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Original Article

A comparative study of the effects of trunk exercise program in aquatic and land-based therapy on gait in hemiplegic stroke patients

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Abstract. [Purpose] The purpose of this study was to compare the effects of aquatic and land-based trunk exercise program on gait in stroke patients. [Subjects and Methods] The subjects were 28 hemiplegic stroke patients (20 males, 8 females). The subjects performed a trunk exercise program for a total of four weeks. [Results] Walking speed and cycle, stance phase and stride length of the affected side, and the symmetry index of the stance phase significantly improved after the aquatic and land-based trunk exercise program. [Conclusion] These results suggest that the aquatic and land-based trunk exercise program may help improve gait performance ability after stroke.
Key words: Aquatic and land-based trunk exercise, Gait, Stroke

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INTRODUCTION

The restoration of an optimal gait is a major goal in the rehabilitation of stroke patients[1–3]. Several changes in gait are seen after stroke, such as decreased velocity, asymmetrical stance phase and stride length, and so forth[4–6]. An abnormal gait after a stroke is caused by many physical conditions such as muscle weakness, abnormal muscle tone, and disorders in balance and posture control, which are all detrimental to gait ability[7]. Recently, many results from studies on the relationship between trunk muscle activity and the gait function of stroke patients have been being reported. The loss of selective trunk control is a major functional deficit in post-stroke patients that leads to abnormal gait parameters[8–11]. Trunk exercises have a beneficial

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effect on trunk functions including the improvement in standing balance and mobility in stroke patients; they are particularly effective in improving balance, gait, and functional ability[12]. In a previous study, it was suggested that trunk performance was significantly related to gait and functional ability in stroke patients[13]. Aquatic therapy has also been suggested as an effective approach to improve trunk activity[14]. There are many studies on the effect of trunk exercise on gait ability in stroke patients that did not consider the exercise environment. However, comparative studies between aquatic trunk exercise and land-based trunk exercise have rarely been conducted. Therefore, the purpose of the present study was to compare aquatic trunk exercise and land-based trunk exercise on the effectiveness of trunk exercise program on gait ability in hemiplegic stroke patients.

SUBJECTS AND METHODS

The participants of this study were 28 hemiplegic stroke patients (20 males and 8 females) who received a diagnosis of stroke and were either admitted to or were receiving treatment at the outpatient center. Patients were randomly allocated to either the aquatic exercise group (13 patients) or the land-based exercise group (15 patients) by drawing lots. The inclusion criteria were (1) a history of only one cerebrovascular accident, (2) a Mini–Mental State Examination (MMSE) score>24 points, (3) the ability to walk independently, (4) no significant musculoskeletal conditions (fracture, back pain, and so forth), and (5) no contraindications to participation in the exercise program[5, 6]. The aquatic exercise group participated in concentrated aquatic therapy for four weeks (30 min sessions for 3 days/week) in a therapeutic pool with a water depth equal to the xiphoid process and a water temperature of 30 °C[15]. The aquatic therapy program was based on Halliwick, Watsu, and trunk exercise programs. The main objective of the program was to improve trunk muscle activation in stroke patients. The program included warm-ups, trunk-specific exercises, and cool-down periods[16, 17]. The warm-up period (5 min) consisted of trunk control with a Hallwick 10-point program including exercises for sagittal rotation control, transversal rotation control, longitudinal rotation control, and combined rotation control[12]. The trunk exercise period (20 min) consisted of abdominal hollowing, abdominal bracing, anteroposterior pelvic tilts, and mediolateral pelvic tilts[18]. Finally, the cool-down period (5 min) consisted of a Hallwick 10-point program (sagittal rotation control, transversal rotation control, longitudinal rotation control, and combined rotation control) and Watsu techniques for muscular relaxation and stretching[19, 20]. The aquatic therapy program was conducted by physiotherapists who had participated in a certified Halliwick and Watsu therapy course. The land-based exercise group performed exercise three times a week for one month. The exercise included 3 sets held for 5 seconds, each maintained for about 30 minutes with a 1-minute rest between sets. The trunk exercises consisted of six subparts: bridge exercises, curl-ups with arms crossed, curl-ups with straight reaching, curl-ups with diagonal reaching, abdominal hollowing, and quadruped exercises[21–25]. Bridge exercises were performed in the supine position. Both knees were flexed at 90° and the feet were hip-width apart while resting on the floor. Arms were crossed over the chest to minimize arm support, and the therapist placed his hands vertically along the lateral aspect of the bilateral knee joint to maintain a hip abduction of 30°. The subject was instructed to lift his or her pelvis comfortably at a self-selected speed while the trunk, pelvis, and thigh were aligned in a straight line. This position was then held for 5 seconds[21, 22]. The curl-up exercise consisted of three parts: shoulder curl-ups with the arms crossed, curl-ups with straight reaching, curl-ups with diagonal reaching, and shoulder curl-ups with the arms crossed. The knees were flexed at 90°. For the curl-up exercise, the subject elevated the trunk until the scapular lifted from the mat[22]. For abdominal hollowing, the participant was instructed to draw the lower part of the abdominal up and in toward the spine without moving the trunk or pelvis. A pressure biofeedback unit (TN37343, Chattanooga Group, Inc., USA) was used to ensure that the subjects were performing the exercise correctly. A pressure cuff unit was placed under the lumbar spine and was inflated to 40 mmHg before the exercise was performed. When the subject performed the hollowing correctly, the pressure either stayed at 40 mmHg or decreased, and the subjects tilted until the abdomen was hollow. This position was then held for 5 seconds[23, 24]. For the quadruped exercise, the participant was initially positioned in a 4-point stance with the knees and hands on the floor with hips flexed to 90° and hands beneath the shoulder joint. In a 2-point stance, the subjects performed a contralateral arm and leg raise. The subject flexed the arm until the lower body segment was parallel to the trunk. This position was then held for 5 seconds[25]. Gait ability was measured using a motor-driven treadmill (Gait trainer 2 analysis system Inc, America, Biodex Medical Systems), which was adjusted to each subject's comfortable walking speed[5, 6]. This equipment can analyze walking factors such as walking speed, walking cycle, affected side stance phase, affected side stride length, symmetry index of stance phase, and symmetry index of stride length through a sensor installed on the treadmill floor[5, 6]. Statistical analyses were conducted using PASW software (version 18.0; SPSS, Quarry Bay, Hong Kong) to calculate averages and standard deviations. The data are expressed as the mean ± standard error (SE) of the measurements. A paired t-test was conducted to compare the participants before and after the trunk exercise. The statistical significance level was set at α=0.05. The protocol for this study was approved by the Committee of Ethics in Research of the University of Yongin, in accordance with the terms of Resolution 5-1-20. Furthermore, all volunteers or their next of kin provided informed consent for participation in the study.

