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Effect of Task-Oriented Bilateral Movements on Arm Global Synkinesis and Activities of Daily Living in Patients with Stroke

Background: Stroke patients exhibit arm global synkinesis (GS), involuntary movement due to muscle weakness and irregular muscle tension. But currently there are few studies examined the effects of GS on activates of daily living in stroke patients.
Objectives: To investigate the effects the effects of task-oriented bilateral movements, which promote brain plasticity and are based on neurological theory, using the unaffected arm and the affected arm.
Design: Quasi-randomized trial.
Methods: Twenty stroke patients were randomly assigned to experimental group Ⅰ (n=10) and experimental group Ⅱ (n=10). Before the intervention, arm GS was measured using surface electromyography, and the Motor Activity Log evaluated the quantitative and qualitative uses of the affected arm in daily life. The same items were measured four weeks later.
Results: The changes in the GS of the arm of experimental group Ⅰ showed statistically significant differences only in bending motions ($P<.05$). Both groups showed statistically significant differences in the amount of use (AOU) and the quality of movement (QOM) scores ($P<.01$). Comparing the groups, statistically significant differences in GS appeared during bending motions ($P<.05$), and in the AOU ($P<.01$) and the QOM scores ($P<.05$).
Conclusion: The intervention in GS reduced the abnormal muscle tension of the affected side by increasing the use of the ipsilateral motor pathway, indicating its effectiveness in improving upper limb functions with smooth contraction and relaxation of the muscles.

Keywords: *Stroke; Global synkinesis; Amount of use; Quality of movement; Activities of daily living*

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INTRODUCTION

Stroke patients show declines in upper limb functions due to abnormal muscle tone and coordination disorder, which reduce performance of the body's functional movements, such as personal hygiene, eating, and dressing.[1,2] These difficulties in basic activities of daily living (ADL), lead to decline in the stroke patient's quality of life.[3] Although the improvement of arm function among the parts of the body is particularly important for quality of life,[4] only about 5% of stroke patients recover normal arm function.[5] As stroke patients repeatedly experience failure when they perform functions with the affected arm, they develop dependency on the unaffected arm and use it more frequently, leading to reduction in the affected arm's functional activities.[6] This results in further functional disorder of the affected arm due to muscle weakening and contracture.[7] Since functional recovery of the arm becomes more difficult as the stroke patient enters the chronic phase, arm recovery of stroke patients is an important part of rehabilitation therapy and a challenge that must be overcome later.[8] There are a variety of therapeutic approaches for controlling stroke patients' movements and improving arm function, which are based on the neuroplasticity theory.[9] Representative methods for the recovery of the stroke patients' arm function include constraint-induced movement therapy, mental practice, mirror therapy, virtual reality, bilateral training, and task-oriented training.[10] Stroke patients mainly receive treatment only for the affected upper limb without much experience in coordinating their two hands in performing their ADL. One treatment method presented to compensate for such problems and enable diverse therapeutic approaches for patients is bilateral upper limb training using both hands.[11] Bilateral upper limb training refers to the symmetrical (in-phase) or asymmetrical (anti-phase) movements of the upper limb[12] and is based on neurological theory for improving the voluntary movement of the affected upper limb by stimulating the primary somatosensory area, thereby increasing the activation of the primary and supplementary motor areas.[13] Task-oriented training is helpful for functional improvement of patients because it promotes appropriate movements through repeated implementations of tasks[14] and leads to active use of the affected side, thereby causing reversible changes in the relevant areas of the brain.[15] In addition, it can be applied efficiently for improvement of patients' functions by composing it with tasks that can be experienced during daily life.[16] Global synkinesis (GS), which can be used as an important evaluation index for measuring functional impairment of stroke patients, refers to a phenomenon in which a voluntary movement of one arm of a stroke patient causes symmetrical involuntary movement in the same muscle of the other arm.[17,18] Motor activity log (MAL) can assess the frequency of use of the affected upper limb and the quality of the movement of the affected upper limb in hemiplegic patients to investigate the use of the affected side upper limb during ADL.[19] However, the paretic arm of stroke patients exhibits abnormal movements, such as homologous co-contraction, due to muscle weakening and irregular muscle tension. Stroke patients have fewer opportunities for input stimulation due to their life pattern in which the unaffected side is more frequently used, and therefore they cannot expect large effects for recovery. To solve these problems, this study aimed to compare the effects of task-oriented bilateral movements, which promote brain plasticity and are based on neurological theory, using the unaffected arm and the affected arm together with a view to providing clinical basic data for fast return to society by improving stroke patients' quality of life.

