J. Phys. Ther. Sci.
27: 751–754, 2015

Original Article

Effects of bilateral training on motor function, amount of activity and activity intensity measured with an accelerometer of patients with stroke

Sunhwa Shim, MSc, OT[1)], Jinhwa Jung, PhD, OT[2)*]

[1)] *Department of Occupational Therapy, Yonsei University, Republic of Korea*
[2)] *Department of Occupational Therapy, Semyung University: 65 Semyung-ro, Jecheon-si, Chungbuk 390-711, Republic of Korea*

Abstract. [Purpose] This study investigated the recovery of arm function and the functional use of the affected limb in real life of stroke patients after bilateral arm training. [Subjects] Twenty patients with stroke were randomly allocated to the BT (bilateral training group, n=10) and UT (unilateral training group, n=10) groups. [Methods] The BT group performed functional tasks with both hand symmetrically, the UT group performed tasks with only the affected hand for 30 minutes a session 5 times a week over 6 weeks. Before and after the intervention, accelerometers (Actisleep), functional independence measure (FIM) and manual function test (MFT) were used to assess subjects' abilities. [Results] The BT group showed a significant improvement in FIM total score, motor subtotal score and MFT score of affected side compared to the UT group. The BT group showed a more quantitative increase in the amount of activity of the affected side than the UT group. Regarding activity intensity, the BT group showed a decrease in the sedentary level and an increase of the moderate level on the affected side compared to the UT group. [Conclusion] We found that programs tailored to the characteristics of stroke patients and continuous monitoring of physical activity using an accelerometer minimized possible future disability and improved the patients' quality of life.

Key words: Accelerometers, Bilateral training, Stroke

(This article was submitted Sep. 1, 2014, and was accepted Oct. 21, 2014)

INTRODUCTION

Bilateral arm coordination is a key component of normal arm motor function and it determines the quality of the performance of activities of daily living (ADLs). The majority of ADLs such as putting on a shirt, zipping up a jacket, or pouring a drink are tasks that generally require the use both arms. Performance of these ADLs requires successful coordinate of the movements of both upper extremities[1)]. Stroke survivors have difficulty in coordinating the use of both arms owing to an impairment or loss of motor function in the affected arm due to neurological damage. Although hemiplegic patients can go through the process of natural neurological recovery of motor function, the recovery rate of the affected arm is less than 15% with more than 60% of stroke patients showing limitations in their ability to perform ADLs[2)]. Arm coordination disorders can lead to a reduced quality of life and act as a major obstacle to return to home and community[3)]. Thus, recovering arm coordination is important for promoting improvements in the ability to perform ADLs, which are essential goals of rehabilitation for stroke patients.

The recovery of arm motor function is an essential component of the re-acquisition of functional independence in stroke rehabilitation[4)]. Although a diversity of therapeutic approaches have been attempted, functional recovery of the affected arm of stroke patients is still difficult. While constraint induced movement therapy (CIMT) has been demonstrated to have some positive therapeutic benefits including improvement of upper extremity function and ADL[5, 6)], there are safety issues associated with it, and the procedure can lead to patient discomfort because the non-affected limb is restricted during therapy. Furthermore, patients are limited to partial extension of the fingers and wrist of the affected arm because of the restriction of the non-affected arm during treatment. Because restriction of the non-affected limb limits the execution and success of CIMT, this method has strict inclusion criteria that limit the participation of severely impaired patients[7, 8)]. However, there are various therapeutic interventions that can be used for patients who are not eligible to participate in CIMT, such as bilateral arm training (BT).

BT focuses on the rehabilitation of stroke patients whose recovery of arm motor function does not meet the criteria for CIMT, and it involves using both arms[9)]. It is thought that the non-affected arm promotes relearning of various skills

*Corresponding author. Jinhwa Jung (E-mail: otsalt@nate.com)

required for recovery of the affected arm[10, 11]. Many studies have reported that this therapeutic technique can significantly improve the use of the affected arm as it incorporates the principles of task specificity and intensity. BT is similar to CIMT, but it does not restrict the non-affected side[11, 12]. Some studies that analyzed the effect of BT on the recovery of stroke patients have shown successful neurophysiological, kinematic, cerebral activation, and motor behavior outcomes. However, there is currently no objective data showing whether patients are properly using their improved arm function in real life so the causal description in the improvement of quality of life has a limitation. Other studies have used self-evaluation tools to assess the functional use of the affected arm following training; however, this method has reliability issues related to the subjective information reported by patients and their personal recall[10, 13].

Thus, this study aimed to demonstrate the effect of BT, consisting of a variety of tasks, on the recovery of arm function and the functional use of affected arm in the real life of stroke patients.

