Original Article

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The Accessibility and Effect of Cardiac Rehabilitation in COVID-19 Pandemic Era

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Objective: To prospectively compare the efficacy of conventional center-based cardiac rehabilitation (CBCR) and home-based cardiac rehabilitation (HBCR) during the coronavirus disease 2019 (COVID-19) pandemic.

Methods: Ninety patients were divided into HBCR and CBCR groups based on cardiovascular risk stratification and individual preference. The CBCR group performed supervised in-hospital exercise training 2–3 times/week and subsequent self-exercise at home. The HBCR group performed self-exercise at home after one or two sessions of exercise education. The cardiopulmonary exercise test results at baseline and those at the 3-, 6-, and 12-month follow-ups were analyzed as primary outcome.

Results: The peak oxygen consumption (peak VO_2, mL/kg/min) in the CBCR group was 20.1 and 24.0 at baseline and 12 months, respectively, showing significant improvement (p=0.006). In the HBCR group, it only increased from 24.4 to 25.5, showing suboptimal improvement. A significant increase in the Korean activity scale/index was confirmed only in the CBCR group (p=0.04). The cardiovascular outcome did not differ between the two groups, nor did the dropout rate or demographic factors.

Conclusion: During the COVID-19 pandemic, only CBCR was associated with a significant improvement in peak VO_2 and physical activity levels, a finding that differs from those of other studies and seems to be affected by COVID-19. Therefore, in situations where the importance of HBCR is emphasized, it is essential to introduce measures to monitor and enhance exercise adherence among participants.

Keywords: Cardiac rehabilitation, COVID-19, Pandemics, Secondary prevention

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INTRODUCTION

Cardiac rehabilitation (CR) is an integral component of the continuum of care for patients with various cardiovascular diseases. However, the global CR participation rate remains low and suboptimal—among eligible candidates, it is approximately 30%–40%. Over 80% of United States (US) patients do not participate in CR and, in South Korea, this figure is much lower at approximately 6% [1-3]. Participation is especially low in female, elderly, and individuals with a lower socioeconomic status who are uninsured [3,4]. Reluctance to participate in group rehabilitation sessions, exercise schedules, occupational issues, transportation and expenses are known barriers to CR participation [5]. Home-based CR (HBCR) was introduced in the 2000s as an alternative strategy to expand participation in CR [5-7]. Theoretically, HBCR could overcome various access-relat-

ed barriers to center-based CR (CBCR), including geographic, socioeconomic, and logistical factors [3].

Additionally, during the coronavirus disease 2019 (COVID-19) pandemic, safe distancing measures have led to the cessation of CBCR programs [8-10]. According to a global survey, approximately 75% of CR programs were completely or temporarily discontinued, which is about 4,400 programs worldwide [10]. This further increased the need for home-based programs [7]. Along with recent developments in technology, previous research on wearable devices for heart rate monitoring used during exercise has proven their accuracy and validity [10-12], and HRCR programs have demanded a more widespread involvement of such virtual or digital tools [7].

Regarding therapeutic efficacy, most previous clinical trials and systematic reviews have shown comparable improvements in peak oxygen consumption (peak VO_2) in individuals assigned to HBCR and CBCR [3,5,6,13]. The magnitude of improvement in cardiorespiratory fitness (CRF) also appears to be similar for HBCR and CBCR [3].

To the best of our knowledge, this is the first study to compare the efficacy and multifaceted properties of participants in CBCR and HBCR, during COVID-19 pandemic era prospectively. This study was conducted in a single center with one of the most active CR programs in South Korea [1]. Fortunately, this hospital was able to run CR program without any cessation of original CR programs or reduction of CR providing staffs even during COVID-19. The authors intended to identify the influence of COVID-19 pandemic on newly attending CR participants.

METHODS

Ethics statement

The study protocol was approved by the Institutional Review Board of Inje University (No. SGPAIK 2020-12-010). This study was registered with the Clinical Research Information Service (CRIS, KCT0006299). All the participants provided written informed consent.

