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ARTICLE

Application of Cardiac Rehabilitation Aerobic Exercise in Patients with Stable Angina in Coronary Heart Disease

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Abstract

Aims/Background A novel exercise protocol for cardiac rehabilitation aerobic (CRA) has been developed by Hebei Sport University, demonstrating efficacy in patients with coronary heart disease (CHD). The objective of this study was to evaluate the impact of CRA on precise cardiac rehabilitation (CR) for CHD patients presenting with stable angina pectoris.

Methods The study cohort comprised patients with stable angina who were categorized into three groups: the CRA group (n = 35), the power bicycles (PB) group (n = 34), and the control group (n = 43). In addition to standard treatment, the CRA group underwent a 12-week CRA-based CR intervention, while the PB group participated in a similar program centered on PB exercise, and the control group received only standard treatment.

Results At the end of the 12-week intervention, significant differences were observed among the groups in several physiological parameters, including systolic blood pressure (SBP), fasting blood glucose (FBG), triglycerides (TG), total cholesterol (TC), low-density lipoprotein (LDL), Glycated Haemoglobin (Hb-A1c), peak oxygen uptake (Peak VO_2), anaerobic threshold (AT), and Peak VO_2/heart rate (HR) ($p < 0.05$). Both the CRA and PB groups showed significant reductions in SBP, FBG, TG, TC, LDL, and Hb-A1c compared to the control group ($p < 0.05$). Additionally, both groups exhibited significant improvements in Peak VO_2, AT, and Peak VO_2/HR ($p < 0.05$). Intra-group analysis revealed that the CRA group showed significant improvements from baseline to post-intervention in SBP, diastolic blood pressure (DBP), FBG, TG, TC, high-density lipoprotein (HDL), LDL, Hb-A1c, Peak VO_2, AT, and Peak VO_2/HR ($p < 0.05$). Similarly, the PB group demonstrated significant improvements across these parameters ($p < 0.05$).

Conclusion Both CRA and PB exercises are safe and effective for achieving precise CR in patients with CHD. A 12-week CRA intervention, conducted three times per week for 30 minutes per session, significantly improves cardiopulmonary function and biochemical makers in patients with stable angina. These improvements are comparable to those achieved through PB exercise in precise CR.

Key words: cardiac rehabilitation; stable angina; aerobic exercise; coronary heart disease

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Introduction

Cardiac rehabilitation (CR) demonstrates efficacy in managing coronary heart disease (CHD), reducing medical costs, and improving patients' quality of life (Hansen et al, 2022; McDonagh et al, 2022). Extensive research has shown that

exercise can reduce cardiovascular risk factors and enhance the quality of life for CHD patients (Powell et al, 2018; Smith et al, 2018). A study has demonstrated that precisely controlled exercise loads, such as those provided by power bicycles (PB), can effectively ameliorate the condition of patients with chronic cardiovascular diseases, including angina (de Barcelos et al, 2022). However, the implementation of precise exercise loads using PB is often hindered by limitations in facilities and equipment. Traditional methods, including target heart rate and subjective perception, fail to ensure the precision in intervention intensity and safety required (Kotseva et al, 2018; Sun et al, 2020). Consequently, the development of a universally applicable and easily implementable precise exercise program remains a significant challenge in CR.

Stable angina pectoris, a prevalent condition in China, has received insufficient attention in the field of CR (Supervia et al, 2019). The participation rate of Chinese patients with CHD in precision CR training remains notably low, primarily due to the necessity for specialized equipment and the complexity of CR techniques (Chinese Medical Association et al, 2021). The patients in the Department of Rehabilitation at the First Hospital of Hebei Medical University were treated using various rehabilitation methods, all of whom have achieved positive therapeutic effects. These rehabilitation methods include PB rehabilitation therapy and CR exercise therapy, the latter developed by Hebei Sport University. To evaluate the effectiveness of CR exercise therapy, we conducted a retrospective analysis of treatment outcomes for CHD outpatients who received treatment in the Department of Rehabilitation at the First Hospital of Hebei Medical University in recent years.

