J. Phys. Ther. Sci.
25: 1219–1222, 2013

Comparison of Effects of a Proprioceptive Exercise Program in Water and on Land the Balance of Chronic Stroke Patients

Seul Ki Han, MS, PT[1)], Myung Chul Kim, PhD, PT[1)*], Chang Sik An, PhD, PT[1)]

[1)] *Department of Physical Therapy, Faculty of Health Science, Eulji University: 212 Yangji-dong, Sujeong-gu, Seongnam-si, Gyeonggi-do 461-815, Republic of Korea*

Abstract. [Purpose] The purpose of this study was to compare changes in balance ability of land exercise and underwater exercise on chronic stroke patients. [Subjects] A total of 60 patients received exercise for 40 minutes, three times a week, for 6 weeks. [Methods] Subjects from both groups performed general conventional treatment during the experimental period. In addition, all subjects engaged in extra treatment sessions. This extra treatment consisted of unstable surface exercise. The underwater exercise group used wonder boards in a pool (depth 1.1m, water temperature 33.5 °C, air temperature 27 °C) dedicated to underwater exercise, and the land exercise group used balance mats. [Result] The joint position sense, sway area, Berg Balance Scale showed significant improvements in both groups. However, the joint position sense test, sway area, and Berg Balance Scale showed there was more improvement in the underwater exercise group than in the land exercise group. [Conclusion] The results suggest that underwater exercise is more effective than land exercise at improving the joint position sense and balance of stroke patients.
Key words: Underwater exercise, Joint position sense, Balance

(This article was submitted March 27, 2013, and was accepted May 10, 2013)

INTRODUCTION

Most stroke survivors suffer aftereffects of impairments in motor, sensory, cognitive, perceptive, psychological, social, and physical functions[1)]. Additionally, 65% of stroke patients experience loss of tactile sense, the protection reaction, and proprioceptive sense[2)]. The proprioceptive sense is closely correlated with balance ability[3)]. Since declined balance ability reduces functional activities and increases the incidence rate of falls[4)], one of the physical functions that must be recovered first in stroke patients is balance ability[5)]. However, the body sway applied during land balance training psychologically increases fear of falling and thus acts as a factor to limit balance training[6)]. In this respect, Svedenhag et al. reported that the psychologically unstable state can be relieved, and mental stability can be induced through underwater techniques[7)]. Exercise in underwater environments helps stroke patients to safely and comfortably improve their motor ability by providing low-risk exercise environments that support their bodies and reduce their fear of falling and the possibility of sudden damage[8)]. Additionally, the slow-moving environment in water caused by viscosity and drag force can also help people reduce the velocity-dependent spastic response[9)].

Noh et al. reported that when 25 chronic stroke patients performed underwater exercise for eight weeks in a study intended to examine the effects of ai-chi and halliwick exercises on stroke patients' bodily balance and muscle force, the patients' balance ability and knee flexor muscle force improved[10)]. Lee Dong-Jin et al. reported that when 34 chronic stroke patients divided into an underwater group and a land group received training for 12 weeks in a study intended to examine the effects of underwater and land task-oriented training on the patients' balance ability, the underwater group showed larger improvement in static and dynamic balance than the land group[11)]. Park et al. reported that when 44 chronic stroke patients divided into an underwater exercise group and a land exercise group had performed exercise for six weeks in a study intended to examine the effects of underwater exercises using buoyant apparatuses on joint position senses and Performance-Oriented Mobility Assessment (POMA), the underwater group showed larger improvement in their joint position senses and POMA than the land exercise group[12)].

Recently, underwater exercise has gained more attention for stroke rehabilitation[9)]. Therefore, underwater exercises are considered to be able to satisfy the social demands for more effective and safer therapeutic interventions. However, studies on underwater exercises are still insufficient, and previous studies did not apply the same exercise program to underwater and land exercises or implement underwater proprioceptive sense exercise programs.

In this respect, this study was intended to implement the same proprioceptive sense exercise program underwater and on the land in patients with hemiplegia resulting from stroke in order to examine the effects of the exercise program on the patients' balance ability.

