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Original Article

Effects of upper limb robot-assisted therapy in the rehabilitation of stroke patients

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Abstract. [Purpose] The aim of this study was to examine the effects of upper limb robot-assisted therapy in the rehabilitation of stroke patients. [Subjects and Methods] Fifteen stroke patients with no visual or cognitive problems were enrolled. All subjects received robot-assisted therapy and comprehensive rehabilitation therapy for 30 minutes each. The experimental group received a conventional therapy and an additional half hour per weekday of robot therapy. The patients participated in a total of 20 sessions, each lasting 60 minutes (conventional therapy 30 min, robot-assisted therapy 30 min), which were held 5 days a week for 4 weeks. [Result] The patients showed a significant difference in smoothness and reach error of the point to point test, circle size and independence of the circle in the circle test, and hold deviation of the playback static test between before and after the intervention. On the other hand, no significant difference was observed in the displacement of the round dynamic test. The patients also showed significant improvement in the Fugl-Meyer Assessment and Modified Barthel Index after the intervention. [Conclusion] These kinematic factors can provide good information when analyzing the upper limb function of stroke patients in robot-assisted therapy. Nevertheless, further research on technology-based kinematic information will be necessary.
Key words: Robot-assisted therapy, Stroke, Upper limb

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INTRODUCTION

Stroke is ischemic or hemorrhagic brain damage that causes neurological deficits, such as a sensory, motor, cognitive, speech, and visual disabilities[1)]. More than 85% of stroke patients experience unilateral paralysis, and more than 69% of them suffer damage to upper extremity function[2)]. A range of interventions, such as constraint-induced movement therapy, functional electrical stimulation, biofeedback, and transcranial magnetic stimulation, have been used for stroke patients[3–6)]. Many studies have reported that intensive training of the upper limb is needed to recover the nervous system and motor control.

With the recent technological advances related to improvement of upper limb function for stroke patients, robots are being presented as a new intervention in rehabilitation. Upper limb robot-assisted therapy has the features of automated repetition, high intensity and interactive feedback, and it was found to be more effective in improving the motor function of stroke patients[7–9)]. These robot therapies with objective and reliable means to monitor the condition of the patients can be provided as an intervention for rehabilitation. Masiero et al. reported that robot therapy for acute stoke patients was effective in improving upper limb function and decreasing the level of movement damage[10)]. A systematic review on the effectiveness of robot therapy reported a positive effect in improving the upper limbs[8, 11)].

Robot-assisted therapy offers motor practice to relearn motor skills without a therapist's assistance. Most robot-assisted therapies for motor practice not only allow assistance in movement and guidance but also provide accurate feedback information. Most robot therapy is based on the assumption that brain recovery involves activity-dependent plasticity[12)]. To provide a further understanding of neural plasticity, it is important to consider the options of new technologies regarding the motor function of stroke patients.

Most randomized controlled studies have shown the benefits of upper limb robot-assisted therapy for acute stroke patients. These studies have reported that stroke patients who received robot-assisted therapy showed significant gains in motor control and the activities of daily livings[13, 14)]. The improvement in the movement skills of the upper limbs has an important effect on functional recovery and independent performance. Therefore, this study examined the effects of upper limb robot-assisted therapy in the rehabilitation of stroke patients.

SUBJECTS AND METHODS

Fifteen stroke patients with no visual or cognitive

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problems (mini-mental state examination score >24 points) were enrolled in this study. The subjects were required to demonstrate at least a trace muscle contraction in the wrist extensors and a score of >10 in the Fugl-Meyer Assessment (FMA). All subjects gave their written informed consent to participation in the experiments in accordance with the ethical standards of the Declarations of Helsinki. Table 1 lists the general characteristics of the subjects.

The patients were admitted to the same hospital and assigned to the same team of rehabilitation professionals for the intervention. The experimental group received conventional therapy and an additional half hour per weekday of robot therapy. The patients participated in a total of 20 sessions, each lasting 60 minutes (conventional therapy 30 min, robot-assisted therapy 30 min), which were held 5 days a week for 4 weeks.

The novel InMotion Shoulder-Elbow Robot, MIT-MANUS (Interactive Motion Technologies, Inc., Cambridge, MA, USA), which was been designed for clinical neurological applications, was used. This robot that was capable of sensing and recording the position and velocity in the horizontal plane with a 2° of freedom (DoF) robotic device for the upper limb that provides shoulder-elbow training in the horizontal plane with a supported forearm. Smoothness is the patient's ability to quickly and accurately move the arm from a center position to targets in each of eight compass directions. The reach error is the difference between the patients' actual reach endpoints and the endpoint targets. The circle size is the average area of the patient's circular movements. The independence is a measure of the degree of circularity of the movement. The hold deviation is the average deviation distance when attempting to maintain the arm against resistance across the eight directions. The displacement is the patients' ability to move the arm against resistance in each of eight compass directions.