Methods

Study Subjects

This study included outpatients treated at the Department of Rehabilitation at the First Hospital of Hebei Medical University, from January 2022 to August 2023. Participants were allocated to three groups: the cardiac rehabilitation aerobic (CRA) group (n = 35), who received the CRA exercise treatment developed by Hebei Sport University; the PB group (n = 34), who used PB; and the control group (n = 43), who received conventional CR treatment. Diagnostic criteria followed the "Guidelines for Diagnosis and Treatment of Stable Coronary Heart Disease" (Knuuti et al, 2020).

Inclusion criteria: (1) individuals aged 40–70 years; (2) individuals diagnosed with stable angina pectoris of CHD; (3) individuals with normal cognitive function; (4) individuals with ability to provide informed consent and adhere to the intervention protocol.

Exclusion criteria: (1) individuals with systolic blood pressure (SBP) $\geq$160 mmHg and/or diastolic blood pressure (DBP) $\geq$100 mmHg; (2) individuals with presence of rapid cardiac arrhythmia; (3) individuals with high-degree or complete atrioventricular block; (4) individuals with post-implantation of cardiac pacemaker; (5) individuals with New York Heart Association (NYHA) class III or IV; (6) individuals without ability to complete the entire study protocol; (7) individuals with

a cute endocarditis; (8) individuals with obstructive hypertrophic cardiomyopathy; (9) individuals with symptomatic severe aortic stenosis, decompensated heart failure, acute pulmonary embolism, deep vein thrombosis, acute pericarditis or myocarditis, acute aortic dissection; (10) individuals with chronic lung disease with dyspnea; (11) individuals with recent stroke or transient ischemic attack with associated cognitive dysfunction; (12) individuals with unresolved clinical problems, such as infection, severe anemia, electrolyte imbalance, or hyperthyroidism.

This study was approved by the Ethics Committee of the First Hospital of Hebei Medical University (approval No.20210380). The research was conducted in line with the ethical principles outlined in the Declaration of Helsinki.

Data Collection for Physical Examination

Physical examinations were conducted at the Department of Rehabilitationat baseline (week 0) and at the end of the observation (week 12). Data collection encompassed the following parameters: height, weight, body mass index (BMI), and resting blood pressure.

Cardiopulmonary Exercise Test (CPET)

Cardiopulmonary exercise testing (CPET) is the gold standard for evaluating patients' exercise capacity (Writing Committee Members and ACC/AHA Joint Committee Members, 2022). A specific exercise bicycle load increment protocol was determined based on each patient's physiological condition, progressing until the exercise endpoint was achieved or specific positive indicators were observed. Peak oxygen uptake (Peak VO_2), anaerobic threshold (AT), and Peak VO_2/heart rate (HR) (Peak VO_2/HR) were measured and recorded during the exercise test.

Routine CR Program

In addition to specialized treatment for patients with stable angina, a comprehensive CR program was implemented, encompassing dietary and nutritional counseling, lifestyle modification interventions, and psychological support.

PB Program

Patients underwent precise load training using PB based on CPET results. The precision exercise prescription included: (1) frequency (3 sessions per week, once daily, for 12 weeks); (2) intensity (warm-up phase: 10% of peak power, High-Intensity Interval Training (HIIT): high-intensity exercise at 80% to 90% of peak power for 3 minutes, followed by low-intensity exercise at 20% to 30% of peak power for 2 minutes, repeated for 6 cycles); (3) cool-down: power set to 0 watts; (4) duration (warm-up for 5 minutes, training for 30 minutes, and cool-down for 5 minutes, total session duration: 40 minutes).

