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Effects on Static and Dynamic Balance of Task-Oriented Training for Patients in Water or on Land

DONGJIN LEE, PT, PhD[1)], TAESUNG KO, PT, PhD[2)], YOUMI CHO, PT, MS[3)]

[1)]*Department of Physical Therapy, Gwangju Health College University: 683–3, Sinchang-dong, Gwangsan-gu, Gwanju 506-701, South Korea. TEL +82 62-958-7776*
[2)]*Department of Physical Therapy, Daewon University College*
[3)]*Department of Physical Therapy, Shinsung University*

Abstract. [Purpose] The purpose of this study was to give task-oriented training to stroke patients in water and on land and compare their static balance and dynamic balance. A total of 10 types of task-oriented training were given in water and on land. [Subjects] A total of 34 patients received training for 50 minutes, three times a week, for 12 weeks. [Methods] The 34 patients were randomly divided into an in-water training group and an on-land training group. The patients received the same task-oriented training for 12 weeks. [Results] When the groups' static balance was compared, the in-water training group showed significant improvements in anteroposterior velocity (mm/s) and mediolateral velocity (mm/s) with eyes open (EO) and eyes closed (EC). The on-land training group showed significant improvements in values other than anteroposterior velocity (mm/s) with EC. When the groups' dynamic balance was compared, there was a statistically significant difference between the groups at 12 weeks. The in-water training group showed significant reductions in the time and distance taken to implement a task. [Conclusion] According to the results, task-oriented training received by chronic stroke patients in water was more effective at improving static balance and dynamic balance than on-land training.
Key words: Balance, Task-oriented training, Water

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INTRODUCTION

Preventing falls is an important objective in the rehabilitation of acute or chronic stroke patients. Risk factors of falls include balance or gait impairment, difficulties in activities of daily living, inactivity, visual impairments, and reduced lower limb strength[1)]. When balance has been impaired due to reduction in the weight bearing capacity of a stroke patient's paretic lower limbs, the stability of the body is impaired due to increased postural sways and reduced static reactions[2)]. The deficits in balance, gait, etc of chronic hemiparetic stroke patients become important determinants of ambulatory activity levels[3)]. Among stroke patients, balance problems while dressing are the strongest risk factors for falling (odd ratio, 7.0) and residual balance problems are also a strong risk factor of falling[4)].

A motor learning model for the physical rehabilitation of stroke patients has been proposed[5)]. The absence of ongoing exercise or activity programs after patients are discharged from a rehabilitation center is becoming much overlooked factor that can exacerbate a patient's disability or handicap. Task-oriented training is designed to provide opportunities to practice tasks while increasing weakened muscular strength in order to overcome the factor held to be inhibiting improvement of chronic stroke patients' functions. In addition, since many individuals can participate in the training simultaneously, this type of training helps reduce related costs[6].

The inherent characteristics of water include hydrostatic pressure, buoyancy, and density, while dynamic characteristics including streamline and friction resistance created by turbulent water flows, work as advantages that enable human bodies to practice balanced and coordinated motions in water[7]. Exercises in water can provide special rehabilitation environments suitable for patients with functional limitations, and improves in balance through the resistance of water against the upper limbs, the lower limbs, and the body. These are some of the beneficial effects of training in water, and on-land training programs can be appropriately transformed into in-water programs[8]. Researchers have reported that, in patients with arthritis, in-water exercises improved muscular strength, reduced pain, and improved flexibility, coordination, balance and agility[9]. In addition, water exercises have been reported to be effective at promoting stroke patients' and late poliomyelitis patients' cardiovascular fitness (VO_2max), maximal workload, muscle strength, peak load, and fitness at the peak heart rate. However, the improvement of balance achieved by water exercises was not significant[10,12]. On the other hand, task-related exercises on land designed to strengthen the lower extremities enhanced the Berg balance score, speed, and distance[13]. Individual studies show some differences among the effects related to balance in water after muscle strengthening, and stretching, however, studies on the balance of stroke patients during in-water exercises are insufficient.

