J. Phys. Ther. Sci.
27: 3529–3531, 2015

Original Article

Effects of stationary cycling exercise on the balance and gait abilities of chronic stroke patients

Sung-jin Kim, PT, MS[1)], Hwi-young Cho, PT, PhD[2)], You Lim Kim, PT, MS[1)], Suk-min Lee, PT, DDS, PhD[1)*]

[1)] *Department of Physical Therapy, College of Health Science, Sahmyook University: 815 Hwarangro, Nowon-gu, Seoul 139-742, Republic of Korea*
[2)] *Department of Physical Therapy, College of Health Science, Gachon University, Republic of Korea*

Abstract. [Purpose] The objective of this study was to investigate the effects of stationary cycling exercise on the balance and gait abilities of chronic stroke patients. [Subjects] Thirty-two chronic stroke patients were randomly assigned to an experimental group (n=16) or a control group (n=16). [Methods] All of the subjects received the standard rehabilitation program for 30 minutes, while the experimental group additionally participated in a daily session of stationary cycling exercise for 30 minutes, 5 times per week for 6 weeks. To assess balance function, the Berg Balance Scale and timed up-and-go test were used. The 10-m walking test was conducted to assess gait function. [Results] Both groups showed significant improvements in balance and gait abilities. The improvements in the Berg Balance Scale and timed up-and-go test scores (balance), and 10-m walking test score (gait) in the stationary cycling exercise group were significantly greater than those in the control group. [Conclusion] This study demonstrated that stationary cycling exercise training is an effective intervention for increasing the balance and gait abilities of chronic stroke patients. Therefore, we suggest that stationary cycling training is suitable for stroke rehabilitation and may be used in clinical practice.
Key words: Gait, Balance, Stationary cycling

(This article was submitted Jul. 14, 2015, and was accepted Aug. 19, 2015)

INTRODUCTION

Post-stroke gait dysfunction is a major impediment that affects functional ambulation[1)]. It is caused by a complex interplay of motor, sensory, and cognitive impairments[2)]. These neurological deficits are the prime cause of reduced quality of life and social participation[3)]. Thus, gait and balance recovery is regarded as a chief goal in stroke rehabilitation[4)].

Until now, various exercise programs such as progressive exercise[5, 6)], muscle strength exercise[7)], rhythmic pattern exercise[8, 9)], and virtual training[10)] have been used to regain the balance, mobility, and endurance of stroke patients in clinical and research settings. Among these interventions, repetitive motor training can alter brain representation maps and is mainly and basically used for managing the motor function recovery in stroke patients[11)]. However, which specific therapeutic modalities most efficient repetitive motor training remains unclear.

Skilled activity is necessary to drive brain changes that might lead to improvements in functional activities such as gait[12)]. Stationary cycling, which requires less balance capability, has been used for training patients with or without nervous system disorders who have difficulty in maintaining balance and independent gait[13)]. Cycling and walking share similar locomotor patterns of reciprocal flexion and extension movements and alternating muscle activation of antagonists[14)]. Cycling can improve functional mobility and acts as a pseudo walking task-oriented exercise[2)]. Besides improving muscle strength, cycling exercise also facilitates muscle control of the lower limbs, which may allow putting more weight on the affected leg while standing. For this reason, stationary cycling exercise has been used with various other interventions in the clinical environments[15)]. However, the pure effect of cycling exercise is uncertain in chronic stroke patients. Therefore, this study investigated the effects of stationary cycling exercise on the balance and gait abilities of chronic stroke patients.

