability was considered to have been induced by improvement in the muscular strength of the hip flexors and extensors on the paralyzed side limb, a result of the underwater treadmill gait training, and the reduction of buoyancy, and postural stability was attributed to a 60% increase in the weight bearing ability in the stance phase[17, 20, 32)].

In the present study, unlike previous studies, both the underwater treadmill group and control group showed significant improvements. For patients without hemiplegia, underwater gait training would increase dynamic balance ability more than overground gait training due to their balanced weight support. On the other hand, for our stroke patients, the underwater treadmill gait training was ineffective at improving the dynamic balance ability due to the decrease in weight on the paralyzed side limb which was supported by buoyancy.

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