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Review Article

Is robot-assisted therapy effective in upper extremity recovery in early stage stroke? —a systematic literature review

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Abstract. [Purpose] The aim of this study was to systematically investigate the effects of robot-assisted therapy on the upper extremity in acute and subacute stroke patients. [Subjects and Methods] The papers retrieved were evaluated based on the following inclusion criteria: 1) design: randomized controlled trials; 2) population: stroke patients 3) intervention: robot-assisted therapy; and 4) year of publication: May 2012 to April 2016. Databased searched were: EMBASE, PubMed and COCHRAN databases. The Physiotherapy Evidence Database (PEDro) scale was used to assess the methodological quality of the included studies. [Results] Of the 637 articles searched, six studies were included in this systematic review. The PEDro scores range from 7 to 9 points. [Conclusion] This review confirmed that the robot-assisted therapy with three-dimensional movement and a high degree of freedom had positive effects on the recovery of upper extremity motor function in patients with early-stage stroke. We think that the robot-assisted therapy could be used to improve upper extremity function for early stage stroke patients in clinical setting.
Key words: Stroke, Robot, Upper extremity

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INTRODUCTION

Impairment of upper extremity motor function is a common complication after stroke, and it occurs in approximately 85% of early stage patients[1)]. In particular, permanent impairment of upper extremity motor function was reported in more than 50% of stroke survivors[2)] and most recovery for motor and functional movement in stroke occurs in the first 3 months after the onset of stroke[3)]. Thus, active therapeutic intervention for recovery of motor function in early stages of stroke is essential[4, 5)]. According to a previous study, repetitive therapeutic program induces rearrangement of the cerebral cortex and neuroplasticity, which contribute to recovery of functional movements[6–8)]. Thus, in stoke rehabilitation, physical and occupational therapists provide manipulation and therapeutic exercises consisting of repetitive training. However, it is difficult to control the quantity of the appropriate treatment only by the subjective judgment of the therapists.

In recent years, robotic device has been used as a therapeutic intervention to improve functional movement of stroke patients[9)]. The use of robotic device in stroke rehabilitation minimizes the physical burden of therapists, and not only enables repetitive therapy with high intensity but also provides diversity in the patterns of therapy using only a simple manipulation. With these features, robot-assisted therapy is possible to provide a quantitative and objective treatment to the patients[10)]. Furthermore, robot-assisted therapy is more effective in providing motivation and an active exercise than traditional therapy[9, 10)]. Therapeutic robots currently are being actively used in stroke rehabilitation[11)], especially as an effective intervention for

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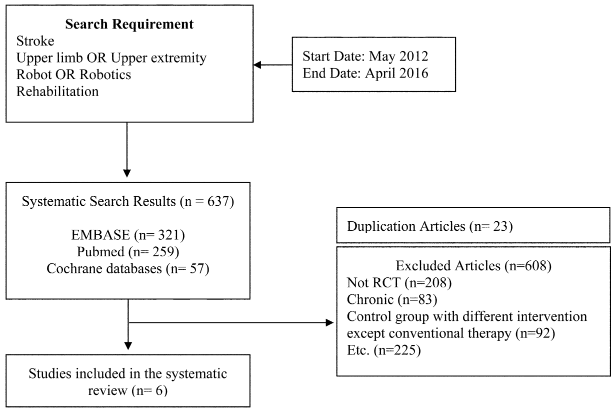

Fig. 1. Flow diagram of selection process

enhancing upper extremity function[12]. This way, current technical advantages not only provide safety to stroke patients, but also are leading the development of robot-assisted rehabilitation for intensive rehabilitation[10]. Because a large portion of the recovery in stroke occurs in the acute and subacute stage, robot-assisted therapy is being actively performed in acute- and subacute-stage patients[13]. However, the effects of robot-assisted rehabilitation therapy for upper extremity are analyzed differently according to the type of robots. Therefore, the aim of this study was to systematically investigate the effects of robot-assisted rehabilitation on the upper extremity in patients with acute and subacute stroke.

SUBJECTS AND METHODS

We searched journal articles published in international journals from May 2012 to April 2016 via the EMBASE, PubMed, and COCHRAN databases. The search formula was “Stroke AND (Upper limb OR Upper extremity) AND (Robot OR Robotics) AND Rehabilitation.” Only journal articles printed in English were included in this study, and the articles were reviewed by physical therapists specializing stroke with more than 5 years of work experience. Based on the search method of this study, 321 articles were searched in EMBASE, 259 articles in Pubmed and 57 articles in COCHRAN databases, for 637 articles in total. The 637 articles identified in the initial search were evaluated based on the following inclusion criteria: (1) adult (20 years or above) patients with stroke; (2) early stage (acute, subacute) stroke patients within 3 months of onset; (3) randomized controlled trails; (4) analyzed by tools for upper extremity functional assessment. Articles reporting studies targeting chronic stroke patients, pilot studies, literature analyses, reviews, studies combining robot-assisted therapy and special therapy in the intervention method, studies comparing effects of different types of robots, and studies using robots for purposes other than the intervention method were excluded. Of the 637 articles searched, there were 83 studies targeting chronic stroke patients, 208 studies that were not randomized controlled trails, 92 articles combining robot-assisted therapy with therapies other than conventional therapy, and an additional 225 excluded articles. In addition, there were 23 overlapping journal articles from online search engines, and these were also excluded. Finally, 6 journal articles were selected and analyzed in this study (Fig. 1). The selected papers were analyzed with regard to the methodological quality using the Physiotherapy Evidence Database (PEDro) scale. After a primary evaluation by 3 evaluators, cross-evaluation was performed, and the final decision was reached after discussion in case of a difference in opinion. The articles were categorized as “high quality” if the PEDro scale was 4 or higher, and as “low quality” if the scale was 3 or lower[7].

