

The feasibility and effectiveness of smartwatch device on the adherence to the home-based cardiac rehabilitation in patients with coronary heart disease: A randomized controlled trial.

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Abstract

Background: Digital technologies have the potential to address many of the challenges associated with the traditional center-based CR (CBCR), but the remote home-based cardiac rehabilitation (HBCR) model remains a challenge.

Objective: This study is designed to investigate the feasibility, and efficacy of a smartwatch-facilitated HBCR model in patients with coronary heart disease (CHD).

Methods: It was a single-center, randomized, non-blind, and parallel-controlled study.

We recruited patients aged 18 years or older with coronary heart disease from a tertiary hospital in Jilin Province, China. The intervention group received a 3-month smartwatch-based HBCR program involving remotely delivered real-time feedback, supervision, and education. The control group received conventional HBCR. Adherence is the primary outcome of the trial, assessed by the Home-Based Cardiac Rehabilitation Exercise Adherence Scale. The secondary outcomes include cardiopulmonary function, measured by cardiopulmonary exercise testing, anxiety (General Anxiety Disorder-7), depression (Patient Health Questionnaire-9), and quality of life (36-Item Short Form Health Survey) at 3 months.

Results: Between January 1, 2023, and December 30, 2023, 62 patients (mean age 59.93±10.06 years), of whom 33.3% were female and 66.6% were male, were recruited and subsequently randomly assigned to the smartwatch group (n=32) or control group (n=30). No difference was detected in the baseline characteristics between the two groups. After the intervention, the subjects in the smartwatch group performed significantly better in peak VO₂, home-based cardiac rehabilitation adherence, GAD-7, PHQ-9, and some other parameters than those in the control group.

Conclusions: This feasibility study showed that the smartwatch device was well-accepted and effective in supporting a home-based cardiac rehabilitation model for patients with coronary heart disease (CHD). Clinical Trial: ChiCTR2400088039; <https://www.chictr.org.cn/bin/project/edit?pid=215602>

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Original Manuscript

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Trial Registration:

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Keywords: Smartwatch; digital technology; Home-based cardiac rehabilitation; adherence; anxiety; depression; quality of life.

Introduction

Background

Coronary heart disease (CHD), as the leading cause of death globally, presents significant public

health and economic challenges[1-3]. Exercise-based cardiac rehabilitation(CR), an important management strategy for CHD, is strongly recommended by clinical practice guidelines from the American College of Cardiology (ACC), American Heart Association (AHA), and European Society of Cardiology (ESC)[4, 5]. Despite its recognized benefits, access to these services remains limited for many patients in China due to barriers such as accessibility, time constraints, and uneven economic and technological development across regions[6]. As an alternative, home-based cardiac rehabilitation (HBCR) is similarly effective in improving clinical outcomes[7]. However, the benefits of HBCR largely depend on long-term adherence. Previous studies have reported that adherence to HBCR is controversial[8, 9].

With the development of mobile health(mHealth) technology, remote cardiac rehabilitation programs now utilize the capabilities of internet-connected devices, wearable monitors, smartphones, and smartwatches. These tools enable the delivery of comprehensive rehabilitation services that were previously available only through in-person sessions at medical facilities[10]. The American Heart Association (AHA) has noted that mHealth technologies play a crucial role in enhancing physical activity, supporting smoking cessation, promoting weight loss, managing blood glucose levels, and controlling hypertension[11]. The World Health Organization (WHO) has emphasized the role of digital health technologies in improving healthcare delivery, particularly for chronic disease management and rehabilitation[12]. Studies across various countries have demonstrated the effectiveness of digital platforms, mobile applications, and wearable devices in supporting CR. For instance, a study in Canada reported that tele-rehabilitation programs provided comparable outcomes to in-person CR in terms of functional recovery and patient satisfaction[13]. Additionally, mHealth technologies now allow for the near real-time monitoring of patient performance data at home. This capability covers various aspects of physical activity, such as intensity, duration, distance traveled, number of steps, and sedentary periods, as well as vital signs like heart rate and blood pressure, thus facilitating remotely supervised home-based cardiac rehabilitation (HBCR) programs.