SUBJECTS AND METHODS

This study recruited forty patients with stroke in Gyeonggi province of Korea in 2013. The criteria for inclusion in the study included: having suffered a first stroke at least 6 months earlier; no musculoskeletal condition and no other neurological disorders. The subjects' general characteristics are summarized in Table 1. All of the protocols used in this study were approved by the University of Semyung. Before participation, the procedures, risks, and benefits were explained to all the participants, who gave their informed consent. The participants' rights were protected according to the guidelines of the University of Semyung.

Twenty patients with stroke participating in rehabilitation medicine were randomly assigned to either the bilateral training group (BT) or the unilateral training group (UT). Initial assessments included the mini-mental state examination (MMSE), and the Fugl-Meyer Assessment of Motor Function-upper extremity (FMA-U). Accelerometer (Actisleep) data collection, the functional independence measure (FIM) and the manual function test (MFT) were performed both before and after intervention. The intervention consisted of functional tasks such as opening and closing drawers, table cleaning, and moving objects, and it was conducted for 30 minutes a session 5 times a week over 6 weeks. The BT group performed tasks with both hands symmetrically, the UT group performed tasks with only the affected hand[14].

Accelerometers can be used to measure the level of arm use in real life. In this study, an Actisleep (GT3X+, LLT, USA) accelerometer was used. It is a portable three-axis motion sensor about the size of a watch (4.6×3.3×1.5 cm) and weights 19 g. It is worn on the wrist, waist and ankle to get data, and it can be used to assess rehabilitation, sports, obesity, diabetes mellitus, or sleep, depending on the wearing site. The measurement range covers 0.05–2 G, and the sampling rate is 30 Hz. Physical activity is continuously recorded on built-in memory which has a capacity of about 30 days data. The data can be saved on a computer using a USB cable. Activity is measured in counts, and energy consumption level of physical activity, the number of steps, intensity of illumination, and the intensity of physical activity are calculated using the count value[15]. The longer the body is used, the more repeats of the same motion, and the greater the intensity of motion, the higher the activity count recorded. To investigate the physical activity amount in real life, this study used the mean motion of axis y, axis x, axis z, axis total, amount of activity and activity intensity (sedentary, light, lifestyle, moderate, vigorous).

Table 1. General characteristics of the subjects

	BT	UT
Gender (male/female)	9/1	8/2
Age (year)	54.3 ± 18.5	58.7 ± 9.9
Lesion side (right/left)	5/5	3/7
Duration (month)	7.9 ± 2.0	7.7 ± 2.2
MMSE (score)	22.7 ± 4.5	17.8 ± 8.1
FMA-U (score)	33.2 ± 13.7	28.7 ± 8.9

All variables are mean±SD. BT: bilateral training group; UT: unilateral training group; MMSE: mini mental state examination test. FMA-U: Fugl-Meyer assessment of motor function- upper extremity

SPSS ver. 12.0 was used to calculate averages and standard deviations. Descriptive statistics were used to analyze subjects' general characteristics and the independent t-test was used to test the significance of differences in FIM, MFT and accelerometer measures. For all data, statistical significance was accepted at values of $p<0.05$.

RESULTS

The changes of FIM, MFT, amount of activity and activity intensity before and after the intervention are shown in Tables 2 and 3. The BT group showed a significant improvement in FIM total score, FIM motor subtotal score, and MFT score of affected side compared to the UT group ($p<0.05$). The results for the amount of activity and activity intensity measured by accelerometers indicate that the BT group showed a greater quantitative increase than the UT group in the amount of activity (axis y and axis total) of the affected side ($p<0.05$). Regarding activity intensity, the BT group showed a decrease in the sedentary'level of affected side, and an increase in the moderate'level of the affected side compared to the UT group ($p<0.05$).

DISCUSSION

This study aimed to demonstrate the effect of bilateral arm training, consisting of a variety of tasks, on the recovery of arm function and functional use of the affected limb in the real life of stroke patients.

Both groups showed differences in FIM total scores and FIM motor subtotal scores after training ($p<0.05$), and the BT group showed a significant improvement in the FIM total score and the FIM motor subtotal score compared to the UT group ($p<0.05$). A randomized experimental study by Whitall et al. reported improved spatial and temporal recovery of arm function after bilateral training three times a week

Table 2. Comparison of FIM and MFT

Item	Subtest	BT		UT	
		Pre	Post	Pre	Post
FIM	Motor*	51.7±16.8	65.6±13.8*	53.8±18.5	57.8±16.9*
(score)	Cog	30.1±5.0	30.9±4.6	27.1±8.1	27.5±8.0
	Total*	81.8±19.6	96.5±14.9**	80.9±24.5	85.3±22.5*
MFT	A*	15.8±5.6	21.3±6.5**	11.1±5.0	12.5±5.6*
(score)	NA	29.3±1.2	29.5±1.2	29.4±1.2	29.7±1.4

