



Original Article

# The effects of bilateral movement training on upper limb function in chronic stroke patients

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**Abstract.** [Purpose] This study compared the functional and kinematic changes associated with two rehabilitation protocols: bilateral and unilateral movement training. [Subjects and Methods] Twenty-five patients with chronic stroke were randomly assigned to two training protocols for four weeks of training. Each training session consisted of three tasks. The tasks were performed with either the impaired and unimpaired arms moving synchronously (bilateral training) or with the impaired arm alone (unilateral training). To compare the changes associated with each rehabilitation protocol, functional and kinematic assessments were performed before and after the interventions. The functional state of each patient was measured by the Box and Block Test, and the kinematic variables were assessed by three-dimensional motion analysis. The Box and Block Test was used to assess the functional abilities of the affected upper limb. Kinematic measurements of upper limb movement were measured with a 3-dimensional motion analysis system. [Results] Results showed that the bilateral movement group had significantly improved motion of the shoulder compared to the unilateral movement group. [Conclusion] Bilateral movement training should be used to improve upper limb function in patients with chronic stroke.

**Key words:** Bilateral movement training, Stroke, Upper limb function

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## INTRODUCTION

For motor recovery in patients with stroke, repetitive and intensive practice of voluntary motor control is essential. Utilizing this concept, diverse treatment methods, such as constraint-induced movement therapy<sup>1)</sup>, electromyographic biofeedback<sup>2)</sup>, virtual reality<sup>3)</sup>, and task-oriented training<sup>4)</sup> have been attempted for recovery of upper-limb control in patients with stroke. However, such treatment methods have focused on unilateral movement of the paretic upper extremity.

Bilateral exercise is a training method that utilizes the non-paretic limb in order to promote functional recovery of the damaged limb through the interlimb coupling effect. To achieve this effect, both hands are drawn into coordinated positions by the muscle groups of identical structures, and combined into one coordinated unit. In order to obtain the interlimb coupling effect in the upper limbs, both the paretic side and the non-paretic side should be repetitively and intensively trained in a simultaneous manner. In this way, the paretic arm will couple with the movement pattern of the non-paretic arm and, accordingly, the function of the paretic arm will improve<sup>5)</sup>. When movement occurs in only one of the upper limbs, inhibition of activation in the same-sided hemisphere takes place; however, while performing symmetric bilateral movement tasks, both the left and the right cerebral hemispheres are activated, reducing inhibition between the hemispheres and thereby promoting recovery of the paretic limb<sup>6)</sup>.

Extensive research has been done to clarify the effects of bilateral exercise, but the results have been controversial. Some research has asserted that the interlimb coupling effect does not improve the performance of the paretic arm in patients with hemiplegia resulting from stroke<sup>7)</sup>. However, other studies have shown that bilateral movement increases the function of

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the paretic arm in patients with chronic stroke, suggesting the potential role of bilateral movement in recovering upper limb function after stroke<sup>8</sup>).

Therefore, in order to help clarify the effect of bilateral movement through diverse tasks, the subjects of this study were asked to perform tasks that did not force mirror-symmetric movement but required coordination between both hands. The results derived from this study will provide information that is useful for clarifying the effects of bilateral movement and for systemizing efficient rehabilitation treatment methods.

## SUBJECTS AND METHODS

Twenty-five inpatients and outpatients with stroke at a nursing facility located in N City were divided into a bilateral movement group (n=13) and a unilateral movement group (n=12). The bilateral group had five males and eight females, while the unilateral group had three males and nine females. The bilateral group and unilateral group each had six subjects with a paralyzed right side, while seven and six subjects, respectively, had a paralyzed left side. The average age and average disease duration of the bilateral group were 78.8 years old and 83.0 months, respectively, and 72.9 years old and 77.8 months in the unilateral group, respectively. All subjects understood the purpose of the study and provided written informed consent prior to participation, in accordance with the ethical standards of the Declaration of Helsinki.

The selection criteria for the participants were as follows: (1) hemiplegia resulting from cerebrovascular disease, (2) no pain in either arm, (3) no cognitive or perceptive disorders limiting the ability to follow therapist directions, (4) onset of stroke six or more months before the study, and (5) flexion and extension of the wrists and fingers of  $\geq 15^\circ$ .

