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Original Article

Effects of health management combined with aerobic exercise on cardiopulmonary function in patients with spinal cord injury

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Abstract: Purpose: Cardiopulmonary dysfunction caused by spinal cord injury (SCI) seriously affects the rehabilitation and daily life of patients. This paper aims to demonstrate that health management combined with aerobic exercise can effectively influence the effect of SCI on the cardiopulmonary function of patients. Methods: One hundred and twenty-four SCI patients were included and divided into a study group (SG) or a control group (CG) according to different rehabilitation training modes. Patients in SG received health management combined with aerobic exercise, while those in CG adopted routine aerobic exercise. Cardiopulmonary function, spinal cord function, daily living indexes (Barthel indexes), scores of negative emotions (anxiety and depression), and quality of life (QOL) were compared between the two groups. Results: The spinal cord function and Barthel indexes improved notably in both groups after treatment, but compared with CG, the spinal cord and cardiopulmonary indicators in SG were better. The anxiety and depression scores were lower. The Barthel indexes and QOL scores were higher after treatment. Conclusions: This study demonstrates that health management combined with aerobic exercise can effectively influence the effect of SCI on cardiopulmonary function of patients, which can improve the QOL and alleviate negative emotions of patients.

Keywords: Spinal cord injury, aerobic exercise, health management, cardiopulmonary function

Introduction

Spinal cord injury (SCI) interrupts the connection between the nerve center and the spinal cord, and causes motor, sensory, and autonomic nerve dysfunction [1, 2]. Although great progress has been made in the treatment of SCI, new strategies and programs are still needed to intervene in secondary diseases triggered by SCI [3].

The loss of autonomic nervous function seriously impairs the normal implementation of cardiovascular, respiratory, and gastrointestinal functions in patients with SCI [4, 5]. Today, cardiovascular disorders have become the main cause of morbidity and death in patients with chronic SCI [6]. Squair et al. [7] proposed that myocardial atrophy and left ventricular systolic function caused by SCI depended on the severity of injury. Chorpa et al. [8] believed that chronic SCI patients were accompanied by cardiovascular disease risk factors such as dyslipidemia, hypertension, and type 2 diabetes. SCI also leads to pulmonary dysfunction. After establishing SCI model in rats, Chu et al. [9] found that lung tissues presented pathological changes such as pulmonary congestion and alveolar collapse, and lung cell apoptosis increased. According to Berlowitz et al. [10], respiratory muscle training could improve respiratory muscle function and vital capacity changes caused by SCI.

Exercise is one of the common means to improve the cardiopulmonary function in patients with SCI. Studies [11] have shown that weight-supported treadmill combined with residual limb muscle-strengthening training can effectively improve the dynamic and static balance of SCI patients. The protective and promoting effects of exercise on cardiopulmonary

Table 1. General information

	Study group (n=68)	Control group (n=56)	t/χ²	P
Age	45.36±6.33	43.87±5.92	1.343	0.1818
Gender				
Male	37 (54.41)	29 (51.79)		0.8569
Female	31 (45.59)	27 (48.21)		
BMI (kg/m²)	20.66±0.78	20.42±0.82	1.666	0.0983
Smoking history				0.8523
Yes	24	21		
No	44	35		
History of alcoholism				0.1942
Yes	22	25		
No	46	31		
Marital status				0.5677
Married	43	39		
Single	25	17		
Degree of injury				0.3662
Complete injury	11	13		
Incomplete injury	57	43		
Duration of injury				0.8316
< 5 years	15	14		
≥ 5 years	53	42		

functions of SCI patients should not be neglected. Jorgensen et al. [12] showed that physical exercise improved body mass index (BMI) and cardiovascular health in elderly patients with SCI. Alajam et al. [13] pointed out that sports training could promote the recovery of cardiopulmonary function and alleviate organ dysfunction induced by SCI. As one of the common exercise programs in SCI therapy, aerobic exercise has been shown to be able to not only effectively promote cardiopulmonary function repair in SCI patients, but also increase the serum myoghostatin level [14, 15].

