Original Article

PTRS Physical Therapy Rehabilitation Science

pISSN 2287-7576
eISSN 2287-7584

Phys Ther Rehabil Sci
2012, 1 (1), 17-21
www.jptrs.org

The effect of a water exercise on gait characteristics in the elderly post stroke patients

Hee-Sung Lim[a], Suk-Min Lee[b]

[a]Department of Physical Therapy, The Graduate School, Sahmyook University, Seoul, Republic of Korea
[b]Department of Physical Therapy, College of Health and Welfare, Sahmyook University, Seoul, Republic of Korea

Objective: To investigate the effect of long-term water exercise on gait parameters in the elderly post stroke patients.
Design: One group pretest-posttest design.
Methods: Twenty elderly post stroke patients (age: 56.5±10.1 years, height: 168.6±5.8 cm, body mass: 69.3±6.9 kg, handicapped level: 2.5±0.8) participated in this study. Participants took part in gait training of 1 hour per day, three days per week, for three months. Participants' gaits were analyzed to find the effect of 3 months water exercise by a 3-D motion analysis with 8 infrared camera and 1 force plate (sampling frequency: 100 and 1,000 Hz, respectively). A paired t-test was used to find the significance with significant level as 0.05.
Results: Gait velocity, step length & step width significantly increased, and asymmetric index for gait parameters significantly decreased after the water exercise ($p < 0.05$).
Conclusions: The water exercise effectively affect on patients' gait ability and electromyography analysis will be needed further study.

Key Words: Gait, Stroke, Water

Introduction

Stroke is known to be one of the biggest causes of adult disability today. According to the statistics of World Health Organization, there are about 15 million new stroke patients each year and one third of them suffer permanent impairment [1,2]. In South Korea, stroke is one of the top three disease-inflicted causes of death and shows the highest death rate among circulatory system diseases [3].

After the injury, most stroke patients experience hemiplegia, which refers to paralysis of one side of the body caused by cerebrovascular disorders. As hemiplegia patients mainly use the healthier side of the body during physical activities, they show more asymmetrical movement in comparison to healthy people by, for instance, standing with 61-81% of their weight inclined on the healthier side of their body [4]. Also, they show more obvious difference from normal people while gaiting, which is the most important physical activity in everyday life, which serves as a measure of the conditions of hemiplegia patients. In other words, because stroke patients - when gaiting - try to move the center of gravity quickly to the healthier side of their body due to unstableness of the impaired side, the stance and swing periods of the impaired side become shorter, which leads to slower gait speed, increased pattern of asymmetrical gait, and deteriorated balance [5,6]. Such decline results in limitation to patients' independence in everyday life and secondary damages such as falling, which acts as a substantial obstacle for them in returning to the society [7,8]. Therefore, reports have been made that the most important goal in rehabilitation of stroke patients is to maximize the independence of motor skills like gaiting [9-12].

Received: 15 May, 2012 **Revised:** 9 July, 2012 **Accepted:** 30 July, 2012

Corresponding author: Suk-Min Lee

Department of Physical Therapy, College of Health and Welfare, Sahmyook University, 815 Hwarang-ro, Nowon-gu, Seoul 130-742, Republic of Korea
Tel: 82-2-3399-1632 **Fax:** 82-2-3399-1639 **E-mail:** leesm@syu.ac.kr

Many researchers believe that the decline of motor skills and balance in stroke patients is due to weakened muscular strength on the impaired part of their body, and conducted studies through various mediations to improve the independence of the patients' motor skills, that is gaiting and balance. In other words, the researchers report that the muscular strength, balance, and stability of the impaired side of patients' body improved with resistance muscular training [13,14], gaiting on a treadmill [15-17], proprioceptive neuromuscular facilitation [18,19], and treadmill gait training based on task-oriented approach [12,20-22].

However, the exercise programs in previous studies, despite having many advantages for improving motor skills of stroke patients, can have potential limitations in carrying out the exercises. In other words, for physically weakened patients, aerobic exercise like treadmill on the ground or muscular training can cause excessive stress or pain on joints and muscle, and these concerns have been reported to reduce the amount of exercise for patients who need exercise. Therefore, there should be a way to improve patients' muscular strength without the risk of injury.

Unlike exercising on the ground, exercising in the water has the advantage of reducing the burden on the joints because the weight is reduced by buoyancy, and the high density helps patients exercise without the risk of injury. These advantages have been reported to enable patients to have time to control their motion in the water and experience various movement errors without injury [23]. Also, water exercise causes resistance to the entire body and, therefore, isokinetic muscular contraction as well as balanced development of agonistic and antagonistic muscles, according to a report [23], and therefore, it is thought to be more suitable than exercise on the ground for patients who are at a physical disadvantage.