CRA Program

The CRA program was developed by the research group of the "Hebei Province Key Research and Development Program——Research on Health Promotion Technology of Precision exercise Intervention on CR population". Patients were required to wear a cardiac monitoring system during exercise. The exercise pre-

scription included: (1) exercise frequency (3 sessions per week, once daily, for 12 weeks); (2) exercise intensity [warm-up: Borg score between 8–10 (Expert consensus group for the diagnosis, assessment, and management of dyspnea, 2014); load training where the patient follows CRA at the rate of 1 beat/second (8–8 beats), the amplitude and frequency of the CRA actions are adjusted based on the monitored peripheral oxygen saturation, heart rate and self-Borg scores]; (3) adjustment criteria [Condition 1: heart rate increased to (220-age) $\times$ 0.8; Condition 2: peripheral blood oxygen saturation is maintained at 90 $\pm$ 1%; Condition 3: Borg score between 14–16. After 3 minutes, the movement rhythm is slowed down to maintain a Borg score of 9–10 for 2 minutes, repeated for 6 cycles]; (4) cool-down: end the CRA, perform stationary marching for 2 minutes, and stretch for 3 minutes.

Biochemical Tests

All subjects underwent fasting cubital venous and blood samples were collected in the morning to assess liver function (Alanine Aminotransferase, ALT; Aspartate Aminotransferase, AST), renal function (Creatinine, Cr; Blood Urea Nitrogen, BUN; Uric Acid, UA) and metabolic parameters, including fasting blood glucose (FBG), triglycerides (TG), high-density lipoprotein (HDL), low-density lipoprotein (LDL), total cholesterol (TC), and Glycated Haemoglobin (Hb-A1c).

Statistical Analysis

Data analysis was conducted using SPSS software (version 25.0, IBM Corp, Armonk, NY, USA). Continuous variables are presented as mean $\pm$ standard deviations (SD) or medians with interquartile ranges, depending on their distribution. Normality of data distribution was assessed using the Shapiro-Wilk test, and one-way analysis of variance (ANOVA) was employed for normally distributed data with homogeneous variances, followed by post hoc comparisons using the Student-Newman-Keuls (SNK) test when applicable. For non-normally distributed or heteroscedastic data, group differences were assessed using the Kruskal-Wallis (KW) test. Changes between initial and final values (pre- and post-exercise training) were analyzed using paired *t*-tests for normally distributed data and Wilcoxon signed-rank tests for non-normally distributed data. Statistical significance was established at $p < 0.05$.

Results

Baseline Characteristics, Biochemical Parameters and CEPT Indicators

A total of 112 participants were included in the study, with 35 subjects in the CRA group, 34 in the PB group, and 43 in the control group. No cases of sudden death, acute cardiovascular or cerebrovascular events, or significant physical discomfort were reported. Liver and renal function tests indicated no abnormalities across all three groups at baseline (0 weeks) or after the end of 12 weeks.

Compared to baseline measurements, the CRA group showed statistically significant improvements in SBP, DBP, FBG, TG, TC, HDL, LDL, Hb-A1c, Peak VO_2, AT, and Peak VO_2/HR at the end of the 12-week intervention ($p < 0.05$).

Table 1. Comparison of parameters at baseline and after 12 weeks among the CRA, PB, and control groups.

