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The Impact of Robot-Assisted Training on Upper Limb Function in Elderly Stroke Patients

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Abstract: *Objective:* To investigate the effects of robot-assisted training on upper limb function in elderly stroke patients. *Methods:* Seventy elderly stroke patients treated in the Rehabilitation Medicine Department of Jiangsu Provincial Organ Hospital from January 2023 to December 2023 were randomly divided into an intervention group (n = 35) and a control group (n = 35). In addition to conventional rehabilitation and nursing care, both groups received 40 minutes of daily upper limb training. The control group underwent entirely manual training, whereas the intervention group received a combination of 20 minutes of manual and 20 minutes of robot-assisted training. All participants completed this protocol five times weekly for four weeks, with assessments of upper limb motor function and activities of daily living (ADL) conducted pre- and post-intervention. *Results:* After treatment, both groups showed significant increases in Fugl-Meyer Assessment (FMA-UE) and Barthel Index (BI) scores compared to before treatment ($p < 0.01$). The intervention group had higher FMA-UE scores than the control group ($p < 0.05$), while there was no significant difference in BI scores between the two groups after treatment ($p > 0.05$). *Conclusion:* Robot-assisted training can improve upper limb motor function and enhance ADL capabilities in elderly stroke patients.

Keywords: Stroke; Robot-assisted training; Upper limb function

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1. Introduction

Stroke is one of the leading causes of death and disability worldwide, characterized by high incidence, high disability rates, high recurrence rates, and substantial economic burdens, posing a severe threat to human life and health [1]. Research has found that 6 months after stroke onset, 65% of patients still experience upper limb dysfunction [2]. Robot-assisted training is an emerging rehabilitation technology that has gradually gained popularity both domestically and internationally in recent years and has been increasingly applied in clinical practice. Robot-assisted training can reduce reliance on therapist manpower and provide continuous, stable, and high-intensity training [3,4]. Therefore, this study conducted robot-assisted training on elderly stroke patients and employed relevant scales to evaluate the therapeutic effects and assess the impact of this method on the upper limb function of stroke patients.

2. Research subjects and methods

2.1. Research subjects

This study took elderly stroke patients who were diagnosed and treated in the Rehabilitation Medicine Department of Jiangsu Provincial Official Hospital from January 2023 to December 2023 as the research subjects. Based on clinical manifestations and cranial imaging examinations, all patients had met the diagnostic criteria for stroke established at the Fourth National Cerebrovascular Disease Conference [5].

2.1.1. Inclusion criteria

(1) Aged 60 years or older
(2) Diagnosed with first-time ischemic or hemorrhagic stroke, with a disease duration exceeding one month
(3) Clear consciousness, without severe cognitive dysfunction, and able to cooperate in completing assessments and treatments

2.1.2. Exclusion criteria

(1) Previous treatment with botulinum toxin injections
(2) Bilateral cerebrovascular lesions
(3) Severe neuropsychological disorders (e.g., significant aphasia, visual dysfunction, severe psychiatric symptoms)
(4) Movement limitations due to bone and joint diseases
(5) Severe osteoporosis

Ethical approval was obtained from the hospital's ethics committee, and written informed consent was acquired from all participants.

2.2. Research methods

2.2.1. Grouping

A single-blind, randomized, controlled clinical study was conducted, with 70 patients randomly (by random number) divided into an intervention group (robot training group) and a control group (conventional treatment group), with a total observation period of 4 weeks. There were no significant differences between the two groups in terms of gender, age, disease duration, stroke type, and hemiplegic side ($p > 0.05$), as shown in **Table 1**.

Table 1. Comparison of baseline data between the two groups of patients

Group	Gender (M/F, n)	Age (years)	Disease duration (months)	Hemiplegic side (L/R, n)	Stroke type (Infarction/ Hemorrhage, n)
Intervention (n = 35)	18/17	70.14 ± 5.33	6.63 ± 5.62	15/20	21/14
Control (n = 35)	16/19	68.74 ± 5.79	6.91 ± 5.11	15/20	18/17

2.2.2. Intervention

All patients received routine rehabilitation nursing and body position management to minimize noxious stimuli, including pressure sores, pain, urinary retention, urinary tract infections, constipation, venous thrombosis, fractures, temperature drops, emotional disturbances, sleep disorders, and other factors that may exacerbate or induce spasticity. Routine rehabilitation treatments included:

(1) Positional transfer training
(2) Occupational therapy, such as rolling cylinders and using inclined sanding boards
(3) Activities of daily living training
(4) Other modalities: hand-cranked bicycles, physical therapy (electromyographic biofeedback, wax therapy, electrical stimulation), etc.

2.2.3. Grouping

(1) Control group

Patients in the control group received one-on-one upper limb manual training using the Bobath technique, conducted by a rehabilitation therapist. The treatment was administered five times a week, with each session lasting 40 minutes, over a period of four weeks.

(2) Intervention group

Patients in the intervention group underwent one-on-one upper limb manual training using the Bobath technique for 20 minutes, followed by robot-assisted upper limb training for another 20 minutes. This regimen was also administered five times a week for four weeks.

Upper limb training was conducted using the BURT upper limb rehabilitation robot (EM-BURT02, Estun Medical Technology Co., Ltd., Nanjing). The robot allows for adjustments in training difficulty, assistance time, and weight reduction support to train various joints of the upper limb. The game settings are highly relevant to the motor demands of daily life, and visual feedback was provided through a virtual reality scenario displayed on a monitor. The training modes include active, assisted, resistive, and passive modes, which were adjusted based on the patient's motor function. Games that align with normal motor patterns were selected for training.