*To whom correspondence should be addressed.
E-mail: 01095584468@nate.com

SUBJECTS AND METHODS

Subjects

The subjects who participated in this study were 62 stroke patients hospitalized in D hospital located in Daejeon, Korea. To minimize the possibility of spontaneous recoveries, the subjects were selected from chronic stroke patients with onset at least six months previously, who had no internal medical disease such as diabetes, had no heart disease and no orthopedic problems, scored 24 or more on the Mini-Mental State Examination-Korea, had no visual problems, and could walk at least 15 m by themselves. These subjects had been given explanations until they sufficiently understood this experiment. Then the subjects or their guardians signed consent forms for participation in this experiment. General characteristics of the study subjects are as shown in Table 1.

Table 1. General characteristics of the subjects (M±SD)

		UG (n=31)	LG (n=31)
Age (years)		56.1±7.3	56.6±10.0
Height (cm)		158.2±9.6	161.3±6.4
Weight (kg)		63.4±9.0	61.9±7.9
Onset (Month)		15.2±5.1	16.1±5.4
K-MMSE		26.3±3.7	27.0±3.4
Sex	Male	15	13
	Female	16	18
Affected side	Right	14	15
	Left	17	16

K-MMSE, Mini-Mental State Examination-Korea
UG, Underwater group; LG, Land group

Methods

The proprioceptive sense exercise program in the present study was created referring to the proposal by Melzer[13] and Hupperets et al.[14] and implemented a total of 18 times, 3 times per week, for 6 weeks from January 2011. All the study subjects performed exercises for a total of 40 minutes each time consisting of 30 minutes of main exercises, 5 minutes of warming up exercises and warming down exercises underwater or on the land depending on their groups. The underwater exercise group used wonder boards in a pool (depth 1.1 m, water temperature 33.5 °C, air temperature 27 °C) dedicated to underwater exercise, and the land exercise group used balance mats in an exercise treatment room in the hospital building. The overall exercise programs for the underwater exercise group and the land exercise group were the same, and three sets consisting of 10 repetitions of motions at different levels were performed. The details of the exercise program are as follows.

(1) One-legged knee flexion: The subjects placed one foot toward the front and one toward the rear, with one on the land and the other on the wonder boards (balance mats), and then bent and straightened the knees while pushing the body forward. (2) Toe stand: The subjects stood on the wonder boards (balance mats) with the feet comfortably apart laterally and repeated motions to raise and lower the heels. (3) One-legged stance: The subjects stood on the wonder boards (balance mats) on one foot (for 30 seconds). (4) Knee flexion of both legs: The subjects stood with their feet comfortably apart laterally with one foot in the water and the other foot on the wonder boards (balance mats) and bent and straightened the knees. (5) Weight shift: The subjects stood with their feet comfortably apart laterally with one foot in the water and the other foot on the wonder boards (balance mats) and moved the pelvis laterally.

The joint position sense test is a method of assessing the position of individual body segments without a visual aid, and it can also be applied to the proprioceptive sense in hemiplegic patients[15]. In this study, we employed the Biometrics (Biometrics Ltd. UK) motion analysis system that helped us compose a base unit that digitizes the analog joint angles and an electrogoniometer that measures the joint motion angle. The joint position sense test was performed as an active setting-active reproduction test. For the active setting-active reproduction test, the subjects were asked to actively move their joints within the full motion range, maintain an arbitrary angle in the middle for 3 seconds, and remember the joint angle as the reference angle. After 10 seconds of rest, the subjects were asked to press a button while actively reproducing the reference angle within one second. The zero point of the motion analysis system operating software was adjusted when the subjects were sitting. After covering the eyes of the subjects with an eye patch and checking the maximum joint motion range of the knee joint, a reference angle was set in the middle of the joint motion range. Measurement was started after allowing the patients to practice sufficiently with the decided reference angle. The duration for one measurement was seven seconds: two seconds each at the beginning and the end were discarded, and the three seconds in the middle were recorded as the measurement value. The measurement was repeated three times, and the mean value was calculated.

In this study, balance was measured using a Good Balance system (Metitur, 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[11]. The measuring methods used included measuring for each 30 seconds while the patient kept his or her eyes open and closed for 30 seconds in each state.

The Berg balance test was performed by applying daily living motions and is largely divided into three areas: the ability to maintain postures, the ability to voluntarily control movements, and reflexes to external factors comprised of a total of 14 evaluation items. The performance of each item is scored between 0 points at the minimum and 4 points at the maximum, and thus the full score of the test is 56 points[16].