According to different treatment methods, the enrolled SCI patients were divided into a study group (SG; health management combined with aerobic exercise intervention) or a control group (CG; routine rehabilitation training). Then, cardiopulmonary exercise testing (CPET) was performed to evaluate patients' cardiopulmonary function, and to evaluate the effect of health management combined with aerobic exercise on cardiopulmonary function, rehabilitation, daily life, quality of life (QOL), and negative emotions of patients. Such that, reliable scientific data for effective rehabilitation training programs for SCI patients could be provided.

Materials and methods

General information

One hundred and twenty-four SCI patients were assigned into SG or CG according to different rehabilitation methods. Consisting of 37 males and 31 females, there were 11 cases of complete injury and 57 cases of incomplete injury in SG, with an average age of 45.36±6.33 years. In CG, there were 56 patients (29 males and 27 females), including 13 cases of complete injury and 43 cases of incomplete injury, with an average age of 43.87±5.92 years. There were no statistically significant differences between the two groups in gender, age, BMI, degree of injury, history of smoking and alcoholism, marital status, and duration of injury (**Table 1**). Inclusion criteria: patients aged 16-60 years, who were diagnosed with C1-C12 of SCI, without cardiovascular, cerebrovascular diseases or lung diseases were included. Exclusion criteria: those with unconsciousness or mental disorders; those with SCI due to tumors; those with infections or severe complications that were not suitable for rehabilitation therapy; and those with spinal instability without internal fixation. The study was approved by the hospital ethics committee and the patient's written informed consent was obtained in accordance with the Declaration of Helsinki.

Methods

SG adopted health management combined with aerobic exercise program, while CG adopted an aerobic exercise program. Mainly containing upper limb tension training, upper limb lifting dumbbells, wheelchair exercises, wheelchair basketball, and wheelchair table tennis, the specific training mode of aerobic exercise was selected according to the patient's condition and wishes. The aerobic exercise intensity was 40-60% of the oxygen uptake $VO2_{peak}$. Aerobic exercise training, which lasted for 4 weeks, was conducted 30 min a day for 5 days per week. Health management: the patient's information about their condition and family