In China, the development of mHealth HBCR programs is still in the nascent stages; research on patient acceptance and adherence to these mHealth-enabled HBCR programs remains sparse.

Objectives

This randomized controlled trial was designed to assess the feasibility of a remote HBCR program supported by a smartwatch device and to determine whether this innovative mHealth HBCR model enhances adherence to CR and improves other outcomes related to cardiovascular disease prevention.

Method

Study design and participants

This study was a single-center, 2-arm parallel design randomized controlled trial performed in a tertiary hospital in Jilin Province, China, from January 2023 to December 2023.

Inclusion criteria

(1) age of more than 18 years old. (2) diagnosed with CHD(including myocardial infarction and stable angina), the clinical manifestations and cardiovascular-related examination indicators were stable.

Exclusion criteria

- (1) Unstable angina pectoris, acute myocardial infarction, uncontrolled atrial tachycardia, asthma, obstructive hypertrophic cardiomyopathy, severe pulmonary hypertension, acute myocarditis, severe valvular heart disease, and other conditions where cardiopulmonary exercise testing is contraindicated (nerve, skeletal muscle, and rheumatic diseases).
- (2) Uncontrolled hypertension(systolic blood pressure > 160 mmHg or diastolic blood pressure > 100 mmHg at rest).
- (3) Uncontrolled heart failure(NYHA class III-IV).
- (4) Have severe motor, cognitive, mental illnesses, or visual impairment limiting the smartphone and smartwatch use.
- (5) high-risk for falls
- (6) Unwilling or unable to provide informed consent.

Randomization

The participants enrolled were randomized 1:1 to receive the smartwatch device-based CR or usual care CR alone.

Participants were assigned to either the control or the intervention group at a ratio of 1:1 through computerized randomization. Due to the nature of the intervention, neither the participants nor the outcome assessors were blinded to the group assignments.

Care providers involved in the study were assigned based on their roles to ensure consistency and minimize potential bias. A dedicated team of cardiac rehabilitation specialists and research staff was responsible for participant enrollment, baseline assessments, and follow-up evaluations. To maintain protocol adherence, healthcare providers delivering the intervention were specifically trained in the use of the smartwatch-based rehabilitation program, while those managing the control group followed standard cardiac rehabilitation guidelines. Importantly, the care providers administering the intervention did not overlap with those assessing outcomes to reduce potential bias. Additionally, all care providers were blinded to the study hypotheses and instructed to follow standardized procedures

for patient interactions.

Control group

Participants in the control group will receive a standard HBCR program based on the secondary prevention guidelines[14].

Intervention group

The smartwatch-based HBCR program will be delivered through a smartphone application (app). At the time of discharge, participants in the intervention group were provided with a smartwatch pre-installed with the intervention application. Additionally, they were instructed to download the corresponding mobile app onto their personal smartphones via the designated app stores. A step-by-step user guide was provided, and trained healthcare staff conducted a one-on-one demonstration to ensure participants could successfully log in, navigate the interface, and utilize key features such as exercise tracking, medication reminders, and data sharing. Technical support was available through a dedicated helpline to assist with any issues related to app access or usage during the study period. The intervention consists of the following(Figure 1):