The purpose of this study was to examine the effects on dynamic and static balance of chronic stroke patients given the same task-oriented training in water or on land to prevent falling.

SUBJECTS AND METHODS

Subjects

Thirty-four chronic stroke patients participated in the experiment. All the patients were outpatients who visited a rehabilitation center located in Cheongju, South Korea. The study subjects were selected from those patients, who voluntarily agreed to participate in the experiment, could independently walk at least 10 m, had a Brunnstrom stage 4 or higher lower limb recovery stage, had a mini-mental state examination (MNSE) score of at least 24, and had a Modified Barthel Index (MBI) of at least 75. Patients who had any other neurological deficit or serious damage to their vision were excluded. Since the study was carried out at two separate locations, the randomization was done in blocks. Seventeen patients (10 males and 7 females: mean age 62.06 ± 13.36) formed the water-based training group (WG), and 17 patients (6 males and 11 females: mean age 61.41 ± 8.44) formed the land-based training group (LG). Informed consent was received from all of the participants in the experiment, and the experiment was carried out as a single blinded experiment.

Methods

In-water exercises were conducted using a total of 10 tasks. The exercise intensity was Borg category scale 11 (fairly light) and 13 (somewhat hard) as measured by the Rating of Perceived Exertion (RPE)[9]. The exercise methods were created by applying the methods used in previous studies conducted in water and on land[12,14]. The 10 tasks were as follows. (1) Warming-up included arm lifts, ankle circles, and stretching of the trunk, thigh and calf muscles. (2) Balance tasks included standing against the resistance of water with feet in parallel and tandem. (3) Heel lifts. (4) Coordination and muscular strength tasks included lifting one leg with adduction and abduction movements of the legs, and drawing an "8" on the ground with the feet. (5) Balance and muscular strength tasks included stepping forward, backward, and sideways. (6) Balance and ability to move tasks included unilateral and bilateral slow arm movements and slow forward and backward walking. (7) Endurance and ability to move tasks included walking forward and backward as fast as possible, jogging in place with arm movements, and walking sideways first to one side and then to the other as fast as possible. (8) Ability to move tasks included a dual task of moving while holding a ball in the unaffected hand and stopping on a verbal order given by the physical therapist. (9) Mobility and balance in turning task included walking 3 m, turning around a target point and coming back. (10) Cooling-down included arm lifts, ankle circles, and stretching of the trunk, thigh, and calf muscles. Each task was carried out for 4 minutes followed by a rest for 1 minute, and thus the tasks were carried out for 50 minutes in total.

The pool was 14 m × 5 m and 1.25 m to 1.5 m in depth, and was constructed to be suitable for carrying out general gait training and diverse tasks. The temperature of the water was maintained at 33–34 °C, which is higher than the temperature of general swimming pools, 25 –28 °C, in order to prevent sudden muscular contractions due to shivering from cold temperatures and to maximize the treatment effects[15)].

The 10 tasks were carried out as on-land exercises for 50 minutes at the same RPE intensity, 11–13. For the second task, the water resistance was replaced by appropriate resistance given by physical therapists. The in-water and on-land exercise programs were implemented by four physical therapists educated in the exercise programs for 12 weeks. In addition, during the in-water and on-land exercises, if any patient reported a side effect such as dizziness, the patient was instructed to stop the exercise immediately.

In this study, balance was measured using the Good balance system (Metitur Co., Ltd., Jyväskylä, Finland). This equipment has been commercialized as equipment for measuring the static and dynamic balance of the elderly, stroke patients, etc. and is widely used[16,17)]. Static balance was measured with the moving line drawn by the center of pressure formed on the force plate from the center of the body weight of the patient in the direction of gravity by assuming the left-right sway direction and the front-rear sway direction as X and Y axes and measuring the average velocity on the individual axes as the mediolateral velocity and the anteroposterior velocity in units of mm/s. The measuring methods used included measuring for 30 seconds while the patient kept his or her eyes open and measuring for 30 seconds while the patient kept his or her eyes closed. The dynamic balance was measured with the time (sec) and distance (mm) taken to move from the center point to each target and then come back. Before measuring, the patients were sufficiently informed about how to use the equipment. SPSS (SPSS Inc, version 12.0) program was used for statistical analyses. Before the experiment, independent t-tests were conducted to test the homogeneity of each group, and Pearson's χ^2 test was conducted to test the homogeneity of the gender, diagnosis, and number of affected patients. The independent t-test was used to compare the water-based training group with the land-based training group at baseline and 12 weeks. The paired t-test was used to compare the status of each group before the experiment with the patients' status at the end of the experiment. Values with $p<0.05$ were recognized as being significant.