Sample size calculation

G*Power 3.1.9.7 was used for the sample size calculation. A one-tailed t-test was performed, with a effect size of 0.35, a significance level of α=0.05 and a power of 90% [14,15]. A required total sample size of 63 was determined. Considering a loss-to-follow-up rate of 20%, we recruited more than 76 participants for this study.

Study design and participants

This single-center, prospective, comparative study recruited outpatients from the CR clinic at the Inje University Sanggye Paik Hospital from March 2021 to February 2022. This hospital continued their CR program during the COVID-19 pandemic without any reduction in CR-providing staff. Eligible participants were patients newly diagnosed with stable angina, acute coronary syndrome, heart failure, valvular disease, or aortic disease who visited the CR clinic after discharge. The exclusion criteria were: (1) contraindications to cardiopulmonary exercise testing (CPX) or CR exercise training according to the American Heart Association guidelines [16]; (2) other medical conditions preventing participation in the CPX or CR exercise training.

At the first visit to the CR clinic—usually within a week of discharge for patients undergoing percutaneous coronary intervention or within 4 weeks after coronary artery bypass grafting or valvular surgery—all participants underwent the CPX as a baseline to check cardiorespiratory responses to exercise stress and were administered several questionnaires.

Intervention

For the CPX, a real-time recording 12-channel electrocardiograph (CASE; GE-Marquette), respiratory gas analyzer (Quark CPET; COSMED Co.) with a virus filter attached at the mask–tube interface, automatic blood pressure and pulse monitor (TANGO M2; SunTech Medical Inc.), and treadmill (T-2100; GE Healthcare) were used.

Following the modified Bruce protocol, the CPX was administered in the following order: at rest, during exercise, and during recovery. The test was terminated in accordance with the American Heart Association "Indications for termination of exercise testing" guidelines [16]. To assess changes in CRF, the peak VO_2, maximal metabolic equivalents, rate–pressure product, rating of perceived exertion, heart rate, and blood pressure were measured.

Participants were divided into a CBCR or an HBCR group based on risk stratification for exercise-related adverse cardiovascular events [17] and/or personal circumstances. In detail, participants with low risk were recommended to go through HBCR and participants with moderate/high risk were recommended to go through CBCR initially. However, depending on individual circumstances (where they live, how long it takes

from their house to the hospital, whether they are participating in economic activities) or personal preference on center-based or home-based training, the final group was allocated in line with real-world CR practice.

The CBCR group underwent supervised exercise training in a hospital setting and was subsequently switched to home-based self-exercise. The maximum number of in-hospital exercise sessions was 36, which is the upper limit covered by the Korean National Health Insurance Service. The HBCR group performed home-based exercise training. All the participants were educated on risk factor management and nutrition as well.

The CBCR group attended supervised exercise training while wearing quarantine masks, with real-time electrocardiographic, heart rate, and rating of perceived exertion monitoring. Training sessions were conducted 2–3 times/ week in a hospital setting. Each training session comprised a 10-minute warm-up, 30-minute exercise session, and 10-minute cooldown. The exercise intensity was set based on 60%–85% of the heart rate reserve value. If patients had COVID-19 symptoms, tested positive for COVID-19 using a self-test kit, or their family or partner was infected, the hospital visit was discontinued. After completing the in-hospital training sessions, the participants were instructed to continue aerobic training at home.

In the HBCR group, the exercise prescriptions were the same as those in the CBCR group; however, the participants exercised by themselves at home after one or two sessions of education. They were intermittently contacted to encourage self-exercise.

All participants visited CR clinic for follow-up CPX and appointments with a CR specialist at 3, 6, and 12 months. To enhance patient compliance with home-based training, the attending physician reviewed the previous self-exercise methods and reeducated every participant at each visit.

Outcome parameters

For the primary outcome, a follow-up CPX was performed at 3, 6, and 12 months in the same manner as that at baseline. When the participants were lost to scheduled follow-up CPX, a registered nurse in CR clinic called the patient and asked for the reason of dropping out.