- (1) Real-time monitoring: With high-precision sensors, the smartwatch continuously tracks the patient's heart rate, blood pressure, and blood oxygen levels during exercise. Furthermore, the smartwatch could calculate the number of calories burned during the exercise session, helping patients understand their energy expenditure and adjust their exercise intensity accordingly. This comprehensive real-time monitoring enables both patients and healthcare providers to track progress and make informed decisions to optimize the effectiveness and safety of the HBCR program.
- (2) Automatic reminder: Specific prescriptions set by the system are transmitted to the patient's smartwatch, providing daily reminders at designated times. For example, the doctor inputs the medication prescription into the system and sets reminder times. At 8 AM each day, the patient receives a reminder to take antihypertensive medication, including the specific name, dosage, and other important instructions. At 8 PM each evening, the smartwatch reminds the patient to take their statin medication (such as simvastatin, atorvastatin, rosuvastatin, or pravastatin) with the specific dosage. Additionally, every Monday, Wednesday, and Friday (or at patient-chosen intervals), the patient receives a notification of their exercise plan for the day, based on their exercise prescription. At 6 AM each day, the patient is reminded of their daily hydration goal, such as drinking 1500-2000 ml of water. If the smartwatch shuts down due to low battery or other reasons, it will send any missed reminders once it is powered back on. After the patient completes a task, they can mark it as "Completed," which will automatically be sent into the

hospital information system.

- (3) Health education: After enrollment, the eligible participants will receive app-based messages regarding dietary habits, physical activity, prevention of hypertension, diseases, cardiovascular disease, and knowledge of smoking cessation. The app also included educational resources for symptom management and other CR-related topics in the form of text, images, and videos in the native language.
- (4) Data sharing: Each day, we share with patients and their caregivers a summary of their motion data via the app installed on their smartphones. By sharing these results, the healthcare providers give feedback, which is then sent to the caregivers for supervision and guidance.
- (5) Individualized follow-up: The app would pop up the goal achievement according to pre-set intervals automatically. The participants had to reply depending on whether they had achieved the tasks or not, in addition to the Borg scale score to evaluate the exercise intensity.

Data Collection and outcome measures

Data were collected at baseline and 3 months. The demographic and clinical data were collected from questionnaires or electronic medical records.

The primary outcome measure was HBCR adherence as assessed using the Home-based exercise training adherence questionnaire (HETAQ), which is composed of seventeen items across the following domains: program comprehension; patient motivation; family support, and peer support. The total score ranged from 0 to 100 (higher scores indicating greater HBCR adherence), and ≥ 60 was considered to adhere well to the HBCR program[15].

Secondary outcomes included exercise capacity, quality of life, and psychological distress. Exercise capacity was measured by the cardiopulmonary exercise testing (CPET). The parameters obtained from the CPET, including oxygen consumption (VO_2), minute ventilation (VE), carbon dioxide output (VCO_2), peak metabolic equivalents (METs), peak VE/ VCO_2 ratio, ventilatory efficiency (VE/ VCO_2 slope), work efficiency ($\Delta VO_2/\Delta WR$), $\dot{V}O_{2\text{ plus}}$ and anaerobic threshold (AT).

The quality of life (QOL) was assessed with the 36-item Short-Form Health Survey (SF-36), with the score ranging from 0 to 100, and higher scores reflect better QoL[16]. Depression and anxiety symptoms were measured using the Patient Health Questionnaire 9-item scale (PHQ-9) and the Generalized Anxiety Disorder 7-item scale (GAD-7)[17, 18]. Scores on the PHQ-9 range from 0 to 27, with no depression, mild, moderate, moderately severe, and severe depression. Scores on the GAD-7 range from 0 to 21 points, with mild, moderate, and severe levels of anxiety symptoms. Higher points on these scales were closely related to psychological distress.

Sample Size

Sample size calculation was performed using the results of the preliminary study, which showed that the HETAQ score was 85.99 ± 6.68 in the intervention group vs 72.68 ± 12.93 in the control group. With the 95% confidence interval, 80% power, 5% type I error, and 10% dropout rate, we determined a minimum of 16 participants per group in recruitment. The calculation was based on two independent T tests, using PASS 15 version.

Statistical Analysis

Data was analyzed using the intention-to-treat principles by the Statistical Package for Social Sciences software (SPSS, version 26.0). Statistical analyses were conducted by an independent statistician who was blinded to group assignments. The dataset was anonymized, with group labels concealed during statistical processing to prevent bias in interpretation.