SUBJECTS AND METHODS

Subjects

This study was approved by the Institutional Bioethics Committee (SH-IRB 2020-57). From the stroke patients who were receiving hospital treatment at J Hospital in Jeollanam-do from June 2020 to August 2020, twenty patients were selected who understood the purpose of this study and agreed to participate. The selection criteria were hemiplegic patients who had been diagnosed with stroke at least six months ago but not more than two years ago, had no joint construction or limit in the range of joint motion, did not show hemi-neglect in the motor-free visual perception test, and were at recovery stage 3 or 4 of the Brunnstrom stages of the arm and recovery stage 3 or 4 of the Brunnstrom stages of the hand. The 20 male stroke patients were randomly assigned to experimental group I (n=10) to receive the intervention of task-oriented symmetrical upper limb movements and experimental group II (n=10) to receive the intervention of task-oriented asymmetrical upper limb movements in Table 1.

Table 1. General characteristic

Items	Experimental I (n=10) M±SD	Experimental II (n=10) M±SD	*P*
Age (years)	71.01 ± 4.87	73.91 ± 9.32	.143
Height (㎝)	157.70 ± 5.27	160.03 ± 5.84	.563
Weight (㎏)	62.90 ± 5.21	67.92 ± 6.41	.602
BMI (㎏/㎡)	24.73 ± 1.98	25.58 ± 2.65	.709
Brunnstrom stages (Arm)	3.41 ± .51	3.50 ± .52	.673
Brunnstrom stages (Hand)	3.53 ± .52	3.36 ± .48	.388

Outcome Measures

Measurement of global synkinesis

Two channels of the surface electromyography MP 100 system (Biopac, USA) were used. The sampling rate for signal collection was set to 1,000 Hz, and the frequency band filter was set to 30-450 Hz. The subjects wore a brace with a shoulder joint angle of 0° and an elbow joint angle of 90° with palm supination to fix their posture in a comfortable sitting position on a chair. Recording electrodes were attached to the bellies of the triceps muscle and the biceps muscle of the paretic arm, and the ground electrode was attached to a nearby area that did not interfere with movements. Maximum contraction was applied to the directions of the flexion and extension of the elbow joint of the non-paretic arm for three seconds respectively while verbally encouraging the subjects to relax the paretic arm. The signals activated on the paretic arm while the foregoing movements were repeated three times were collected. Thereafter, signals in the comfortable sitting posture were collected for three seconds three times to collect the reference point signals of the paretic arm.[18]

Motor activity log (MAL) assessment

MAL is a tool to assess self-awareness of the use of the upper limb that was developed to strengthen the quantitative and qualitative uses of the affected upper limb in daily life.[20] It enables self-measurement of 30 activities of daily living in terms of the amount of use (AOU) of the affected upper limb and the quality of movement (QOM). The higher the score, the higher the affected side usage and quality of movement. It is a highly reliable test tool with inter-rater reliability of r=.92.[19]

Interventions

Task-oriented symmetrical upper limb movement

In the intervention for experimental group I, the patient was instructed to maintain the trunk and head in neutral positions in a comfortable sitting position on a chair placed in front of a table and perform a towel push for 10 minutes followed by a rest for 5 minutes, repeated twice. This was performed three times per week for four weeks. In addition, to enable the patient to concentrate his/her attention on the training task, targets were set at the points corresponding to 100% and 60% of the length of the patient's arm. When performing the task, the patient was asked to simultaneously extend the normal arm and the paretic arm to the target point (Figure 1).[21]

Figure 1. Task-oriented symmetrical upper limb movement

Task-oriented asymmetrical upper limb movement

To apply the intervention of experimental group II, the patient was instructed to maintain the trunk and head in neutral positions in a comfortable sitting position on a chair placed in front of the table and perform a towel push for 10 minutes followed by a rest for 5 minutes, repeated twice, three times per week for four weeks. In addition, to enable the patient to concentrate his/her attention on the training task, targets were set at the points corresponding to 100% and 60% of the length of the patient's arm, and when performing the task, the patient was asked to extend the normal arm and the paretic arm to each target point in turn (Figure 2).[22]

