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Original Research

Role of early short-term cardiac rehabilitation in patients undergoing pacemaker implantation

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Exercise-based cardiac rehabilitation (CR) improves the clinical outcomes in patients with cardiovascular diseases. However, few data exist regarding the role of early short-term CR in patients undergoing pacemaker (PM) implantation. We assessed whether short-term CR following PM implantation was sufficient to improve both physical function and quality of life (QOL). A total of 27 patients with a 6-minute walking distance (6MWD) of less than 85% of the predicted value on the day following PM implantation were randomly assigned to either the CR group (n = 12, 44.4%) or the non-CR group (n = 15, 55.6%). The CR group involved individualized exercise-based training with moderate intensity for 4 weeks after PM implantation. Cardiopulmonary exercise test (CPET), 6MWD, muscle strength, and Short Form (SF)-36 were assessed at baseline and at the 4-week follow-up. After a mean follow-up period of 38.3 days, both groups showed significantly improved 6MWD. Peak oxygen uptake improved in both groups on CPET, but the difference was not statistically significant. Knee extension power and handgrip strength were similar in both groups. Regarding QOL, only the CR group showed improved SF-36 scores in the items of vitality and mental health. There was no difference in any subscale in the non-CR group. Neither lead dislodgement nor significant changes in PM parameters were observed in any patient. Early short-term CR following PM implantation was associated with improved psychological subscales and can be safely performed without increasing the risk of procedure-related complications.

Keywords

Bradycardia; Pacemaker; Exercise; Cardiac rehabilitation

1. Introduction

Bradyarrhythmia is responsible for cerebral hypoperfusion due to a slow heart rate (HR), resulting in various clinical manifestations of dizziness, lightheadedness, syncope, dyspnea, heart failure, or transient confusion [1]. Consequently, patients are at risk of a sedentary lifestyle attributable to a fear of bradycardia-induced symptom development. It has detrimental effects on daily living and health-related quality of life (QOL), which may persist even after permanent pacemaker (PM) implantation. The annual prevalence of permanent PM implantation ranges from approximately 260 to 469 per 100,000 persons, and its rate has been growing rapidly due to aging [2, 3]. However, despite many PM implantations performed worldwide, the role of cardiac rehabilitation (CR) in the early phase has not been robustly evaluated in patients undergoing PM implantation.

CR is a comprehensive exercise, education, and behavior modification program for secondary prevention of cardiovascular diseases [4]. The most commonly accepted indications for CR include coronary artery disease, heart failure, and post-cardiac surgery [5, 6]. PM recipients should also be considered eligible for CR because they can be advised about physical activity and receive special attention regarding psychological adaptation to living with implanted devices [7]. However, even though many patients with cardiac diseases already have a permanent PM, exercises, in particular resistance training, are limited for these patients due to the lack of safety of early CR in consideration of PMs [8].

We sought to investigate the role of early short-term CR following permanent PM implantation in patients with clinically significant documented bradyarrhythmia.

2. Methods

2.1 Study design and population

This was a single-center, randomized, controlled pilot study. Patients who required permanent PM implantation were candidates for the study. The exclusion criteria included patients for whom exercise was contraindicated, age over 75 years, achieved greater than 85% of the predicted maximal

walking distance during the 6-minute walking test (6MWT) on the day following PM implantation, or refusal to participate. Finally, eligible patients were randomly assigned to either the CR or non-CR groups using computer-generated random permutation sequences.

2.2 Pacemaker implantation

Under intravenous anesthesia, an approximately 5 cm long incision was made in either the left or right upper chest, and a subcutaneous pocket was created. The unilateral axillary vein was punctured, followed by guidewire insertion. Thereafter, PM leads were advanced along the guidewires toward the right ventricle and/or right atrium depending on the type of PM. At the site representing the appropriate capture threshold, sensing value, and lead impedance, leads were screwed and the proximal ends were anchored tightly on the subcutaneous layer. The generator and leads were connected, and the generator was buried inside the pocket. After suturing the subcutaneous and cutaneous layers, hemostasis was performed by compression with gauze above the incision site overnight.

