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Evaluation of Task-Oriented Training Combined with Lower Limb Rehabilitation Robot on Improvement of Motor Function and Ankle Joint Function in Stroke Patients with Hemiplegia

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Abstract: *Objective*: To evaluate the effect of task-oriented training combined with a lower limb rehabilitation robot on improving motor function and ankle joint function in stroke patients with hemiplegia. *Methods*: Sixty-three stroke patients with hemiplegia admitted to our hospital from January 2022 to June 2024 were randomly divided into observation group (32 cases) and control group (31 cases) using the envelope method. The control group received task-oriented training, while the observation group received additional lower limb rehabilitation robot training. The motor function (Fugl-Meyer Assessment of Lower Extremity, FMA-LE) and ankle joint function (Active Dorsiflexion Range of Motion, DF AROM) were compared between the two groups. *Results:* After treatment, the levels of FMA-LE and DF AROM in both groups increased significantly, and the improvement in each index in the observation group was better than that in the control group ($P < 0.05$). *Conclusion*: The combination of task-oriented training and lower limb rehabilitation robot training can more effectively improve the overall motor function of the lower limbs and the active dorsiflexion ability of the ankle joint in stroke patients with hemiplegia.

Keywords: Stroke; Hemiplegia; Task-oriented training; Lower limb rehabilitation robot; Motor function; Ankle joint function

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1. Introduction

Stroke is one of the leading causes of long-term disability among adults, and its high incidence, disability rate, and fatality rate impose a heavy burden globally [1]. In China, as the population ages, the number of patients with hemiplegia after a stroke continues to rise, significantly affecting patients' daily living skills and quality of life, and increasing the pressure on family and social care [2]. Hemiplegic patients often suffer from significant lower limb motor dysfunction, especially ankle joint control disorders, which severely limit walking ability [3].

Although traditional rehabilitation training can improve patients' motor function, it often fails to meet the need for efficient rehabilitation due to issues such as insufficient intensity and imprecise movements. Task-oriented training focuses on targeted functions and encourages patients to actively participate through daily functional tasks. It is increasingly valued in the field of neuro-rehabilitation and can effectively promote the reconstruction of motor functions. Meanwhile, lower limb rehabilitation robots, with their advantages of high-intensity, high-repetition, standardized gait training, and precise control of trajectory and mechanical parameters, offer new possibilities for improving training efficiency [4, 5]. This study intends to combine task-oriented training with lower limb rehabilitation robot training to evaluate its effectiveness in improving the overall lower limb motor function and active ankle joint mobility in stroke patients with hemiplegia. The goal is to provide practical evidence for optimizing clinical rehabilitation strategies. The report is as follows:

2. Materials

2.1. General information

Sixty-three patients with hemiplegia due to stroke, admitted to our hospital from January 2022 to June 2024, were selected. They were randomly divided into observation and control groups using the envelope method, with 32 and 31 patients, respectively. There was no statistically significant difference in basic data between the two groups ($P > 0.05$), as shown in **Table 1**. This study was approved by the hospital ethics committee and complied with the relevant ethical principles of the Helsinki Declaration.

Table 1. Comparison of general information between the two groups ($\bar{x}\pm s$/n)

Characteristics	Observation group (n=32)	Control group (n=31)	t/χ^2	*P*-value
Male/Female	18/14	19/12	0.165	0.685
Age (years)	40-65	43-64	0.053	0.958
	51.15 ± 5.11	51.08 ± 5.41		
Disease Duration (months)	1–6	1–7	1.390	0.170
	2.91 ± 0.46	3.08 ± 0.51		

2.2. Inclusion and exclusion criteria

2.2.1. Inclusion criteria

(1) Aged between 18 and 65.
(2) Meeting the diagnostic criteria for stroke in the Guidelines for the Prevention and Treatment of Cerebrovascular Diseases in China, and confirmed by cranial CT or MRI.
(3) Having clear lower limb motor dysfunction.
(4) In the recovery phase, with a disease duration of 1 to 7 months after onset.
(5) Able to understand and cooperate with simple instructions from the rehabilitation therapist.
(6) The patient or their legal guardian voluntarily participates in this study and signs a written informed consent form.

2.2.2. Exclusion criteria

(1) Severe heart, lung, liver, or kidney failure.

(2) Contraindications for the use of lower limb rehabilitation robots.
(3) Severe contractures, deformities, or unhealed fractures in the affected lower limb joints that significantly affect gait or hinder the wearing of the robot.
(4) Comorbidities such as Parkinson's disease, spinal cord injury, multiple sclerosis, or other central or peripheral nervous system diseases that may cause gait abnormalities.