For the secondary outcomes, medical records and other variables, such as demographic (age, sex, body mass index, smoking history [packs per day×year]), geographic (mode of transport, distance and time travelled to hospital visits), and socioeconomic variables (family composition, monthly income, type of insurance), were obtained at baseline.

Questionnaires assessing activity parameters (weekly exercise time in minute), functional status (Korean activity scale/ index, KASI), quality of life (Korean version of 5 level EuroQoL-5 Dimension, EQ-5D-5L) and mood status (Patient Health Questionnaire-9, PHQ-9) were administered at baseline, 3, and 12 months.

The KASI, a Korean version for Duke Activity Status Index, consists of 15 questions about functional capacity with the score ranging from 0 to 79. Depending on the sum of the score, functional classification of KASI is divided into class I, KASI≥46; class II, 46>KASI≥24; class III, 24>KASI≥4; and class IV, KASI<4 respectively [18].

The EQ-5D-5L comprises questions about current health status in the following dimensions; mobility, self care, usual activities, pain/discomfort, and anxiety/depression. Scores for each response are 1, no problems; 2, slight problems; 3, moderate problems; 4, severe problems; and 5, extreme problems. EQ-5D-5L uses preference weights unique to South Korean population and the total score calculated from the 5 digit data set ranges from -0.066 to +1. -0.066 stands for the worst status of health and quality of life and +1 stands for the best [19].

The PHQ-9 is a self-reported questionnaire for screening depressive symptom. It consists of nine items, with the sum of scores ranging from 0–27. The score divides into 5 categories: 0–4, minimal or no depression; 5–9, mild depression; 10–14, moderate depression; 15–19, moderate-severe depression; and 20–27, severe depression [20].

Statistical analysis

All data were analyzed using SPSS statistics version 25.0 (IBM Corp.), and values are presented as mean±standard deviation or numbers and percentages. A t-test and paired t-test were used to compare the averages between groups and paired values within a specific group, respectively. Missing values due to patients who were lost to follow-up were excluded from the analysis. When the number of samples per group did not exceed 30, non-parametric tests were performed using the Mann–Whitney U-test and Wilcoxon signed-rank tests. To analyze the within-group peak VO_2 improvement from baseline, we used peak VO_2 ratio (%), which is calculated as peak VO_2 at follow-up/ peakVO_2 at baseline.

RESULTS

For baseline characteristics, most variables did not differ be-

tween the groups (Table 1). However, the proportion of men, unstable angina, smoking history, and left ventricular ejection fraction showed significant differences—all were higher in the HBCR group, with less proportion of ST-segment elevation myocardial infarction (STEMI).

The mean baseline peak VO_2 in the HBCR and CBCR group was 24.4 and 20.1, respectively, with significantly higher values in the HBCR group (Table 2). During follow-up, both groups showed an improvement in peak VO_2, although only the CBCR group showed a significant improvement from baseline. Furthermore, from 3 to 12 months, the mean peak VO_2 in both the groups did not differ significantly. However, the average peak VO_2 in the HBCR group was consistently higher than that in the CBCR group. The peak VO_2 ratio in the CBCR group showed gradual increases at 116%, 118%, and 120% at 3, 6, and 12 months, respectively; contrastingly, the HBCR group showed peak VO_2 ratios of 103%, 107%, and 107%.

The KASI score was higher in the HBCR than in the CBCR group at baseline and at 3 months; however, at 12 months, the values did not differ significantly (Table 3). The EQ-5D-5L score was higher in the HBCR group at baseline. Similar to the KASI score, the EQ-5D-5L score in the CBCR group increased during the study, and the mean EQ-5D-5L score did not differ significantly at the end of the study. The PHQ-9 showed decrease in CBCR group at 12 month (Table 3).

We recruited 45 participants for each group; however, owing to the COVID-19 pandemic and various other reasons, only 52 participants (CBCR, 27; HBCR, 25) completed the study, surpassing the presumed loss-to-follow-up rate of 20% (Fig. 1). Apart from some subsets of monthly income, no socioeconomic or geographical factors differed between the groups (Table 4), nor did the loss-to-follow-up time points and reasons (Table 5).