Figure 2. Task-oriented asymmetrical upper limb movement

Data and Statistical Analysis

SPSS 20.0 for Windows was used to calculate the means and standard deviations of the measurement items. The normality test was performed using the Shapiro-Wilks test, and the homogeneity of the general characteristics of the study subjects was tested with Levene's equivariance test. A paired t-test was used to compare changes within the groups, and an analysis of covariance (ANCOVA) was used to compare changes between the groups. The significance level was set to α=.05.

RESULTS

Changes in arm GS and daily life in experimental group I

There was a statistically significant decrease in GS during bending motions ($P<.05$), and there were statistically significant increase in the AOU and the QOM scores ($P<.01$) (Table 2).

Table 2. Changes in arm GS and daily life in experimental group I

Items		Experimental group I (n=10)		t	P′
		Pre-test M±SD	Post-test M±SD		
GS	Flexion	.10 ± .03	.06 ± .03	3.192	.011*
	Extension	.08 ± .05	.07 ± .04	.356	.734
MAL	AOU	1.94 ± .25	2.59 ± .39	−5.678	.001**
	QOM	2.08 ± .34	2.63 ± .21	−6.589	.002**

′Paired t-test
*$P<.05$, **$P<.01$
GS: Global synkinesis, MAL: Motor activity log, AOU: Amount of use, QOM: Quality of movement

Table 3. Changes in arm GS and daily life in experimental group II

Items		Experimental group II (n=10)		t	P′
		Pre-test M±SD	Post-test M±SD		
GS	Flexion	.10±.02	.08±.02	1.546	.156
	Extension	.07±.03	.08±.06	−0.232	.822
MAL	AOU	1.91±.24	2.13±.31	−5.610	.007*
	QOM	2.08±.25	2.45±.20	−5.495	.004*

′Paired t-test
*$P<.01$
GS: Global synkinesis, MAL: Motor activity log, AOU: Amount of use, QOM: Quality of movement

Table 4. Changes in arm GS and daily life between the groups

Items			Pre-test M±SD	Post-test M±SD	F	P′
GS	Flexion	E-group I	.10 ± .03	.06 ± .03	5.085	.038*
		E-group II	.10 ± .02	.08 ± .02		
	Extension	E-group I	.08 ± .05	.07 ± .04	0.66	.800
		E-group II	.07 ± .03	.08 ± .06		
MAL	AOU	E-group I	1.94 ± .25	2.59 ± .39	12.407	.003**
		E-group II	1.91 ± .24	2.13 ± .31		
	QOM	E-group I	2.08 ± .34	2.63 ± .21	5.825	.027*
		E-group II	2.08 ± .25	2.45 ± .20		

′ANCOVA
*$P<.05$, **$P<.01$
GS: Global synkinesis, MAL: Motor activity log, AOU: Amount of use, QOM: Quality of movement

Changes in arm GS and daily life in experimental group II

There were statistically significant increase in the AOU and the QOM scores only in changes in daily life ($P<.01$) (Table 3).

Changes in arm GS and daily life between the groups

There was a statistically significant difference in GS during bending ($P<.05$), and there were statistically significant differences in the AOU score ($P<.01$) and the QOM score ($P<.05$) (Table 4).

