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The effects of an additional weight aquatic exercise program on balance and lower extremity strength in persons with stroke: randomized controlled study

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Objective: The purpose of this study was to investigate the effects of an additional weight aquatic exercise program on the balance and lower extremity strength on aquatic environment in persons with stroke.
Design: Randomized controlled trial.
Methods: All subjects were randomly divided into three groups where thirteen subjects were in the additional weight aquatic exercise group, twelve subjects in the aquatic exercise group, and fifteen subjects in the control group. Subjects received a graded aquatic exercise program for 30 minutes, with 3 sessions per week for 6 weeks, and subjects in all groups received conventional physical therapy. All subjects were assessed with the Medical Research Council (MRC), the Berg Balance scale (BBS), Timed Up and Go test (TUG), and 10-meter walk test (10MWT) pre and post intervention.
Results: The MRC, BBS, TUG, and 10MWT scores significantly improved post-intervention (p<0.05), and the control group also had significantly improved in all areas post-treatment (p<0.05). In addition, it has been confirmed that the additional weight aquatic exercise group had significantly improved in MRC, BBS, and TUG scores compared with the aquatic exercise and control group (p<0.05).
Conclusions: The findings of this study suggested that the additional weight aquatic exercise program improves lower extremity and balance in persons with stroke.

Key Words: Balance, Gait, Rehabilitation, Stroke

Introduction

Stroke survivors with motor function loss and muscle weakness due to neurological symptoms, such as sensory abnormality and decreased exercise capacity, show limitations in basic mobility such as walking and stair climbing [1,2]. In addition, person with stroke show greater body sway in weight shift compared to normal subjects due to improper posture control [3]. Because of these problems, persons with stroke who have difficulty in normal walking use various compensatory movements to maintain functional walking. Such abnormal compensatory movement is inefficient compared to normal walking and consumes a lot of energy [4]. As a result, stroke survivors exhibit slow walking speed and asymmetric gait pattern due to decreased stride length and ratio in the affected side stance phase [5,6]. Such gait disorders increase the likelihood of secondary damage such as falls [7]. Therefore, restoring the balance and walking ability of persons with stroke is essential for functional independence in everyday life [8]. Therefore, proper exercise methods are needed to improve walking ability of stroke patients.

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Balance involves maintaining postural stability by maintaining the center of gravity. Such balance has static and dynamic balance ability to control the stability of the human body during dynamic movement [9]. Park *et al*. [10] reported that aquatic exercise using the special properties of water provides stability and exercise effects that cannot be obtained from ground motion, as a means of recovering this normal balance ability. These effects are not only balanced but also have a positive effect on psychological depression. In addition, aquatic exercise performed in an aquatic environment provides significant therapeutic advantages in reducing muscle tension, improving stability and functional mobility for posture control. Among the characteristics of water, buoyancy can reduce stress placed onto the muscles and joints and can assist in establishing a rhythmical gait pattern in contrast with the over-ground gait training [11,12]. In particular, Park *et al*. [10] reported that underwater gait training showed a decrease in asymmetric gait patterns compared to over-ground gait training. Jung *et al*. [13], applied weights to the lower limbs during the performance of underwater gait training. The results showed increased stability of the lower limbs due to weight application, which minimized the effects of floatation of the lower limbs. Lam *et al*. [14] reported that the weight loading on the affected limb showed an increase in the walking ability as well as an increase in the swing phase with hip flexor muscle activation. In addition, Arnold *et al*. [15] and Hinman *et al*. [16] obtained results showing improved leg strength and balance ability through a combination of an underwater walking training and aquatic exercise program. After that, Katsura *et al*. [17] showed that dynamic balance ability is improved by participating in an underwater exercise program using weights. Although the subject was not a neurologically affected patient, the results showed evidence that the program is an effective exercise method. Although studies on the effect of aquatic exercise programs using various tools on balance and gait ability have been conducted, there are insufficient studies on stroke survivors participating in underwater exercise programs using additional weights. Therefore, the purpose of this study was to investigate the effects of aquatic exercise programs with weight application on the lower extremities and balance ability in persons with stroke.