The statistical analysis followed the intention-to-treat (ITT) principle, meaning all randomized participants were included in their originally assigned groups, regardless of adherence to the intervention. For participants who remained in the trial but did not use the application as prescribed were still included in the analysis. Their adherence data were categorized separately in exploratory analyses to assess potential differences in outcomes based on actual app usage.

Baseline comparisons will be performed by descriptive statistics. The categorical variables will be summarized as frequencies and percentages, and the quantitative variables will be expressed as means $\pm$ standard deviation or medians (interquartile range) depending on the distribution of the values. Differences in the outcomes between groups were assessed using independent-sample t-tests and the Mann-Whitney U test. The $p\text{-value} \leq 0.05$ was considered significant.

Ethical Considerations

This study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki and approved by the institutional review board (IRB) of the Affiliated Hospital of Changchun Traditional Chinese Medicine (approval no. CCZYFYKYLL2023-164). All participants provided written informed consent before enrollment in the study. The consent process ensured that participants were fully informed about the study's purpose, procedures, potential risks, and benefits.

Results

Overview

Figure 2 illustrates the CONSORT diagram of the flow of participants (CONSORT-EHEALTH checklist is provided in Multimedia Appendix 1). A total of 70 eligible populations were randomly assigned to the smartwatch group ($n=35$; intervention group) or usual care ($n=35$). During the follow-up period, 3/35 participants dropped out in the intervention group and 5/35 dropped out in the control group. In the intervention group, two participants withdrew due to technical difficulties with

the application, and one due to loss of interest. In the control group, three participants were lost to follow-up, and two withdrew due to personal reasons unrelated to the study.

Table 1 shows the baseline characteristics of patients included in this study. There were no significant differences between the two groups at baseline respecting the sociodemographic and clinical variables. Respectively. The overall mean age of the participants in the intervention and control groups was 59.93 ± 10 and 62.67 ± 4.89 years.

Table 1 Baseline characteristics.

Vable	Total(n=62)	Intervention group□n=32□	Control group (n=30)	X2 /t	p
Gender(n,%)				0	1.0
Male	37(59.6)	18□56.2□	19□63.3□		
Female	25(40.4)	14□43.8□	11□36.7□		
Age(y)	59.93 ± 10	62.67 ± 4.89	57.2 ± 13	1.52	0.14
Height□cm□	167.3 ± 7.25	167.07 ± 6.96	167.53 ± 7.76	-0.17	0.86
Weight□kg□	69.4 ± 14.1	69.3 ± 17.89	69.5 ± 9.58	-0.03	0.97
BMI□kg/m2□	25.47 ± 3.96	25.97 ± 3.9	24.9 ± 4.08	0.67	0.5
Marital status(n,%)				1.034	1.0
Married	60(96.8)	32□100□	28□93.3□		
Singel, divorced, or windowed	2(3.22)	0□0□	2□6.7□		
Employment status				1.64	0.44
Retired	20(32.3)	10□31.2□	10□33.3□		
Empoyed	32(51.6)	18□56.2□	14□46.7□		
Others	10(16.1)	4□12.5□	6□20□		
Medicine(n,%)					
Antiplatelets	58(93.5)	28□87.5□	30□100□	1.15	0.59
Statins	42(67.7)	18□56.2□	24□80□	1.29	0.45
β-blocker	4(6.5)	2□6.25□	2□6.7□	0	1