3. Methods

3.1. Control group

Received a structured, task-oriented training program designed by professional rehabilitation therapists, including:

3.1.1. Muscle strength and joint range of motion training

(1) Bridge exercise in a supine position: Patients were instructed to lie on their back, bend their knees, and place their feet flat on the bed surface. They were then asked to place their hands 5–15cm above their abdomen as a target point. They actively lifted their pelvis off the bed until it touched their hands, maintained this position for 3–5 seconds, and then slowly lowered it. This exercise was repeated 10–15 times per set.
(2) Straight leg raise exercise for the affected lower limb: Patients were instructed to keep their knee straight and lift their lower limb 15cm off the bed surface, maintain this position for 3–5 seconds, and then slowly lower it. This exercise was repeated 10–15 times per set.
(3) Adduction, abduction, and knee flexion control training for the affected lower limb: Patients performed active movements in various directions within a painless range, repeating each direction 10-15 times.

3.1.2. Core control and trunk stability training

(1) Supine position with hands behind the head: Patients simultaneously or alternately lifted their head, shoulders, and lower limbs off the bed surface to strengthen their abdominal and back muscles. They maintained the lifted position for 5–10 seconds and repeated this exercise 5–10 times.
(2) Sitting forward lean and side picking practice: Patients sat on a stable chair while the therapist placed light objects at different distances in front, behind, and on the sides. Patients were instructed to lean forward or laterally to pick up the objects and return them to their original positions, repeating each direction 10 times. This exercise focused on training dynamic trunk balance and control.

3.1.3. Balance and postural transfer training

(1) Sit-to-stand transfer training: Gradually transition from using armrests for support to independently standing up and sitting down without assistance, completing 10–15 transfers each time.
(2) Standing balance training: The patient stands with feet apart, and the therapist guides them to shift their center of gravity forward, backward, left, and right, maintaining each direction for 5–10 seconds. Gradually reduce the support area of both feet, including standing with feet together and assisted single-leg standing.
(3) Perform combined exercises of stepping and shifting the center of gravity in different directions while standing.

3.1.4. Functional gait training

(1) Flat ground walking training: Set a fixed distance, initially using a walking aid or therapist assistance, gradually increasing step length, decreasing step width, and increasing walking speed until achieving independent, symmetrical, and stable walking.

(2) Simulation training for ascending and descending stairs: Use training steps to practice weight-bearing and controlled descent with the affected lower limb.

(3) Integration of daily life tasks: Simulate stepping over low obstacles, walking on different surfaces, walking while carrying items, etc. All training actions require the patient's active and focused participation. The therapist closely observes the quality of movements, level of fatigue, and safety, and dynamically adjusts the difficulty of tasks based on the patient's weekly performance. The training frequency is set to 30 minutes per session, twice a day, 5 days a week, with continuous intervention for 12 weeks.

3.2. Observation group

Patients in this group underwent additional lower extremity rehabilitation robot (Lokomat system) assisted training based on the completion of the same personalized task-oriented rehabilitation training program as the control group. Before training, professionally certified therapists performed individualized fitting for patients, measured and adjusted equipment parameters to match patients' lower extremity length, circumference, and joint mobility. Soft cushions or foot drop correction belts were used to ensure comfort and safety when necessary. During training, the robot's weight support system (initially set to approximately 50% of body weight, gradually reduced based on tolerance and performance, but maintained above 20%) was utilized to reduce weight-bearing. Programmed control of the driving device provided gait guidance force and speed regulation (starting speed of approximately 1.2–1.4 km/h, adjustable). Therapists set walking training task modules appropriate to the patient's functional level. With precise mechanical support and movement trajectory guidance provided by the robot, the focus was on strengthening coordinated movement patterns of the lower extremities, gait symmetry, perception of weight-bearing on the affected side, and active participation. Patients were particularly encouraged to attempt active extension of the affected calf during robot-assisted walking to complete specific tasks such as touching target objects with their toes, to promote dissociated movement. Robot training was set to 30 minutes per session, twice a day, five days a week, for 12 weeks.

3.3. Observation indicators

3.3.1. Motor function

The lower extremity motor function of the two groups of patients before and after treatment was evaluated using the FMA-LE. This scale contains 17 items that evaluate lower extremity reflexes, flexor/extensor synergies, selective motor control, coordination, and speed, involving multi-joint movements such as hip, knee, and ankle. Each item is scored on a scale of 0 (cannot perform), 1 (partial), or 2 (full), with a total score ranging from 0–34. A higher score indicates better motor function, fewer abnormal movement patterns, and stronger selective motor control.

3.3.2. Ankle joint function

The active dorsiflexion range of motion (DF AROM) of the ankle joint was measured using a universal goniometer. The standard position was supine with the knee extended. The stationary arm was aligned with the long axis of the fibula, and the axis was positioned slightly anterior to the lateral malleolus. The moving arm was parallel to the fifth metatarsal. The patient actively dorsiflexed their toes to the maximum angle (avoiding compensation), and the degree between the moving arm and the stationary arm was recorded.