Statistical comparisons of the results were made using a Wilcoxon test. The SPSS 18.0 statistical software (SPSS, Chicago, IL, USA), was used for statistical analyses. A p value < 0.05 was considered significant.

RESULTS

Table 2 lists the scores for upper limb motions before and after the intervention. The patients showed a significant difference in smoothness and reach error of the point to point test, circle size and independence of the circle in the circle test, and hold deviation of the playback static test between before and after the intervention ($p<0.05$, $p<0.001$). On the other hand, no significant difference was observed in the displacement of the round dynamic test. The patients also showed significant improvement in the FMA and Modified Barthel Index (MBI) after the intervention ($p<0.001$) (Table 3).

DISCUSSION

The main aim of this study was to determine if robot-assisted therapy is an effective intervention for the recovery of upper limb function of stroke patients. The results showed that there are positive effects on upper limb function after robot therapy. The results support the primary hypothesis that robot-assisted therapy would improve the upper limb motor function of stroke patients[10, 14)].

The smoothness value of the point to point test was significantly different from that before the intervention. This result is similar to that of a previous study, which reported improved smoothness of motor function after robot-assisted therapy[15)]. The InMotion robot in this study has a back-drivable impedance-controlled system that allows for almost frictionless smoothness. Therefore, repetitive task training through robot-assisted therapy can help improve the smoothness of patients' motor function. In particular, Rohrer et al. reported that the improved smoothness of motor function resulted in more natural recovery rather than training of learning[16)]. On the other hand, the reach error of the point to point

Table 1. General characteristics of the subjects

Characteristics		N	%
Gender	Male	13	86.67
	Female	2	13.33
Age	40–49	8	53.33
	50–59	3	20.00
	60 and above	4	26.67
Cause	Hemorrhage	4	26.67
	Infarction	11	73.33
Affected side	Right	8	53.33
	Left	7	46.67
Time since stroke (months)	0–6	10	66.67
	7 and above	5	33.33

Table 2. Comparison of scores for upper limb motion from before and after the intervention

		Before	After
Point to point	Smoothness[1]	0.45±0.07	0.53±0.05***
	Reach error[2]	0.03±0.04	0.01±0.00*
Circle	Circle size[3]	0.02±0.00	0.02±0.00***
	Independence[4]	0.75±0.12	0.81±0.09***
Playback static	Hold deviation[5]	0.06±0.02	0.04±0.02***
Round dynamic	Displacement[6]	0.13±0.01	0.12±0.02

*$p<0.05$; ***$p<0.001$
[1]Ratio of mean velocity/max velocity (optimal score ~0.53). [2]Accuracy of reaching the middle of the target (perfect score=0). [3]Measured area of circle (the higher the score, the better). [4]Measured ratio between the x and y axes (max score=1). [5]Measured displacement from center point (optimal score=0). [6]Measured average distance to target with resistance (max score=0.14 m)

Table 3. Comparison of the changes in FMA and MBI between before and after the intervention

	Before	After
Fugl-Meyer Assessment (FMA)	39.33±12.68	44.13±12.86***
Modified Barthel Index (MBI)	63.67±18.02	68.13±18.11***

***$p<0.001$

test showed a reduction after the intervention, but there was no significant difference from that before the intervention[15].

The circle test is an indicator of the shoulder and elbow active range of motion. The circle size and independence value of the circle test were significantly different compared with those to that before the intervention. This result is similar to that of a previous study and indicates that a possible increase in the movement range and more accurate movement of the shoulder and elbow[17, 18].

There are some thought about motor learning studies. These studies reported that the point to point test was related to the retention task and that the circle test was related to the transfer task (generalization of skill)[19]. These values of the kinematic evaluation will help clinicians understand the information pertaining to patients' motor recovery. Therefore, clinicians should carefully consider this information.

The effect of the measured value of the hold deviation and displacement on the upper limb function after robot therapy has not been reported[19]. All the hold deviations and displacements showed a decrease after the intervention, but only the hold deviation showed a statistically significant difference between before and after the intervention. This means that the paretic hand improved or maintained its ability to hold its position against the provided robot power. On the other hand, the displacement overcoming the resistance movement did not improve.

The FMA and MBI values showed significant improvement. These findings support the results of previous studies on the effects of robot-assisted therapy. On the other hand, there is no a consistent conclusion that robot-assisted therapy has an effect on the activities of daily living[9, 10, 14, 15]. In fact, it is believed that the activities of daily living are promoted by the improvement in the learning motor skills because the MBI measures a common disorder of daily living and not arm function.

The limitations of this study were the small sample and the lack of a control group. Therefore, the results should be interpreted carefully. On the other hand, this study is a worthy pilot study because movement analysis was performed through an evaluation of the affected factors. These kinematic factors can provide good information when analyzing the upper limb function of stroke patients in robot-assisted therapy. Nevertheless, further research on technology-based kinematic information will be necessary.

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