2.3 Cardiac rehabilitation program

The patients in the CR group participated in hospital-based phase II rehabilitation, that is, the exercise training, while staff such as nurses and exercise physiologists monitor patients' responses to exercise. The CR program was performed in an ambulatory setting, so all subjects in the CR group visited the training center in the hospital on schedule after discharge. They received exercise-based rehabilitation 8 times (3 times a week for the first 2 weeks and once a week for the next 2 weeks). CR programs were independent of the etiology of bradycardia and included personalized exercise and education. The 60-minute exercise program consisted of flexibility, aerobic, and resistance exercises based on the American Association of Cardiovascular and Pulmonary Rehabilitation guidelines [9]. To avoid PM lead displacement, the patients maintained the ipsilateral shoulder moving within a range of 90° while performing the exercises. A lower-extremity recumbent ergometer was used for aerobic exercises with intensities of 55%–70% of the HR reserve. For resistance exercises, step-box workouts including step-ups, lateral step-overs, and squats were performed in 3 sets of 12–15 repetitions.

2.4 6-minute walking test

The 6MWT is a simple test to assess the submaximal level of functional capacity in a patient while walking on a flat, hard, and straight 30 m corridor for 6 min [10]. Patients were instructed to walk as far as possible. The 6-minute walking distance (6MWD) was defined as the measured distance during the 6MWT, changes in the 6MWD before and after each test, and resting and peak HRs during the exercise were measured. All participants completed the 6MWT on the subsequent day and were reassessed in the 4th week after PM implantation.

2.5 Cardiopulmonary exercise test

All patients underwent symptom-limited cardiopulmonary exercise tests (CPET) using electronically braked recumbent cycle ergometer testing (Quark CPET, Cosmed, Rome, Italy) with a continuous ramp (10 watts per 2 min) protocol. A real-time recording 12-channel electrocardiograph (Q-stress cardiac stress system, Quinton Instrument Co., Boston, MA, USA), a respiratory gas analyzer (Quark CPET, Cosmed, Rome, Italy), an automatic blood pressure (BP) and pulse monitor (Tango M2, Sun Tech Medical, Morrisville, NC, USA), and an ergometer (Angio CPET, Lode, Groningen, Netherlands) were used. The HR, BP, and Borg rating of perceived exertion (RPE) based on the 6–20 scale were recorded at the middle of each stage. The exercise test consisted of four phases: 3 min of rest, 3 min of unloaded cycling, ramp exercise, and recovery. The patients were encouraged to adopt a comfortable cadence, between 40 and 60 rpm throughout the test. The tests were terminated if the patients failed to maintain a cycle cadence of 40 rpm for more than one min despite encouragement or if the termination criteria were met [11].

2.6 Muscle strength

Handgrip strength was assessed using a hand-held digital grip dynamometer (Jamar Hydraulic Hand Dynamometer; Sammons Preston Patterson Medical Products Inc., Bolingbrook, IL, USA) [12]. In a seated position with the elbow flexed at 90°, the patients were asked to squeeze the dynamometer as hard as possible to measure the maximum force exerted by each hand three times. Knee extension (KE) power was measured using a digital hand-held dynamometer (Jtech Medical, Salt Lake City, UT, USA) [13]. Patients sat in a chair with folded arms and knees bent at a 35° angle. The best results from these three attempts were recorded.

2.7 Short Form-36 questionnaire

QOL assessment was determined based on SF-36 scores. The SF-36 is a self-administered 36-item questionnaire consisting of two parts: the physical component summary (PCS) including general health, physical function, body pain, and role physical, and the mental component summary (MCS) including role emotion, social functioning, vitality, and mental health. The PCS and MCS scores are the sum of the four respective components. Each score was transformed to a scale of 0–100, with lower scores indicating greater disability (i.e., poor QOL).