Methods

Participants

This study included a pretest-posttest control group design where the subjects were divided according into intervention methods, such as the additional weight aquatic exercise program group, aquatic exercise program group, or control group. Forty subjects who were admitted in Chungnam National University Hospital in Daejeon. In addition, the subjects were not experienced in aquatic exercise program, and the stroke participants were those who had no overlapping diseases within the past 6 months after the onset of stroke to minimize the possibility of natural restoration. To minimize the selection bias, the following selection criteria were applied randomly to the three groups. The inclusion criteria were as follows: (1) diagnosis of stroke (after minimum 6 months); (2) ability to walk 10 minutes with or without an assistive device; (3) impairment of balance ability (maximum berg balance scale score 45); (4) cognitive abilities enabling communication (minimum Mini-Mental Status Examination score 24); (5) medically stable and free of major cardiovascular or other medical conditions; and (6) no history of orthopedic surgery within the past 6 months and seizure. Subject general characteristics can be viewed in Table 1. This study trained forty-two patients for six weeks, but two patients were discharged. Four therapists intervened to conduct the study on a large number of patients. All groups measured lower extremity strength and balance abilities before intervention. For objective evaluation, three therapists with at least five years of clinical experience conducted the evaluation. This study was approved by the Institutional Review Board of the Sahmyook University (IRB No. 2-1040781-AB-N-01-2016112HR), and all subjects provided their informed consent after being explained of the study details (Figure 1).

Intervention

Aquatic exercise program

The aquatic exercise program involved wearing a sandbag on the affected side ankle that was 5% of the body weight. For the aquatic exercise program, the exercises were conducted in a pool with water at chest height depth and temperatures of 30°C to 32°C. The aquatic exercise program applied in this study was a program that was made by modifying the exercise program from preceding studies conducted in the form of sufficient stretching and strengthening in the water. The movements performed were weight shifting, single leg stance, and various task-orientated exercises in the standing posture (climbing, squatting, heel lifting, kicking, and step up and step down). After 10 minutes of exercise, 20 minutes of gait training was performed (Table 2, Figure 2).

Table 1. Characteristics of participants (clinical features) (N=40)

Characteristic	Additional weight (n=13)[a]	Non-weight (n=12)[b]	Control (n=15)	F (*p*)
Age (y)	55.5 (9.98)	56.9 (4.42)	57.0 (10.90)	0.830 (NS)
Height (cm)	167.4 (6.55)	165.5 (4.33)	165.9 (7.49)	0.630 (NS)
Weight (kg)	67.9 (4.95)	66.9 (6.96)	68.0 (8.67)	0.932 (NS)
Delay (mo)	7.3 (1.12)	7.1 (1.85)	7.8 (1.76)	0.630 (NS)
MMSE-K	28.3 (1.03)	28.5 (1.16)	28.5 (0.74)	0.898 (NS)
Gender				0.606 (NS)
Male	8	9	9	
Female	5	3	6	
Hemiplegic side				0.179 (NS)
Left	10	4	8	
Right	3	8	7	
Mechanism				0.185 (NS)
Haemorrhage	4	8	9	
Ischaemia	9	4	6	

Values are presented as mean (SD) or number only.
MMSE-K: Mini-Mental Status Examination-Korea, NS: non-significant.
[a]Applying additional weight aquatic exercise program group, [b]General aquatic exercise program group.

