ISSN 2706-6819 Vol. 7, Issue 1: 1-5, DOI: 10.25236/IJFM.2025.070101

Study on the Effects of Aerobic Exercise Rehabilitation Training on Cardiopulmonary Function and Rehabilitation Outcomes in Patients with Hemiplegia after Cerebral Infarction

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Abstract: *This study evaluated the effectiveness of supplementing basic rehabilitation therapy with aerobic exercise for patients with hemiplegia following cerebral infarction. A total of 174 patients were randomly divided into a control group receiving only basic therapy and an intervention group that also underwent aerobic exercise. After treatment, the intervention group demonstrated significant improvements in cardiopulmonary function (P < 0.05). While the control group did not. Although both groups showed enhancements in motor function and activities of daily living (P < 0.05), there were no significant differences between them in these areas. Thus, combining aerobic exercise with basic rehabilitation proved beneficial for improving cardiopulmonary function in patients with hemiplegia after cerebral infarction.*

Keywords: *cerebral infarction; hemiplegia; aerobic exercise; cardiopulmonary function; rehabilitation training; Fugl-Meyer Assessment; Barthel Index*

1. Introduction

Cerebral infarction, a common cerebrovascular disease particularly prevalent among the middle-aged and elderly, often results in severe motor dysfunction, including hemiplegia, profoundly affecting patients' daily activities and quality of life. Rehabilitation training remains the cornerstone of treatment for post-cerebral infarction hemiplegia, with aerobic exercise rehabilitation training (AERT) emerging as a pivotal therapy for promoting motor function recovery [1,2].

In recent years, advancements in rehabilitation medicine have led to a deeper understanding and recognition of AERT's efficacy in enhancing the rehabilitation outcomes of patients with hemiplegia after cerebral infarction [3,4]. Building upon previous research findings and clinical experiences, this study endeavors to further investigate the effects on improving of AERT on the cardiopulmonary exercise function of these patients through a well-designed prospective study. The objective is to provide a scientific foundation for the clinical application of AERT, ultimately aiming to optimize the rehabilitation strategies for this patient population.

The research results, detailed in the subsequent sections, offer valuable insights into the potential benefits and mechanisms of AERT in the rehabilitation of patients with hemiplegia after cerebral.

2. Materials and Methods

2.1. Study Subjects

This study employed a prospective design, enrolling 174 patients with cerebral infarction-induced hemiplegia who were admitted to the hospital between September 2019 and September 2023 as the research subjects. Using a random number table method, these patients were randomly divided into a control group and an intervention group, resulting in 87 patients in each group. The inclusion criteria were as follows: ① meeting the diagnostic criteria for cerebral infarction [4]; ② confirmed by

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imaging examinations such as cranial CT or MRI, with good patient compliance; ③ first-time onset of the disease, with a disease duration of no more than 6 months; ④ patients voluntarily participating in the study and providing informed consent. The exclusion criteria included: ① age less than 18 years or greater than 80 years; ② unstable vital signs, unable to undergo cardiopulmonary exercise testing; ③ history of brain trauma, aphasia, parenchymal or central nervous system lesions, disturbance of consciousness, etc.; ④ presence of cardiopulmonary insufficiency, hepatic or renal failure, infectious diseases, mental disorders, etc.; ⑤ severe spasticity on the affected side, severe joint movement limitations, epileptic seizures, disease progression, or death; ⑥ withdrawal from the study or loss to follow-up. This study was approved by the hospital's medical ethics committee, and all participants signed informed consent forms. There were no statistically significant differences in baseline characteristics between the two groups ($P > 0.05$), indicating comparability. The specific details are shown in Table 1.

Table 1: Comparison of Clinical Baseline Characteristics between the Two Groups

Group	n	Gender (Male/ Female)	Age (years, x±s)	Hemiplegic Side			Course of Disease (d, x±s)	Infarct Location		
				Left	Right			Basal Ganglia		Other
Control Group	87	52/35	56.60±7.38	38		49	68.08±11.03	56		31
Intervention Group	87	48/39	57.08±8.04	31		56	71.40±13.74	64		23
χ^2/t Value		0.418	0.266		0.796		1.110		0.882	
P Value		0.512	0.782		0.372		0.270		0.348	

2.2. Control Group

Following acute-phase treatment for cerebral infarction and within 2 to 14 days of stable vital signs, patients in the control group received routine neurologic medication maintenance therapy along with standard rehabilitation training. The standard rehabilitation training encompassed basic disease knowledge education, self-care guidance, language training, cognitive function training, swallowing function training, and more. Additionally, it included proper positioning of the affected limb, walking training, stair climbing training, and activities of daily living (ADL) training. Each training session lasted for 30 to 60 minutes, continuing for 1 month.