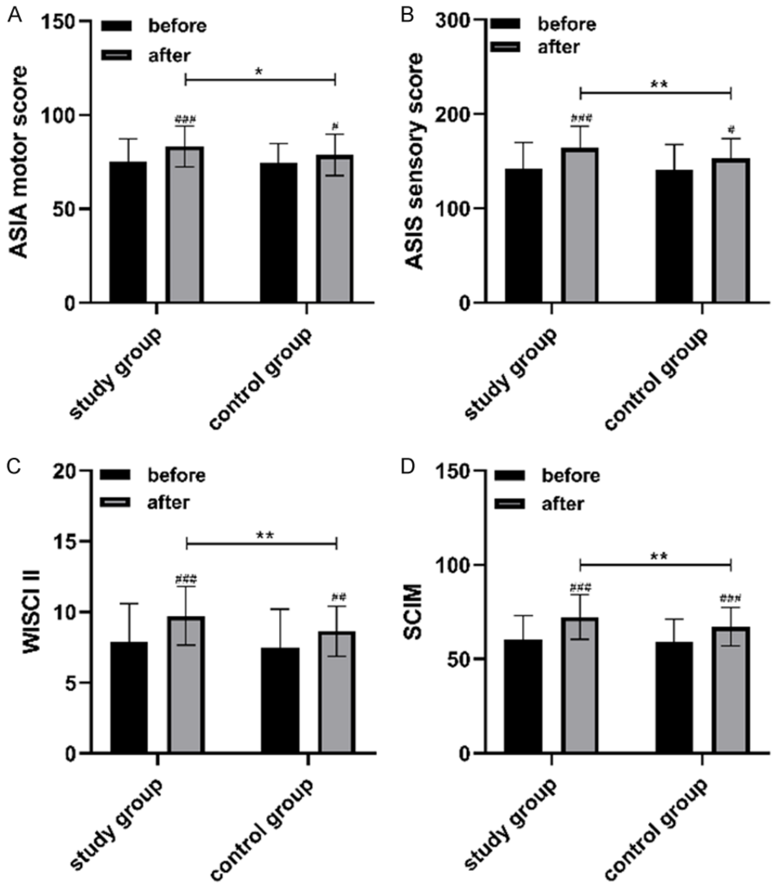

Figure 1. Evaluation of rehabilitation status. A. Comparison of ASIA motor scores between the two groups before and after treatment; B. Comparison of ASIA sensory scores between the two groups before and after treatment; C. Comparison of WISCI II between the two groups before and after treatment; D. Comparison of SCIM between the two groups before and after treatment; study group (n=68), control group (n=56). * indicates $P < 0.05$ vs control group, and ** indicates $P < 0.01$ vs study group. # indicates $P < 0.05$ vs before treatment, ## indicates $P < 0.01$ vs before treatment and ### indicates $P < 0.001$ vs before treatment.

was collected and a management plan was developed based on the patient's condition and self-care ability. In addition, the hospital publicized the management skills, health management symptoms, life, emotions, and complications to patients and their families, so as to cultivate their awareness and improve the effectiveness in the prevention and response of complications and medication.

Outcome measures

Cardiopulmonary function was evaluated by cardiopulmonary exercise testing (CPET). Indicators such as patients' peak oxygen consumption ($VO2_{peak}$), anaerobic threshold (AT), peak metabolic equivalent of energy (MET_{peak}), peak oxygen consumption and heart rate ($VO2/HR_{peak}$), peak respiratory exchange rate (RER_{peak}=VCO2/VO2), peak minute ventilation (VE_{peak}), peak work rate (WR_{peak}), peak heart rate (HR_{peak}), rest heart rate (HR_{rest}), rest systolic blood pressure (SBP_{rest}), rest diastolic blood pressure (DBP_{rest}), peak systolic blood pressure (SBP_{peak}), and peak diastolic blood pressure (DBP_{peak}) were detected. The American Spinal Injury Association (ASIA), motor score (AMS), ASIA sensory score (ASS), walking index spinal cord injury II (WISCI II), and spinal cord independent measure (SCIM) were used as rehabilitation assessment indicators. Serum total cholesterol (TC), triglyceride (TG), low-density lipoprotein cholesterol (LDL-C), and high-density lipoprotein cholesterol (HDL-C) were measured under fasting conditions. The activities of daily living (ADLs) of the patients were evaluated by Barthel indexes, and the QOL of the patients was evaluated by the WHOQOL-BREF table developed by the World Health Organization. The degree of anxiety and depression was assessed by Hamilton Anxiety Scale (HAMA) and Beck Depression Inventory (BDI) respectively.

Statistics and analysis

The collected data were analyzed statistically by SPSS20.0, and visualized by GraphPad Prism 8.0. The measurement data were recorded as mean ± SEM, the data before and after treatment were compared by paired sample t-test, and the comparison between SG and CG was done by independent sample t-test. The counting data were expressed in the form of n (%), and compared by the chi-square test between groups. All data were double-tailed,

Table 2. Comparison of CPET

	Study group (n=68)	Control group (n=56)	t	P
$VO2_{peak}$ [ml/kg·min]	17.67±4.39	15.33±4.22	3.017	0.0031
AT [ml/kg·min]	13.97±3.68	12.62±3.75	2.016	0.0460
MET_{peak}	5.24±1.32	4.72±1.19	2.281	0.0243
VE_{peak} (L/min)	40.06±8.37	36.96±8.59	2.028	0.0447
HR_{peak} (/min)	146.52±21.28	135.96±18.76	2.899	0.0044
HR_{rest} (/min)	86.22±8.21	90.24±8.94	2.607	0.0103
WR_{peak} (w)	109.36±25.36	88.21±21.87	4.914	< 0.0001
$VO2/HR_{peak}$ (ml/beat)	8.23±1.52	7.58±1.67	2.266	0.0252
RER_{peak}	1.18±0.23	1.22±0.21	1.002	0.3183