For the data processing in this study, the paired sample t-test was performed to test the difference before and after the exercise in each group, and the independent sample t-test was performed to test the difference between the groups. The SPSS 18.0 software for Windows was used for the analysis, and a significance level, α, of 0.05 was chosen.

Table 2. A comparison of pre- and post-intervention JPS, sway area, and BBS in the underwater exercise and land exercise groups (M±SD)

			Pre	Post	diff
JPS (˚)		UG (n=31)	4.84±1.04	3.07±1.34*	1.78±1.11†
		LG (n=31)	4.66±1.55	3.58±1.52*	1.08±1.13
SA (mm^2/s)	EO	UG (n=31)	53.22±26.52	39.89±21.21*	13.33±11.46†
		LG (n=31)	60.02±16.53	54.36±15.50*	5.66±7.97
	EC	UG (n=31)	61.79±21.26	35.56±12.72*	26.23±13.21†
		LG (n=31)	66.65±14.85	52.85±19.31*	13.80±16.07
BBS		UG (n=31)	39.35±8.32	44.16±7.84*	−4.81±1.89†
		LG (n=31)	40.90±4.10	42.39±6.87*	−1.48±1.36

*Paired sample t-test $p<0.05$; †Independent sample t-test $p<0.05$.
Diff, pre-post; UG, underwater group; LG, land group; JPS, joint position sense; SA, sway area; EO, eyes open; EC, eyes closed; BBS, Berg Balance Scale

RESULTS

The underwater exercise group and land exercise group showed a significant decrease in joint position sense errors ($p<0.05$), and the change was greater in the underwater exercise group than the land group ($p<0.05$) (Table 2).

The underwater exercise group and land exercise group showed a significant decrease in sway area (eyes open and closed) ($p<0.05$), and the change was greater in the underwater exercise group than in the land group ($p<0.05$) (Table 2).

The underwater exercise group and land exercise group showed a significant increase in Berg Balance Scale (BBS) ($p<0.05$), and the change was greater in the underwater exercise group than the land group ($p<0.05$) (Table 2).

DISCUSSION

The purpose of this study was to compare changes in balance ability with land exercise and underwater exercise in chronic stroke patients. In the results of the present study, joint position sense errors significantly decreased in the underwater exercise group that implemented the proprioceptive exercise program, and the decreases in the underwater exercise groups were more significant compared with the land exercise group. Through these results, it could be seen that the proprioceptive exercise programs in the present study were effective in improving proprioceptive senses, and in particular, the underwater exercise program was more effective. Nashner and Peters stated that after proprioceptive sense improving exercises, posture swaying when the eyes were closed showed larger improvement than those when the eyes were open[17]. In the present study, based on the results of functional standing balance tests, the decreases in swaying areas before and after exercises were performed were larger when the exercises were performed with the eyes closed than when the exercises were performed with the eyes open. This is considered to be associated with the fact that when implementing the exercise programs, the land exercise group performed exercises only within the limit of stability due to fear of falling, while the underwater exercise group challenged the limit of stability without any fear of falling. In general, hemiplegia patients tend to support their weight less with the lower extremity on their paretic side in standing postures and show asymmetrical characteristics of postures, which reduce the patients' functional abilities[18] and act as a major cause of the patients' falling[19]. Therefore, equal weight bearing by the lower extremity on the paretic side should be induced[20]. However, it is considered that during training using unstable surfaces on the land, patients will support more weight with the lower extremity on their unaffected side. On the other hand, during underwater balance exercises, the patients can support their weight with the lower extremities on both the paretic and unaffected sides in order to maintain balance on the buoyant apparatus, since the buoyant apparatus will be lost and float away easily if the patients support their weight only with the lower extremity on their unaffected side. Therefore, underwater exercises are considered more advantageous for equal weight bearing by both lower extremities.

Consequently, through the present study, it could be seen that underwater proprioceptive sense exercise programs implemented by stroke patients were effective in improving the patients' proprioceptive sense and balance ability.