2.3. Intervention Group

On the basis of receiving the same treatment as the control group, patients in the intervention group also underwent personalized aerobic exercise rehabilitation training. The specific training content included:

Indoor Exercise: Based on the patient's sitting balance and personal preferences, activities such as cycling training or hydraulic resistance training were selected. During cycling training, patients were required to extend their upper limbs and pedal with their lower limbs on a bicycle, using knee stabilizers to assist in maintaining knee stability. Initially, the unaffected side led the affected side in pedaling, and as the muscle strength of the affected side improved, it gradually shifted to the affected side leading the unaffected side. Each training session lasted for 20 to 30 minutes, 5 times a week. Hydraulic resistance training involved using hydraulic upper limb trainers and hydraulic hand and foot load trainers for upper and lower limb resistance training, with each side trained for 30 minutes each time, 5 to 6 times a week. After 2 weeks of training, the training time was appropriately increased based on the patient's condition.

Outdoor Exercise: Based on the severity of the patient's condition and rehabilitation progress, gradual outdoor exercise training was conducted. The exercise intensity was set to a level that would not cause fatigue to the patient, with 3 to 5 sessions per week, conducted 1 to 2 hours after meals. The forms of exercise included walking, standing while using public transportation, gymnastics, Tai Chi, cycling on flat ground, jogging, playing table tennis, etc., avoiding high-intensity exercises such as long-distance running and swimming. Each exercise session lasted for 20 to 30 minutes, with a total daily exercise time of 30 to 60 minutes, continuing for 1 month.

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2.4. Assessment Methods

Cardiopulmonary exercise testing, motor function assessment, and ADL ability assessment were conducted on both groups of patients 1 day before the intervention and 1 month after the intervention.

Cardiopulmonary Exercise Testing: The German Jaeger Master Screen cardiopulmonary exercise testing system was used to measure patients' anaerobic threshold, peak oxygen uptake, and peak minute ventilation.

Motor Function Assessment: The simplified Fugl-Meyer scale was used to assess the motor function status of patients' upper and lower limbs. The total score range of this scale is from 0 to 100, with the upper limb section including 33 items and a total score of 66, and the lower limb section including 17 items and a total score of 34. A higher total score indicates milder motor dysfunction [5].

ADL Ability Assessment: The modified Barthel index was used to assess patients' ADL abilities. This index employs a 5-point scoring system with a total score of 100, including items such as bed-to-chair transfer, walking, eating, dressing, toileting, bowel control, bladder control, stair climbing, bathing, and personal hygiene. A higher total score indicates better ADL ability [6].

2.5. Statistical Analysis

Data processing was performed using SPSS 25.0 statistical software. Normally distributed measurement data are expressed as ($x \pm s$) and analyzed using the t-test; count data are expressed as [n (%)] and analyzed using the χ^2 test. A P-value < 0.05 was considered statistically significant.

3. Results

3.1. Comparison of Cardiopulmonary Exercise Test Results before and After Intervention in Both Groups

There were no statistically significant differences in the cardiopulmonary exercise test indicators before and after treatment in the control group ($P > 0.05$). In the intervention group, the anaerobic threshold, peak oxygen uptake, and peak minute ventilation after treatment were significantly higher than before treatment, with statistical significance ($P < 0.05$). The anaerobic threshold, peak oxygen uptake, and peak minute ventilation in the intervention group after treatment were all higher than those in the control group, with statistical significance ($P < 0.05$). See Table 2.

Table 2: Comparison of physiological indexes of physiological indexes between control group and intervention group before and after intervention

Group	n	Parameter	Before Intervention	After Intervention	t-value	P-value
Control Group	87	Anaerobic Threshold (AT) [ml/(kg·min)]	10.17±1.95	11.07±2.59	1.795	0.073
Intervention Group	87	Anaerobic Threshold (AT) [ml/(kg·min)]	10.99±2.08	13.04±1.85	5.358	<0.001
Control Group	87	Peak Oxygen Uptake (VO_2 peak) [ml/(kg·min)]	12.68±2.97	14.15±3.65	0.284	0.763
Intervention Group	87	Peak Oxygen Uptake (VO_2 peak) [ml/(kg·min)]	13.06±2.74	18.06±3.43	5.595	<0.001
Control Group	87	Peak Ventilatory Volume (L/min)	30.76±5.73	31.97±4.89	0.957	0.326
Intervention Group	87	Peak Ventilatory Volume (L/min)	29.07±6.26	36.58±4.36	5.684	<0.001

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3.2. Comparison of FMA Scale and Barthel Index Before and After Intervention between Two Groups

After the intervention, both the FMA scale and Barthel Index scores were significantly higher than those before the intervention in both groups, with statistically significant differences ($P < 0.05$). However, there were no statistically significant differences in the FMA scale and Barthel Index scores between the two groups after the intervention ($P > 0.05$). See Table 3.