2.8 Study endpoints

The primary endpoint was any improvement in the physical function. Parameters included the 6WMD, handgrip strength, KE power, peak VO_2, and ventilator equivalents of CO_2 (VE/VCO_2) as the values corresponding to functional capacities. The secondary endpoints included changes in PM parameters and improvements in QOL, as reflected by the SF-36 scores.

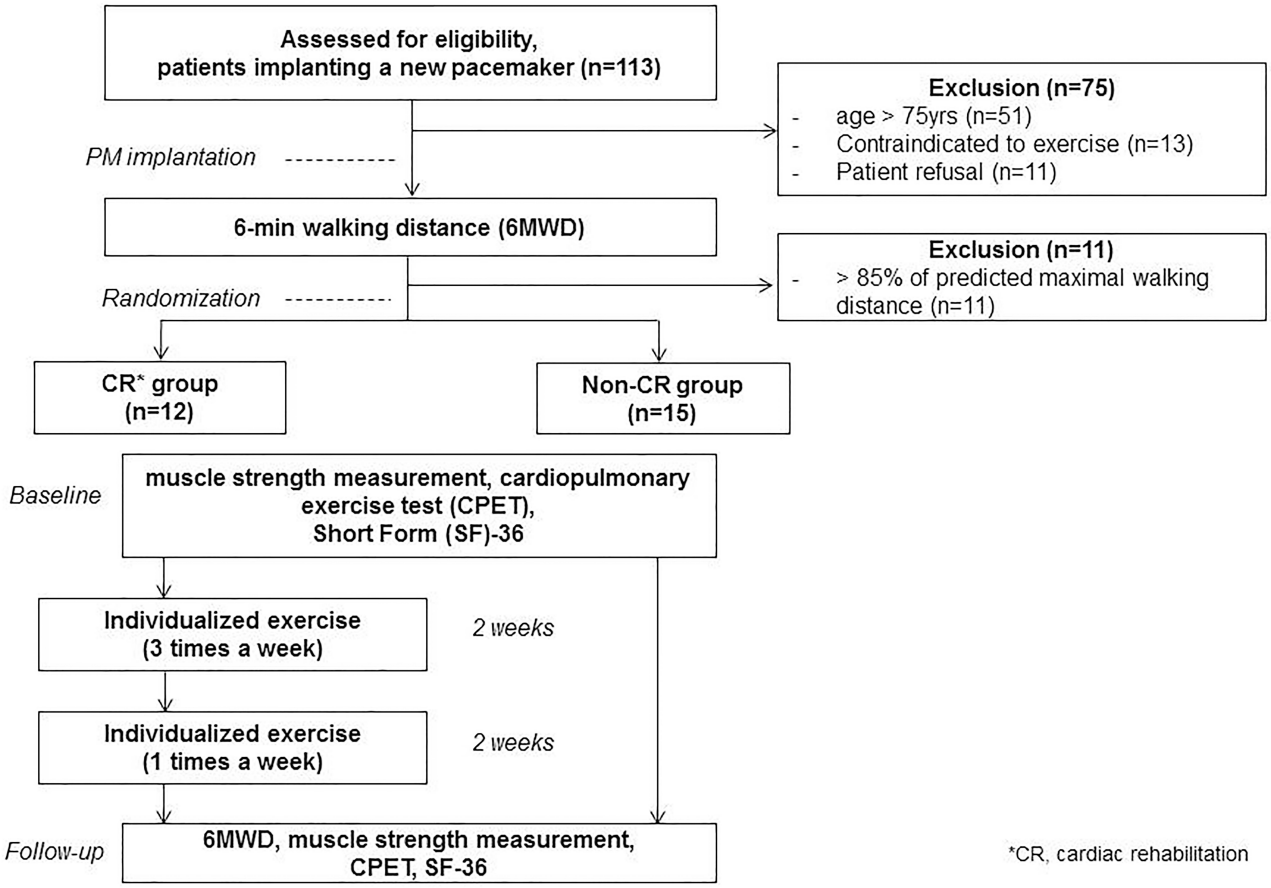

Fig. 1. Study protocol. Flow chart describes the number of patients who were eligible for the study, examinations at baseline and follow-up, and schedules for CR program.