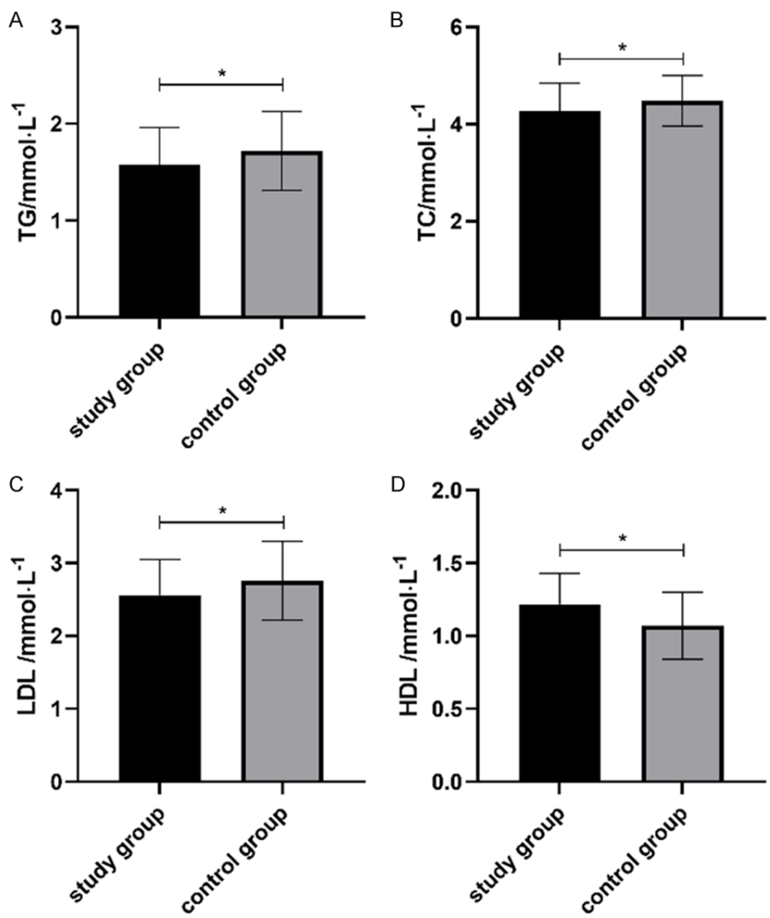

Figure 2. Comparison of blood lipid levels between the two groups. A. Comparison of triglyceride (TG) between the two groups; B. Comparison of serum total cholesterol (TC) between the two groups; C. Comparison of low-density lipoprotein cholesterol (LDL-C) between the two groups; D. Comparison of high-density lipoprotein cholesterol (HDL-C) between the two groups; study group (n=68), control group (n=56). * indicates P < 0.05.

Results

Evaluation of rehabilitation status of patients in the two groups

As demonstrated in **Table 1**, there were no statistically significant differences between the two groups in gender, age, body mass index (BMI), degree of injury, history of smoking and alcoholism, marital status, and duration of injury. In **Figure 1**, the rehabilitation status of SCI patients in the two groups was evaluated by AMS, ASS, WISCI, and SCIM. The AMS, ASS, WISCI, and SCIM increased significantly in both groups after treatment. The increase in SG was significantly higher than that in CG (P < 0.05). The above results showed that the two groups of patients recovered well, but the recovery was better in SG than in CG.