Table 1. Baseline characteristics of patients in CBCR group and HBCR group

Characteristic	CBCR (n=45)	HBCR (n=45)	p-value
Age (yr)	60.4±9.5	60.0±7.4	0.77
Sex, male:female	34:11	42:3	0.02
Height (m)	1.65±0.30	1.67±0.57	0.16
Weight (kg)	68.9±14.0	73.8±10.0	0.07
Body mass index (kg/m^2)	25.2±4.4	26.2±2.7	0.19
LVEF (%)	50.7±13.6	58.0±6.5	0.003
Patients with smoking history	31 (68.8)	39 (86.7)	0.04
Smoking history (packs per day×yr)	16.7±18.0	24.3±17.5	0.04
Current diagnosis			
STEMI	14 (31.1)	6 (13.3)	0.04
Non-STEMI	13 (28.9)	9 (20.0)	0.33
UA	4 (8.9)	14 (31.1)	0.008
SA	9 (20.0)	10 (22.2)	0.80
Others[a)]	5 (11.1)	6 (13.3)	0.75
Comorbidity			
HTN	23 (51.1)	22 (48.9)	0.84
DM	16 (35.6)	8 (17.8)	0.06
Dyslipidemia	11 (24.4)	15 (33.3)	0.36
Previous MI	6 (13.3)	4 (8.9)	0.51
PAOD	0 (0)	0 (0)	-
Ischemic stroke	0 (0)	2 (4.4)	0.16
Hemorrhagic stroke	0 (0)	1 (2.2)	0.32
Cancer	2 (4.4)	2 (4.4)	1.00
Management			
PCI	35 (77.8)	36 (80.0)	0.80
CABG	4 (8.9)	2 (4.4)	0.40
No. of diseased vessel	1.3±0.9	1.1±0.8	0.35

Values are presented as mean±standard deviation, number only, or number (%).
CBCR, center-based cardiac rehabilitation; HBCR, home-based cardiac rehabilitation; LVEF, left ventricle ejection fraction; STEMI, ST-segment elevation myocardial infarction; UA, unstable angina; SA, stable angina; HTN, hypertension; DM, diabetes mellitus; MI, myocardial infarction; PAOD, peripheral artery obstructive disease; PCI, percutaneous coronary intervention; CABG, coronary artery bypass graft.
[a)]Others: valve disease, tumor, heat failure and others.

Table 2. Changes of cardiopulmonary exercise test results in two groups during 12-month follow-up

CPX result	CBCR	HBCR	p-value
Peak VO_2			
Baseline	20.1±5.3	24.4±4.4	<0.001
3 mo	23.0[a)]±4.6	24.8±4.6	0.10
6 mo	23.6[b)]±5.1	24.6±5.1	0.49
12 mo	24.0[b)]±5.0	25.5±4.8	0.30
Maximal METs			
Baseline	5.7±1.5	7.0±1.3	<0.001
3 mo	6.6[a)]±1.3	7.1±1.3	0.10
6 mo	6.7[b)]±1.5	7.0±1.4	0.49
12 mo	6.9[c)]±1.4	7.3±1.4	0.30
Peak VO_2 ratio (%)			
3 mo	116±15	103±13	<0.001
6 mo	118±22	107±11	0.02
12 mo	120±21	107±13	0.02

Values are presented as mean±standard deviation.
CPX, cardiopulmonary exercise test; CBCR, center-based cardiac rehabilitation; HBCR, home-based cardiac rehabilitation; peak VO_2, peak oxygen consumption (mL/kg/min); METs, metabolic equivalents; peak VO_2 ratio, (follow-up peak VO_2 at each month/baseline peak VO_2)×100.
Significant difference from the baseline, within group: [a)]p=0.008, [b)]p=0.006, [c)]p=0.002.