2.9 Statistical analyses

Continuous variables were tested for normal distribution. Normally distributed continuous variables were expressed as means and standard deviations. For those which did not, they were expressed as medians (interquartile range). Categorical variables were expressed as numbers and percentages. For inter- or intragroup comparisons, continuous variables were compared using the Student's *t* test, Mann-Whitney U test, or Wilcoxon signed rank test, as appropriate and categorical variables were compared using Fisher's exact test. Statistical significance was set at $p < 0.05$. All statistical analyses were performed using SPSS version 21.0 (SPSS Inc., Chicago, IL, USA).

3. Results

3.1 Population characteristics

Of 113 consecutive patients who were scheduled to undergo new PM implantation, 75 patients were excluded as they were patients for whom exercise was contraindicated, were older than 75 years, or refused to participate. The remaining 38 patients underwent the 6WMT on the day following PM implantation, and 11 patients who achieved greater than 85% of the predicted maximal walking distance were also excluded. Finally, 27 patients (mean age 65.1 years, male 29.6%) were eligible for this study and randomly assigned to either the CR (n = 12, 44.4%) or non-CR (n = 15, 55.6%) groups. All the participants performed CPET, underwent measurements of muscle strength, and completed a QOL survey. Patients in the CR group received individualized exercise-based rehabilitation from the day following PM implantation for a total of 8 times. Meanwhile, those in the non-CR group visited a device clinic conventionally 2 weeks after the procedure. In the 4th week, the results of the 6MWT, CPET, muscle strength measurement, and SF-36 scores were obtained for all patients (Fig. 1).

The baseline characteristics and demographic data of the 2 groups are shown in Table 1. Despite the overall crossover rate of 22.2% (5 patients from CR to non-CR group and 1 patient from non-CR to CR group), mainly due to far distance to a rehabilitation center, there were no differences in comorbidities, medications, cardiac function, indications of PM implantation, or PM mode between both groups. Adherence to the rehabilitation program was 89.6% among the 12 patients in the CR group and 93.3% of patients in the non-CR group.

Table 1. Baseline characteristics.

	CR group (n = 12)	Non-CR group (n = 15)	*p* value
Age, year	67.8 ± 4.9	62.9 ± 7.2	0.061
Male sex	3 (25%)	5 (33.3%)	0.696
BMI, kg/m^2	24.8 ± 3.3	24.8 ± 3.4	0.998
HT	7 (58.3%)	6 (40.0%)	0.449
DM	2 (16.7%)	3 (20.0%)	0.612
Dyslipidemia	3 (25%)	3 (20%)	0.557
HFrEF	0 (0.0%)	1 (6.7%)	0.556
Old CVA	1 (8.3%)	2 (13.3%)	0.586
Valvular heart disease	0 (0.0%)	0 (0.0%)	1.000
Previous heart surgery	0 (0.0%)	0 (0.0%)	1.000
Anti-thrombotic agent			0.967
No	9 (75%)	11 (73.3%)	
Anti-PLT agent	1 (8.3%)	1 (6.7%)	
Anticoagulant	2 (16.7%)	3 (20.0%)	
Beta-blocker	5 (41.7%)	9 (60.0%)	0.449
Non-DHP CCB	0 (0.0%)	0 (0.0%)	1.000
Other AAD	2 (16.7%)	3 (20.0%)	0.612
LVEF	60.0 (56.5, 60.0)	60.0 (56.5, 60.0)	0.939
RVSP	35.3 ± 9.9	29.8 ± 8.1	0.156
PM indication			0.456
SSS	7 (58.3%)	8 (53.3%)	
AV block	4 (33.3%)	7 (46.7%)	
AF with SVR	1 (8.3%)	0 (0.0%)	
PM mode			0.444
VVI	1 (8.3%)	0 (0.0%)	
DDD	11 (91.7%)	15 (100%)	
R mode on	5 (41.7%)	4 (26.7%)	0.448
Lower Rate	60.0 (60.0, 60.0)	60.0 (60.0, 60.0)	0.107
FU duration, day	32.0 (28.5, 44.0)	29.0 (24.3, 43.5)	0.251