Comparison of cardiopulmonary function between the two groups

In this section, we used CPET, a key index, to evaluate the cardiopulmonary function of patients. It identified no cardiopulmonary adverse events in all patients during the test (see **Table 2** for CPET indexes of the two groups after rehabilitation treatment). Compared with CG, $VO2_{peak}$, AT, MET_{peak}, VE_{peak}, HR_{peak}, WR_{peak}, and $VO2/HR_{peak}$ were statistically higher and the HR_{rest} was significantly lower in SG (all P < 0.05). There was no statistical difference in RER_{peak} between the two groups (P > 0.05).

with 95% as its confidence interval. A statistically significant difference was assumed at P < 0.05.

Dyslipidemia is associated with various cardiovascular diseases. **Figure 2** is a comparison of blood lipid levels between two groups of

Table 3. Barthel indexes

	Study group (n=68)	Control group (n=56)	t	P
Before treatment	44.87±6.98	45.97±6.72	0.888	0.3762
After treatment	72.99±7.02	62.85±6.92	8.056	< 0.0001
t	23.421	13.111		
P	< 0.0001	< 0.0001		

Table 4. Comparison of quality of life between the two groups

	Study group (n=68)	Control group (n=56)	t	P
Physical domain	20.33±4.39	18.56±4.28	2.260	0.0256
Psychological domain	21.53±5.11	19.36±5.02	2.372	0.0193
Social relationship domain	9.32±2.35	8.59±2.09	1.809	0.0729
Environmental domain	21.39±5.62	22.97±5.27	1.602	0.1117
Total quality of life score	73.61±10.37	67.35±11.23	3.222	0.0016

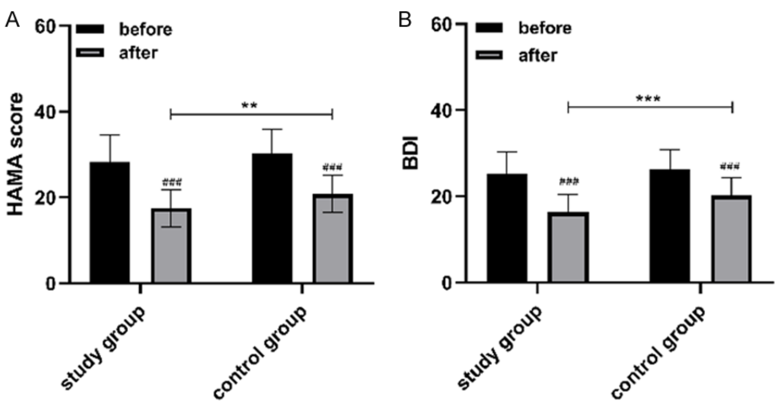

Figure 3. Comparison of anxiety and depression between the two groups. A. Comparison of HAMA scores between the two groups before and after treatment; B. Comparison of BDI scores between the two groups before and after treatment. study group (n=68), control group (n=56). ** indicates P < 0.01 vs control group, *** indicates P < 0.001 vs control group, and ### indicates P < 0.001 vs before treatment.

patients after treatment. SG presented significantly lower. TG, TC, and LDL levels while notably higher HDL level than CG, with statistically significant differences (P < 0.05). Based on the above results, we can see that the cardiopulmonary function in SG was better than that in CG after treatment.

Comparison of ability of daily living and QOL between the two groups

In this paper, Barthel indexes were used to evaluate the ability of daily living of patients, including eating, bathing, dressing, and walking. **Table 3** shows the Bartherl indexes of the two groups after treatment. Balrtherl indexes elevated significantly in both groups after treatment, and the Balrtherl indexes in SG (72.99 ±7.02) were higher than those in CG (62.85±6.92), with statistically significant differences.

The WHOQOL-BREF table developed by the World Health Organization was applied in this part to assess the QOL of patients in the domains of physiology, psychology, social relations, and environment. **Table 4** shows the comparison of the QOL between the two groups after rehabilitation. Compared with CG, the scores of physiological domain, psychological domain, and total QOL were higher than those in SG (P < 0.05), but no statistical differences were observed in social relationship domain and environmental domain (P > 0.05).

