

# Postural Balance of Stroke Survivors in Aquatic and Land Environments

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**Abstract.** [Purpose] The purpose of this study was to investigate the effect of an aquatic environment on the balance of stroke patients compared to a land environment. [Subjects and Methods] Forty-six subjects participated in this study. They were divided into a land exercise (LE) group (13 males, 10 females) and an aquatic exercise (AE) group (12 males, 11 females). Exercises were conducted six times a week for six weeks. Balance was assessed through parameters of sway of the center of pressure. [Results] The exercises improved the balance abilities of both groups with eyes open. With eyes closed, balance ability improved more in the AE group, and AE was more important than vision for improving the balance ability of stroke patients. [Conclusion] This study found that stroke patients had better balance in an aquatic environment than in a land environment.

**Key words:** Aquatic environment, Postural balance, Stroke

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## INTRODUCTION

Stroke survivors have poor balance and decreased loading on the hemiparetic leg. Deficits in balance control can contribute to low performance in functional activities and to a high incidence of falls among stroke survivors<sup>1)</sup>. To date, many therapeutic exercise interventions have been used to prevent physical inactivity and the resultant secondary complications in chronic stroke patients<sup>2)</sup>. Aquatic therapy has gained a wide level of acceptance as a method of treatment for musculoskeletal and neurological disorders, disabling pain conditions, and balance disorders as it allows a patient to perform a comprehensive rehabilitative program<sup>3)</sup>. The water provides resistance but minimizes biomechanical stress on muscles and joints, which is important for such individuals when exercising<sup>4)</sup>. The support offered by water allows more independent upright postures. There may be an increase in afferent stimulation from greater cutaneous inputs, muscles may fire more freely because patients are less fearful of movement, and activity in water may facilitate vestibular inputs<sup>5)</sup>. When submerged, hydrostatic pressure promotes equal resistance to all muscle groups being worked and provides a greater sense of stability. It has been suggested that because there is no stationary resting position in water, muscles are activated continuously to stabilize the position of the body<sup>3)</sup>. This stabilization may allow a patient to gain more strength, flexibility, and more importantly, improve balance<sup>6)</sup>. Balance, which is the ability to maintain a position and react to a perturbing force, is important in rehabilitation<sup>7)</sup>. Also, balance training may offer better

outcomes when performed in an aquatic environment<sup>6)</sup>. Therefore, we investigated the effects of aquatic exercise programs on the balance ability of stroke survivors.

## SUBJECTS AND METHODS

The subjects who participated in this study were 46 stroke patients hospitalized in H hospital located in Daejeon, Korea. The inclusion criteria were that participants had experienced a stroke at least six months before enrollment, had hemiparesis secondary to a first stroke, were medically stable, had no internal medical disease such as diabetes, had no heart disease, had no orthopedic problems, scored 24 or higher in the Mini Mental State Examination-Korea, had no visual problems, and could walk at least 15 m by themselves. These subjects were given explanations until they sufficiently understood the objectives and method of this experiment. Ethical approval was given by the Hansalang Hospital Committee of Medical Ethics, and consent was obtained from subjects or their guardians prior to their inclusion in the study. Exclusion criteria were uncontrolled hypertension, arrhythmia, and unstable cardiovascular status. The experiment was conducted with the subjects divided into a land exercise (LE) group and an aqua exercise (AE) group. Participants were randomly assigned to either the LE group or the AE group.

The LE group consisted of 13 males and 10 females; age (mean  $\pm$  SD)  $56.6 \pm 3.9$  years, height  $165.1 \pm 7.1$  cm, body weight  $62.8 \pm 6.5$  kg. The cause of stroke was cerebral infarction for 9 subjects and cerebral hemorrhage for 14

subjects. Ten subjects had right hemiplegia and 13 had left hemiplegia. The modified barthel index was 80–83 for 4 subjects and above 84 for 19 subjects.

The AE group consisted of 12 males and 11 females; age (mean  $\pm$  SD)  $54.56 \pm 8.27$  years, height  $169.25 \pm 8.40$  cm, body weight  $66.92 \pm 8.91$  kg. The cause of stroke was cerebral infarction for 9 subjects and cerebral hemorrhage for 14 subjects. Eleven subjects had right hemiplegia and 12 had left hemiplegia. The modified barthel index was 80–83 for 5 subjects and above 84 for 18 subjects.