RESULTS

The age of the in-water group was 62.06 and that of the on-land group was 61.41; the time since the onset of stroke of the in-water group was 12.06 months and that of the on-land group was 13.89 months, and there were no significant differences between the groups. The in-water group consisted of 7 females (41.2%) and 10 males (58.8%), and the on-land group consisted of 11 females (64.7%) and 6 males (35.3%). Regarding diagnosis, the in-water group had 10 patients with infarction (58.8%) and 7 patients with hemorrhage (41.2%), and the on-land group had 9 patients with infarction (52.9%) and 8 patients with hemorrhage (47.1%). For the affected side: in the in-water group, 12 patients were affected on the left side (70.6%) and 5 patients were affected on the right side (29.4%), and in the on-land group, 11 patients were affected on the left side (64.7%) and 6 patients were affected on the right side (35.3%). No differences between gender, diagnosis, and affected sides were observed between the groups. Therefore, the general characteristics were homogenous at the start of the experiment (Table 1).

In the static balance measurements, the on-land group and the in-water group showed significant decreases in the mediolateral velocities with EO and EC, whereas only the in-water group demonstrated significant decreases in anteroposterior velocities with EO and EC ($p<0.05$) (Table 2).

In the dynamic balance measurements, there was a statistically significant difference between both groups in the times and distances at 12 weeks ($p<0.05$). The in-water group was the only group that demonstrated statistically significant decreases in the times and distances taken to carry out the tasks ($p<0.05$) (Table 3).

DISCUSSION

Chronic stroke patients report they have difficulties in daily life even after they are discharged from hospital due to injuries from falls

Table 1. Subject demographics

Characteristics		WG (n=17)		LG (n=17)	
		N (%)	Mean (SD)	N (%)	Mean (SD)
Age (years)		NA	62.06 (13.36)	NA	61.41 (8.44)
Sex	Female	7 (41.2)	NA	11 (64.7)	NA
	Male	10 (58.8)	NA	6 (35.3)	NA
Diagnosis	Infarction	10 (58.8)	NA	9 (52.9)	NA
	Hemorrhage	7 (41.2)	NA	8 (47.1)	NA
Affected side	Left	12 (70.6)	NA	11 (64.7)	NA
	Right	5 (29.4)	NA	6 (35.3)	NA
Time since onset (months)		NA	12.06 (3.33)	NA	13.89(3.25)

WG, water-based training group; LG, land-based training group; SD, standard deviation; N, number; NA, not applicable.

Table 2. Anteroposterior and mediolateral velocities of sway when the eyes were open and when the eyes were closed at the baseline and 12 weeks

Variables		WG (n=17)		LG (n=17)	
		baseline	12 weeks	Baseline	12 weeks
EO	Anteroposterior velocity (mm/s)	11.3 (4.1)	8.2 (3.4) *	12.6 (2.8)	10.1 (4.3) *
	Mediolateral velocity (mm/s)	8.5 (4.4)	5.7 (3.4) *	9.1 (3.0)	6.1 (2.5) *
EC	Anteroposterior velocity (mm/s)	13.1 (2.7)	9.2 (3.3) *	13.7 (4.2)	10.4 (4.0)
	Mediolateral velocity (mm/s)	10.1 (2.6)	6.6 (2.8) *	10.6 (4.6)	7.4 (2.3) *

Values shown are means (standard deviation). *p<0.05. EO, eyes open; EC, eye closed; WG, water-based training group; LG, land-based training group.