Characteristics	Weeks	CRA group	PB group	Control group	Z/t^1	p^1	Z/t^2	p^2	Z/t^3	p^3
n (%)		35 (31.25)	34 (30.36)	43 (38.39)	-	-	-	-	-	-
n (male/female)		16/19	15/19	20/23	-	-	-	-	-	-
Age (year)		57.69 ± 6.60	56.15 ± 6.12	57.51 ± 8.13	-	-	-	-	-	-
SBP (mmHg)	0 w	134.63 ± 15.99	132.35 ± 14.95	132.21 ± 16.61	–4.73	<0.01	–4.63	<0.01	–1.28	0.20
	12 w	125.51 ± 11.05	123.50 ± 9.69	130.26 ± 12.80						
DBP (mmHg)	0 w	84.80 ± 10.96	86.65 ± 10.29	85.58 ± 10.99	8.31	<0.01	–4.87	<0.01	–2.30	0.20
	12 w	80.80 ± 10.56	81.53 ± 8.21	84.51 ± 11.04						
FBG (mmol/L)	0 w	5.95 ± 1.24	5.78 ± 0.75	5.73 ± 0.87	4.06	0.02	11.69	<0.01	0.13	0.90
	12 w	5.15 ± 0.39	4.94 ± 0.56	5.71 ± 0.75						
TG (mmol/L)	0 w	1.54 (1.28, 2.50)	1.80 (1.49, 2.37)	1.85 (1.50, 2.72)	–5.57	<0.01	–2.44	<0.01	–0.92	0.36
	12 w	1.09 (0.81, 1.42)	1.45 (1.21, 1.72)	1.80 (1.45, 2.23)						
TC (mmol/L)	0 w	5.12 ± 0.76	5.38 ± 0.76	5.41 ± 0.71	–5.75	<0.01	7.32	<0.01	1.43	0.16
	12 w	4.29 ± 0.63	4.33 ± 0.60	5.29 ± 0.78						
HDL (mmol/L)	0 w	1.06 (0.88, 1.19)	1.20 (0.97, 1.32)	1.12 (1.01, 1.30)	–2.57	<0.01	0.70	0.49	–1.76	0.09
	12 w	1.20 (0.94, 1.32)	1.23 (1, 1.45)	1.20 (1.01, 1.36)						
LDL (mmol/L)	0 w	3.38 ± 0.56	3.49 ± 0.60	3.47 ± 0.59	–5.75	<0.01	–5.66	<0.01	1.93	0.06
	12 w	2.71 ± 0.47	2.58 ± 0.46	3.35 ± 0.62						
Hb-A1c (%)	0 w	5.97 ± 0.61	5.94 ± 0.54	5.87 ± 0.61	–5.75	<0.01	–5.66	<0.01	1.25	0.22
	12 w	5.40 ± 0.30	5.34 ± 0.31	5.75 ± 0.53						
Peak VO_2 (L/min)	0 w	1.13 ± 0.27	1.17 ± 0.33	1.12 ± 0.31	–5.75	<0.01	–10.16	<0.01	0.49	0.63
	12 w	1.31 ± 0.32	1.36 ± 0.40	1.11 ± 0.31						
Peak VO_2 (mL/min·kg)	0 w	15.45 ± 3.36	16.31 ± 3.96	14.97 ± 4.08	–16.81	<0.01	–5.66	<0.01	–1.80	0.08
	12 w	18.55 ± 3.94	19.66 ± 4.94	15.12 ± 4.05						
Peak VO_2 (% pred)	0 w	0.61 ± 0.15	0.64 ± 0.12	0.62 ± 0.12	–13.01	<0.01	–15.11	<0.01	–0.99	0.32
	12 w	0.71 ± 0.18	0.75 ± 0.12	0.61 ± 0.13						
AT (L/min)	0 w	0.82 ± 0.19	0.83 ± 0.20	0.79 ± 0.20	–14.28	<0.01	–5.66	<0.01	0.71	0.48
	12 w	0.95 ± 0.21	0.99 ± 0.25	0.79 ± 0.20						

Table 1. Continued.

Characteristics	Weeks	CRA group	PB group	Control group	Z/t^1	p^1	Z/t^2	p^2	Z/t^3	p^3
AT (mL/min·kg)	0 w	11.30 ± 2.52	10.82 ± 1.72	10.71 ± 2.99	–16.92	<0.01	–11.05	<0.01	–1.60	0.11
	12 w	13.45 ± 2.85	14.30 ± 2.97	10.81 ± 2.92						
AT (% pred)	0 w	0.45 ± 0.13	0.47 ± 0.10	0.44 ± 0.10	–11.42	<0.01	–14.20	<0.01	–0.19	0.85
	12 w	0.52 ± 0.15	0.55 ± 0.11	0.44 ± 0.10						
Peak VO_2/HR (mL/beat)	0 w	9.37 ± 1.90	9.64 ± 2.17	9.29 ± 1.98	–12.12	<0.01	–14.10	<0.01	0.79	0.43
	12 w	10.65 ± 2.10	10.96 ± 2.34	9.26 ± 1.99						
Peak VO_2/HR (% pred)	0 w	0.84 ± 0.18	0.87 ± 0.17	0.85 ± 0.16	–8.74	<0.01	–11.35	<0.01	0.49	0.63
	12 w	0.93 ± 0.21	0.98 ± 0.21	0.85 ± 0.16						

Note: [1] CRA group, [2] PB group, [3] Control group. CRA, cardiac rehabilitation aerobic; PB, power bicycles; SBP, systolic blood pressure; DBP, diastolic blood pressure; FBG, fasting blood glucose; TG, triglycerides; TC, total cholesterol; HDL, high-density lipoprotein; LDL, low-density lipoprotein; Hb-A1c, Glycated Haemoglobin; Peak VO_2, peak oxygen uptake; AT, anaerobic threshold; HR, heart rate.