SUBJECTS AND METHODS

This study was designed as a randomized, double-blind, pretest-posttest controlled trial. In this study, 38 chronic stroke patients who were hospitalized were recruited. All experimental procedures and contents were explained to each participant, who provided written informed consent thereafter. All of the experimental procedures were approved by the institutional review board of Sahmyook University. The inclusion criteria were as follows: presence of hemiparesis secondary to stroke that had occurred in the past 6

*Corresponding author. Suk-min Lee (E-mail: leesm@syu.ac.kr)

Table 1. General characteristics of the subjects

	Experimental group (n = 16)	Control group (n = 16)
Gender (male/female)	12/4	13/3
Age (years)	65.2 ± 6.4	61.7 ± 6.1
Height (cm)	165.0 ± 7.9	169.0 ± 6.1
Weight (kg)	69.5 ± 10.4	66.8 ± 10.0
Lesion side (right/left)	7/9	10/6
MMSE (score)	26.10 ± 1.74	25.80 ± 2.12

Data are expressed as mean ± SD.
MMSE: Mini-Mental State Examination

Table 2. Changes in balance and gait abilities

		Experimental group	Control group
BBS score	Pretest	36.15 ± 5.98	37.06 ± 5.61
	Posttest	37.90 ± 5.65*	37.44 ± 5.62
	Post−Pre	1.75 ± 1.52*,†	0.40 ± 0.88
TUG (sec)	Pretest	25.11 ± 5.40	24.19 ± 3.47
	Posttest	16.74 ± 3.07*	19.48 ± 3.90*
	Post−Pre	−8.4 ± 4.35†	−4.71 ± 4.86*
10MWT (sec)	Pretest	44.75 ± 18.40	45.93 ± 13.22
	Posttest	37.74 ± 15.70*	43.96 ± 12.04*
	Post−Pre	7.02 ± 7.02*,†	1.96 ± 3.13*

BBS: Berg Balance Scale; TUG: timed up-and-go; 10MWT: 10-m walking test
Significant difference, paired t test: *$p < 0.05$; significant difference, independent t test: †$p < 0.05$

months; ability to walk 10 m independently with or without an assistive device; ability to communicate and understand, with a Mini-Mental Status Examination score of more than 21 points; no visual disorders or visual field deficit; and no known musculoskeletal conditions that would affect the ability to walk safely. The 6 subjects who refused to participate in the present program or did not meet the inclusion criteria were excluded from the study.

The subjects were randomly assigned to the following 2 groups by using a table of random sampling numbers: the experimental and the control group. Evaluation and data analysis were performed by a single physical therapist. Both the subjects and the therapist were blinded to group assignments of the patients. All of the participants were evaluated before training and at the end of the 4-week training period. The patients in the experimental group performed the cycling exercise 30 minutes a day, 5 times a week for 4 weeks. Both groups received traditional therapy for 30 minutes per session, 5 times a week for 4 weeks. Stationary bicycle training has been used in order to improve the balance and walking abilities of stroke patients. In this study, only the lower extremity part of a dual-extremity ergometer (Super Dynamic 3000, Shingwang Medical) was used.

To perform the exercise, the patient mounted a stationary bicycle safely under supervision, and the therapist adjusted the position of the seat and tied the ankles and calf to the pedals. The therapist was fully aware of the order and method of the stationary bicycle training, and the patients performed the exercise after receiving instructions and familiarizing themselves with the ergometers, including test runs. The resistance was set at 1 of 4, which corresponded to 25–30 W on the stationary bicycle. The patient was riding the bicycle at 50–60 rpm without stopping, for 30 min, 5 times a week for 6 weeks.

The subjects' balancing skills were rated using the Berg Balance Scale (BBS; range, 0–56), and the timed up-and-go (TUG) test was used to evaluate dynamic balance abilities. The patients were asked to stand up, walk at a comfortable speed to a point marked 3 m away from their chair, turn around, walk back, and sit down in the chair. The total time required to complete this process was measured with a stopwatch. Three trials were performed, and the mean time was recorded. The cut-off TUG test score that indicated normal versus below normal performance was 12 seconds. The intra-rater ($r = 0.99$) and inter-rater ($r = 0.98$) reliability values were high[16]. The BBS and TUG test scores were obtained by an experienced physical therapist blinded to the group assignment.

Gait ability was measured by using the timed 10-m walking test (10MWT). For the 10MWT, 10 m was measured on the floor by using a tape measure, and the start and end points were marked with tape. In order to provide sufficient distance for acceleration and deceleration, intervals of 2 m were added before the start and after the end marks. The subjects were instructed to walk as usual at a comfortable speed. The 10-m walking time was measured with a stopwatch for the period from the moment the subject's feet passed the starting line to the moment they crossed the finish line. The subjects practiced once, and all measurements were made 3 times, using the average value of the 3 measurements in the analysis. . For the 10MWT, the test-retest and inter-rater reliability have been reported to be 0.95 and 0.90, respectively; both of these values are very high[17].