RESULTS

Table 1 shows the general and clinical characteristics of the 28 stroke patients. Walking speed and cycle, stance phase and stride length of the affected side, and the symmetry index of the stance phase significantly improved after the aquatic and land-based trunk exercise program (Table 2).

DISCUSSION

The loss of trunk control is a major functional deficit that causes gait disturbance in stroke patients. Previous studies have reported that trunk performance remains impaired after a stroke, which is detrimental to balance, gait, and functional ability, highlighting the importance of trunk rehabilitation[13)]. Other studies have found that trunk flexor and extensor muscle weakness correlates with Berg Balance Scale scores and locomotion and transfer items of the Functional Independence Measure[26)]. Our study demonstrated the effects of four weeks of trunk exercise in aquatic and land-based environments on gait parameters. According to our data, gait parameters were improved in both groups despite the short period of intervention. A slow pace and asymmetric gait are most common problems in gait in stroke patients[12)]. Many previous studies have suggested that the most important parameter to target in stroke patients is walking speed[12)]. Perry suggested that gait velocity is a useful indicator that represents clinical trends, gait quality, and the degree to which gait velocity is abnormal in both hemiplegic

Table 1. General characteristics of the participants

Variable	Exercise environment	
	Aquatic trunk exercise	Land-based trunk exercise
Age (yrs)	50.5 ± 2.9	37.9 ± 4.4
Gender		
Male (%^{a}/%^{b})	10 (76.9/35.7)	10 (66.7/35.7)
Female (%^{a}/%^{b})	3 (23.1/10.7)	5 (33.3/17.9)
Height (cm)	166.4 ± 1.9	168.9 ± 2.2
Weight (kg)	66.6 ± 2.9	68.6 ± 3.3
BMI (kg/m²)	24.0 ± 0.8	23.9 ± 0.8
Caused of stroke		
Infarction (%^{a}/%^{b})	10 (76.9/35.7)	9 (60.0/32.1)
Hemorrhage (%^{a}/%^{b})	3 (23.1/10.7)	6 (40.0/21.4)
Paretic side		
Right (%^{a}/%^{b})	10 (76.9/35.7)	7 (46.7/25.0)
Left (%^{a}/%^{b})	3 (23.1/10.7)	8 (53.3/28.6)
Onset (mo)	24.1 ± 3.8	17.2 ± 2.2
K-MMSE (score)	24.9 ± 0.4	25.3 ± 0.2

All data are presented as the mean± SE. ^{a}Percentage in exercise program. ^{b}Percentage of all participants. BMI: body mass index, K-MMSE: Korean version of the Mini-Mental State Examination

Table 2. Changes after four weeks of trunk exercise program in hemiplegic stroke patients