The specific training methods are as follows

(1) For patients with hemiplegic upper limbs at Brunnstrom Stage IV, the active motion mode was selected. Patients move their upper limbs to manipulate the robotic arm in a three-dimensional space, and a certain level of resistance can be set for active resistive training of the hemiplegic upper limb.
(2) For patients with the affected upper limb at stage III of the Brunnstrom classification for hemiplegia, the assisted exercise mode was selected. A certain amount of auxiliary force was provided according to the condition of the patient's limb to help the patient achieve maximum full-space range of motion of the affected upper limb.
(3) For patients with the affected upper limb at stage II of the Brunnstrom classification for hemiplegia, the passive exercise mode was selected, and the robot should provide guiding force to drive the affected upper limb for passive training.

2.3. Efficacy evaluation

An experienced therapist not involved in the treatment will evaluate all patients before treatment and after 4 weeks of treatment using the following indicators.

2.3.1. Fugl-Meyer assessment for upper extremity (FMA-UE)

Motor function of the affected upper limb was assessed using the Fugl-Meyer Assessment for the Upper Extremity (FMA-UE). This 33-item scale has a maximum score of 66, with higher scores denoting superior motor function.

2.3.2. Barthel index (BI)

Patient independence in performing activities of daily living (ADLs) was assessed using the Barthel Index (BI). This 100-point scale was comprised with 10 sub-items, where a higher total score reflects a greater level of functional independence.

2.4. Statistical analysis

All data was processed using SPSS 21.0 software. For continuous data, if each group satisfies normality and the variances between the two groups were equal, the statistical description was represented by the mean ± standard deviation, and the *t*-test was used for inter-group comparison; otherwise, the median and interquartile range was considered for statistical description, and the rank sum test will be used for inter-group comparison.

All statistical tests were two-tailed, and a *p*-value < 0.05 has indicated a statistically significant difference.

3. Results

3.1. Comparison of FMA-UE scores

Prior to treatment, no significant difference in FMA-UE scores was observed between the two groups ($p > 0.05$). Following the 4-week intervention, both groups exhibited a significant increase in scores compared to their baselines ($p < 0.01$). Notably, the robot-assisted training group achieved a significantly higher FMA-UE score than the conventional treatment group at the end of the treatment ($p < 0.05$). See **Table 2**.

Table 2. Comparison of FMA-UE scores between two groups before and after treatment

Group	Before treatment	After treatment	Within-group	
			t-value	*p*-value
Intervention group (n = 35)	26.83 ± 8.20	36.71 ± 7.27	-5.335	< 0.01
Control group (n = 35)	25.66 ± 7.62	32.94 ± 7.23	-4.104	< 0.01
t-value (Between-group)	-0.619	-2.176		
p-value (Between-group)	0.538	0.033		

3.2. Comparison of BI scores

Before treatment, the two groups had comparable BI scores ($p > 0.05$). Following the 4-week intervention, both groups demonstrated significant improvements in their BI scores from baseline ($p < 0.01$). However, no significant difference was observed between the robot-assisted training group and the conventional treatment group at this stage ($p > 0.05$). See **Table 3**.

Table 3. Comparison of BI scores between two groups before and after treatment

Group	Before treatment	After treatment	*t*-value	*p*-value
Intervention (n = 35)	40.43 ± 9.80	56.00 ± 8.89	-6.959	< 0.001
Control (n = 35)	41.29 ± 11.59	56.57 ± 11.74	-5.481	< 0.001
Between-group *t*-value	0.334	0.229		
Between-group *p*-value	0.739	0.819		

4. Discussion

Motor dysfunction after stroke is the most common complication of stroke and a significant factor affecting patients' ability to live independently [6,7]. Given that the upper limbs have a larger projection area in the cerebral cortex, perform more delicate functions, and have more complex motor functions than the lower limbs [8], their recovery is much more challenging. Currently, clinical approaches to improve upper limb function in stroke patients include exercise therapy, occupational therapy, physical factor therapy, and traditional medical therapies. However, satisfactory outcomes have not been achieved, and there is a continuous need to explore more effective treatment methods for patients.

Robot-assisted training is an emerging rehabilitation treatment technology that has been gradually gaining popularity domestically and internationally in recent years. It can reduce reliance on therapist manpower and provide continuous, stable, high-intensity training with greater repeatability [3,4]. Additionally, robot-assisted training incorporates game elements, enhancing treatment enjoyment and encouraging patient motivation and active participation. A meta-analysis included 19 randomized controlled trials, and the statistical results showed that robot-assisted training is effective for improving upper limb motor function in stroke patients [9]. This study of 70 randomized patients revealed that after 4 weeks, both robot-assisted and conventional training groups showed significant improvements in FMA-UE scores. However, the robot-assisted group demonstrated superior upper limb recovery compared to the control group, aligning with previous findings.

Zhang Haiyan et al. conducted a 4-week upper limb rehabilitation robot-assisted training on 20 patients and found that the modified Barthel score in the robot group was superior to that in the conventional group [10]. Patel et al. combined virtual reality technology with upper limb rehabilitation robots and found that it could better improve patients' ability to perform activities of daily living [11]. Another study discovered that the efficacy of upper limb robot-assisted therapy in improving activities of daily living was similar to that of conventional therapy [12]. This study found that Barthel scores significantly increased in both groups after treatment, but there was no significant difference in BI scores between the robot-assisted training group and the conventional therapy group. This inconsistency may be related to factors such as patient age, disease duration, condition severity, treatment duration, robot type, and the combination of robot training with other modalities.

5. Conclusion

In summary, upper limb robot-assisted training provides significant improvements in motor function and activities of daily living for elderly stroke patients. However, this study has some limitations: the short-term (4-week) study requires long-term follow-up, the small sample size necessitates multi-center large-sample studies, and the lack of exploration into mechanisms requires further investigation.

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Disclosure statement

The authors declare no conflict of interest.

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