Table 2. Comparison of basic parameters, biochemical indicators, and data of CEPT at baseline and 12 weeks among groups.

Characteristics	Weeks	CRA group	PB group	Control group	$F/H/\chi^2$	p^a	p^b	p^c	p^d
Age (year)	-	57.69 ± 6.60	56.15 ± 6.12	57.51 ± 8.13	0.49	0.61	-	-	-
n (male/female)	-	16/19	15/19	20/23	0.05	0.98	-	-	-
SBP (mmHg)	0 w	134.63 ± 15.99	132.35 ± 14.95	132.21 ± 16.61	0.26	0.77	0.55	0.51	0.97
	12 w	125.51 ± 11.05	123.50 ± 9.69	130.26 ± 12.80	3.63	0.03	0.46	<0.01	<0.01
DBP (mmHg)	0 w	84.80 ± 10.96	86.65 ± 10.29	85.58 ± 10.99	0.26	0.78	0.48	0.75	0.67
	12 w	80.80 ± 10.56	81.53 ± 8.21	84.51 ± 11.04	1.50	0.23	0.77	0.11	0.20
FBG	0 w	5.95 ± 1.24	5.78 ± 0.75	5.73 ± 0.87	1.24	0.54	0.90	0.76	0.93
	12 w	5.15 ± 0.39	4.94 ± 0.56	5.71 ± 0.75	13.97	<0.01	0.19	<0.01	<0.01
TG	0 w	1.54 (1.28, 2.50)	1.80 (1.49, 2.37)	1.85 (1.50, 2.72)	3.44	0.18	0.60	0.51	0.92
	12 w	1.09 (0.81, 1.42)	1.45 (1.21, 1.72)	1.80 (1.45, 2.23)	30.85	<0.01	0.16	<0.01	<0.01
TC	0 w	5.12 ± 0.76	5.38 ± 0.76	5.41 ± 0.71	1.66	0.20	0.15	0.09	0.85
	12 w	4.29 ± 0.63	4.33 ± 0.60	5.29 ± 0.78	27.9	0.01	0.84	<0.01	<0.01

Table 2. Continued.