Variable	Exercise environment			
	Aquatic trunk exercise		Land-based trunk exercise	
	Pre-ATEP	Post-ATEP	Pre-LTEP	Post-LTEP
Walking speed (cm/sec)	51.4 ± 5.1	57.9 ± 7.0*	46.5 ± 2.3	52.6 ± 2.3*
Walking cycle (cycle/sec)	0.4 ± 0.0	0.4 ± 0.0*	0.6 ± 0.0$^\#$	0.6 ± 0.2$^{*\#}$
Affected side stance phase (sec/%)	36.2 ± 4.2	46.5 ± 3.0*	37.0 ± 2.4	41.6 ± 2.4*
Affected side stride length (cm)	60.2 ± 4.5	67.7 ± 5.4*	49.3 ± 1.7$^\#$	52.5 ± 1.5$^{*\#}$
Symmetry index of stance phase (%)	62.6 ± 12.4	84.2 ± 9.0*	62.2 ± 6.6	75.0 ± 7.7*
Symmetry index of stride length (%)	92.9 ± 5.5	97.0 ± 5.7	108.6 ± 6.1	103.0 ± 4.1

All data are presented as the mean ± SE. ATEP: aquatic trunk exercise program; LTEP: land trunk exercise program; *paired t-test between pre- and post-treatment. $^\#$independent t-test between groups. $^{*\#}p<0.05$

stroke patients and healthy patients[12]. In addition, velocity is easy to measure and is closely related to the patient's clinical condition. However, an increase in gait velocity without improvement in symmetry suggests that compensatory strategies are retained and amplified. Therefore, improvements in gait velocity in stroke patients should be accompanied with improvements in symmetry[27]. According to our data, participants in both groups had improved walking speed and improved stance phase and stride length of the affected side. Some gait parameters differed between the baseline and posttreatment; however, the changes were not significant. As a result, our data demonstrated that trunk exercise improves the gait ability of stroke patients irrespective of the environment. Previous studies on the relationship between gait ability and trunk exercise have demonstrated the effectiveness of trunk exercise using various tools, but these tools were insufficient for the analysis of gait parameters in stroke patients. Our study used Gait Trainer 2, which analyzed gait parameters by a sensor installed on the treadmill's floor, similar to the GAITRite system. These methods were proven by many studies to be adequately assess gait parameters in hemiplegic stroke patients. Further, our results concur with those of previous studies evaluating the gait trainer system for measuring gait parameters in stroke patients[22–24]. According to previous studies, water buoyancy can aid posture control in stroke patients. Therefore, we sought to examine aquatic trunk exercises as an effective method to improve gait ability in patients who experienced difficulty controlling the trunk. However, both trunk exercises in water and on land-based were found improve gait parameters in stroke patients. However, further systematic and scientific studies in neurorehabilitation and other fields are needed to confirm the effects of therapy[28, 29].