3.4. Statistical methods

Statistical analysis was performed using SPSS 21.0 software package in our hospital. Measurement data were expressed as mean ± standard deviation ($\bar{x}\pm s$) and followed a normal distribution. The t-test was used for comparisons between groups. Count data were expressed as relative numbers, and the chi-square test (x^2 test) was used for comparisons between groups. The rank sum test was used to compare clinical efficacy. A *P*-value < 0.05 was considered statistically significant.

4. Results

4.1. Comparison of motor function between the two groups

Before treatment, there was no significant difference in FMA-LE levels between the two groups ($P > 0.05$). After treatment, FMA-LE levels in both groups increased significantly, and the improvement in various indicators in the observation group was better than that in the control group ($P < 0.05$), as shown in **Table 2**.

Table 2. Comparison of motor function between the two groups before and after treatment ($\bar{x}\pm s$)

Group	Cases (n)	Before treatment	After treatment
Observation group	32	15.24 ± 3.11	25.11 ± 2.94*
Control group	31	15.18 ± 3.08	22.69 ± 3.01*
t-value	-	0.077	3.228
p-value	-	0.939	0.002

Note: Compared with the same group before treatment, *$P < 0.05$

4.2. Comparison of ankle joint function between the two groups

Before treatment, there was no significant difference in DF AROM levels between the two groups ($P > 0.05$). After treatment, the DF AROM levels of both groups increased significantly, and the improvement of each index level in the observation group was better than that in the control group ($P < 0.05$), as shown in **Table 3**.

Table 3. Comparison of ankle joint function levels between the two groups before and after treatment ($\bar{x}\pm s$, °)

Group	Sample size (n)	Before treatment	After treatment
Observation group	32	10.08 ± 1.41	15.41 ± 1.52*
Control group	31	10.11 ± 1.39	13.08 ± 1.61*
t-statistic	-	0.085	5.908
p-value	-	0.933	< 0.001

Note: Compared with the same group before treatment, *$P < 0.05$

5. Discussion

Stroke leads to damage in the brain's motor control areas, particularly affecting the corticospinal tract, which causes typical lower limb movement disorders and difficulties in ankle dorsiflexion for hemiplegic patients [6]. In this study, the control group underwent task-oriented training, which focuses on designing functional tasks close to daily life, such as bridging exercises, sit-to-stand transfers, center of gravity shifts, and walking training. This approach encourages patients to actively participate and repeat exercises, utilizing the principle of neurological reorganization to promote compensation in areas surrounding or contralateral to the damaged brain regions, gradually rebuilding normal motor control patterns [7]. However, task-oriented training heavily relies on patient initiative and therapist guidance accuracy. In practice, patients often struggle to maintain standard movements and sufficient training intensity due to muscle weakness, fatigue, or incorrect compensatory patterns, especially during ankle dorsiflexion, which requires precise control. This may limit further improvement in its effectiveness [8]. Although the data from the control group in this study showed some improvement in FMA-LE and DFAROM, the magnitude of improvement was relatively limited.

The observation group integrated lower limb rehabilitation robot training into task-oriented training to address its limitations. The robot system provides patients with a stable movement guidance framework through precise mechanical support and preset physiological gait trajectories [9]. Its weight-reducing support function allows patients to perform near-normal walking posture training in the early stages of muscle weakness, significantly reducing abnormal compensations and posture errors caused by fear of weight-bearing or insufficient strength. More importantly, the robot can enforce precise joint movement trajectories, continuously providing correct proprioceptive input, especially during the gait swing phase and ankle dorsiflexion movements. This high-intensity, highly repetitive, and highly standardized training can more effectively stimulate the sensorimotor cortex and spinal motor circuits, promoting the encoding and consolidation of correct movement patterns in the brain and accelerating the process of neurological reorganization [10]. This may be the key reason for the more significant improvement in FMA-LE scores in the observation group.

Improvements in ankle function, especially the increase in active dorsiflexion range of motion (DFAROM), were also observed to be more advantageous in the observation group in this study. Ankle dorsiflexion control is crucial for ground clearance and heel contact during the gait cycle. Robot training accurately guides ankle dorsiflexion movements throughout the gait cycle, especially at the end of the swing phase. This not only directly stretches the contracted plantar flexor muscle groups but also strengthens the active contraction ability of dorsiflexor muscle groups, such as the tibialis anterior muscle, under correct movement patterns. The real-time and consistent mechanical feedback provided by the robot helps patients perceive and control ankle position and movement more clearly, optimizing the afferent proprioceptive information and thereby more effectively rebuilding the central nervous pathway for active ankle control.

6. Conclusion

In summary, the combined application of lower limb rehabilitation robot training based on conventional task-oriented training can more effectively improve the overall lower limb motor function and active ankle dorsiflexion ability of stroke patients with hemiplegia.

Disclosure statement

The author declares no conflict of interest.

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