The subjects performed each exercise in the physical therapy room of the nursing facility five times per week for six weeks. The exercise tasks were composed of hanging a ring, cleaning a desk with a towel, and imitating the action of drinking water.

The ring-hanging task involved raising two rings (total diameter, 16 cm; handle diameter, 2.5 cm) at the same time and hanging them on a pole fixed to a desk (height: 35 cm). Twenty repetitions were counted as one set, and subjects performed a total of three sets. A 30-second rest was given between each set. Subjects who found it difficult to perform the task with the paretic hand held one ring with both hands to perform the task.

In order to clean the desk with a towel, subjects unfolded their palms and placed both hands side by side on the towel. They were then asked to clean the desk where a drawing had been made with chalk. Subjects who found it difficult to perform the task completed it with the paretic hand placed on top of the non-paretic hand. This task was conducted repetitively for five minutes.

For the water-drinking task, the subjects were asked to imitate drinking water by raising a cup with one hand and bringing it to the mouth. Ten repetitions were counted as one set, and subjects performed three sets of this exercise. A 30-second rest was given between each set. Subjects who found it difficult to perform the task with the paretic hand held the cup with both hands.

Before and after the six-week exercise intervention, a Box and Block Test and three-dimensional (3D) motion analysis were conducted. The Box and Block Test is a standardized evaluation tool used to measure hand manipulation ability and upper limb dexterity<sup>9</sup>; the score is based on the number of blocks moved by the subject in one minute. A real-time 3D motion analyzer (CMS-20, Zebris Medizintechnik GmbH, Germany) was used to compare kinetic changes in the upper limbs<sup>10</sup>. Using this equipment, dynamic changes during repetitive exercises of the shoulders and elbows were measured. In order to compare changes in upper-limb motion, the amplitude and variability of each repeated exercise were measured.

The collected data were encoded for each subject and recorded on a computer. The values of the amplitude and variability measured by the Box and Block Test and the 3D motion analyzer differed between the two groups before the training exercises were performed. Therefore, an analysis of covariance was conducted with the before-exercise values as covariates, to examine the differences between the two groups after six weeks of exercise. For all analyses, SPSS for Windows version 18.0 (SPSS Inc., Chicago, IL, USA) was used, and the significance level was set at  $p < 0.05$ .

## RESULTS

There was no significant difference between the bilateral-exercise group and the unilateral-exercise group according to the analysis of covariance for the Box and Block Test results from before the exercises and six weeks after the exercises. The amplitude of the shoulders, examined with the 3D motion analyzer, increased significantly in the bilateral-exercise group compared to the unilateral-exercise group six weeks after the intervention. However, there was no significant difference in the amplitude of the elbows between the two groups. There was no significant difference between the two groups in the variability of the shoulders and elbows (Table 1).

## DISCUSSION

Upper-limb function disorders occur in 55–75% of stroke patients, and rehabilitation of the upper limbs usually takes more time and is less effective than rehabilitation of the lower limbs. Accordingly, this study intended to verify a more

**Table 1.** Comparison of outcomes

	Group	Pre	Post
Box and Block Test	Bilateral	21.3 ± 10.0	27.9 ± 10.2
	Unilateral	25.9 ± 8.6	30.3 ± 8.4
Shoulder amplitude (°)	Bilateral	55.3 ± 23.0	66.6 ± 23.2*
	Unilateral	60.8 ± 19.0	61.3 ± 15.3
Elbow amplitude (°)	Bilateral	60.8 ± 27.7	77.7 ± 22.0
	Unilateral	82.7 ± 18.8	88.5 ± 19.3
Shoulder variability (%)	Bilateral	13.2 ± 5.9	10.5 ± 5.0
	Unilateral	9.3 ± 4.9	9.8 ± 4.7
Elbow variability (%)	Bilateral	15.1 ± 8.6	9.2 ± 4.4
	Unilateral	7.8 ± 4.8	5.8 ± 2.9

\*p&lt;0.05

efficient treatment method by comparing the effects of applying bilateral-task and unilateral-task exercises on upper-limb function recovery in patients with chronic stroke with hemiplegia.