Table 3. Changes of secondary parameters in two groups during 12-month follow-up

Activity scale and questionnaire	CBCR	HBCR	p-value
KASI			
Baseline	53.6±15.7	63.5±13.3	0.002
3 mo	58.7±13.7	67.5±9.0	0.004
12 mo	61.5[a]±13.5	67.0±10.2	0.12
Exercise time (min/wk)			
Baseline	258±166	227±225	0.46
3 mo	287±167	317±257	0.58
12 mo	291±320	254±188	0.64
EQ-5D-5L			
Baseline	0.815±0.136	0.860±0.047	0.04
3 mo	0.808±0.167	0.869±0.068	0.06
12 mo	0.869±0.040	0.875±0.046	0.62
PHQ-9			
Baseline	4.62±5.06	3.67±4.10	0.33
3 mo	3.23±3.66	3.03±3.64	0.84
12 mo	2.58[b]±2.37	2.04±2.60	0.46

Values are presented as mean±standard deviation.
CBCR, center-based cardiac rehabilitation; HBCR, home-based cardiac rehabilitation; KASI, Korean activity scale/index; EQ-5D-5L, Korean version of 5 level EuroQoL-5 Dimension; PHQ-9, Patient Health Questionnaire-9.
Significant difference from the baseline, within group: [a]p=0.04, [b]p=0.02.

Patients with COVID-19 related issues are provided in Supplementary Table S1.

Concerning clinical outcomes in the CBCR group, one participant was re-hospitalized for coronary artery bypass graft and another died at home, both at the 12-month follow-up. In the HBCR group, one participant at 1 month and three at 3 months were re-hospitalized for two coronary artery and two peripheral artery interventions, respectively.

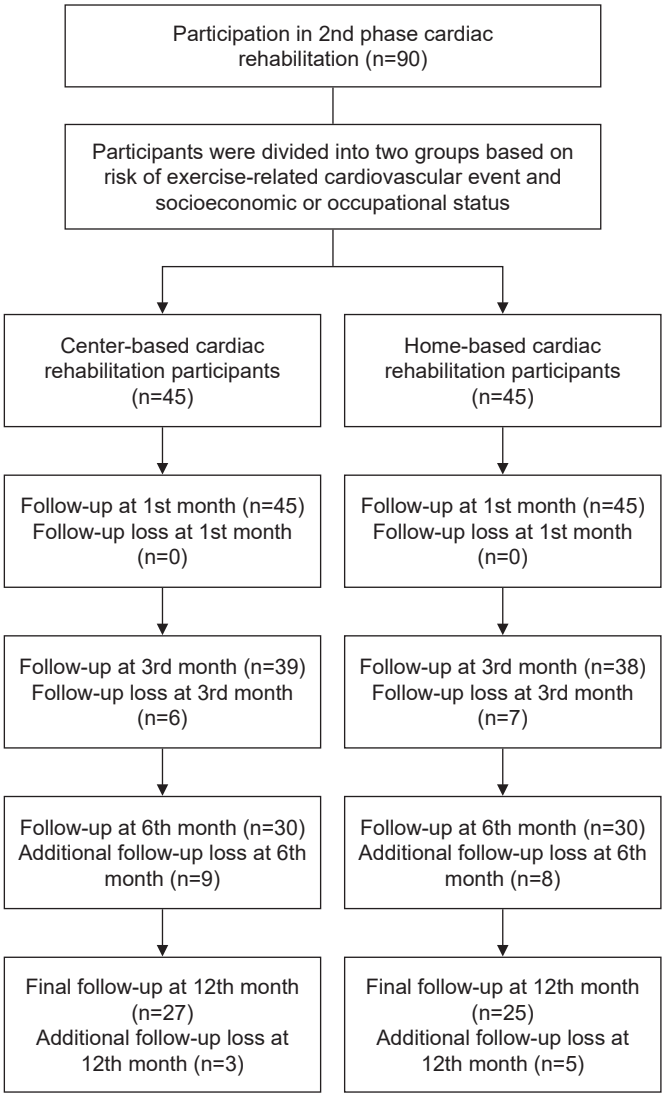

Fig. 1. Flowchart diagram of the participants and loss-to-follow-up during the study period.