ACEI/ARB	16(25.8)	10□31.3□	6□20□	1.67	0.39
CCB	12(19.4)	6□18.8□	6□20□	0.18	1
WBC□× 10 ⁹ /L□	5.76±1.11	5.56±1.04	5.94±1.18	-0.91	0.36
RBC□× 10 ¹² /L□	4.68±0.69	4.43±0.49	4.91±0.77	-1.99	0.06
Platelets□× 10 ⁹ /L□	210.48±65.4	196.5±85	223.53±38.2	-1.11	0.27
Hemoglobin□g/L□	149.72±38.35	157.64±52.73	142.33±15.44	1.07	0.29
Low-density lipoprotein (mmol/L)	2.66±0.78	2.6±0.76	2.71±0.82	-0.38	0.7
Total cholesterol (mmol/L)	4.51±0.8	4.32±0.82	4.69±0.77	-1.27	0.21
High-density lipoprotein (mmol/L)	1.16±0.29	1.1±0.21	1.21±0.34	-1.0	0.30
Triglyceride□mmol/L□	1.54±0.72	1.59±0.85	1.49±0.58	0.39	0.69
Blood urea nitrogen□mmol/L□	6.17±2	6.49±2.5	5.86±1.29	0.86	0.39
Serum creatinine (μmol/L)	82.4±29.99	84.6±40.85	80.2±13.59	0.39	0.69
blood glucose, □mmol/L□	6.15±1.75	6.48±2.39	5.81±0.63	1.04	0.3
LV□mm□	47.12±4.67	47.29±5.95	46.92±2.74	0.19	0.84

Primary Outcome

At 3 months, the mean ± SD HETAQ score on the intervention group was 89.17±9.29 and 72.50±17.17 in the control group (p=0.003). However, there was no overall significant difference between the groups in the domains of peer support (p=0.311)(Table 2).

Table 2 HETAQ score Differences Between Groups at 3 Months

	Patient's perception	Patient's motivation	Family support	Peer support	Total score
Intervention group (n=32)	90.66±12.9 1	88.33±11.70	75.56±9.65	56.94±13.4 2	89.17±9.29
Control group (n=30)	50.83±19.1 7	58.05±22.4 1	59.00±18.7 5	50.83±18.5 8	72.50±17.1 7
t	7.68	4.639	3.041	1.033	3.307
p	0.000	0.000	0.005	0.311	0.003

Secondary Outcomes

Regarding the CPET parameters, only the peak VO_2 differed within and between groups postintervention. After intervention, the peak VO_2 in the intervention group was significantly superior to its in the control group (19.8 ± 4.3 vs 15.88 ± 2.3 , $P < 0.05$) (Table 3).

Table 3 Comparing CPET parameters at baseline and after the intervention.

CPET	Intervention group (n=32)		P ^a	Control group (n=30)		P ^b
	Baseline	3 month		Baseline	3month	
Peak VO_2 (ml/kg/min)	15.66 ± 3.3	19.8 ± 4.3	0.002	16 ± 1.6	15.88 ± 2.3	0.1
Peak Mets	4.37 ± 0.64	5.17 ± 0.55	0.000	4.88 ± 0.74	5.55 ± 1.7	0.3
Peak O_2 plus (ml/beat)	9.46 ± 2.47	10.41 ± 2.59	0.004	10.15 ± 1.94	9.2 ± 2.11	0.7
Peak VE (ml/kg/min)	35.51 ± 5.74	38.58 ± 6.88	0.192	39.71 ± 7.96	41.32 ± 9.52	0.6
AT (ml/kg/min)	$11.5 (10.1, 12.85)$	$13.6 (11.95, 14.9)$	0.012	$12.4 (5.88, 13.65)$	$12.4 (11.35, 16.4)$	0.5
VE/ VCO_2	$26.61 (23.48, 30.33)$	$26.18 (24.2, 28.25)$	0.069	$25.32 (22.39, 25.98)$	$23.43 (20.59, 25.94)$	0.1
$\Delta \text{VO}_2 / \Delta \text{WR}$ (ml/min/w)	8.31 ± 1.58	8.71 ± 1.54	0.422	8.28 ± 1.38	9.11 ± 2.53	0.9

VO_2 : Oxygen Consumption, Mets: Metabolic Equivalent of Tasks, VE: Ventilation, AT: Anaerobic Threshold, VE/ VCO_2 : Ventilatory Equivalent for Carbon Dioxide; $\Delta \text{VO}_2 / \Delta \text{WR}$: functional gain” or the increase in VO_2 per W.

p^a derived from test T1 (3 months) vs. T0 (baseline).

p^b derived from test T0 intervention group vs. T0 control group.

p^c derived from test T1 intervention group vs. T1 control group.