This experiment was conducted over six weeks during June and July 2010. Exercises were conducted six times a week for six weeks (35-minute sessions). Three sets were implemented for each type of exercise, with ten repetitions per set. The land exercises were carried out in the exercise therapy room at the hospital, and the aquatic exercises were performed in the indoor aquatic exercise therapy room at the hospital. The subjects in both groups also received conventional exercise therapy six times a week. Different exercise programs were performed by the LE group and the AE exercise group.

The LE group used the exercise methods of Dean<sup>8)</sup> and Evert et al.<sup>9)</sup> The following exercises were performed by the land exercise group.

1. Improving the stability of the lower trunk using the upper limbs. In the supine position, a square pillow was placed under the knee joint so that the angles of the hip joint and the knee joint were at 90 degrees. The muscle at the back of the neck was lengthened and the epigastric region was pushed to the distal part, elevating the head of the patient. Then, both scapulae were displaced in the anterior direction, and the upper limbs were abducted. At the same time, the head was directed to the knees, and the trunk was maintained straight.
2. Walking back and forth, walking right and left, and standing still.
3. Anterior tilt and posterior tilt of the pelvis in a sitting position. A therapist moved the pelvis of the patient in front of the patient, holding the outer sides of the pelvis.
4. Stretching the arms forward, downward, and toward both sides in the sitting position.
5. Standing with both feet together.
6. Repeated lifting and lowering of the heels within a range in which the patient would not fall down, standing in a comfortable position and keeping both feet wide.

The exercises carried out by the land exercise group followed to the exercise methods of Itshak et al.<sup>10)</sup>, Peter et al.<sup>11)</sup>, and Carin et al.<sup>12)</sup> The following exercise programs were performed by the aquatic exercise group.

1. Standing on a board while maintaining balance in the water.
2. If a stable state could be maintained in Exercise 1, the patient bent and spread the hip and knee joints as slowly as possible in the water.
3. Walking while wearing a floating cuff in the water.

4. Moving the hip and knee joints around while holding a water noodle between the legs as if riding a bicycle in the water.
5. Standing on a balance board while keeping the eyes closed and wearing a floating cuff in the water.
6. Jumping in a given area of the pool while wearing a floating cuff and keeping both feet together.

For the aquatic exercises, a floating cuff, belt, balance board and water noodle were used. The cuff provides buoyancy in the lower extremity and the belt helps subjects to maintain an independent standing posture in the water. The balance board helps subjects with sitting balance, coordination and pelvis stability exercises in the water. The water depth was constant at 1.3 m, and the water temperature was kept at 33–35°C for the aquatic exercises.

Static balance assessed with parameters of sway of the center of pressure (COP) which were measured by the Good Balance System (Metitur Ltd, Jyväskylä, Finland). The subjects were instructed to stand on the force platform in the most comfortable posture while maintaining a distance of 5–6 cm between their heels. Each measurement was carried out for 30 seconds. Each measurement was carried out three times with the eyes open and then three times with the eyes closed, and average values were obtained. For the measurements, the environment was kept warm, calm and bright, and the subjects wore simple clothes. The force platform is constructed in the shape of a triangle (800×800×800 mm). The signals from the amplifier were input to a computer via a 12-bit transducer, and the sampling frequency of each channel used to record the information was 50 Hz. In this experiment, the mediolateral movement distance and the anteroposterior movement distance of the COP of each subject were assumed as the X-axis and Y-axis of the subject respectively. The values for each axis were divided by the measurement time to calculate the average speed. The velocity moment is the area described by the movements of the COP per second and this value is related to the distance from the geometrical center point of the entire test and the velocity of the movement during the same period of time<sup>13)</sup>. Consequently, the moments were interpreted as the total COP sway. The independent t-test was used to determine within-subject changes between baseline and follow-up. For group and vision information, differences in outcome variables meeting mathematical assumptions were examined using two-way ANOVA. Duncan's post hoc test was then used to determine whether differences existed across each group. All statistical analyses were performed using SPSS (version 12.0 for Windows, SPSS Inc., Chicago, IL, USA). Values of  $p < 0.05$  were considered significant.