AAD, antiarrhythmic drug; AF, atrial fibrillation; AV, atrioventricular; BMI, body mass index; CCB, calcium channel blocker; CR, cardiac rehabilitation; CVA, cerebrovascular accident; DHP, dihydropyridine; DM, diabetes mellitus; FU, follow-up; HFrEF, heart failure with reduced ejection fraction; HT, hypertension; LVEF, left ventricular ejection fraction; PLT, platelet; PM, pacemaker; RVSP, right ventricular systolic pressure; SSS, sick sinus syndrome; SVR, slow ventricular response.

3.2 Functional performance - 6MWT and muscle strength measurement

Fig. 2 compares the functional performance based on the 6MWT and muscle strength measurements at baseline and during follow-up in each group. As shown in Fig. 2A, the mean 6MWD increased significantly in both groups 4 weeks after PM implantation. There was no intergroup difference at baseline or during the follow-up period. Regarding muscle strength, KE power and handgrip strength did not differ between the groups (Fig. 2B,C).

3.3 Cardiopulmonary exercise test

Functional capacity measured based on peak VO_2 increased from baseline, but there was no statistical significance in either group (Fig. 3A). The increase in the peak HR was significant only in the CR group (Fig. 3B). Other parameters, including the end-tidal partial pressure of carbon dioxide ($P_{ET}CO_2$), VE/VCO_2, Borg RPE, respiratory exchange ratio (RER), and exercise duration, did not differ. There was neither desaturation nor arrhythmic events during the exercises in either group.

3.4 Pacemaker issues

Four weeks after PM implantation, statistically significant, but clinically insignificant subtle changes from baseline were found in p wave sensing and ventricular lead impedance in the CR group, and both lead threshold and ventricular lead impedance in the non-CR group (**Supplementary Table 1**). No intergroup differences were observed. During the exercises, no Wenckebach upper rate response or 2:1 conduction events occurred. Neither hematoma at the procedure site nor lead dislodgement was noted in any patient.

3.5 Quality of life

As shown in Table 2, only the CR group showed significant improvements in self-reported SF-36 scores in the items of vitality (42.1 ± 15.9 to 57.2 ± 15.4, $p = 0.042$) and mental health (50.3 ± 18.3 to 68.2 ± 22.4, $p = 0.046$). Meanwhile, no scores in the non-CR group demonstrated differences compared to baseline values.

4. Discussion

To the best of our knowledge, this is the first randomized controlled trial to demonstrate the efficacy and safety of early short-term CR in patients undergoing new PM implantation. This study showed subjective improvement in psychological subscales in patients undergoing a 4-week rehabilitation program without concern about procedure-related complications.

The benefits of CR programs are well-established for various cardiovascular diseases by improving cardiorespiratory fitness, muscle strength, QOL, myocardial perfusion, and left ventricular reverse remodeling [14–17]. Meanwhile, limited data exist regarding the role of early CR after PM implantation [18]. Exercise capacity is impaired in patients who are dependent on artificial pacing and patients requiring permanent PM are at risk of a sedentary state; therefore, improvements in physical performance as well as psychological state are needed in these patients [7, 19, 20].

In our study, 6MWD was significantly increased in both groups. Four weeks after PM implantation, all patients in this study showed greater than 80% of the predicted 6MWD and did not complain of difficulties in daily living activities. However, either group did not show improved peak VO_2 during a maximally symptom-limited CPET, which is the gold standard for evaluating aerobic fitness [21, 22]. The reason for this discrepancy might be due to a short training duration which was not enough to be reflected on CPET, unlike 6WMT as a submaximal test [9].