REFERENCES

1) Sabari JS: Motor control, Motor recovery after stroke, In: Deusen JV & Brunt D. Assessment in Occupational Therapy and Physical Therapy, W. B. Saunders Company, 1997, pp 249–271.
2) Kerrigan DC, Karvosky ME, Riley PO: Spastic paretic stiff-legged gait: joint kinetics. Am J Phys Med Rehabil, 2001, 80: 244–249. [Medline] [CrossRef]
3) Niam S, Cheung W, Sullivan PE, et al.: Balance and physical impairments after stroke. Arch Phys Med Rehabil, 1999, 80: 1227–1233. [Medline] [CrossRef]
4) Teasell R, McRae M, Foley N, et al.: The incidence and consequences of falls in stroke patients during inpatient rehabilitation: factors associated with high risk. Arch Phys Med Rehabil, 2002, 83: 329–333. [Medline] [CrossRef]
5) Horak FB: Clinical assessment of balance disorders. Gait Posture, 1997, 6: 76–84. [CrossRef]
6) Winstein CJ, Gardner ER, McNeal DR, et al.: Standing balance training: effect on balance and locomotion in hemiparetic adults. Arch Phys Med Rehabil, 1989, 70: 755–762. [Medline]
7) Svedenhag J, Seger J: Running on land and in water: comparative exercise physiology. Med Sci Sports Exerc, 1992, 24: 1155–1160. [Medline]
8) Hauer K, Specht N, Schuler M, et al.: Intensive physical training in geriat-

ric patients after severe falls and hip surgery. Age Ageing, 2002, 31: 49–57. [Medline] [CrossRef]

9) Jung T, Lee D, Charalambous C, et al.: The influence of applying additional weight to the affected leg on gait patterns during aquatic treadmill walking in people poststroke. Arch Phys Med Rehabil, 2010, 91: 129–136. [Medline] [CrossRef]
10) Noh DK, Lim JY, Shin HI, et al.: The effect of aquatic therapy on postural balance and muscle strength in stroke survivors–a randomized controlled pilot trial. Clin Rehabil, 2008, 22: 966–976. [Medline] [CrossRef]
11) Lee D, Ko T, Cho Y: Effects on static and dynamic balance of task-oriented training for patients in water or on land. J Phys Ther Sci, 2010, 22: 331–336. [CrossRef]
12) Park J, Lee D, Lee S, et al.: Comparison of the effects of exercise by chronic stroke patients in aquatic and land environments. J Phys Ther Sci, 2011, 23: 821–824. [CrossRef]
13) Melzer I, Elbar O, Tsedek I, et al.: A water-based training program that include perturbation exercises to improve stepping responses in older adults: study protocol for a randomized controlled cross-over trial. BMC Geriatr, 2008, 8: 19. [Medline] [CrossRef]
14) Hupperets MD, Verhagen EA, van Mechelen W: The 2BFit study: is an unsupervised proprioceptive balance board training programme, given in addition to usual care, effective in preventing ankle sprain recurrences? Design of a randomized controlled trial. BMC Musculoskelet Disord, 2008, 9: 71. [Medline] [CrossRef]
15) Bouët V, Gagery Y: Muscular exercise improves knee position sense in hummans. Neurosci Lett, 2000, 289: 143–146. [Medline] [CrossRef]
16) Berg K, Wood-Dauphinee S, David G: Measuring balance in the elderly: preliminary development of an instrument. Physiother Can, 1989, 41: 304–311. [CrossRef]
17) Nashner LM, Peters JF: Dynamic posturography in the diagnosis and management of dizziness and balance disorders. Neurol Clin, 1990, 8: 331–349. [Medline]
18) Mudie MH, Winzeler-Mercay U, Radwan S, et al.: Training symmetry of weight distribution after stroke: a randomized controlled pilot study comparing task-related reach, Bobath and feedback training approaches. Clin Rehabil, 2002, 16: 582–592. [Medline] [CrossRef]
19) Di Fabio RP, Badke MB: Extraneous movement associated with hemiplegic postural sway during dynamic goal-directed weight redistribution. Arch Phys Med Rehabil, 1990, 71: 365–371. [Medline]
20) Holt RR, Simpson D, Jenner JR, et al.: Ground reaction force after a sideways push as a measure of balance in recovery from stroke. Clin Rehabil, 2000, 14: 88–95. [Medline] [CrossRef]