Characteristics	Weeks	CRA group	PB group	Control group	F/H/χ^2	p^a	p^b	p^c	p^d
LDL	0 w	3.38 ± 0.56	3.49 ± 0.60	3.47 ± 0.59	0.40	0.67	0.40	0.50	0.84
	12 w	2.60 ± 0.47	2.69 ± 0.46	3.34 ± 0.61	33.35	<0.01	0.32	<0.01	<0.01
Hb-A1c	0 w	5.97 ± 0.61	5.94 ± 0.54	5.87 ± 0.61	0.07	0.97	0.82	0.46	0.62
	12 w	5.40 ± 0.30	5.34 ± 0.31	5.75 ± 0.53	20.14	<0.01	0.60	<0.01	<0.01
Peak VO_2 (L/min)	0 w	1.13 ± 0.27	1.17 ± 0.33	1.12 ± 0.31	0.16	0.92	0.58	0.84	0.44
	12 w	1.31 ± 0.32	1.36 ± 0.40	1.11 ± 0.31	9.21	0.01	0.55	0.01	<0.01
Peak VO_2 (mL/min·kg)	0 w	15.45 ± 3.36	16.31 ± 3.96	14.97 ± 4.08	1.18	0.31	0.35	0.58	0.13
	12 w	18.55 ± 3.94	19.66 ± 4.94	15.17 ± 4.05	19.75	<0.01	0.29	<0.01	<0.01
Peak VO_2 (% pred)	0 w	0.61 ± 0.15	0.64 ± 0.12	0.62 ± 0.12	0.36	0.70	0.43	0.89	0.50
	12 w	0.71 ± 0.18	0.75 ± 0.12	0.61 ± 0.13	9.10	<0.01	0.29	<0.01	<0.01
AT (L/min)	0 w	0.82 ± 0.19	0.83 ± 0.20	0.79 ± 0.20	0.60	0.74	0.99	0.50	0.50
	12 w	0.95 ± 0.21	0.99 ± 0.25	0.79 ± 0.20	15.77	<0.01	0.42	<0.01	<0.01
AT (mL/min·kg)	0 w	11.30 ± 2.52	10.82 ± 1.72	10.71 ± 2.99	1.72	0.42	0.43	0.30	0.86
	12 w	13.45 ± 2.85	14.30 ± 2.97	10.86 ± 2.30	26.98	<0.01	0.23	<0.01	<0.01
AT (% pred)	0 w	0.45 ± 0.13	0.47 ± 0.10	0.44 ± 0.10	0.41	0.81	0.56	0.73	0.34
	12 w	0.52 ± 0.15	0.55 ± 0.11	0.44 ± 0.10	13.24	<0.01	0.30	0.01	<0.01
Peak VO_2/HR (mL/beat)	0 w	9.37 ± 1.90	9.64 ± 2.17	9.29 ± 1.98	0.26	0.77	0.70	0.85	0.67
	12 w	10.65 ± 2.10	10.96 ± 2.34	9.26 ± 1.99	7.11	<0.01	0.55	0.01	<0.01
Peak VO_2/HR (% pred)	0 w	0.84 ± 0.18	0.87 ± 0.17	0.85 ± 0.16	0.35	0.84	0.81	0.89	0.86
	12 w	0.93 ± 0.21	0.98 ± 0.21	0.85 ± 0.16	4.85	<0.01	0.24	<0.01	<0.01

Note: [a] data were analyzed by repeated measurements within groups; [b,c,d] data were analyzed by post-hoc-tests; [b] CRA group *vs* PB group; [c] CRA group *vs* Control group; [d] PB group *vs* Control group. CEPT, cardiopulmonary exercise testing.

Similar statistically significant improvements were observed in the PB group ($p < 0.05$). In contrast, the control group demonstrated no significant changes in any of these parameters ($p > 0.05$) (Table 1).

Baseline and End-of-Observation Comparisons among Groups

At baseline, no statistically significant differences were observed in SBP, DBP, TG, TC, LDL, Hb-A1c, Peak VO_2, AT, and Peak VO_2/HR among the three groups ($p > 0.05$). Following the 12-week intervention, significant differences were observed among the three groups in SBP, FBG, TG, TC, LDL, Hb-A1c, Peak VO_2, AT, and Peak VO_2/HR. Both the CRA group and the PB group showed significant reductions in SBP, FBG, TG, TC, LDL, and Hb-A1c compared to the control group ($p < 0.05$). Additionally, both groups exhibited significant improvements in FBG, Peak VO_2, AT, and Peak VO_2/HR compared to the control group ($p < 0.05$). No statistically significant differences were observed between the CRA and PB groups for these parameters ($p > 0.05$) (Table 2).

Discussion

The individualized exercise program is crucial for effective exercise rehabilitation in patients with CHD, with exercise intensity being a key component directly associated with patient safety and treatment efficacy (Cattadori et al, 2018; Sabbahi et al, 2022). This study examined the outcomes of an intervention using the CRA protocol, developed by Hebei Sport University, for patients with stable angina pectoris. The efficacy of cardiopulmonary function and exercise rehabilitation was evaluated through CPET to determine the optimal exercise load heart rate (Ambrosetti et al, 2021). Exercise rhythm and intensity were adjusted based on heart rate and blood oxygen saturation monitored via wrist devices, combined with Borg score, to achieve precise exercise loading.

