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Research on the Rehabilitation Effect of Upper Limb Rehabilitation Robot Combined with Isokinetic Muscle Strength Training for Hemiplegic Patients in the Recovery Phase of Stroke

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Abstract: *Objective*: To explore the rehabilitation effect of upper limb rehabilitation robots combined with isokinetic muscle strength training on hemiplegic patients in the recovery phase of stroke, and to provide a more effective intervention plan for clinical rehabilitation treatment. *Methods*: One hundred and sixty type 2 stroke patients with hemiplegia in recovery phase treated at Jintan First People's Hospital from May 2020 to May 2025 were selected as the research subjects. They were divided into a control group (n=80) and an observation group (n=80) using a random number table method. The control group received isokinetic muscle strength training, while the observation group received additional upper limb rehabilitation robot-assisted intervention based on the control group's treatment. The general information (age, gender, course of disease), Brunnstrum staging, Barthel index, FMA score, and facial expression pain score were compared between the two groups. *Results*: After treatment, the indicators of both groups improved compared to before treatment. The observation group showed significant advantages in improving various indicators. In terms of Brunnstrum staging, the number of patients in stage IV and above was significantly higher than that in the control group; in terms of the Barthel index, the increase was more significant than that of the control group ($P = 0.000 < 0.001$). In terms of the FMA score, the increase was more pronounced ($P = 0.000 < 0.001$); and in terms of facial expression pain assessment, the decrease was more evident ($P = 0.000 < 0.01$). *Conclusion*: The combination of upper limb rehabilitation robots and isokinetic muscle strength training can significantly improve the recovery of limb function and activities of daily living in hemiplegic patients during the recovery phase of stroke, and reduce pain. Compared with simple isokinetic muscle strength training, the rehabilitation effect is better, and it is worthy of clinical application.

Keywords: Upper limbs; Rehabilitation robots; Isokinetic muscle strength training; Stroke; Hemiplegia; Rehabilitation

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1. Introduction

Stroke is a common cerebrovascular disease that harms human life and health, with high incidence, disability, and fatality rates [1]. Among stroke patients, approximately 50% to 70% experience limb dysfunction, especially hemiplegia, which significantly impacts their survival and quality of life. Upper limb function plays a crucial role in human daily activities. However, recovery from upper limb hemiplegia caused by stroke is often difficult, posing a heavy burden on patients and their families. Various rehabilitation therapies, such as physical therapy, occupational therapy, and traditional rehabilitation, can be employed for stroke patients in the recovery phase. Isokinetic muscle strength training is an advanced rehabilitation method that provides matched resistance based on the patient's muscle strength, effectively improving muscle strength and joint mobility [2]. In recent years, with the rapid development of robotics, upper limb rehabilitation robots have gradually been widely used in stroke recovery. Through precise motion control and feedback mechanisms, these robots provide repetitive and standardized exercise training to patients, promoting the recovery of neurological function. However, there is relatively limited research on the role and effectiveness of upper limb rehabilitation robots and isokinetic muscle strength training in stroke recovery. Therefore, this study aims to explore the combined effect of these two approaches on the rehabilitation of stroke patients, providing a more scientific and effective method for clinical stroke treatment.

2. Materials and methods

2.1. General information

This article presents a prospective study conducted at the Jintan First People's Hospital in Changzhou City. The study included 160 patients with hemiplegia in the recovery phase of type 2 stroke, treated between May 2020 and May 2025. The patients were randomly divided into a control group (n=80) and an observation group (n=80) using a random number table.

2.1.1. Inclusion criteria

(1) Meet the diagnostic criteria for stroke in the "Chinese Guidelines for the Diagnosis and Treatment of Acute Ischemic Stroke 2023" or "Chinese Guidelines for the Diagnosis and Treatment of Cerebral Hemorrhage 2019".
(2) In the recovery phase of stroke (1-6 months after onset).
(3) Unilateral upper limb hemiplegia.
(4) Patients and their families provided informed consent and signed the informed consent form.

2.1.2. Exclusion criteria

(1) Combined with severe dysfunction of important organs such as heart, lungs, liver, and kidneys.
(2) Presence of severe cognitive impairment or mental illness, unable to cooperate with rehabilitation training.
(3) Presence of severe organic lesions such as fractures or joint dislocations in the affected upper limb.
(4) Withdrawal from the study midway or failure to complete rehabilitation training as prescribed.

2.2. Methods

Both groups of patients received basic treatment, including medication (such as antiplatelet aggregation, lipid regulation, blood pressure, and blood sugar control), routine nursing, and health education.