RESULTS

A quality evaluation of the 6 journal articles finally selected was performed using the PEDro scale. Scores ranged from 7 to 10, so the quality of the articles was high, with an average score of 7.66 (Table 1). There was one study comparing robot-assisted therapy and conventional therapy[14], and the remaining 5 studies combined robot-assisted therapy with general or conventional therapies as the intervention method[15–19]. The intervention time ranged from 30 to 180 minutes per day, and the time allotted for upper extremity robot-assisted therapy was 30–40 minutes. Therapy was performed 3–7 days per week (Table 2). The subjects enrolled in the 6 selected studies were older adults, with an average age of 66 years, and there were 278 early stage (acute and subacute) patients in total, within three months after the onset of stroke. The characteristics of rehabilitation robots used in the selected studies are described in Table 3. The robots used in the studies were categorized by their applied body and exercise motion.

Table 1. Methodological quality assessment of the study (1: yes, 0: no)

	Takahashi et al. (2016)	Prange et al. (2015)	Masiero et al. (2014)	Sale et al. (2014a)	Hesse et al. (2014)	Sale et al. (2014b)
Randomized allocation	1	1	1	1	1	1
Concealed allocation	1	1	1	1	0	1
Baseline comparability	1	1	1	1	1	1
Subjects blinded	1	1	0	0	1	0
Therapists blinded	0	0	0	0	0	0
Assessor blinded	1	1	0	1	0	0
Data for at least 1 outcome from >85% of subjects	1	1	1	1	1	1
No missing data or if missing, intention-to-treat analysis	1	1	1	1	1	1
Between groups analysis	1	1	1	1	1	1
Point estimates and variability	1	1	1	0	1	1
Total score (/10)	9	9	7	7	7	7

Table 2. Characteristics of the included primary studies

Authors (year)	Frequency of intervention	Robot device	Participants: Number (E/C)	Participants: Age (years)	Participants: Time from stroke (days)	Intervention time (E vs. C)	Outcome measure	Conclusion
Takahashi et al. (2016)	80 min/day 7 day/wk 6 wk	ReoGo	30/30	20–80	28–56	RT (40 min) + TR (40 min) vs. self guided therapy (40 min)+ TR (40 min)	F-M, WMF MAL	RT may improve upper extremity recovery
Prange et al. (2015)	30 min/day 3 day/wk 6 wk	Armeo Boom Volketswil	35/33	E: 60.3 C: 58.0	7–84	RT (30 min) vs. TR (30 min)	F-M, VAS	RT is as effective as conventional therapy
Masiero et al. (2014)	120 min/day 5 day/wk 7 months	NeReBot	14/16	E: 65.6 C: 66.8	With-in 15	RT (40 min) + TR (80 min) vs. TR (120 min)	F-M, FIM, MAS, B-B	RT can be used in partial substitution of conventional therapy
Sale et al. (2014a)	225 min/day 5 day/wk 6 wk	MIT-MANUS	26/24	E: 67.7 C: 67.7	30 ± 7	RT (45 min) + TR (180 min) vs. TR (45 min) + TR (180 min)	F-M, MAS pROM, MI	RT can contribute to increasing motor recovery
Hesse et al. (2014)	60 min/day 5 day/wk 4 wk	Bi-Manu-Track Reha-Digit Reha-Slide Reha-Slide duo	25/25	E: 71.4 C: 69.7	56	RT (30 min) + individual arm therapy (30 min) vs. individual arm therapy (60 min)	F-M, B-B, MAS	RT is clinically equally effective to individual therapy
Sale et al. (2014b)	40 min/day 4–5 day/wk 4–5 wk	Amadeo Robotic System	11/9	E: 67.0 C: 72.5	30 ± 7	Individually ex (180 min) + RT (40 min) vs. Individually ex (180 min) + TR (40 min)	F-M, B-B, MAS, FIM	RT can significant decrease in motor impairment