In this study, resistance exercises were performed in the CR group. Although it was statistically insignificant likely due to the small sample size, a numerical increase from baseline in KE power was noted only in the CR group. Resis-

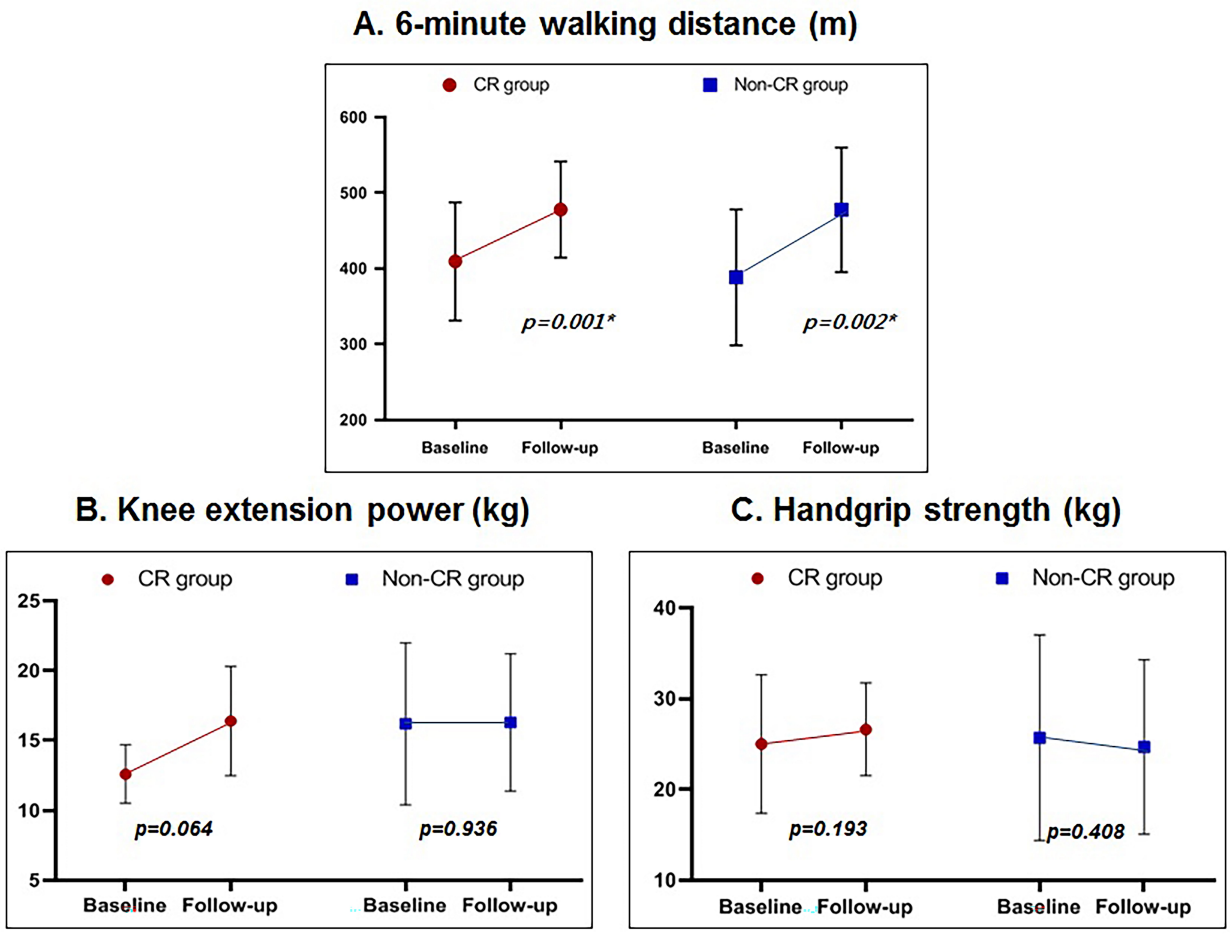

Fig. 2. Changes in physical performance in each group at baseline and during the follow-up period. (A) 6-minute walking distance, (B) knee extension power, and (C) handgrip strength. Data are represented as mean ± standard deviation.