The control group received isotonic muscle training. An isotonic muscle training device was used to train the main joints of the affected upper limb, such as shoulder joint flexion/extension, abduction/adduction, and elbow joint flexion/extension. The movement speed was set at 60°/s and gradually increased to 180°/s based on the situation[3]. Each movement was performed in 3 sets, with 10–15 repetitions per set. The training intensity was adjusted to a level tolerable for the patient. Each training session lasted approximately 30 minutes, conducted 5 times per week for 8 consecutive weeks.

The observation group received additional upper limb rehabilitation robot-assisted intervention based on the control group's treatment. Using an upper limb rehabilitation robot, patients were seated comfortably with their affected upper limbs fixed to the robotic arm. Robot parameters were adjusted according to the patient's limb size and motor ability. Training modes included passive, active-assisted, and active movements, gradually transitioning based on the patient's recovery [4]. During training, the robot continuously monitored the patient's movements through sensors and provided appropriate feedback and guidance. Each training session lasted approximately 30 minutes, conducted 5 times per week for 8 consecutive weeks.

2.3. Observation indicators

(1) General information: Age, gender, and duration of illness.

(2) Brunnstrum staging: The Brunnstrum assessment method is used to stage the motor function of the affected upper limb of the patient, which is divided into stages I-VI. Stage I represents flaccidity, and Stage VI represents normal function. The higher the stage, the better the motor function recovery. Evaluations were conducted before treatment and after 8 weeks of treatment.

(3) Barthel Index: It is used to evaluate patients' activities of daily living, including 10 items such as eating, bathing, dressing, and toileting. The total score is 100, and a higher score indicates stronger daily living activities. Evaluations were conducted before treatment and after 8 weeks of treatment.

(4) FMA score: The Fugl-Meyer Assessment Scale is used to evaluate patients' limb motor function. The total score for the upper limbs is 66, and a higher score indicates better limb motor function. Evaluations were conducted before treatment and after 8 weeks of treatment.

(5) Facial expression pain score: The Facial Expression Pain Scale (FPS-R) is used, which assesses patients' pain levels through six different cartoon images of facial expressions (from smiling to crying). A score of 0 indicates no pain, and a score of 10 indicates the most severe pain. Evaluations were conducted before treatment and after 8 weeks of treatment.

2.4. Statistical methods

Data were analyzed using SPSS 27.0 statistical software. Measurement data conforming to a normal distribution are represented by ($\bar{x} \pm s$), and paired t-tests were used for intragroup comparisons; count data are represented by [n(%)], and chi-square tests were used for intergroup comparisons. A P-value < 0.05 was considered statistically significant.

3. Results

3.1. Comparison of general information between the two groups of patients

There were no statistically significant differences in age, gender, or duration of illness between the two groups of patients ($P > 0.05$), as shown in **Table 1**.

Table 1. Comparison of general information between the two groups of patients

Group	Cases (n)	Age (Mean±SD, years)	Gender (Male/Female)	Disease duration (months)
Control group	80	56.21 ± 4.38	48/32	7.18 ± 0.31
Observation group	80	57.25 ± 4.39	46/34	7.11 ± 0.29
χ^2/*t*-value		1.500	0.103	1.475
p-value		0.136	0.748	0.142

3.2. Comparison of Brunnstrum staging between the two groups

After treatment, the number of patients in the observation group with Brunnstrum staging of IV and above was significantly higher than that in the control group, as shown in **Table 2**.

Table 2. Comparison of Brunnstrum staging between the two groups

Group	Grade	Brunnstrom stage					
		Before treatment			After treatment		
		Upper limb	Hand	Lower limb	Upper limb	Hand	Lower limb
Control group (n=80)	I	21	39	7	0	8	0
	II	24	13	17	20	33	4
	III	16	13	33	34	21	36
	IV	15	8	16	16	9	23
	V	3	4	7	9	6	17
	VI	1	3	0	1	3	0
Observation group (n=80)	I	48	59	29	0	1	0
	II	16	10	27	2	14	0
	III	14	7	20	33	32	10
	IV	1	4	3	33	22	46
	V	1	0	1	10	10	22
	VI	0	0	0	2	1	2

3.3. Comparison of Barthel Index between the two groups

After treatment, the Barthel Index increased in both groups, but the increase was more significant in the observation group ($P = 0.000 < 0.001$), as shown in **Table 3**.

Table 3. Comparison of Barthel Index between the two groups

Group	Barthel Index	
	Before treatment	After treatment
Control group (n=80)	39.88 ± 20.48	47.56 ± 21.23
Observation group (n=80)	34.13 ± 17.44	74.00 ± 17.46
t-value	1.192	8.603
p-value	0.058	0.000

3.4. Comparison of FMA scores between the two groups

After treatment, the FMA scores increased in both groups, but the increase was more significant in the observation group ($P = 0.000 < 0.001$), as shown in **Table 4**.