The Statistical Package for the Social Sciences (SPSS) ver. 18.0 was used for data analysis. Descriptive statistics was used to analyze the general characteristics of the subjects. In order to examine the effects of the intervention in each group, a paired t test was conducted. In order to investigate differences between the groups, an independent t test was performed. For all data, the α level was set at 0.05.

RESULTS

The demographic characteristics of the participants are shown in the Table 1. No statistically significant differences in baseline values were observed between the 2 groups.

As shown in Table 2, the experimental group showed significant improvements in BBS, TUG test, and 10MWT scores after the intervention ($p < 0.05$), whereas the control group showed significant improvements in their TUG test and 10MWT scores, but not in their BBS score ($p < 0.05$). Moreover, the experimental group showed greater improvement than the control group in 3 outcome measurements ($p < 0.05$).

DISCUSSION

The aim of this study was to test the effects of cycling exercise on the balance and gait abilities of chronic stroke patients. The results demonstrated that the stationary cycling exercise supplemented with conventional therapy led to better balance and gait abilities than the conventional therapy alone.

First, the stationary cycling training was found to have a positive effect on dynamic balance as measured by using the TUG test. The results are similar to those obtained in a previous study by Kim et al., who compared ergometer bicycle training with treadmill walking training in stroke patients and reported significant improvement in TUG test scores in both groups, although the differences between the groups were not significant[18]. This suggests that the effectiveness of cycling training in improving locomotor function is similar to the effectiveness of treadmill exercise in stroke patients. Preliminary evidence suggests that cycling training programs reduce musculoskeletal impairment after stroke. In terms of muscle strength, cycling exercise enabled patients to bear more weight on the affected leg. A study by Kuo and Zajak suggested that the muscles that may be particularly important for this purpose are the hamstrings, rectus femoris, gastrocnemius, and tibialis anterior. These were all activated during the cycling task, which requires reciprocal flexion and extension movements of the hip, knee, and ankle[19]. It is interesting that Lustosa et al. reported a significant correlation between muscle strength and improvement in TUG test score. Therefore, we assumed that in this study the mechanism of TUG test score improvement in stroke patients was muscle strengthening[20].

Second, cycling exercise improved gait abilities in chronic stroke patients. This result is similar to those of previous studies. Repetitive bilateral training and treadmill walking with or without suspension have a positive effect on walking ability[21]. Repetitive practice is known to be important for motor learning, as the repetitions enable the system to coordinate muscle synergies[5]. Cycling and walking share similar locomotor patterns of repetitive reciprocal flexion and extension movements. Hence, stationary cycling exercise, which employs reciprocal movement of the lower limbs and requires coordination of corresponding muscles, effectively increased the gait ability.

Cycling training stimulates motor regions in the central nervous system and activates the cerebral cortex which eventually improves motor learning and balance. This effect certainly applies to chronic stroke patients. Based on the results, stationary cycling training can be effective in rehabilitation of stroke patients with gait and dynamic balance deficits.

This study has the following limitations that we plan to address in future studies, including the small sample size and relatively short intervention duration. Further large-scale, long-term controlled clinical studies are required to verify the clinical benefits of stationary cycling exercise training.