The significant differences are marked in bold.

Changes in PHQ-9 and GAD-7 scores in the two groups are shown in Table 4. At baseline, there was no significant difference in the mean PHQ-9 and GAD-7 scores between the two groups ($p > 0.05$). After the 3-month intervention, the mean PHQ-9 and GAD-7 scores of the intervention group were lower than those at baseline ($p < 0.05$), whereas the scores for the control group showed no differences over the same period (Figure 3).

The mean SF-36 scores of the intervention and control groups at baseline were 971.29 ± 116 points and 1087.64 ± 93.57 points, respectively. The scores did not differ significantly between the two groups ($p > 0.05$). After the intervention, the scores for the following domains (bodily pain, social

function, general health, energy, physical role, emotional function, mental health, and health transition) improved significantly in the intervention group, whereas the control group showed no change. The between-group changes after intervention showed significant differences between the bodily pain-social function, energy, physical role, and health transition domains (Table 4).

Table 4. Comparison of anxiety, depression, and quality of life between the two groups before and after intervention.

	Intervention group n=32		Control group n=30	
	Baseline	3 month	Baseline	3 month
Anxiety and depression				
PHQ-9	7.6±3.4	3.2±1.01 ^{ab}	6.67±3.66	5.2±3.57
GAD-7	6.33±2.55	1.93±0.96 ^{ab}	5.87±4.09	4.13±3.15
QoL (SF-36)				
Physical function(PF)	90(90,95)	95(90,95)	90(90,93.75)	95(90,95)
Bodily pain(BP)	52(0,87.5)	62(49,74) ^{ab}	0(0,68.75)	80(80,88.5)
Social Functin(SF)	67.52±13.95	61.53±17.34 ^{ab}	69.44±10.72	83.61±11.69
General health(GH)	45(40,52)	50(43,52) ^a	45(41.25,50)	52(45,60.75)
Energy(VT)	52.31±17.27	62.46±12.02 ^{ab}	52.08±12.33	72.25±9.23
Physical role(RP)	50(0,87.5)	25(25,62.5) ^{ab}	0(0,68.75)	100(75,100)
Emotional function	33.33(16.66,66.67)	33.33(16.66,66.67) ^a	33.33(0,58.33)	83.33(33.33,100)
Mental health(MH)	53.23±20.35	69.23±17.46 ^a	59.67±12.92	78.33±7.71
Health transition	25(25,50)	36(25,75) ^{ab}	25(25,43.75)	75(50,75)
Total score	971.29±116	523.51±69.72 ^{ab}	1087.64±93.57	678.3±62.48 ^a

^aCompared with the same group after intervention, $P < 0.05$.

^bCompared with the control group after intervention, $P < 0.05$.

Discussion

Our findings support the overall intervention effect of the novel smartwatch-assessed HBCR for the enhancement of CR adherence, peak VO_2 , and QoL, while reducing depression and anxiety symptoms, which implied that the proposed wearable device was well received. These effects appear to be meaningful and may translate into future applications for patients participating in the HBCR program.

Recently, the development of wearable devices has attracted attention given the advances in health care. Previous studies on the technology of HBCR have mainly included telephone, smartphone applications, and remote monitoring systems[19-21]. We have provided evidence that patients who underwent comprehensive HBCR based on the smartwatch application demonstrated better adherence and improved peak VO_2 after 3 months.

Non-adherence to HBCR is a major problem, especially for females, the elderly, and ethnic minority

populations[22]. As previous studies reported, unlike the center-based CR, the adherence for HBCR was usually in the lower range[23]. The adherence to HBCR is mainly determined by external factors, such as environmental factors, social factors, transportation factors, and patient-self factors. We believe that the smartwatch's feature of automatic reminder function has led to changes in patients' exercise behavior, thereby improving their adherence to physical activity. The reminder function has been reported to encourage patients' behavior toward better adherence[24].