The European Society of Cardiology (ESC) guidelines (Pelliccia et al, 2021) emphasize the importance of exercise tests or cardiopulmonary exercise in assessing cardiovascular status and providing personalized exercise recommendations on the type and intensity of exercise. CPET provides an objective assessment of exercise tolerance and facilitates the determination of safe and effective exercise levels, thereby preventing undue physiological stress (Guazzi et al, 2012). In this study, a precise exercise intervention was implemented through personalized bicycle power load training, combined with dietary nutrition, lifestyle management, and psychosocial support, to strengthen the stability with CHD over a 12-week period. The results showed that patients who received intervention with CRA and PB precision load intervention exhibited normalization of blood pressure, FBG, and blood lipid abnormalities. Notably, no serious adverse events, such as malignant arrhythmias or syncope, occurred during the precise exercise control period in both groups.

In this study, CPET was used to evaluate function changes before and after CRA and PB interventions in patients with stable CHD. Significant improvements in cardiovascular function parameters (Peak VO_2, AT, and Peak VO_2/HR) were observed after 12 weeks of intervention, indicating enhanced ventricular contraction pump capacity, circulation oxygen capacity, lung ventilation, ventilation function,

and overall cell metabolic capacity. No significant differences were found between the CRA and PB groups, suggesting similar efficacy for both interventions in patients with stable angina.

A previous study has shown that regular and long-term exercise improves cardiopulmonary fitness, myocardial aerobic metabolic capacity, myofibrillar Adenosine Triphosphatase (ATPase) activity, cross-bridge activation levels, myocardial contractility, and cardiac output (Taylor et al, 2021). Additionally, it increases functional reserves by boosting muscle oxidase enzyme activity, skeletal muscle oxidation ability, blood oxygen uptake, and arteriovenous oxygen difference, while improving endothelial function and reducing sympathetic nervous system tension (Atchley et al, 2009; Besnier et al, 2017; Pearson and Smart, 2017). In this study, intervention with CRA and precise power load cycling significantly improved circulatory and respiratory functions, as well as their coordination, compared to pre-intervention levels. These improvements likely stem from the aforementioned physiological mechanisms.

The findings of this study demonstrate that both CRA and power cycling effectively improve cardiovascular fitness in patients with stable angina due to CHD. Both interventions led to significant reductions in BMI, SBP, DBP, and improvements in blood glucose, lipid levels, and other biochemical makers. The results underscore the efficacy of CRA as an aerobic exercise in the rehabilitation of stable angina patients. Given its minimal equipment requirements, CRA can be broadly promoted and applied in various settings.

However, this study has limitations, including a small sample size and a relatively short observation period. Future research should focus on expanding the sample size and extending the observation period to provide a more comprehensive evaluation of the role of CR in patients with stable angina due to CHD.

CRA demonstrates significant potential for clinical application in the rehabilitation of patients with stable angina resulting from CHD. The minimal equipment requirements of CRA make it an accessible and cost-effective option, facilitating broader implementation across diverse healthcare settings. A 12-week CR program demonstrates the capacity to significantly enhance cardiopulmonary function and ameliorate biochemical markers, highlighting its efficacy, rivaling that of PB exercises.

Conclusion

In conclusion, the CRA intervention demonstrates significant potential for clinical application in the rehabilitation of patients with stable angina due to CHD.

Key Points

- The study compared the impact of CRA and PB exercise on patients with stable angina in CHD.
- Both CRA and PB interventions significantly improved cardiopulmonary and biochemical parameters compared to the control group.
- No significant differences were observed between the CRA and PB groups in the measured outcomes, suggesting similar efficacy.
- CRA, with its minimal equipment requirements, can be widely promoted for CR.

Availability of Data and Materials

All experimental data included in this study can be obtained by contacting the first author if needed.

Author Contributions

YL and JZ contributed equally to this study. JZ, YL, YBP and SYL designed the research study. JZ, YL, HZ, JT, WY, LTC, XS, XMF and JW performed the research. HZ, JT, WY, LTC, XS, XMF and JW analyzed the data. JZ, YL, YBP and SYL drafted the manuscript. All authors contributed to the important editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

This study was approved by the Ethics Committee of the First Hospital of Hebei Medical University (approval No.20210380). The research was conducted in line with the ethical principles outlined in the Declaration of Helsinki. All participants were fully informed about the content of this study and provided informed consent.

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Conflict of Interest

The authors declare no conflict of interest.

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