REFERENCES

1) Wade DT: Measurement in neurological rehabilitation. Curr Opin Neurol Neurosurg, 1992, 5: 682–686. [Medline]
2) Katz-Leurer M, Sender I, Keren O, et al.: The influence of early cycling training on balance in stroke patients at the subacute stage. Results of a preliminary trial. Clin Rehabil, 2006, 20: 398–405. [Medline] [CrossRef]
3) Chang JT, Morton SC, Rubenstein LZ, et al.: Interventions for the prevention of falls in older adults: systematic review and meta-analysis of randomised clinical trials. BMJ, 2004, 328: 680. [Medline] [CrossRef]
4) Yang YR, Tsai MP, Chuang TY, et al.: Virtual reality-based training improves community ambulation in individuals with stroke: a randomized controlled trial. Gait Posture, 2008, 28: 201–206. [Medline] [CrossRef]
5) Thielman GT, Dean CM, Gentile AM: Rehabilitation of reaching after stroke: task-related training versus progressive resistive exercise. Arch Phys Med Rehabil, 2004, 85: 1613–1618. [Medline] [CrossRef]
6) Yoo J, Jeong J, Lee W: The effect of trunk stabilization exercise using an unstable surface on the abdominal muscle structure and balance of stroke patients. J Phys Ther Sci, 2014, 26: 857–859. [Medline] [CrossRef]
7) Bohannon RW: Muscle strength and muscle training after stroke. J Rehabil Med, 2007, 39: 14–20. [Medline] [CrossRef]
8) Thaut MH, McIntosh GC, Rice RR: Rhythmic facilitation of gait training in hemiparetic stroke rehabilitation. J Neurol Sci, 1997, 151: 207–212. [Medline] [CrossRef]
9) Kim CY, Lee JS, Lee JH, et al.: Effect of spatial target reaching training based on visual biofeedback on the upper extremity function of hemiplegic stroke patients. J Phys Ther Sci, 2015, 27: 1091–1096. [Medline] [CrossRef]
10) Mirelman A, Patritti BL, Bonato P, et al.: Effects of virtual reality training on gait biomechanics of individuals post-stroke. Gait Posture, 2010, 31: 433–437. [Medline] [CrossRef]
11) Sacco K, Cauda F, D'Agata F, et al.: Reorganization and enhanced functional connectivity of motor areas in repetitive ankle movements after training in locomotor attention. Brain Res, 2009, 1297: 124–134. [Medline] [CrossRef]
12) Hancock NJ, Shepstone L, Winterbotham W, et al.: Effects of lower limb reciprocal pedalling exercise on motor function after stroke: a systematic review of randomized and nonrandomized studies. Int J Stroke, 2012, 7: 47–60. [Medline] [CrossRef]
13) Brown DA, Kautz SA, Dairaghi CA: Muscle activity adapts to anti-gravity posture during pedalling in persons with post-stroke hemiplegia. Brain, 1997, 120: 825–837. [Medline] [CrossRef]
14) Raasch CC, Zajac FE: Locomotor strategy for pedaling: muscle groups and biomechanical functions. J Neurophysiol, 1999, 82: 515–525. [Medline]
15) Kautz SA, Brown DA: Relationships between timing of muscle excitation and impaired motor performance during cyclical lower extremity movement in post-stroke hemiplegia. Brain, 1998, 121: 515–526. [Medline] [CrossRef]
16) Flansbjer UB, Holmbäck AM, Downham D, et al.: Reliability of gait performance tests in men and women with hemiparesis after stroke. J Rehabil Med, 2005, 37: 75–82. [Medline] [CrossRef]
17) Collen FM, Wade DT, Bradshaw CM: Mobility after stroke: reliability of measures of impairment and disability. Int Disabil Stud, 1990, 12: 6–9. [Medline] [CrossRef]
18) Kim CS, Bae SS: The comparison of effect of treadmill and ergometer training on gait and balance in stroke. J Korean Soc Phys Med, 2010, 25: 435–443. [CrossRef]
19) Kuo AD, Zajac FE: A biomechanical analysis of muscle strength as a limiting factor in standing posture. J Biomech, 1993, 26: 137–150. [Medline] [CrossRef]
20) Lustosa LP, Silva JP, Coelho FM, et al.: Impact of resistance exercise program on functional capacity and muscular strength of knee extensor in pre-frail community-dwelling older women: a randomized crossover trial. Rev Bras Fisioter, 2011, 15: 318–324. [Medline] [CrossRef]
21) Hesse S, Bertelt C, Jahnke MT, et al.: Treadmill training with partial body weight support compared with physiotherapy in nonambulatory hemiparetic patients. Stroke, 1995, 26: 976–981. [Medline] [CrossRef]