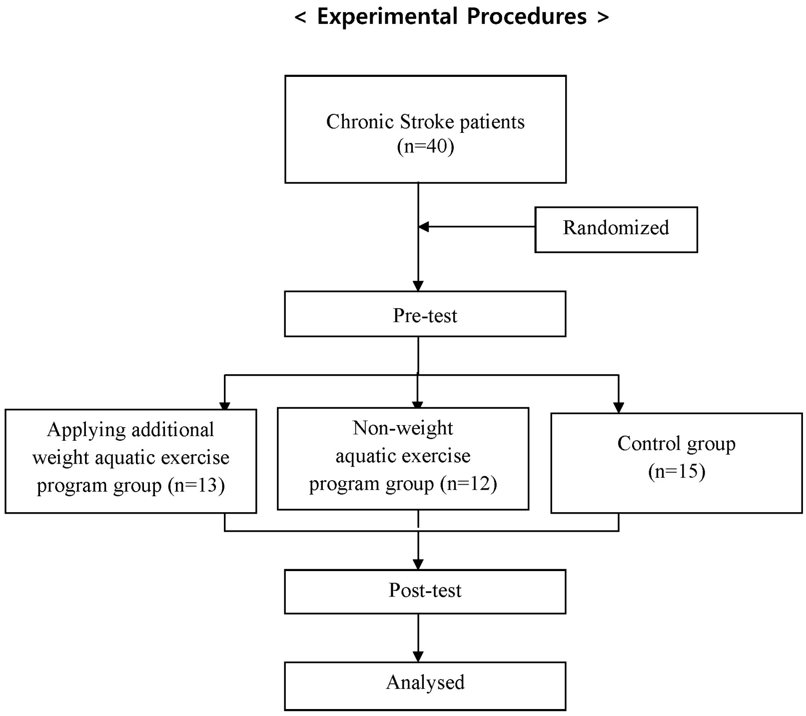

Figure 1. Enrollment of stroke patients.

For mediation of speed during underwater gait training, researchers used metronomes to adjust to the tempo of the subject's comfortable walking speed. The intervention periods for the subjects were 6 weeks, 3 times a week, for 30 minutes each. In addition, all patients who participated in the study participated conventional physical therapy for 6 weeks, 5 times a week. For subject safety, guidance during training was provided by physical therapists with 3 or more years of experience of aquatic exercise training and one assistant per subject as research assistants.

Outcome measures

Medical Research Council

The Medical Research Council (MRC) is the clinical

Table 2. Aquatic exercise program

Aquatic exercise program course	Time
First. Weight shift and stretching in a static posture in the water 1. Weight shifting in various directions and single leg standing 2. Stretching in various directions Second. Weight shift and task-oriented training in a single leg standing position in water 1. Hold on Single leg standing position 2. Squatting 3. Step up & Step down 4. Ankle exercise (heel up and down in stand posture) 5. Kicking	20 minutes
Third. Underwater gait training	10 minutes

Figure 2. Aquatic exercise program & underwater gait training.

method for evaluating muscle strength as a sequence scale. MRC assesses the strength of the agonist and antagonist muscles of a variety of persons with neurological disease, including stroke. The MRC is divided into six grades: Normal (5), Good (4), Fair (3), Poor (2), Trace (1), and Zero (0). Hip flexion, extension, abduction, knee flexion, extension, ankle dorsiflexion, plantar flexion of affected side lower extremity was assessed and was calculated as 0 points out of a total of 30 points. The mean value was taken from three measurements, and to minimize the degree of fatigue, there was a 30-second rest period between measurements.

Berg Balance scale

The Berg Balance Scale (BBS) includes 14 items that can quantitatively assess balance and fall risk. Each item can be scored between 0 to 4 points, with a maximum of 56 points possible. A score of 45 or less represents the need for use of an assistive device, a score of 41 to 44 represents having a low risk of falls, 21 to 40 represents having a greater fall risk, and a score of 0 to 20 represents having a very high fall risk. The duration of the BBS is approximately 15 minutes and evaluates both static and dynamic balance abilities. The therapist who performed the BBS before and after intervention had greater than 3 years of experience in the clinic.

Timed Up and Go test

The Timed Up and Go test (TUG) evaluates the duration of the process of rising from a sitting position, walking 3 meters, and then returning to the chair and assuming a complete seated position. The subjects performed the TUG three times in order to obtain an average value. The TUG has a reliability of r=0.99 and a high inter-rater reliability of r=0.98.

10-meter walking test

The 10-meter walk test (10MWT) is a standardized test used to assess gait ability, and can be used to assess gait disabilities in those with neurological damage.