## RESULTS

The LE group and the AE group showed significant improvements with eyes open in X-speed, Y-speed and Velocity Moment after the exercises ( $p < 0.05$ ). Therefore, the exercises improved the balance abilities of both groups (Table 1). With eyes closed, the AE group showed significant improvements in X-speed, Y-speed and Velocity Moment after the exercises ( $p < 0.05$ ), but the LE group did

**Table 1.** A comparison of balance by group and vision information (M ± SD) (unit: mm/s)

Balance	Group	Condition	Pre	Post	Duncan
X-speed***	Land group	eyes closed <sup>a</sup>	12.5 ± 5.3 <sup>a</sup>	11.5 ± 4.8	c,d>a,b
		eyes open <sup>b*</sup>	14.3 ± 3.7 <sup>a</sup>	12.5 ± 3.0	
	Aqua group	eyes closed <sup>c*</sup>	12.5 ± 5.5	8.6 ± 4.0	
		eyes open <sup>d***</sup>	13.8 ± 5.5	8.7 ± 3.5	
Y-speed**	Land group	eyes closed <sup>a</sup>	14.7 ± 3.7	13.4 ± 3.8	d,c>c,a>a,b
		eyes open <sup>b*</sup>	16.9 ± 4.7	15.3 ± 4.8	
	Aqua group	eyes closed <sup>c</sup>	14.5 ± 4.3	11.4 ± 3.4	
		eyes open <sup>d***</sup>	15.4 ± 4.4	10.2 ± 3.0	
Velocity Moment**	Land group	eyes closed <sup>a</sup>	62.6 ± 22.4	57.8 ± 20.1	d,c>a,b
		eyes open <sup>b*</sup>	72.0 ± 22.8	61.9 ± 29.2	
	Aqua group	eyes closed <sup>c**</sup>	61.1 ± 36.6	36.9 ± 24.7	
		eyes open <sup>d***</sup>	65.8 ± 29.2	34.2 ± 14.0	

\*p<0.05, \*\*p<0.01, \*\*\* p=0.01; X-speed, mediolateral sway; Y-speed, anteroposterior sway.

not. Therefore, the exercises improved the eyes closed balance ability of the AE group (Table 1).

Changes in balance ability were determined by vision information in the LE and AE groups. There were significant differences related to visions between the groups (Table 1). Therefore, balance ability changed with group and also with vision information. Post hoc analysis of the groups showed significant differences in the X-speed and Velocity Moment irrespective of vision information (p=0.01). Y-speed showed significant differences in the AE group with the eyes closed and in both vision conditions in the LE group (p<0.01) (Table 1).

## DISCUSSION

This study demonstrated that six weeks of aquatic therapy improved the static balance of stroke survivors. The buoyancy of the water may allow stroke patients to move with less effort and in movement planes that would be impossible on land without assistance<sup>13</sup>. Thus, the subjects may be able to perform some activities in the water more readily than they are able to on dry land. Repeated and intensive movement training in the water environment may produce substantial changes, leading to improved balance control<sup>2</sup>.

In this study, we did not measure dynamic balance, because the subjects' balance ability was poor. The effects of exercise group and vision on balance were examined. The results indicate that balance ability is affected by exercise group rather than by vision. Both groups had better open-eye, medial/lateral, anterior/posterior, and overall balance after the exercises. However, the aquatic exercise group had a greater increase in balance ability than the land exercise group.

These results are similar to those presented in a report which indicated that balance and gait abilities were improved more in an aqua exercise group than in a land exercise group<sup>14</sup>, and a report that indicated that there were more improvements in balance and lower extremity muscular force in an aqua exercise group than in a land exercise group<sup>2</sup>. However, another study of elderly persons reported no difference in balance between an aqua exercise group and a land exercise group<sup>5</sup>. Willen<sup>4</sup> et al. reported

on changes in muscular force, gait and balance induced by aqua tasks on adult patients with infantile paralysis and found only slight improvements, while a control group that received only conventional physical therapy only showed some differences in the degree of pain without any other changes. Their results were also somewhat different from the results of this study.

In this study, the degrees of medial/lateral, anterior/posterior and overall sway decreased in the aqua exercise group but not in the land exercise group. The degrees of medial/lateral and overall balance improved only in the aqua exercise group. Visual information serves a primary role in maintaining orientation, dynamic balance and static balance<sup>15</sup>, and postural sway increases by 20~70% when visual information is lacking, that is, when standing with the eyes closed<sup>16</sup>. In this study, too, the degree of sway was greater with the eyes closed than with the eyes open in both groups. This study also showed that balance abilities were affected by aquatic or land exercises much more than by vision. Therefore, it seems likely that aquatic exercises contribute to the improvement of balance ability regardless of whether or not there is visual information. Therefore, it can be said that the physical conditions of the water environment stimulated patients more effectively than exercise on land and, as a result, stroke patients' balance abilities improved.

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