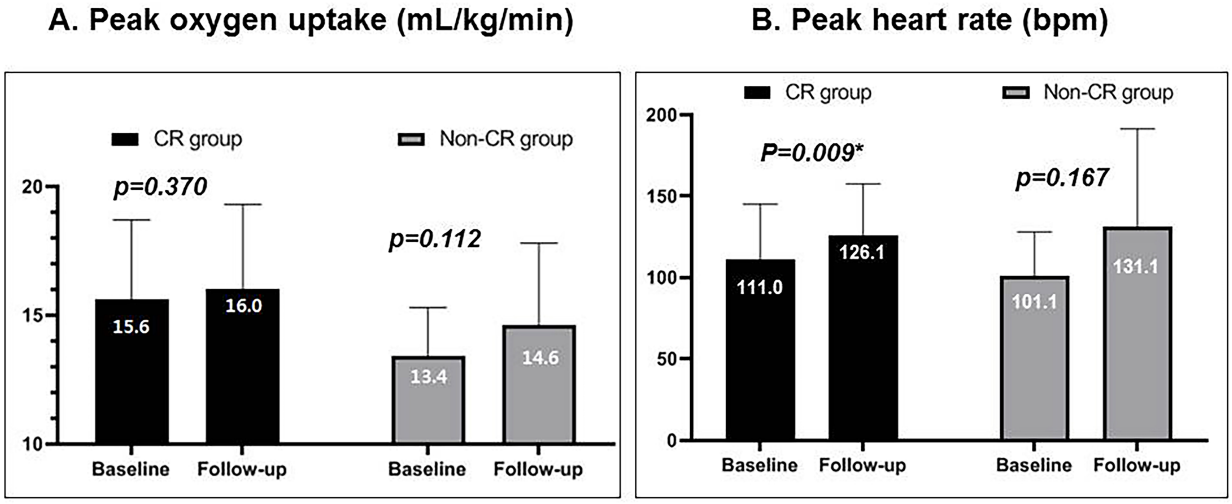

Fig. 3. Cardiopulmonary exercise test. (A) Exercise capacity measured based on the peak oxygen uptake and (B) changes in peak heart rate during the exercises in each group at baseline and during the follow-up period. Data are represented as mean ± standard deviation.

tance additional to aerobic exercises should be considered part of a rehabilitation program for all CR participants [23]. Patients performing combinations of both types of exercise showed greater improvements in exercise capacity and muscle strength [24–26]. Although many patients with coronary disease or heart failure undergo PM implantation, the state

Table 2. Quality of life scores (Short Form-36 scores).

	CR group (n = 12)			Non-CR group (n = 15)		
	Baseline	Follow-up	*p* value	Baseline	Follow-up	*p* value
Physical component summary						
General health	66.4 ± 9.9	60.3 ± 16.4	0.190	57.6 ± 16.9	55.7 ± 10.5	0.575
Physical function	71.8 ± 18.7	70.3 ± 20.1	0.800	81.4 ± 16.2	76.4 ± 15.8	0.140
Body pain	60.0 ± 17.3	64.5 ± 25.8	0.561	67.9 ± 33.3	73.6 ± 21.7	0.554
Role physical	62.5 (62.5, 75.0)	50.0 (50.0, 87.5)	0.087	75.0 (50.0, 100.0)	62.5 (50.0, 100.0)	0.721
Total	67.9 ± 11.7	64.6 ± 17.4	0.484	69.9 ± 16.4	67.7 ± 13.4	0.519
Mental component summary						
Role emotional	83.3 (50.0, 100.0)	50.0 (50.0, 66.7)	0.088	83.3 (50.0, 100.0)	75.0 (50.0, 100.0)	1.000
Social functioning	65.5 ± 18.1	58.2 ± 25.2	0.414	66.4 ± 24.4	76.4 ± 15.9	0.131
Vitality	42.1 ± 15.9	57.2 ± 15.4	0.042*	52.1 ± 17.2	48.2 ± 12.1	0.402
Mental health	50.3 ± 18.3	68.2 ± 22.4	0.046*	61.7 ± 21.1	60.2 ± 18.6	0.146
Total	51.7 ± 12.7	62.3 ± 18.5	0.100	60.2 ± 18.6	63.2 ± 12.5	0.468