Table 4. Comparison of FMA scores between the two groups

Group	FMA score	
	Before treatment	**After treatment**
Control group (n=80)	19.99 ± 17.60	39.26 ± 21.28
Observation group (n=80)	14.68 ± 22.06	78.16 ± 13.81
t-value	1.683	13.715
p-value	0.094	0.000

3.5. Comparison of facial expression pain scores

After treatment, the facial expression pain scores decreased in both groups, but the decrease was more significant in the observation group ($P = 0.000 < 0.01$), as shown in **Table 5**.

Table 5. Comparison of facial expression pain scores between the two groups

Group	Facial pain score (FPS)	
	Before treatment	**After treatment**
Control group (n=80)	2.88 ± 0.80	1.63 ± 0.80
Observation group (n=80)	3.04 ± 0.83	1.29 ± 0.62
t-value	1.241	3.005
p-value	0.216	0.003

4. Discussion

Stroke is a disease caused by the sudden rupture or blockage of blood vessels in the brain, which prevents blood from flowing into the brain and results in damage to brain tissue [5]. In recent years, advancements in medical technology have significantly improved the success rate of acute stroke treatment. However, a considerable number of patients still experience limb dysfunction, particularly upper limb hemiplegia [6]. This not only severely reduces patients' ability to survive but also imposes a heavy economic and medical burden. Therefore, it is essential to explore effective rehabilitation methods to improve the recovery of upper limb function in patients with hemiplegia during the post-stroke recovery phase.

Isokinetic muscle strength training is a training method that utilizes equipment to apply muscle strength corresponding to a preset speed. Its mechanism is based on muscle physiology, employing muscle contraction exercises at different speeds to activate muscle fibers. This aims to enhance muscle strength and endurance and improve responsiveness to movement commands [7]. However, the current technology focuses primarily on improving muscle strength and joint mobility, without targeted exercise for patients' movement patterns and neurological functions. As a result, it is difficult to effectively correct the movement patterns and neurological control impairments of stroke patients, limiting the improvement of their rehabilitation efficacy. The mechanism of upper limb rehabilitation robots is based on neural plasticity theory and motor learning. By simulating normal upper limb movement patterns, robots can provide repetitive and precise movement training to patients, continuously activating neural circuits in the brain and accelerating the reconstruction and recovery of neurological functions [8]. Additionally, through real-time feedback, robots enable timely adjustments to patients' movement posture and intensity, thereby reinforcing correct movement patterns, suppressing abnormal patterns, and improving motor learning efficiency.

This study shows that the improvement in Brunnstrum staging in the observation group was significantly better than that in the control group after treatment. This is because isokinetic muscle strength training enhances patients' muscle strength and joint mobility, while upper limb rehabilitation robots correct abnormal movement patterns and promote neurological function recovery by simulating normal movement patterns. The combination of these two approaches accelerates the recovery process of patients' limb motor function from different levels. Previous studies have also indicated that combining multiple rehabilitation training methods can more effectively promote the recovery of limb motor function in stroke patients. Regarding daily living abilities, the Barthel index in the observation group showed a greater improvement, suggesting that combined therapy is more beneficial for enhancing patients' activities of daily living. This is because combined therapy not only improves patients' limb motor function but also enhances their movement abilities in real-life scenarios through targeted training, enabling them to better perform daily activities such as dressing and eating [9].

Furthermore, related studies have demonstrated that integrating robot-assisted training with conventional rehabilitation techniques can significantly improve the limb motor abilities of stroke patients [10]. The primary reason is that isokinetic muscle strength training can increase muscle strength in the limbs, providing power for limb movements, while upper limb rehabilitation robots enhance patients' body movement accuracy and coordination through precise movement control and feedback. This is consistent with the findings of this study. Additionally, exercise training has been shown to significantly improve limb pain in stroke patients. This is because the combination of these approaches can promote blood circulation in the limbs, reduce muscle spasms, alleviate joint tension, and ultimately achieve pain relief.

5. Conclusion

In summary, the combination of upper limb rehabilitation robots and isokinetic muscle strength training can effectively improve the rehabilitation outcomes of stroke patients with hemiplegia during the recovery phase. This approach has distinct advantages in improving limb function, enhancing activities of daily living, and reducing pain, making it worthy of further clinical promotion and application. However, larger sample sizes, multicenter studies, and long-term follow-up are still needed to more comprehensively evaluate its rehabilitation effectiveness and application value.

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Disclosure statement

The authors declare no conflict of interest.

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