All variables are mean±SD. $^{*}p<0.05$, $^{**}p<0.01$, BT: bilateral training group; UT: unilateral training group; FIM: functional independence measure; Motor: FIM motor subtotal score; Cog: FIM cognition subtotal score; MFT: manual function test; A: affected side; NA: non-affected side

Table 3. Comparison of amounts and intensities of activity measured by accelerometers

	A				NA			
	BT		UT		BT		UT	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Activity	amount (count)							
Axis y	328.2±144.87	479.2±198.0**†	195.4±160.4	236.4±177.4	1,078.9±355.2	1,001.3±400.1	748.3±260.3	753.9±213.3
Axis x	373.8±181.2	847.6±1,049.4	260.4±192.2	267.1±180.4	1,035.0±362.4	968.9±423.4	811.6±279.7	797.1±243.9
Axis z	443.2±258.6	510.9±280.9	275.6±202.5	304.2±213.8	1,193.6±397.6	1,165.4±500.2	826.4±273.9	842.6±237.1
Axis total	1,145.2±533.9	1,837.7±1,097.7†	731.4±541.0	807.7±566.7	3,307.5±1,074.8	3,135.6±1,285.6	2,386.3±757.5	2,393.5±677.2
Activity	intensity (%)							
Sedentary	67.2±16.0	62.1±16.5†	76.9±15.9	77.3±12.7	30.8±19.6	42.1±20.0*	39.5±13.5	44.9±16.7*
Light	23.6±12.5	24.5±10.4	17.3±9.8	16.1±7.2	26.4±9.2	24.8±6.0	30.5±9.0	26.9±9.4
Lifestyle	6.3±4.6	9.9±7.6	4.9±5.7	4.4±3.4	33.1±13.2	25.3±13.2*	25.0±10.3	20.3±11.8
Moderate	2.5±1.8	3.5±2.2†	0.9±1.1	1.7±1.7*	9.7±5.4	7.7±7.9	5.0±4.2	5.7±3.9

All variables are mean±SD. A: affected side; NA: non-affected side; BT: bilateral training group; UT: unilateral training group; within group differences $^{*}p<0.05$, $^{**}p<0.01$, †: significantly greater than CON

for six weeks as well as the maintenance of arm function at follow-up after four months[12]. Furthermore, they analyzed the effect of bilateral training on quality of life, and found a significant improvement following their rehabilitation program. Another study reported improved quality of life using self-reported evaluations which indicated marked improvements in ADLs, instrumental activities of daily living, and social participation[10].

In the MFT, both groups showed differences in the affected side scores after training ($p<0.05$), and the BT group showed a significant improvement in the affected side score compared to the UT group ($p<0.05$). Summers et al. conducted a repeated bilateral task in which 12 chronic patients positioned a round rod 60 times per session for six days. They observed a reduction in reaching time, increased elbow joint angles, and a change in arm function[13]. In another study by Richards et al., 14 stroke patients completed eight sessions over two weeks (two hours per session, four sessions per week) of bilateral tasks that required the repeated placement of nine blocks. These right hemiplegia and lower motor recovery patients showed significant improvements in the function of the affected arm[16].

We used accelerometers to measure the amount and intensity of activity, and the affected side of the group BT showed a significant difference in the amount of activity performed (axis y and axis total) compared to that in the UT group. Increases in the movement along axis y suggest movement in the sagittal plane, representing a quantitative increase in the ability to locate the arm in space. This motion is similar to the reaching of arm function. Because conventional functional rehabilitation programs are performed in a sitting position, the movement in the transverse plane or coronal plane is the primary motion. Therefore, there is a limitation on movement in the sagittal plane, such as reaching, and the present study confirmed that bilateral training facilitates movement in the sagittal plane.

In the BT group, the sedentary level showed a statistically significant decrease, and the moderatelevel showed a significant increase in the activity intensity of the affected side ($p<0.05$). This indicates that bilateral training increased the time subjects spent on high intensity activities. Vega-Gonzalez et al. analyzed the arm activity of 10 stroke patients with mild to severe symptoms using accelerometers at home and in the workplace and compared the findings to those of healthy adults. Their results indicate that healthy adults use their dominant hand 19% more than their non-dominant hand, while stroke patients used the unaffected side 3–6 times more than the affected side[17].

We confirmed the effect of bilateral arm exercise program on arm use in the daily life of chronic stroke patients, and found that the bilateral home exercise program prevents learned non-use, and improves the physical balance of both sides in hemiplegic patients. Programs tailored to the characteristics of stroke patients and continuous monitoring of physical activity using accelerometers minimize disability and improve subjects' quality of life. Intensity of physical activity is an important measure for evaluating physical activity, and measuring the amount and intensity of physical activity using accelerometers is expected to significantly increase in health care management. Application of home exercise programs tailored to the characteristics of stroke patients will have socio-economic effects through the restoration of independent living and improved quality of life. Research to find exercise programs with the greatest efficacy within the same time is continuously needed in the field of public health.