Table 3. Changes in performance times and distances of dynamic balance test at baseline and 12 weeks

Variables	WG (n=17)		LG (n=17)	
	baseline	12 weeks	baseline	12 weeks
Time (sec)	37.3 (12.8)	23.5 (9.1) *†	36.1 (12.0)	31.6 (10.6)
Distance (mm)	1567.7 (404.7)	1154.7 (249.8) *†	1579.0(375.1)	1440.8 (357.6)

Values shown are means (standard deviation).*p<0.05: significant difference in pretest and posttest scores for WG group. †p< 0.05: significant difference between WG and LG groups. WG, water-based training group; LG, land-based training group.

or gait disturbances resulting from disequilibrium[18]. Researchers have reported that the diverse characteristics of water greatly help improve the function of patients who have disorders in balance etc. due to damage to the nervous system[7]. The position of the center of pressure used to evaluate the balance of a stroke patient reflects the ability to control the motions of the trunk and the lower limbs. Increased activity of the plantarflexor muscle tends to move the center of pressure forward while increased activity of the invertor muscle tends to move the center of pressure laterally[19].

It has been reported that, in water, streamlines and turbulent water flows create frictional resistance, and the resistance increases in proportion to velocity. The resistance works evenly from all directions, enabling isokinetic muscle contraction movements during which the pressure of the water stimulates the proprioceptors to help maintain balance[8]. The stimulation arises through active contact with water, whereas exercise on-land has less manual contact. Robert[20] reported that buoyancy and gravity interact during movements in water, and when postural sway occurs, proprioceptive mechanoreceptors are actively stimulated in order to limit the postural sway. In this study, the in-water group showed significant decreases in the velocities of anteroposterior and mediolateral sway with EC and EO and the time and distance taken to carry out the dynamic balance tasks. Therefore, the task-oriented training was more effective when it was carried out in water than when it was carried out on land.

Chu et al.[10] reported that chronic stroke patients aged 62 on average who performed on-land stretching for 10 minutes, in-water warming-up for 5 minutes, aerobic activities (shallow water walking, running, side stepping) for 30 minutes, and light cooling down exercises for 5 minutes for 8 weeks showed significant interactions between time and group in VO_2max, maximal workloads, and gait speeds when compared with a control group that had done only upper limb exercises, while no significant difference was shown in the 14-item Berg Balance Scale[21]. Their results differ somewhat from the results of this study, due to differences in experiment periods and balance measuring tools.

Berger et al.[22] measured pain, static balance, and dynamic balance before and after on-land exercises, before and after in-water exercises for 1 week, and before and after in-water exercises for 4 weeks on land and in a 34 °C hot spa. Although the static balance measured by the centre of foot pressure (COP) did not show any significant difference after both on-land exercises and in-water exercises, the dynamic balance as measured by the Timed Up and Go (TUG) test showed significantly shortened times after balneotherapy was conducted in the spa for 4 weeks, demonstrating that in-water exercises effectively improved dynamic balance, which was consistent with the results of the dynamic balance test conducted in this study.

Thanks to buoyancy, in-water exercises make movements limited by body weight smooth and enable slow adjustment of exercise speeds. In addition, composite neuromuscular mobilization in water should improve proprioceptive inputs[23]. It was also reported that a warm bath relaxes muscles, which would increase contact areas under the feet eventually improving plantar tactile inputs and balance control[24]. Kaneda et al.[25] reported that, after interventions for 12 weeks with a deep water-running exercise (DWRE) and a normal water exercise (NWE), postural-sway distances, tandem-walking, and simple reactions were measured, and DWRE gave better results for postural-sway distance, tandem-walking time, and dynamic balance ability, indicating that depths of water helped to improve diverse human body functions.

This study tested the effects of in-water exercises on the static and dynamic balance of chronic stroke patients. From the results of this study, it can be seen that in-water exercises effectively improved on the balance of chronic stroke patients. Particularly, we think in-water exercise should be effective for fall prevention for stroke patients. Future studies will be necessary to establish the effects of in-water exercises in relation to the time of onset of stroke and diverse water depths and temperatures.

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