While aquatic rehabilitation exercise is thought to be effective for rehabilitation of stroke patients, there are few studies that demonstrated this. Therefore, the purpose of this study is to prove the change in characteristics in gaiting of stroke hemiplegia patients after applying regular water exercise to them for three months, and examine whether it reduces asymmetry that is often found in these patients.

Methods

Subjects

To achieve the purpose of this study, total 20 male patients diagnosed with stroke participated. Patients who experienced other orthopaedic or neurological diseases were excluded and participants were selected among patients diagnosed with class 1-4 brain lesion who are capable of water exercise three times per week (Table 1). Research participants took part in gaiting exercise of 1 hour per day, three days per week, for three months, and no one withdrew in the middle of the program.

Table 1. General characteristics of participants (*N*=20)

Age (yr)	Height (cm)	Body mass (kg)	Handicapped level
56.5 (10.1)	168.6 (5.8)	69.3 (6.9)	2.5 (0.8)

Values are presented as mean (SD).

Asymmetry index

The asymmetry index (AI) used in this study for understanding how much asymmetry in patients' gait has improved after regular water exercise was the Robinson formula [24], and AI= 0 represents perfect symmetry and higher AI means bigger asymmetry.

Data collection

The test for this study was conducted before the beginning and after completion of the 3-month water exercise program. To examine the asymmetry in gait, 3-dimensional motion analysis was performed using eight infrared ray cameras and one force platform, and the sampling frequency was set at 100 Hz and 1,000 Hz. First, selected research subjects who agreed to the test were explained about the procedure, and asked to wear the top and bottom tights and put on markers. After sufficient warm-up, they performed the walking motion on a 10-m track installed in this laboratory. In order to induce natural gait of participants, the walking pace was chosen by their preference and the test was repeated total 10 times.

In order to produce kinematic variables of participants' lower limb, a rigid-link human body model composed of eight segments (trunk, pelvis, left and right feet, legs, and thighs) was used. Each participant was attached with 73 reflective markers on each joint and reference points, to define joint center and body segments, and the 3-dimensional coordinates were obtained by using QTM program. Standing trial was obtained before the test, and was used as a reference data in analyzing the data obtained from this test.

For quantitative analysis, all cameras set the space coor-

dinates by using Nonlinear Transformation, and the left and right, front and rear, and vertical directions were defined as X, Y, and Z axes.

Data and statistical analysis

The scope of data analysis included one gait cycle from the point when the left foot touches the ground to when it touches the ground again. To eliminate experimental errors from the data of marker positions obtained by the text, the data were filtered by the fourth-order Butterworth low-pass filter, with the cut-off frequency of 6.0 Hz. Later, the AI of kinematic and motor mechanical variables of the lower limbs were calculated by using Matlab 7.4.

To fulfil the purpose of this study, paired t-test was conducted by using SPSS ver. 11. 0 (SPSS Inc., Chicago, IL, USA). The statistical significance in this study was set to be $\alpha = 0.05$.

Results

The gait parameters of 20 stroke patients between pre- and post-water exercise are presented in Table 2. All gait parameters (step length: SL, step velocity: SV, step width: SW) showed statistically significant improvement after water exercise ($p < 0.05$). Among these, SV revealed the most increased patterns (58%) followed by SL (28%) and SW (20%).

Table 2. Gait parameters between pre- and post-water exercise (N=20)

	Pre	Post	t	p
SL (cm)	65.4 (6.29)	79.6 (4.7)	3.9	0.001
SV (cm/s)	60.5 (5.2)	95.8 (3.4)	5.2	0.001
SW (cm)	9.9 (0.9)	11.9 (0.9)	3.0	0.008

Values are presented as mean (SD).
SL: step length, SV: step velocity, SW: step width.

Table 3. Asymmetric index for kinematic and kinetic variables between pre- and post-water exercise (N=20)

	Pre	Post	t	p
MHA	11.7 (7.3)	3.5 (2.3)	7.2	0.000
MKA	11.0 (7.8)	4.0 (3.8)	2.9	0.008
MiHA	17.5 (7.1)	10.9 (5.4)	2.8	0.012
MiKA	39.0 (31.2)	31.6 (15.4)	0.9	0.343
VGRF	14.4 (13.5)	9.2 (5.3)	2.4	0.027

Values are presented as mean (SD).
MHA: peak hip angle, MKA: peak knee angle, MiHA: lowest hip angle, Mika: lowest knee angle, VGRF: peak vertical ground reaction forces.