DISCUSSION

We aimed to determine the impact of the COVID-19 pandemic on CR behaviors and the therapeutic efficacy of newly attended HBCR and CBCR. The COVID-19 pandemic has influenced CR implementation, necessitating changes in the content and structure of conventional CR to increase its efficiency and effectiveness [21].

At baseline, the proportion of men, unstable angina in acute coronary syndrome, smoking history, and the ejection fraction were higher in the HBCR group with less proportion of STEMI, potentially because this group included participants with a relatively lower risk of exercise-related adverse cardiovascular events and better physical function. Moreover, since unstable angina is the mildest form of acute coronary syndrome progression, more patients with unstable angina and less patients with STEMI could be included in the HBCR group, reflecting a higher baseline peak VO_2 than in the CBCR group.

Both the CBCR and HBCR groups showed an increase in the average peak VO_2 during the 12-month period. However, only the CBCR group showed a significant improvement from baseline. The peak VO_2 and metabolic equivalents in the CBCR group increased by 3.9 mL/kg/min and 1.2, respectively, at 12 months, constituting a 20% increase from baseline. In the HBCR group, these variables increased by 1.1 mL/kg/min and

Table 4. Socioeconomic and geographic factors of patients in CBCR group and HBCR group

Factor	CBCR (n=45)	HBCR (n=45)	p-value
Family composition			
Solitary	6 (13.3)	8 (17.8)	0.57
With spouse	20 (44.4)	16 (35.6)	0.40
With spouse and children	11 (24.4)	17 (37.8)	0.18
With children	2 (4.4)	0 (0.0)	0.16
Others	6 (13.3)	4 (8.9)	0.51
Monthly income (1 million KRW)			
<0.5	10 (22.2)	3 (6.7)	0.04
0.5–1	2 (4.4)	2 (4.4)	1.00
1–2	5 (11.1)	14 (31.1)	0.02
2–3	8 (17.7)	6 (13.3)	0.77
3–5	12 (26.6)	16 (35.6)	0.37
>5	8 (17.7)	4 (8.9)	0.22
Insurance			
National+personal health insurance	28 (62.2)	33 (73.3)	0.26
National health insurance	13 (28.8)	11 (24.4)	0.64
Medical protection	4 (8.8)	1 (2.2)	0.17
Distance (home–center, km)			
<5	24 (53.3)	28 (62.2)	0.40
5–10	12 (26.6)	8 (17.8)	0.32
10–25	7 (15.5)	7 (15.6)	1.00
25–50	2 (4.4)	0 (0)	0.16
50–100	0 (0)	1 (2.2)	0.32
100–200	0 (0)	1 (2.2)	0.32
>200	0 (0)	0 (0)	-
Travel time (min)			
<30	26 (57.7)	23 (51.1)	0.53
30–60	16 (35.5)	17 (37.8)	0.82
60–120	3 (6.6)	5 (11.1)	0.46
>120	0 (0)	0 (0)	-
Mode of transport			
Pedestrian	6 (13.3)	7 (15.6)	0.77
Bicycle	1 (2.2)	4 (8.9)	0.17
Public transport (bus, subway)	20 (44.4)	15 (33.3)	0.29
Taxi	2 (4.4)	0 (0)	0.16
Own car	16 (35.5)	19 (42.2)	0.52

Values are presented as number (%).
CBCR, center-based cardiac rehabilitation; HBCR, home-based cardiac rehabilitation; KRW, the South Korean "Won," which is the official currency of South Korea.