For the Box and Block Test, there was no difference between the two groups ( $p>0.05$ ). This contrasts with the results of some previous research that asserted that bilateral exercise is more effective than unilateral exercise. Mudie and Matyas<sup>11</sup> compared the effects of unilateral and bilateral exercise in 12 stroke patients. The subjects converted from unilateral exercise to bilateral exercise according to a training schedule, and there was an immediate effect from the performance of bilateral exercises. Cauraugh and Kim<sup>12</sup> reported that the group undergoing electromyographic electrical stimulation and bilateral exercises together demonstrated significantly greater increases in motor function compared to the group undergoing electromyographic electrical stimulation combined with unilateral exercises. These results are similar to those of the present study, which found no differences in functional improvement between bilateral exercise and unilateral exercise. In addition, since electromyographic electrical stimulation and bilateral exercises were performed together, it is therefore inappropriate to argue that the effect stemmed only from the bilateral exercises<sup>13</sup>.

When motor control and the mechanics of the exercises were examined with the 3D motion analyzer, the results differed. Shoulder movement amplitude was significantly increased after six weeks in the bilateral-exercise group compared to the unilateral-exercise group. The amplitude of the elbows was not significantly different between the two groups. This indicates that shoulder movement amplitude was improved in the bilateral-exercise group compared to the unilateral-exercise group, but there was no difference in the amplitude of elbow movement between the two groups. The training tasks used in the present study included ring-hanging, cleaning a desk with a towel, and water-drinking motions, which should utilize the entire upper limb in independent and cooperative ways; however, some subjects performed these tasks by relying compensatory motion of the shoulders because of an associated response. This explains why shoulder movement increased in the bilateral-exercise group, while the two groups showed no differences in elbow movement.

In patients with stroke, the neurological mechanisms of the synchronization phenomenon that occurs with bilateral exercises may be verified through functional MRI (fMRI) or transcranial magnetic stimulation (TMS). According to recent research, the mechanisms related to functional recovery using bilateral exercise include mobilization of the ipsilateral corticospinal pathways and normalization of the inhibition mechanism of the non-paretic hemisphere. It is known that 10–20% of ipsilateral corticospinal pathways are non-crossing. Such non-crossing ipsilateral pathways are included in the recovery mechanism after a stroke, which supports the use of bilateral exercise<sup>11</sup>. In bilateral exercise, in particular when speed increases, there is a tendency for timing to correspond with spatial parameters. Researchers have proposed that bilateral symmetric exercises after a stroke increase the use of the ipsilateral pathways and promote the restriction of symmetry. In research using TMS and fMRI on patients with hemiplegic cerebral palsy, the ipsilateral pathways were used when the lesion in the damaged hemisphere was larger<sup>14</sup>. The effects of bilateral exercise may be explained by such results.

An increase in movement efficiency or degree of softness may be inferred by examining movement deviations. The variability observed on 3D motion analysis represents the degree of consistency of the repetitive movements, and decreased variability means that the movement has become smoother. In the present study, the variability representing movement deviations did not differ between the two groups in the shoulders and elbows ( $p>0.05$ ). In contrast, research by Kim et al.<sup>15</sup> reported that smoothness of movement improved in the bilateral-exercise group compared to the unilateral-exercise group. They employed an assistive exercise device that was manufactured to make mirror-symmetric movement possible. However, in the present study, the subjects performed tasks that required coordination of both hands but that did not force mirror-symmetric movement. The present study also selected bilateral-exercise tasks that are actually performed in daily life. The reason the two research results are different may be found in the differences between the exercise tasks.

In conclusion, this study was useful in showing that bilateral-task exercises may increase movement compared to unilateral-task exercises. Therefore, the results of this study can be utilized to elucidate the effects of bilateral exercises and to

systemize more efficient rehabilitation methods. Nonetheless, this study failed to consider effects stemming from the form, location, and degree of brain damage. Such aspects should be addressed in future research through diverse types of bilateral tasks.

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