ACKNOWLEDGEMENT

This paper was supported by a Semyung University Research Grant of 2013.

REFERENCES

1) Page SJ, Elovic E, Levine P, et al.: Modified constraint-induced therapy and botulinum toxin A: a promising combination. Am J Phys Med Rehabil, 2003, 82: 76–80. [Medline] [CrossRef]
2) Hendricks HT, van Limbeek J, Geurts AC, et al.: Motor recovery after stroke: a systematic review of the literature. Arch Phys Med Rehabil, 2002, 83: 1629–1637. [Medline] [CrossRef]
3) Morris JH, van Wijck F, Joice S, et al.: A comparison of bilateral and unilateral upper-limb task training in early poststroke rehabilitation: a randomized controlled trial. Arch Phys Med Rehabil, 2008, 89: 1237–1245. [Medline] [CrossRef]
4) Whitall J, McCombe Waller S, Silver KH, et al.: Repetitive bilateral arm training with rhythmic auditory cueing improves motor function in chronic hemiparetic stroke. Stroke, 2000, 31: 2390–2395. [Medline] [CrossRef]
5) Yu JH, Kang HK, Jung JH: Effect of modified constraint-induced movement therapy on hand dexterity, grip strength and activities of daily living of children with cerebral palsy: a randomized control trial. J Phys Ther Sci, 2012, 24: 1029–1031. [CrossRef]
6) Rosenstein L, Ridgel AL, Thota A, et al.: Effects of combined robotic therapy and repetitive-task practice on upper-extremity function in a patient with chronic stroke. Am J Occup Ther, 2008, 62: 28–35. [Medline] [CrossRef]
7) Wolf SL, Winstein CJ, Miller JP, et al. EXCITE Investigators: Effect of constraint-induced movement therapy on upper extremity function 3 to 9 months after stroke: the EXCITE randomized clinical trial. JAMA, 2006, 296: 2095–2104. [Medline] [CrossRef]
8) Levine P, Page SJ: Modified constraint-induced therapy: a promising restorative outpatient therapy. Top Stroke Rehabil, 2004, 11: 1–10. [Medline] [CrossRef]
9) Winstein CJ, Miller JP, Blanton S, et al.: Methods for a multisite randomized trial to investigate the effect of constraint-induced movement therapy in improving upper extremity function among adults recovering from a cerebrovascular stroke. Neurorehabil Neural Repair, 2003, 17: 137–152. [Medline] [CrossRef]
10) Lin KC, Chen YA, Chen CL, et al.: The effects of bilateral arm training on motor control and functional performance in chronic stroke: a randomized controlled study. Neurorehabil Neural Repair, 2010, 24: 42–51. [Medline] [CrossRef]
11) McCombe Waller S, Harris-Love M, Liu W, et al.: Temporal coordination of the arms during bilateral simultaneous and sequential movements in patients with chronic hemiparesis. Exp Brain Res, 2006, 168: 450–454. [Medline] [CrossRef]
12) Whitall J, Waller SM, Sorkin JD, et al.: Bilateral and unilateral arm training improve motor function through differing neuroplastic mechanisms: a single-blinded randomized controlled trial. Neurorehabil Neural Repair, 2011, 25: 118–129. [Medline] [CrossRef]
13) Summers JJ, Kagerer FA, Garry MI, et al.: Bilateral and unilateral movement training on upper limb function in chronic stroke patients: a TMS study. J NeurolSci, 2007, 252: 76–82. [Medline] [CrossRef]
14) Stoykov ME, Lewis GN, Corcos DM: Comparison of bilateral and unilateral training for upper extremity hemiparesis in stroke. Neurorehabil Neural Repair, 2009, 23: 945–953. [Medline] [CrossRef]
15) Shim S, Kim H, Jung J: Comparison of upper extremity motor recovery of stroke patients with actual physical activity in their daily lives measured with accelerometers. J Phys Ther Sci, 2014, 26: 1009–1011. [Medline] [CrossRef]
16) Richards LG, Senesac CR, Davis SB, et al.: Bilateral arm training with rhythmic auditory cueing in chronic stroke: not always efficacious. Neurorehabil Neural Repair, 2008, 22: 180–184. [Medline] [CrossRef]
17) Vega-González A, Granat MH: Continuous monitoring of upper-limb activity in a free-living environment. Arch Phys Med Rehabil, 2005, 86: 541–548. [Medline] [CrossRef]