Table 5. Participants lost to follow-up CPX test in CBCR group and HBCR group

	CBCR (n=18)	HBCR (n=20)	p-value
Drop out (mo)			
1	0 (0)	0 (0)	-
3	6 (33.3)	7 (35.0)	0.92
6	9 (50.0)	8 (40.0)	0.55
12	3 (16.7)	5 (25.0)	0.54
Reasons for drop out			
Occupation & busy schedule	1 (5.6)	4 (20.0)	0.20
Distance & travel time	2 (11.1)	4 (20.0)	0.47
Expense	1 (5.6)	1 (5.0)	0.94
Medical issues	3 (16.7)	3 (15.0)	0.89
Musculoskeletal pain	7 (38.9)	4 (20.0)	0.21
Dissatisfaction	4 (22.2)	4 (20.0)	0.87

Values are presented as number (%).
CPX, cardiopulmonary exercise test; CBCR, center-based cardiac rehabilitation; HBCR, home-based cardiac rehabilitation.

0.3 at 12 months, respectively, constituting a mere 7% increase from baseline.

CBCR and HBCR are equally effective in terms of CRF [3,5,6,13] and the magnitude of improvement [3,6]. An average peak VO_2 increase between 2.0 and 3.0 mL/kg/min is reported [3,6,22-24]. Also, although there are discrepancies in the literature, it is generally reported that peak VO_2 improves by about 13% to 35% from the baseline value [25].

However, in our study, only the CBCR group achieved satisfactory peak VO_2 improvement. This can be attributed to several factors. Firstly, there have been reports that greater improvement can be expected from CR if the initial exercise capacity is low [23,25]. Additionally, in studies investigating factors that influence the degree of VO_2 improvement, the number of in-hospital exercise education sessions was identified as an independent factor affecting improvement [25]. In addition, the unsupervised HBCR participants might have performed inappropriate or inadequate exercises. Many studies and interventions in HBCR utilize telephone calls or home visits by healthcare professionals, such as exercise physiologists or nurses, aimed at enhancing adherence and overseeing home exercise [26-28]. In cases involving frequent healthcare provider contact, telephone calls or visits occurred as often as once weekly [27,28]. On the contrary, participants in the HBCR group in this study had minimal contact, limited to follow-up appointments for CPX every few months.

The KASI score was significantly higher in the HBCR than in the CBCR group at baseline and 3 months, indicating that HBCR participants were more physically active from baseline. During the 12 months, the KASI score—reflecting the physical activity level—in the CBCR group significantly increased, al-

though the values did not differ significantly at the end of the study. The average weekly exercise duration gradually increased in the CBCR group. However, in the HBCR group, it only temporarily increased and declined to baseline levels by the end of the study. HBCR participants may have only been physically active in the short-term; in contrast, CBCR participants became more physically active during the study. The HBCR participants may not have shown a significant improvement in CRF since the benefits of aerobic exercise are most significant when performed in the long-term [8].

Regarding quality of life, the EQ-5D-5L score was higher in the HBCR than in the CBCR group at baseline. Similar to the KASI score, the EQ-5D-5L score of the CBCR group increased during the study, as the mean EQ-5D-5L did not differ at 12 months. Additionally, the PHQ-9 score showed a significant decrease at 12 month in the CBCR group. Despite inconsistent results, CR seems to have improved mood and quality of life in both groups, consistent with the findings of previous studies [3,6]. Clinical outcomes, including admission or death due to cardiovascular disease, did not differ between groups, although the number of events was too small for analysis. However, both HBCR and CBCR participation is associated with a markedly reduced risk of readmission and death [3,5,6,29].

Despite the well-known therapeutic effects and benefits, CR has low global participation and maintenance rates [1-5]. There are several barriers to CR participation. A low and high socioeconomic status is linked to low and high referral rates for CR, respectively [30-32]. Moreover, rural inhabitants experience greater barriers to CR, and solitary, old, retired, and poorly educated people with low annual incomes are less willing to participate in CR [32]. These patient groups require special attention to enhance participation rates. In the present study, these non-medical factors were compared between HBCR and CBCR (Table 4). Higher proportion of participants with income lower than 0.5 million KRW/month and between 1.0–2.0 million KRW/month were assigned to CBCR and HBCR respectively. People with a monthly income of less than 0.5 million KRW can be inferred to have irregular or part-time work schedules. Based on this inference, it can be reasoned that they may have more time available to participate in CBCR.