CR, cardiac rehabilitation. *$p < 0.05$.

of PM implantation is a relative contraindication for resistance exercises likely due to the fear of safety [21, 27, 28]. In the current study, there were two safety rules during resistance exercises: prohibition of the Valsalva maneuver and relatively low intensity of lower-extremity exercises, with an RPE of 11–13. Despite neutral results, since no procedure-related event was found with this protocol, combination training might be feasible to apply safely.

With regard to PM parameters, only subtle, clinically insignificant changes were observed in both groups. CPET results or HR response during CR could provide an opportunity to test or adjust PM settings to make patients more comfortable with the device [7, 20]. However, in the current study, there was no evidence of a Wenckebach upper rate response or limited sensor-driven rate during exercise within the study period. No significant complications were observed despite early CR following PM implantation.

In terms of QOL, unlike the non-CR group, only the CR group demonstrated improvements after rehabilitation completion on psychological subscales. This indicated that they developed independence and self-reliance in the performance of activities of daily living. These beneficial effects on mental welfare seemed to be derived from psychological support during each training session from the rehabilitation team personnel. However, no differences were observed regarding physical components in both groups, likely because the baseline values in our patients were already higher than those in other studies including patients with heart failure or ischemic heart disease [29, 30]. The other possibility might be explained by the short study period, which may have been insufficient to reflect subjective improvements physically.

5. Limitations

This study had some limitations. First, the sample size was small and not based on statistical estimation. Second, the training duration was relatively short compared to that in the previous studies. However, this study focused on the short-term effects of CR during the early phase following PM implantation. Third, indications for PM or rate responsiveness were not considered. Fourth, while this study comprised consecutive participants undergoing PM implantation in our institute, selection bias by referring physicians may have been likely. In addition, the crossover rate was 22.2% (6 patients); of these, 5 patients refused to undergo CR. Therefore, the patients who decided to undergo CR were probably health-conscious and more adherent. Regardless of these limitations, this study was unique in that the effectiveness and safety of early short-term CR were investigated for the first time in a population undergoing PM implantation, with an 89.6% adherence rate to the CR program, which was much higher than that found in previous studies [31, 32].

6. Conclusions

In patients undergoing PM implantation, despite no benefits on physical performance, early short-term exercise-based CR is associated with improvements in subjective psychological subscales without increasing the risk of procedure-related complications. These findings support further large-scale studies to investigate the optimal model for the management of patients with PM.

Author contributions

Conceptualization, JA, BJL, and LK; Methodology, SYR; Software, BKK; Validation, JYK; Formal Analysis, JA and KTJ; Investigation, SHL; Data Curation, JCC; Writing – Original Draft Preparation, JA; Writing – Review and Editing, BJL, JSP, HWL; Visualization, JHO; Supervision, JHC and HCL; Project Administration, KSC; Funding Acquisition, JA. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

Ethics approval and consent to participate

Informed consent was obtained from each participant. This study was approved by the Institutional Review Board (IRB) of Pusan National University Hospital (IRB number: H-1803-017-064) and retrospectively registered on clinicaltrials.gov on 20th Aug 2021 (NCT05015075).

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Conflict of interest

The authors declare no conflict of interest.

Supplementary material

Supplementary material associated with this article can be found, in the online version, at https://rcm.imrpress.com/EN/10.31083/j.rcm2204166.

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