Data analysis

The PASW Statstics ver. 19.0 (IBM Co., Armonk, NY, USA) was used for data analysis. A normality analysis was conducted for the general subject characteristics, and the paired t-test was conducted to analyze the differences between each group before and after intervention. The one-way analysis of variance was performed to investigate for significant changes in balance and gait abilities per group after six weeks, the Duncan post-hoc analysis test was conducted, and the level of significant was set at $p<0.05$.

Results

The general and medical subject characteristics

Both general and medical subject characteristics in the additional weight aquatic exercise program group, aquatic ex-

Table 3. Changes in balance ability and muscle strength of the participants in this study (N=40)

Variable	Additional weight (n=13)		Non-weight (n=12)		Control (n=15)		F (*p*)
	Pre-test	Post-test	Post-test	Post-test	Pre-test	Post-test	
MRC (score)	15.30 (0.48)	20.20 (1.04)	15.30 (0.65)	18.50 (0.67)	15.60 (0.72)	18.00 (0.70)	46.70 (<0.001)
Difference (post-pre)	4.80 (0.66)[a,b]		3.10 (0.57)[a]		2.40 (0.73)		
t (*p*)	−25.37 (<0.001)		−19.00 (<0.001)		−12.61 (<0.001)		
BBS (score)	40.70 (1.24)	49.80 (1.99)	41.00 (2.84)	48.10 (1.80)	40.90 (1.80)	46.20 (1.27)	10.35 (<0.001)
Difference (post-pre)	9.00 (2.16)[a,b]		7.00 (1.92)[a]		5.30 (1.79)		
t (*p*)	−14.52 (<0.001)		−12.44 (<0.001)		−13.44 (<0.001)		
TUG (sec)	27.10 (3.31)	14.30 (3.17)	27.80 (4.70)	17.20 (4.30)	27.20 (3.95)	19.50 (2.44)	5.71 (<0.001)
Difference (post-pre)	−12.60 (3.20)[a,b]		−10.50 (4.37)		−7.70 (3.89)		
t (*p*)	13.45 (<0.001)		8.37 (<0.001)		7.68 (0.01)		
10MWT (sec)	28.30 (3.31)	17.30 (1.43)	28.50 (5.38)	19.10 (4.64)	28.40 (3.33)	20.60 (2.40)	2.87 (0.06)
Difference (post-pre)	−11.00 (3.48)		−9.40 (3.91)		−7.70 (3.30)		
t (*p*)	10.93 (<0.001)		8.32 (<0.001)		9.06 (<0.001)		

MRC: Medical Research Council, BBS: Berg Balance scale, TUG: Timed Up and Go test, 10MWT: 10-meter walking test.
[a]Significant difference compared with control ($p<0.05$). [b]Significant difference compared with non-weight ($p<0.05$).

ercise group and control were all homogenous (Table 1).

Balance and gait ability changes

Significant increases in MRC, BBS, TUG, and 10MWT scores were observed in the additional weight exercise group, aquatic exercise group, and control group ($p<0.05$). In addition, the additional weight aquatic exercise group had significantly improved in MRC, BBS, and TUG scores compared with the aquatic exercise and control group ($p<0.05$). Also, the aquatic exercise group (Non-weight) had significantly improved in MRC and BBS scores compared with the control group (Table 3).