REFERENCES

1) Kim MY, Kim JH, Lee JU, et al.: The effects of functional electrical stimulation on balance of stroke patients in the standing posture. J Phys Ther Sci, 2012, 24: 77–81. [CrossRef]
2) Kim MY, Kim JH, Lee JU, et al.: The effect of low frequency repetitive transcranial magnetic stimulation combined with range of motion exercise on paretic hand function in female patients after stroke. Neurosci Med, 2013, 4: 77–83. [CrossRef]
3) Kim MY, Park BS, Kim J: Effects of high frequency repetitive transcranial magnetic stimulation with physical healthy exercise in stroke. Toxicol Environ Health Sci, 2015, 7: 160–170. [CrossRef]
4) Park BS, Kim JH, Kim MY, et al.: Effect of a muscle strengthening exercise program for pelvic control on gait function of stroke patients. J Phys Ther Sci, 2015, 27: 641–644. [Medline] [CrossRef]
5) Park BS, Kim MY, Lee LK, et al.: Effects of conventional overground gait training and a gait trainer with partial body weight support on spatiotemporal gait parameters of patients after stroke. J Phys Ther Sci, 2015, 27: 1603–1607. [Medline] [CrossRef]
6) Park BS, Kim MY, Lee LK, et al.: The effects of a progressive resistance training program on walking ability in patients after stroke: a pilot study. J Phys Ther Sci, 2015, 27: 2837–2840. [Medline] [CrossRef]
7) Carr JH, Shepherd RB, Nordholm L, et al.: Investigation of a new motor assessment scale for stroke patients. Phys Ther, 1985, 65: 175–180. [Medline]
8) Dickstein R, Shefi S, Marcovitz E, et al.: Electromyographic activity of voluntarily activated trunk flexor and extensor muscles in post-stroke hemiparetic subjects. Clin Neurophysiol, 2004, 115: 790–796. [Medline] [CrossRef]
9) Verheyden G, Vereeck L, Truijen S, et al.: Trunk performance after stroke and the relationship with balance, gait and functional ability. Clin Rehabil, 2006, 20: 451–458. [Medline] [CrossRef]
10) Saeys W, Vereeck L, Truijen S, et al.: Randomized controlled trial of truncal exercises early after stroke to improve balance and mobility. Neurorehabil Neural Repair, 2012, 26: 231–238. [Medline] [CrossRef]
11) Mudge S, Rochester L, Recordon A: The effect of treadmill training on gait, balance and trunk control in a hemiplegic subject: a single system design. Disabil Rehabil, 2003, 25: 1000–1007. [Medline] [CrossRef]
12) Perry J: Kinesiology of lower extremity bracing. Clin Orthop Relat Res, 1974, (102): 18–31. [Medline] [CrossRef]
13) Laufer Y, Dickstein R, Chefez Y, et al.: The effect of treadmill training on the ambulation of stroke survivors in the early stages of rehabilitation: a randomized study. J Rehabil Res Dev, 2001, 38: 69–78. [Medline]
14) Bressel E, Dolny DG, Gibbons M: Trunk muscle activity during exercises performed on land and in water. Med Sci Sports Exerc, 2011, 43: 1927–1932. [Medline] [CrossRef]
15) Bithell C: Evidence-based physiotherapy: some thoughts on 'best evidence'. Physiotherapy, 2000, 86: 58–59. [CrossRef]
16) Teixeira-Salmela LF, Olney SJ, Nadeau S, et al.: Muscle strengthening and physical conditioning to reduce impairment and disability in chronic stroke survivors. Arch Phys Med Rehabil, 1999, 80: 1211–1218. [Medline] [CrossRef]
17) Teixeira-Salmela LF, Nadeau S, Mcbride I, et al.: Effects of muscle strengthening and physical conditioning training on temporal, kinematic and kinetic variables during gait in chronic stroke survivors. J Rehabil Med, 2001, 33: 53–60. [Medline] [CrossRef]
18) Garcia MK, Joares EC, Silva MA, et al.: The Halliwick Concept, inclusion and participation through aquatic functional activities. Acta Fisiatr, 2012, 19: 142–150. [CrossRef]
19) Mehrholz J, Kugler J, Pohl M: Water-based exercises for improving activities of daily living after stroke. Cochrane Database Syst Rev, 2011, 1: CD008186. [Medline]
20) Schitter AM, Nedeljkovic M, Baur H, et al.: Effects of passive hydrotherapy WATSU (WaterShiatsu) in the third trimester of pregnancy: results of a controlled pilot study. Evid Based Complement Alternat Med, 2015, 2015: 437650. [Medline] [CrossRef]
21) Choi SA, Cynn HS, Yi CH, et al.: Isometric hip abduction using a Thera-Band alters gluteus maximus muscle activity and the anterior pelvic tilt angle during bridging exercise. J Electromyogr Kinesiol, 2015, 25: 310–315. [Medline] [CrossRef]
22) Chung E, Lee BH, Hwang S: Core stabilization exercise with real-time feedback for chronic hemiparetic stroke: a pilot randomized controlled trials. Restor Neurol Neurosci, 2014, 32: 313–321. [Medline]

23) Beith ID, Synnott RE, Newman SA: Abdominal muscle activity during the abdominal hollowing manoeuvre in the four point kneeling and prone positions. Man Ther, 2001, 6: 82–87. [Medline] [CrossRef]

24) Drysdale CL, Earl JE, Hertel J: Surface electromyographic activity of the abdominal muscles during pelvic-tilt and abdominal-hollowing exercises. J Athl Train, 2004, 39: 32–36. [Medline]

25) Marshall PW, Murphy BA: Core stability exercises on and off a Swiss ball. Arch Phys Med Rehabil, 2005, 86: 242–249. [Medline] [CrossRef]

26) Karatas M, Cetin N, Bayramoglu M, et al.: Trunk muscle strength in relation to balance and functional disability in unihemispheric stroke patients. Am J Phys Med Rehabil, 2004, 83: 81–87. [Medline] [CrossRef]

27) Patterson SL, Rodgers MM, Macko RF, et al.: Effect of treadmill exercise training on spatial and temporal gait parameters in subjects with chronic stroke: a preliminary report. J Rehabil Res Dev, 2008, 45: 221–228. [Medline] [CrossRef]

28) Lee JS, Song DY, Cho WG, et al.: Transplantation of human mesenchymal stem cells into the cisterna magna and its neuroprotective effects in a parkinsonian animal model. Mol Cell Toxicol, 2015, 11: 373–385. [CrossRef]

29) Baek SY, Lee NR, Kim DH, et al.: Protective effect of a novel herbmedicine, Hepad, on apoptosis of SH-SY5Y cells and a rat model of Parkinson's disease. Mol Cell Toxicol, 2015, 11: 223–230. [CrossRef]