DISCUSSION

Stroke patients mainly use the non-paretic upper limb, which is able to perform motions, rather than the paretic upper limb. However, since they receive training concentrated on the paretic side in the treatment of the upper limb, they do not experience coordination of the two hands, which is necessary during daily life.[23] To compensate for this problem, this study used bilateral upper limb movements to treat not only the paretic side but also the non-paretic side in an intervention to evaluate the effects on the GS of the arm and on the upper limb functions. In a study by Hwang et al.,[19] shoulder joint flexion, elbow joint flexion, and finger joint flexion were applied to the non-paretic upper limb, and the action potential of the motor units of the paretic upper limb appearing as a result was named GS. Chen et al.[24] reported that GS was closely related with spasticity and that large changes in GS were effective for smooth daily life. In this study, changes in GS within experimental group I applied with task-oriented symmetrical upper limb movements and experimental group II applied with task-oriented asymmetrical upper limb movements were compared. The results showed that GS statistically significantly decreased only in the bending motion of experimental group I, thereby supporting the results of previous studies. Both upper limbs move symmetrically at the same time, both homologous muscles are activated, and the neural network that controls the paralyzed muscle is activated. However, asymmetric movements cause the normal side cerebral hemisphere to be excessively activated, leading to the inhibition of the paralyzed side cerebral hemisphere. Therefore bilateral upper limb movement has the advantage of reducing the inhibition of the cerebral hemisphere through simultaneous activation of both cerebral hemispheres and promoting the recovery of the affected upper limb. Kim[25] applied functional electric stimulation to 10 stroke patients and observed a video of patients drinking together with the therapist and simultaneously applied motion observation training through imitation training as an intervention. Thereafter, he examined GS and found that the sensory feedback generated by further activating the mirror neurons improved the proper coordination ability of muscles, leading to changes in GS. The comparison of changes in GS between the groups in this study also showed statistically significant differences in GS during bending, thereby supporting previous findings. In experimental group I, the right and left muscle groups were simultaneously activated by symmetrical movements so that the neural networks involved in muscle activation for movements of both upper limbs were similarly activated, leading to positive changes in GS. However, in the comparison of changes in GS between groups in this study, there was no statistically significant difference in GS during extension movement. The reason is that Boissy et al.[26] reported that in stroke patients, when the non-paretic arm muscle contracted, the paretic arm GS increased, resulting in an inadequate effect on muscle function, and Kang and Nam[27] reported that when GS decreased, the excitability of the central nervous system decreased, which positively affected. Therefore, there was no significant difference in the extension of GS, but the mean value decreased, and if the intervention period is increased in the future, a significant difference will be seen. Yang[28] applied bilateral upper limb training to chronic stroke patients for four weeks and examined their ability to perform activities of daily living. According to the results, both the AOU and the QOM scores of the MAL significantly increased. Hong et al.[29] reported that the treatment that intensively trained both hands improved stroke patients' ability for two-hand coordination and reduced dependency on the unaffected upper limb more than the treatment that intensively trained only one hand. In this study too, changes in daily life within experimental group I and experimental group II were compared, and the AOU and the QOM scores of the MAL statistically significantly increased in both groups in line with previous studies. Repetitive task-oriented movements are thought to affect improvement of daily life because these movements are effective in improving the patterns of upper limb movements and manipulation skills,[30] since recovery is promoted with smooth contractions and relaxations of the upper limb muscles. In addition, Summers et al.[31] reported that bidirectional symmetrical movements stimulated the activation of the intact cerebral hemisphere to promote neuroplasticity, thereby improving impaired upper limb functions and controlling movements. The comparison of changes in daily life between the groups in this study also showed statistically significant differences, in line with previous studies. The reason is that bilateral movements reduced the abnormal muscle tension of the affected side with increases in the use of the ipsilateral motor pathway, and the voluntary movement of the unaffected upper limb promoted the movement of the affected upper limb.[32,33] Therefore, the intervention for experimental group I was more effective for improvement of daily life. As for the study limitations, since the study was conducted only with those patients who met the selection criteria, the results cannot be generalized. The effects of physical and environmental factors that could affect the degree of recovery of ADL were not considered. Therefore, future studies should be conducted after overcoming these limitations.

CONCLUSION

Stroke patients reduced the functional activities of their affected arm due to their dependence on the unaffected arm, which led to more frequent use of the arm on the unaffected side in their daily life and further functional disorder of the affected side arm due to muscle weakness and contracture. The intervention for experimental group I was inducing the simultaneous use of both hands and stimulating the nervous system of the cerebral hemisphere, the activation of muscles such as both sides occurs and the excessive activation of the healthy brain is reduced, of the upper limb muscles smooth interaction appears, indicating that it is effective in improving the upper limb function. Therefore, it is recommended that task-oriented symmetrical upper limb movements are used for the smooth daily life of stroke patients.

CONFLICT OF INTERESTS

The author declares that there are no conflicts of interest.

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