Discussion

Functional recovery in persons with stroke is limited by muscle weakness [18]. The weakness of the ankle muscle strength causes problems in balance and walking ability [19]. Based on this evidence, Lee and Kang [20] reported that the loss of balance in persons with stroke was associated with weakening of the ankle muscular strength. This is because the ankle with plantar flexor spasticity does not reach the ground resulting in a shortened stance phase and the push-off not occurring, and the foot-drop is caused at the diagonal period, resulting in slow walking speed and inefficient walking. As a result, those affected by stroke showed asymmetric balance ability and increased risk of falls [21]. Therefore, it is necessary to restore the balance and the walking ability with strengthening of the lower extremities in order to create an effective movement for persons with stroke [20]. The purpose of this study was to investigate the effect of applying additional weight during the participation in an aquatic exercise program in persons with stroke. Masumoto *et al*. [22] suggested that exercises performed in the water was more effective for muscle activation than ground motions, and based on this, Miyoshi *et al*. [23] found increased movement of the hip joint extensor and knee joint extensor plantar flexor muscles. Subsequently, Barela *et al*. [24] studied the difference in muscle activity due to environmental changes, such as buoyancy and viscosity as evidence for the increase in muscle activity. Based on this evidence, Chu *et al*. [25] showed the improvement of strength and endurance of stroke survivors through participating in an aquatic exercise program. The results of this study also showed the improvement of muscle strength. These changes can be attributed to changes in balance and walking ability based on lower extremity strength. Noh *et al*. [26] mentioned that aquatic exercise programs are very effective in improving the balance ability of those affected by stroke. As a basis for this, Chu *et al*. [25] showed that the improvement of balance ability was based on the changes in muscle strength. As a result, the change in balance ability led to improvement of walking ability. This change is due to the advantage of the water environment, which reduces the stress on the joints through buoyancy, which counteracts the gravity felt by the human body on the ground, enabling movement with less force compared with the ground motion [27,28]. It is reported that such underwater gait training improves balance ability by increasing the stance phase and weight transfer ability of the affected side [29,30].

In addition, repetitive task-oriented training in the water has been reported to be an effective intervention for restoring balance and gait ability [15,31,32]. Sim and Oh [33] showed a significant increase in balance and gait ability as a result of applying task-oriented functional training to persons with stroke. It was reported that the task-oriented repetitive training showed an increase in neuro-plasticity focused on the re-organization of the central nervous system and that cerebral cortex and central nervous system activation affected movement speed and balance ability [34]. Based on the results, the aquatic exercise program was very effective in improving balancing ability by observing the changes in balance ability between the aquatic exercise group and control group.

Improvement in walking ability for persons with stroke is a major goal of clinical rehabilitation research [35]. Among them, walking speed is used as a measure of the level of functional recovery in order to perform daily life activities [6]. The underwater gait training showed improvements in walking speed by strengthening of the lower extremity muscles such as the rectus femoris, biceps femoris, and vastus medialis [36,37]. Also, underwater gait training can be conducted easily and with stability by using buoyancy, which also provides psychological stability. In this study, we performed an aquatic exercise program including underwater gait training with these advantages [38]. Park *et al*. [30] suggested that such underwater gait training is based on the improvement of stability of the lower extremity. Therefore, Jung *et al*. [13] mentioned that applying additional weight was used to improve stability by minimizing the floatation of the lower limb. The results of the study also showed stability of the lower limbs and improved walking ability based on appropriate weight shifting. In addition, Lam *et al*. [14] found that over-ground gait training with a weight attached to the ankle joint can lead to effective lower limb movement based on activation of the hip flexor muscles. Katsura *et al*. [17] also showed a significant increase in walking speed after aquatic exercise program with applying additional weight. Based on these previous studies, the results of this study could be similar. The results of this study showed that the applying additional weight was effective for the weight aquatic exercise group compared with the general aquatic exercise group and showed an effective change in balance ability. However, although the gait ability results showed an effective change compared to the pre-test, there was no significant difference between the groups. From these results, it is necessary to include a longer follow-up period and the subsequent course to observe and examine the effects on gait ability.

In conclusion, we conclude that applying additional weight during the performance of aquatic exercise is very effective for improving balance ability due to improvements in lower extremity strength in persons with stroke. However, there are some limitations that affect the results of this study. First, it is difficult to generalize the results due to a small number of subjects. Second, the subjects had various balance and gait abilities. Third, the duration of the study period was six weeks, which was short-term. Fourth, the intervention was performed by several therapists, which may have produced an error in the level of treatment between therapists. Future studies should address these limitations and be conducted for further development of various aspects of aquatic exercise programs for the stroke population.

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Conflict of Interest

The authors declared no potential conflicts of interest with respect to the authorship and/or publication of this article.

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