Factors associated with discontinuing CR, which can be categorized into concerns or dissatisfaction with the CR program itself, and logistical, intrapersonal, and clinical reasons are also well reported [33]. These barriers to CR differ depending on the clinical setting. For example, the traveling time between home and hospital is a known cause of CR discontinuation, but not reported in all studies [33]. CR programs are usually funded for a limited number of sessions, or maybe not at all in some countries [21,34]. Participants without CR coverage by the health insurance would be reluctant to participate in CR. Likewise, various barriers may affect CR participation differently in accordance to specific clinical situation in each centers or region. Identifying region- and hospital-specific CR barriers are essential for enhancing CR participation [34].

Although it depends on the circumstances, approximately 25% of participants discontinue CR [6,31,33]. We predicted a 20% dropout rate when designing this study; however, 42% of participants were lost to follow-up. The reasons provided did not significantly differ between the groups (Table 5). Although only two participants reported medical reasons directly associated with COVID-19 (Supplementary Table S1), considering the unusually high dropout rate, other participants who discontinued CR could have been indirectly affected by COVID-19. Moreover, unlike in a previous study [35] in which most dropouts occurred in the first 3 months, in the present study, most occurred at 6 months. The COVID-19 pandemic may have directly or indirectly influenced the participants to consider dropping out, affecting them for a longer duration.

Here, patients in the HBCR group complained that they could not exercise properly for several reasons. Owing to the COVID-19 pandemic, government quarantine authorities strongly advised the public not to go to crowded places and refrain from going out as much as possible, and public sports facilities and health clubs were mostly closed. Additionally, quarantine masks were mandated when leaving the house. Thus, the participants were afraid or reluctant to go out to their community for exercise.

In the US, the COVID-19 pandemic was associated with cessation of CR programs and decline in CR participation which particularly affected socially vulnerable communities [9]. In the United Kingdom, COVID-19 lockdown restrictions were associated with decreased CR participation, leading to almost 30% of participants being reluctant to continue with CR [7].

The psychological and occupational impacts resulting from pandemic also adversely affected the well-being of health care providers [10].

Under these circumstances, digital therapy and telemedicine have become necessary to provide health care to patients and the concept of home-based cardiac tele-rehabilitation (HBCTR) has emerged [36,37]. Here, HBCR participants were unable

to achieve optimal benefits from participating in CR during the COVID-19 pandemic. Furthermore, dropout rates in both the CBCR and HBCR groups were higher than predicted. The COVID-19 pandemic should be considered an opportunity to transform CR by integrating it with recent technologies [7,21,36]. Recent studies in CR have emphasized the importance of such interventions and highlighted the need for future randomized controlled trials to validate the effectiveness of HBCTR [36-39].

However, there are several concerns regarding tele-rehabilitation. Relevant standard treatment guidelines have not yet been developed satisfactorily. High-tech devices may be less accessible to the elderly or low-income groups resulting in digital inequalities. Also, further studies are required to determine its long-term effects [30]. Additionally, it is important that these new programs include the content of traditional CR, which involves individualized treatment plan with nutritional education, psychological evaluation, risk factor control as well as exercise training [36].

This study has several limitations. First, a relatively small number of participants were originally included and various factors, including the COVID-19 pandemic, adversely affected CR maintenance, resulting in a high dropout rate. Second, the participants were divided into HBCR and CBCR group depending on one's risk of exercise related cardiovascular adverse event and socioeconomic or occupational status. Therefore, the randomization of the participants could not have been performed. Finally, this was a prospective observational study conducted at a single center; therefore, the findings cannot be generalized to patients in different settings.

The COVID-19 pandemic and the associated social restrictions may have adversely affected the maintenance of effective CR behaviors [8]. Strategies to supervise the intensity and content of home-based exercises, such as tele-rehabilitation or CR based on digital therapy, are urgently required to improve the outcomes of HBCR and maintain and improve adherence to CR in the case of another pandemic.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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AUTHOR CONTRIBUTION

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SUPPLEMENTARY MATERIALS

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