Symmetry motion of legs is critical to evaluate the improvement of gait. In this study an asymmetry index of joint movements were computed and the results of 20 stroke patients between pre- and post-water exercise are presented in Table 3. All variables except MiKA (lowest knee angle) showed statistically significant improvement after water exercise ($p < 0.05$). As shown in Table 3, MHA (peak hip angle) revealed the most reduced pattern (70%) followed by MKA (peak knee angle), MiHA (lowest hip angle) and VGRF (vertical ground reaction forces).

Discussion

Improvement of gait ability has become a major interest in rehabilitation research on patients with hemiplegia caused by stroke, and the disability is a major obstacle for stroke patients in living independent life and is used as a measure to estimate the level of recovery for most stroke patients [25-27]. This study was conducted based on the premise that the unnatural gait found in most stroke patients is related to paralysis of the impaired side of their body, and that regular and safe exercise in the water will improve gait ability of the patients.

Comparison of gait characteristics between water exercise and after suggested that the patients' gait characteristics improved significantly after the exercise (Tables 2, 3). Among many gait factors, walking speed is reported to be the most sensitive, significant, and reliable one to assess the overall gait ability of stroke patients [28]. In this study, patients showed 58% improvement in walking speed after three months of water exercise (Table 2, $p < 0.05$). This result seems to indicate that, because exercising in the water is safer than normal exercise on the ground, patients were able to walk safely without fearing injuries. In addition, although it was not measured in this study, water exercise enhanced rectus femoris, biceps femoris, and vastus medialis by resistance of water and increased walk safety and speed at the same time, as suggested by previous studies [29,30].

The result indicates that, after training in the water, patients' step length and width improved by 22% and 20% respectively (Table 2, $p < 0.05$). The result seems to have appeared because, as previous studies suggested [31] although it was not measured in this study, the 3-month gait training in

the water strengthened iliopsoas muscle and extensor and improved the walk stability.

Walking is one of the most characteristic human motion that repeat segments of the left and right. As the left and right segments normally show symmetrical movement, it is used as a barometer in evaluating injury or rehabilitation of the lower limb [32]. In this study, symmetry was checked by obtaining the biggest and smallest angles of the left and right buttocks and knee joints of the patients and the maximum vertical ground reaction force. The result showed that the water exercise improved patients' gait symmetry by 18-70% except for the smallest knee angle (Table 3, $p < 0.05$). In order to increase symmetry of gait variables of stroke patients, the movement of the healthier side of the body should decrease or the impaired side movement should increase. It seems that the main cause of this study result was that the muscular strength of the impaired side was strengthened by exercising in the water and, therefore, showed similar movement to that of the healthier side.

In this study, gait characteristics were analyzed to demonstrate the effect of exercising in the water. However, for this result to be more reliable, it is necessary to examine the change in muscular strength of the lower limb, which is the cause of actual movement. Therefore, future studies will need to check the activity of muscles during walking by using EMG.

This study proved that three months of water exercise was very effective for improving patients' with stroke hemiplegia, and future studies will need to examine the change in muscular strength of the lower limb, which is the actual cause that improved the gait.

