The effect of enhanced trunk control on balance and falls through bilateral upper extremity exercises among chronic stroke patients in a standing position

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Abstract. [Purpose] This study examined the effects of bilateral upper extremity exercises on trunk control, balance, and risk of falls in stroke patients. [Subjects and Methods] A total of 30 study subjects were selected and randomly divided into experimental and control groups containing 15 subjects each, who received bilateral upper extremity activities and conventional rehabilitation treatment, respectively. [Results] There were statistically significant differences between groups in all sub-items and total trunk impairment and Berg Balance scale scores. Significant differences between groups were also observed in all sub-items of the trunk impairment scale, except for static sitting balance. [Conclusion] Bilateral upper extremity exercises are effective for trunk control and balance as well as for fall prevention.

Key words: Bilateral upper extremity exercises, Balance, Stroke

INTRODUCTION

Stroke causes tissue damage due to ruptured blood vessels or blood clots that may block oxygen and nutrient supply, which results in symptoms such as facial muscle weakness, one-sided extremity muscle weakness, gait difficulty, dizziness, and loss of balance and control1). Diminished motor skills lead to use of non-paretic extremities for extended periods of time, which causes muscle weakening on the paretic side relative to the non-paretic side. This results in muscle imbalances, body asymmetry, and impaired balance2, 3). In particular, reduced lower extremity motor skills lead to impaired gait and balance, which increases the risk of falls4). Balance is the ability to maintain a center of gravity and equilibrium during body movements; it is a complicated and dynamic process of controlling and maintaining posture5, 6). Falls are defined as sudden postural changes that result in an inadvertent drop to the floor, ground, or lower level. Diminished balance greatly increases the risk of accidents associated with falls7).

Previous studies have reported the effects of direct trunk, treadmill, and sling exercises on improving balance and preventing falls8–11), and Jung and Lee proposed the development of additional balance-training programs intended to reduce falls12). Bilateral upper extremity activities require the unaffected upper extremities to guide the affected upper extremities in order to improve mobility and trunk control in the affected limbs13). Researchers have also reported that bilateral upper extremity activities reduce stiffening of damaged arms and associated reactions during passive movements and also induced symmetrical movements to activate trunk activity14). Hodge et al. observed that trunk muscles are activated before movement...
of upper extremities through the feed-forward system, and Lehman et al. reported that movement of upper extremities in diverse environments was associated with muscle activity in the rectus abdominis, external oblique, internal oblique, and erector spinae muscles. However, there are few studies on the effects of trunk-control enhancement through bilateral upper extremity exercises on balance and the risk of falls in stroke patients. Therefore, the present study examined the effects of bilateral upper extremity exercises on trunk control, balance, and risk of falls in stroke patients.

SUBJECTS AND METHODS

A total of 30 patients diagnosed with unilateral brain damage based on computed tomography (CT) or magnetic resonance imaging (MRI) findings at F Hospital in Daegu from January–June 2015 were selected as subjects. The selection criteria included disease duration not shorter than six months, a Korean mini-mental state examination (MMSE-K) score not lower than 24 points, and the ability to stand independently. Patients with any high-risk heart disease, medical disease, or musculoskeletal system disease who were unable to undergo training were excluded (Table 1). This study was approved by the Daegu Fatima Hospital Institutional Review Board and informed consent was obtained from each subject after fully explaining the study purpose.

The study subjects were randomly divided into experimental and control groups containing 15 subjects each, who underwent bilateral upper extremity activities and conventional rehabilitation, or nervous-system rehabilitation treatments, respectively. The experimental group underwent nervous system rehabilitation treatment and the bilateral upper extremity activity program for 30 minutes at a time, three times per week for four weeks, for a total of 12 sessions. The control group underwent nervous system rehabilitation treatment for the same duration and number of sessions. Four bilateral upper extremity activities were performed in a specific order. Subject trunk control and balance were evaluated before and after the nervous system rehabilitation treatment and bilateral upper extremity activity program using the trunk impairment scale (TIS) and Berg Balance Scale (BBS).

The bilateral upper extremity exercises used in the experimental group were based on the method presented by Lee et al., except that the position was changed from seated to standing. The exercise methods are described below. As a ready-position to perform the exercises, each patient stood with feet shoulder-width apart. Each bilateral upper extremity activity was performed 10 times per set for a total of three sets. There was a resting period after each set to avoid patient pain and fatigue. During each exercise, the therapist verbally instructed patients to use their affected extremities rather than their unaffected extremities. The bilateral upper extremity activities were as follows:

1. Patients were instructed to place both hands, with fingers locked, so that they were located on the sagittal plane of the body; they were then instructed to bend their arms in the vertical direction until the affected-side shoulder joint reached 90°. The patients then slowly brought both hands back down to the original position.
2. Patients were instructed to place their hands, with fingers locked, comfortably on the sagittal plane of the body, to bend the arms 45° in the diagonal direction to the unaffected side, until the affected-side shoulder joint reached 90°, and then to slowly bring their hands back down. At that time, patients were instructed to look at the end of their hands while turning their trunks naturally.
3. Patients were instructed to place their hands, with fingers locked, comfortably on the sagittal plane of the body, to bend the arms 45° toward a diagonal direction to the affected side, until the affected-side shoulder joint reached 90°, and then to slowly bring their hands back down. At that time, patients were instructed to look at the end of their hands while turning their trunks naturally.
4. Patients were instructed to place their hands, with fingers locked, comfortably on a table and to extend the elbow joints of both arms against the therapist’s manual resistance to stretch the arms forward. At that time, the therapist applied the minimum possible manual resistance.

During all exercises, the therapist stood on the affected side of the patients in order to protect patient safety and prevent falls.

In the present study, the TIS was used to objectively evaluate trunk control in chronic stroke patients. The TIS contains 17 sub-items in three categories: static sitting balance, dynamic sitting balance, and coordination. This tool offers high reliability and validity and can be used to evaluate the degree of trunk motor impairment after stroke. The highest possible TIS score is 23 points, with 0–7 possible points for static sitting balance, 0–10 points for dynamic sitting balance, and 0–6 points for coordination. The BBS, the reliability and validity of which have been recognized, was used to examine balance before and after exercise. The BBS consists of 14 items with 0–4 points applied to each item, for a total possible score of 56 points.

The results were analyzed by using PASW Statistics for Windows, version 18.0. Wilcoxon signed ranks tests were used to compare the non-parametric TIS and BBS scores before and after interventions. Mann-Whitney tests, which are also non-parametric, were used to compare the effects of the interventions between groups. The statistical significance level α was set to 0.05.
RESULTS

Statistically significant differences (p<0.05) were observed in both experimental and control groups in all TIS and the BBS sub-items and totals (Table 2). Table 3 shows the comparison of the effects of the different treatment methods. There were significant differences between groups in all sub-items of the TIS, except for static sitting balance (p<0.05).

DISCUSSION

The present study divided the subjects into control and experimental groups that received either only conventional rehabilitation treatment or underwent bilateral upper extremity exercises along with conventional rehabilitation, respectively, in order to measure the effects of bilateral upper extremity activities on trunk control and balance in chronic stroke patients, using the TIS. The BBS is a balance-evaluation tool, while the TIS provides guidelines for determining stroke patient trunk-function levels and treatment. Since impaired balance is closely related to falls, enhancing the sense of balance can prevent falls12). A prior study on the usefulness of the TIS to predict falls in stroke patient suggested that patients with better trunk control and dynamic balance abilities are less likely to experience falls, and that trunk control and dynamic balance are closely related20).

Both the experimental and control groups showed significant differences in BBS and TIS scores before and after the interventions. This indicates that both conventional rehabilitation treatment and bilateral upper extremity exercises are effective in improving stroke patient trunk control and balance, and are thus helpful for fall prevention.

Comparisons between groups revealed significant differences in the BBS and TIS items for dynamic balance and coordination. Therefore, bilateral upper extremity activities may help for enhancement of dynamic balance and coordination. This finding is consistent with the results of previous studies indicating that stroke patient trunk control affects TIS items related to dynamic balance and coordination18, 21). Enhancement of trunk control through bilateral upper extremity activities is thus believed to provide enhanced dynamic balance and coordination.

A previous study of the relationship between chronic stroke patient precursor fall motions and physical functions reported that TIS-based dynamic balance was the most important variable among balance-related fall-precursor motions22). Bilateral upper extremity activities may help to prevent falls by enhancing this balance.

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

|                     | Experimental group (n=15) | Control group (n=15) |
|---------------------|--------------------------|---------------------|
| Age (years)         | 60±8.4                   | 57.4±10.3           |
| Time since onset (months) | 13.8±3.3               | 15.9±3.84           |
| Gender (M/F)        | 7 / 8                    | 9 / 6               |
| Side (R/L)          | 8 / 7                    | 7 / 8               |

Table 2. Pre- and post-test scores

|                     | Experimental group (n=15) | Control group (n=15) |
|---------------------|--------------------------|---------------------|
|                     | Pre          | Post    | Pre          | Post    |
| BBS                 | 39.7±4.4     | 46.2±4.3*| 39.9±4.7     | 43.2±5.0*|
| TIS Static sitting  | 6.0±1.1      | 6.7±0.5*| 6.2±0.7      | 6.4±0.7*|
| TIS Dynamic sitting | 4.2±1.9      | 5.8±2.2*| 4.3±1.7      | 5.0±2.0*|
| TIS Coordination    | 3.1±1.5      | 4.8±1.5*| 2.8±1.3      | 3.3±1.4*|
| Total               | 13.4±4.1     | 17.4±3.7*| 13.3±3.6     | 14.8±3.8*|