Comparison of negative emotions between the two groups before and after treatment

Negative emotions such as anxiety and depression can affect patients' treatment compliance and motivation. In this study, Hamilton Anxiety Scale (HAMA) and Beck Depression Inventory (BDI) were used to assess the anxiety level of patients and their depression status. **Figure 3** is a comparison of anxiety and depression between two groups of patients before and after treatment. Anxiety and depression scores reduced notably in both groups (P < 0.05), and the scores in SG were statistically lower than those in CG after treatment (P < 0.05).

Discussion

SCI has a devastating effect on the health of patients and is closely related to permanent disability and reduction of life expectancy [16]. SCI-induced systemic injuries and decreased physical activity levels cause patients to remain sedentary, which increases the risk of cardiovascular disease, respiratory disease, and osteoporosis [16, 17]. Although there are various SCI treatment strategies available, the functional recovery of SCI patients remains unsatisfactory [18]. Reasonable exercise training can improve patients' physical quality, thereby improving cardiopulmonary function [19, 20]. Developing reasonable rehabilitation training for SCI is one of the contents of SCI therapy. Since aerobic exercise can effectively improve dyslipidemia, a risk factor of cardiovascular disease [21], it may also promote the recovery of cardiopulmonary function in SCI patients. Previous studies have shown that aerobic exercise exerts positive effects on SCI patients [22]. In this paper, 124 patients with SCI were included to study the therapeutic effect of aerobic exercise combined with health management on SCI patients and the improvement of cardiopulmonary function.

AMS, ASS, WISCI, and SCIM were used to evaluate the rehabilitation status of patients with SCI. As shown in **Figure 1**, AMS, ASS, WISCI, and SCIM all improved in both groups after treatment. The improvement of the above rehabilitation indexes in SG were more significant compared with CG, indicating that health management combined with aerobic exercise had a more effective rehabilitation effect than routine rehabilitation training. CPET, a vital index, was employed to evaluate cardiopulmonary function. As shown in **Table 2** and **Figure 2**, health management combined with aerobic exercise is more effective in improving cardiopulmonary function in SCI patients, contributing to their cardiopulmonary reserve. SCI also seriously prohibits the daily life of patients, while reasonable rehabilitation training may improve their QOL. **Tables 3** and **4** demonstrate that health management combined with aerobic exercise is more helpful to improve the patient's indexes of daily life and QOL. In addition, disability and pathological pain caused by SCI often give rise to anxiety and depression of patients. Therefore, the negative emotions of SCI patients during rehabilitation are also among the key concerns of SCI treatment. **Figure 3** reveals that health management combined with aerobic exercise is more conducive to relieving patients' depression and anxiety, so as to improve their psychological quality and improve their enthusiasm for treatment.

By comparing two rehabilitation training programs, this paper found that health management, combined with aerobic exercise, has a certain application value, but there are still some limitations. To begin with, this paper only discussed the short-term impact of the two schemes on SCI patients and their long-term effects remain to be explored. Secondly, the sample size included in this paper was limited (68 cases in SG and 56 cases in CG), so the sample should be further expanded to investigate the application of health management combined with aerobic exercise in SCI therapy. Thirdly, there is still no complete mechanism to explain the improvement effect of health management combined with aerobic exercise on cardiopulmonary function of SCI patients. Future research should also consider its impact and role from the perspective of molecular mechanism.

In conclusion, by comparing the different effects of health management combined with aerobic exercise and routine rehabilitation training on patients with SCI, we found that compared with the latter, the former is more beneficial to promote the recovery of cardiopulmonary function, improve the QOL, and inhibit the development of negative emotion in patients with SCI, which enjoys potential clinical value in SCI rehabilitation training.

Disclosure of conflict of interest

None.

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