E: experimental group; C: control group; RT: robot-assisted therapy; TR: traditional rehabilitation; F-M: Fugl-Meyer assessment; FIM: motor functional independence measure; FAT: frenchay arm test; MRC: medical research council; MAS: modified ashworth scale; B-B: box and block test; pROM: passive range of motion; MI: motricity index; SULCS: the stroke upper limb capacity scale; IMI: intrinsic motivation inventory; VAS: visual analogue scale; WMF: wolf motor function test; MAL: motor activity log

DISCUSSION

Recovery of motor impairment after stroke is divided into neurological and functional recovery. While neurological recovery can differ by lesion or location of the stroke, the degree of functional recovery depends on motivation for rehabilitation and the external environmental factors[20]. According to the study reported by Duncan et al.[21] because the recovery of motor function in stroke patients occurs rapidly within the first few weeks of onset, stroke rehabilitation in the early stage has an important role in recovery of motor function. The application of robotics to upper extremity rehabilitation in stroke

Table 3. Robot characteristics of the included primary studies

Authors (year)	Robot device	Applied body	Exercise motion	Direction	DOF
Takahashi et al. (2016)	ReoGo	Shoulder Elbow Wrist	†All movement of shoulder, elbow and wrist	‡3D (X,Y,Z)	6
Prange et al. (2015)	Armeo Boom Volketswil	Shoulder Elbow	†All movement of shoulder elbow flexion and extension	‡3D (X,Y,Z)	5
Masiero et al. (2014)	NeReBot	Shoulder	†All movement of shoulder	‡3D (X,Y,Z)	3
Sale et al. (2014a)	MIT-MANUS	Shoulder Elbow	Internal rotation, External rotation Flexion, Extension	Horizontal plane Sagittal plane	2
Hesse et al. (2014)	Bi-Manu-Track	Forearm Wrist	Supination, Pronation Flexion, Extension	Horizontal plane Sagittal plane	2
	Reha-Digit	Finger	Flexion, Extension	Sagittal plane	1
	Reha-Slide	Shoulder Elbow	Flexion, Extension Flexion, Extension	Horizontal plane Sagittal plane	2
	Reha-Slide duo	Shoulder Elbow Finger	Flexion, Extension Flexion, Extension Flexion, Extension	Horizontal plane Sagittal plane	3
Sale et al. (2014b)	Amadeo Robotic System	Finger	†All movement of finger	‡3D (X, Y ,Z)	5

DOF: degree of freedom
†All movement: flexion, extension, abduction, adduction, internal rotation and external rotation
‡3D (X, Y, Z): Horizontal, Sagittal and Coronal plane

rehabilitation is increasing, and a variety of associated studies is being carried out[17, 18]. According to the previous study[22], upper extremity robot-assisted therapy improves not only upper extremity function, but also activities of daily living in stroke. However, another study reported that robot-assisted therapy does not affect the improvement of activities of daily living[19]. In addition, one study demonstrated that robot-assisted therapy showed better result than conventional therapies in stroke patients[23]. Like this, the effectiveness of robot-assisted therapy is still controversial. In particular, unclear evidence for the applied robotics and inconsistency of the onset period of subjects led to difficulty in interpreting the effects of robot-assisted therapy[9]. Therefore, this study systematically reviewed robot-assisted therapy in the early stage of stroke patients within 3 months after onset.

Understanding the purpose of the selected rehabilitation robots is important to understand therapeutic effects of robot-assisted therapy on upper extremity[15, 16]. Robot applied in the distal part of upper extremity was effectiveness in reducing spasticity[17]. Robot applied in the proximal part robot of upper extremity was effectiveness in improvement of motor function and increase in range of motion[15–18, 24]. Moreover, whole upper extremity robots showed improved motor function of the proximal upper extremity and activities of daily living and recovery of upper extremity function[19]. According to our review, robots with high degree of freedom are more effective in recovery of upper extremity function than robots with one-dimensional movement and a low degree of freedom. In particular, rehabilitation robots that are capable of goal-directed training, in which a patient actively participates in upper extremity rehabilitation while watching a monitor, showed even more positive effects than did other rehabilitation robots.

To fully understand the therapeutic effects of upper extremity rehabilitation robots, it is also important to understand the application period (intensity) of robot-assisted therapy. In the 6 selected articles in this review, the treatment time of the experimental group and the control group were not different. The experimental group performed robot-assisted therapy and conventional therapy, and the control group performed two times of conventional therapy. Interestingly, robot-assisted therapy showed similar treatment effectiveness compared with conventional therapy.

This study has some limitations. First, there was only one study comparing the effects of robot-assisted therapy and conventional therapy, and this caused a limitation in confirming the independent effect of robot-assisted therapy. Second, it was hard to generalize results from this study to all patients with early stage strokes, since the number of subjects was quite small in most of the selected studies.

This review confirmed that the robot-assisted therapy with three-dimensional movement and a high degree of freedom had positive effects on the recovery of upper extremity motor function in patients with early-stage stroke. Therefore, we think that the robot-assisted therapy could be used to improve upper extremity function for early stage stroke patients in clinical setting.

Conflicts of interest

The authors have no conflicts of interest to declare.

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