References

1. Khaw KT. Epidemiology of stroke. J Neurol Neurosurg Psychiatry 1996;61:333-8.
2. Mackay J, Mensah G, Mendis S, Greenlund K. The atlas of heart disease and stroke. World Health Organization; 2004.
3. Statistics Korea. The statistic results for cause of death in 2007. Statistics Korea; 2008.
4. Sackeley CM, Bauley B. Visual feedback after stroke with the balance performance monitor: two single-case studies. Clinical Rehabilitation 1993;7:189-95.
5. Lee YH, Kang SJ. Effects of aquatic rehabilitation exercise with land rehabilitation exercise on physical fitness for activities of daily living and range of motion of low limbs in chronic hemiplegia. J Adapt Phys Acti 2009;17:121-41.
6. Alexander LD, Black SE, Patterson KK, Gao F, Danells CJ, McIlroy WE. Association between gait asymmetry and brain lesion location in stroke patients. Stroke 2009;40:537-44.
7. Perry J, Bleck EE. Gait analysis: normal and pathological function. Dev Med Child Neurol 1993;35:1122.
8. Campbell GB, Breisinger TP, Meyers L. Stroke unit fall prevention: an interdisciplinary, data-driven approach. Rehabil Nurs 2006;31:3-4, 9.
9. Pak S, Patten C. Strengthening to promote functional recovery poststroke: an evidence-based review. Top Stroke Rehabil 2008; 15:177-99.
10. Ng MF, Tong RK, Li LS. A pilot study of randomized clinical controlled trial of gait training in subacute stroke patients with partial body-weight support electromechanical gait trainer and functional electrical stimulation: six-month follow-up. Stroke 2008;39:154-60.
11. Mauritz KH. Gait training in hemiplegia. Eur J Neurol 2002;9 Suppl 1:23-9.
12. Werner C, Bardeleben A, Mauritz KH, Kirker S, Hesse S. Treadmill training with partial body weight support and physiotherapy in stroke patients: a preliminary comparison. Eur J Neurol 2002;9:639-44.
13. Sharp SA, Brouwer BJ. Isokinetic strength training and dynamic stability in elerly persons. Gait Posture 1997;10:10-20.
14. Krebs DE, Scarborough DM, McGibbon CA. Functional vs. strength training in disabled elderly outpatients. Am J Phys Med Rehabil 2007;86:93-103.
15. Chen G, Patten C, Kothari DH, Zajac FE. Gait differences between individuals with post-stroke hemiparesis and non-disabled controls at matched speeds. Gait Posture 2005;22:51-6.
16. Franceschini M, Carda S, Agosti M, Antenucci R, Malgrati D, Cisari C; Gruppo Italiano Studio Allevio Carico Ictus. Walking after stroke: what does treadmill training with body weight support add to overground gait training in patients early after stroke?: a single-blind, randomized, controlled trial. Stroke 2009;40:3079-85.
17. Patterson SL, Rodgers MM, Macko RF, Forrester LW. Effect of treadmill exercise training on spatial and temporal gait parameters in subjects with chronic stroke: a preliminary report. J Rehabil Res Dev 2008;45:221-8.
18. Shimura K, Kasai T. Effects of proprioceptive neuromuscular facilitation on the initiation of voluntary movement and motor evoked potentials in upper limb muscles. Hum Mov Sci 2002; 21:101-13.
19. Vander Linden DW, Cauraugh JH, Greene TA. The effect of frequency of kinetic feedback on learning an isometric force production task in nondisabled subjects. Phys Ther 1993;73:79-87.
20. Ivey FM, Hafer-Macko CE, Macko RF. Task-oriented treadmill exercise training in chronic hemiparetic stroke. J Rehabil Res Dev 2008;45:249-59.
21. Sullivan KJ, Knowlton BJ, Dobkin BH. Step training with body weight support: effect of treadmill speed and practice paradigms on poststroke locomotor recovery. Arch Phys Med Rehabil 2002; 83:683-91.
22. Yang YR, Wang RY, Lin KH, Chu MY, Chan RC. Task-oriented progressive resistance strength training improves muscle strength and functional performance in individuals with stroke. Clin Rehabil 2006;20:860-70.
23. Choi JH, Kim HJ. Effect of the PNF and weight training on muscular strength and flexibility of the lower limbs in the elderly. J Phys Growth Mot Dev 2004;12:125-34.

24. Robinson RO, Herzog W, Nigg BM. Use of force platform variables to quantify the effects of chiropractic manipulation on gait symmetry. J Manipulative Physiol Ther 1987;10:172-6.
25. Ada L, Dean CM, Hall JM, Bampton J, Crompton S. A treadmill and overground walking program improves walking in persons residing in the community after stroke: a placebo-controlled, randomized trial. Arch Phys Med Rehabil 2003;84:1486-91.
26. Salbach NM, Mayo NE, Wood-Dauphinee S, Hanley JA, Richards CL, Côté R. A task-orientated intervention enhances walking distance and speed in the first year post stroke: a randomized controlled trial. Clin Rehabil 2004;18:509-19.
27. Yang YR, Yen JG, Wang RY, Yen LL, Lieu FK. Gait outcomes after additional backward walking training in patients with stroke: a randomized controlled trial. Clin Rehabil 2005;19:264-73.
28. Frigo C, Carabalona R, Dalla Mura M, Negrini S. The upper body segmental movements during walking by young females. Clin Biomech (Bristol, Avon) 2003;18:419-25.
29. Masumoto K, Shono T, Takasugi S, Hotta N, Fujishima K, Iwamoto Y. Age-related differences in muscle activity, stride frequency and heart rate response during walking in water. J Electromyogr Kinesiol 2007;17:596-604.
30. Matsumoto I, Araki H, Tsuda K, Odajima H, Nishima S, Higaki Y, et al. Effects of swimming training on aerobic capacity and exercise induced bronchoconstriction in children with bronchial asthma. Thorax 1999;54:196-201.
31. Masumoto K, Shono T, Hotta N, Fujishima K. Muscle activation, cardiorespiratory response, and rating of perceived exertion in older subjects while walking in water and on dry land. J Electromyogr Kinesiol 2008;18:581-90.
32. Mizuike C, Ohgi S, Morita S. Analysis of stroke patient walking dynamics using a tri-axial accelerometer. Gait Posture 2009;30:60-4.