Table 3: FMA and Barthel index intervention effect comprehensive comparison table

Group	n	Parameter	Total score	Before Intervention	After Intervention	t-value
Control Group	87	Fugl-Meyer Assessment (FMA)	57.75+5.73	70.74+6.35	9.183	<0.001
Intervention Group	87	Fugl-Meyer Assessment (FMA)	58.08+6.38	71.90+7.56	8.365	<0.001
Control Group	87	Barthel Index	40.35+5.14	46.04+4.72	5.366	<0.001
Intervention Group	87	Barthel index	39.58+4.10	47.88+4.26	9.072	<0.001

4. Discussion

Hemiplegia, characterized by motor impairments affecting one side of the body, including the upper and lower limbs, facial muscles, is a frequent consequence of acute cerebrovascular diseases. Patients with milder forms may retain some mobility but often exhibit a distinctive hemiplegic gait, featuring flexed upper limbs and extended lower limbs. In severe cases, individuals may become completely bedridden and lose all mobility [7]. Cerebral infarction, a primary cause of hemiplegia, is particularly prevalent among older adults, with decreased cerebral blood flow and hypoperfusion being the fundamental pathological processes. Early rehabilitation training is a vital part of comprehensive treatment for cerebral infarction patients, as it not only expedites the recovery of motor and neurological functions but also minimizes the risk of long-term complications. Research indicates that early rehabilitation can significantly diminish the size of infarction lesions, thereby enhancing motor function [8].

Traditional early rehabilitation for cerebral infarction patients, given their often advanced age, critical condition, and compromised cardiovascular health, typically emphasizes passive and resistance exercises, such as joint flexions and extensions, focusing less on aerobic training. Recently, the benefits of aerobic exercise rehabilitation in post-cerebral infarction hemiplegia recovery have gained recognition. Aerobic exercise not only fosters motor recovery but also alleviates symptoms like pain [9]. Moreover, it distracts patients from pain, boosts their treatment confidence, and accelerates upper limb motor recovery [10].

In our study, cardiopulmonary exercise testing showed no significant changes in the control group's exercise function indicators post-treatment. Conversely, the intervention group, which included aerobic exercise, exhibited notable improvements in anaerobic threshold, peak oxygen uptake, and peak ventilatory volume. These findings underscore the limitations of traditional rehabilitation in enhancing cardiopulmonary function and highlight the efficacy of aerobic exercise in this regard. This may be due to aerobic exercise's ability to induce adaptive enhancements in the cardiopulmonary system and improve oxygen utilization [11].

Both groups demonstrated significant improvements in FMA scores and Barthel Index following the intervention, suggesting that rehabilitation exercise effectively improves muscle tone, motor function, and daily living activities. This is largely due to the diverse and specific nature of the exercises, such as liquid resistance training and equipment-assisted cycling, which are practical, convenient, safe, and reproducible [12]. Consistent indoor and mild-to-moderate outdoor exercises ensure good patient adherence, leading to improved gait, muscle tone, joint range of motion, stability, and coordination [13].

Nevertheless, this study has limitations. The sample size is relatively small, potentially impacting

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the results' reliability. Additionally, the observation period is short, limiting the assessment of aerobic exercise's long-term rehabilitation effects. Future research should involve larger samples and longer observation periods to comprehensively explore aerobic exercise's effects across different patient groups and its combination with other rehabilitation methods.

In conclusion, integrating aerobic exercise rehabilitation into standard rehabilitation treatment for post-cerebral infarction hemiplegia patients significantly enhances their cardiopulmonary function, accelerates motor recovery, and promotes overall functional improvement. This not only supports patients' rehabilitation but also opens new avenues for improving their quality of life, offering valuable insights and methods for clinical practice.

Acknowledgements

This work is supported by the Science and Technology Research Project of the Jilin Provincial Department of Education (NO. JJKH20220071KJ).

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