*p<0.05

Table 3. Comparison of effects between groups

|                     | Experimental group (n=15) | Control group (n=15) |
|---------------------|--------------------------|---------------------|
| BBS                 | −6.4±2.2                 | −3.3±2.3*           |
| TIS Static sitting  | −0.6±1.0                 | −0.2±0.4            |
| TIS Dynamic sitting | −1.6±1.1                 | −0.7±0.9*           |
| TIS Coordination    | −1.7±1.2                 | −0.5±0.5*           |
| Total               | −4.0±2.6                 | −1.5±1.1*           |

*p<0.05
REFERENCES

1) World Health Organization (WHO) Stroke: Cerebrovascular accident health topic September 10, 2015, http://www.who.int/topics/cerebrovascular_accident/en/.
2) Campbell FM, Ashburn AM, Pickering RM, et al.: Head and pelvic movements during a dynamic reaching task in sitting: implications for physical therapists. Arch Phys Med Rehabil, 2001, 82: 1655–1660. [Medline] [CrossRef]
3) Nyberg I., Gustafson Y: Patient falls in stroke rehabilitation. A challenge to rehabilitation strategies. Stroke, 1995, 26: 838–842. [Medline] [CrossRef]
4) Liepert J, Bauder H, Wolfgang HR, et al.: Treatment-induced cortical reorganization after stroke in humans. Stroke, 2000, 31: 1210–1216. [Medline] [CrossRef]
5) Berg KO, Maki BE, Williams JI, et al.: Clinical and laboratory measures of postural balance in an elderly population. Arch Phys Med Rehabil, 1992, 73: 1073–1080. [Medline]
6) Nashner LM, McCollum G: The organization of human postural movements: a formal basis and experimental synthesis. Behav Brain Sci, 1985, 8: 135–150. [CrossRef]
7) Gehlsen GM, Whaley MH: Falls in the elderly: Part II, Balance, strength, and flexibility. Arch Phys Med Rehabil, 1990, 71: 739–741. [Medline]
8) 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]
9) Chung EJ, Lee BH: The effects of treadmill training on dynamic balance and gait function in stroke patients. Phys Ther Rehabil Sci, 2013, 2: 39–43.
10) Kim BH, Lee SM, Bae YH, et al.: The effect of a task-oriented training on trunk control ability, balance and gait of stroke Patients. J Phys Ther Sci, 2012, 24: 519–522. [CrossRef]
11) Park JH, Hwangbo G: The effect of trunk stabilization exercises using a sling on the balance of patients with hemiplegia. J Phys Ther Sci, 2014, 26: 219–221. [Medline] [CrossRef]
12) Jung EI, Lee BH: A Comparison of balance, mobility and balance in stroke patients with Fellers and Nonfallers. J Rehabil Res, 2013, 17: 301–314.
13) Bobath B: Adult hemiplegia: evaluation and treatment; Elsevier Health Sciences. 1990.
14) Davies PM: Steps to follow: a guide to the treatment of adult hemiplegia: based on the concept of K. and B. Bobath; Berlin: Springer-Verlag, 1985.
15) Hodges PW, Cresswell AG, Thorstensson A: Perturbed upper limb movements cause short-latency postural responses in trunk muscles. Exp Brain Res, 2001, 138: 243–250. [Medline] [CrossRef]
16) Lehman GJ, Gordon T, Langley J, et al.: Replacing a Swiss ball for an exercise bench causes variable changes in trunk muscle activity during upper limb strength exercises. Dyn Med, 2005, 4: 6. [Medline] [CrossRef]
17) Lee MH, Kim KD, Park SJ, et al.: The effects of bilateral activities of the upper extremities on stroke patients’ daily living activities. J Phys Ther Sci, 2013, 25: 161–164. [CrossRef]
18) Verheyden G, Nieuwboer A, Mertin J, et al.: The Trunk Impairment Scale: a new tool to measure motor impairment of the trunk after stroke. Clin Rehabil, 2004, 18: 326–334. [Medline] [CrossRef]
19) Berg K: Measuring balance in the elderly: preliminary development of an instrument. Physiother Can, 1989, 41: 304–311. [CrossRef]
20) Park CS: The preliminary study on predicting of fall incidence using the trunk impairment scale in people with subacute stroke. J Spec Educ Rehabilitation Sci, 2013, 52: 45–59.
21) Ann SH, Chung YJ, Park SY: The effects of trunk control ability on balance, gait, and functional performance ability in Patients with etroke. Korean Res Soc Phys Ther, 2010, 17: 33–42.
22) Park CS: The Correlation between Predictive accessory movements and Physical functions of Fall in the Chronic Stroke Patients. Department of Special Education Graduate School Dankook University, 2014.