One of the unique features of the intervention described here was the use of a commercially available smartwatch device to monitor participants' real-time ECG, heart rate, oxygen saturation, physical activity, energy consumption, exercise time, and sleep-related parameters. Indeed, such observations were helpful for patients to manage their activity levels and allow healthcare providers to tailor the individual intensity of exercise through their performance. One of the major advantages of digital health interventions is their ability to deliver care remotely, which is particularly beneficial for patients who may face geographical, mobility, or time-related barriers to attending traditional, in-person rehabilitation programs. The convenience of participating in rehabilitation from home has been shown to increase program participation rates and improve patient satisfaction[13]. This accessibility can be especially important in regions where healthcare resources are limited or for patients with chronic conditions who find frequent hospital visits challenging.

In particular, individualized follow-up led the patients to continue the exercise training and medicine therapy and thus resulted in better adherence in the intervention group. Convenience is another reason for achieving better adherence among the intervention group, it is more convenient to access the smartwatch rather than the smartphone or other wearable devices. However, in this study, we observed no overall significant difference between the intervention and control groups in the peer support domain of the HETAQ scale. This finding suggests that while digital health interventions can enhance self-management and adherence to treatment, their impact on social support may be limited in the absence of structured peer interaction components. Unlike structured cardiac rehabilitation programs that facilitate in-person interactions, our intervention was primarily technology-driven, with limited direct peer engagement. While participants had access to digital educational resources and self-monitoring tools, the intervention did not include dedicated features for fostering peer interaction, which may explain the lack of significant improvement in this domain. Future iterations of the intervention may benefit from incorporating virtual community support or group-based engagement features.

Peak oxygen uptake (peak VO_2), considered the gold standard for assessing aerobic fitness, is known to be an important prognostic factor in patients with CHD. In our study, we observed a significantly

greater improvement in peak VO_2 with the intervention group at 3 months than with the control group. Our findings are similar to the previous study, which reported wearable monitoring devices significantly improved peak VO_2 compared with interventions not using wearable devices[25]. As suggested by a large observational study, a 3.5 ml/kg/min increase in exercise capacity has been associated with an improvement in survival of $\approx 12\%$ [26]. The increase in the smartwatch group is probably of clinical relevance, and if this improvement could be sustained over time, digital remote HBCR will likely lead to improved patient outcomes.

In our study, the smartwatch intervention also improved anxiety, depressive symptoms, and the quality of life. Depression and anxiety are very common in patients with coronary artery disease (CAD) and are predictors of poorer outcomes. Additionally, improving quality of life is also a key component in the secondary prevention of coronary artery disease (CAD)[27]. Notably, the European Society of Cardiology (ESC) has recommended the use of e-health solutions, including mobile apps, to enhance psychosocial health as part of secondary prevention for patients with coronary artery disease (CAD)[28]. However, some studies demonstrate that remote digital CR does not seem to improve patients' psychological status. A recent meta-analysis, which included 20 studies and a total of 4,535 patients, found improvements in both the physical and mental dimensions of quality of life in the eHealth group. However, the differences in overall scores did not achieve statistical significance ($p = 0.15$)[29]. In this study, the personalized, interactive nature of the smartwatch program may have contributed to improved mental health by promoting engagement in regular physical activity and enhancing the patient's sense of social connectedness and support. Additionally, educational resources and real-time guidance may have provided patients with coping mechanisms to deal with the emotional challenges associated with their condition.

Limitation

Despite the promising findings of this feasibility study, several limitations should be considered when interpreting the results. First, the single-center recruitment from Jilin Province (China) may introduce geographic selection bias, as participants shared similar cultural and socioeconomic profiles (urban residents with access to smart devices). Rural populations were underrepresented, potentially inflating adherence rates compared to regions with digital literacy gaps. This selection bias could affect the applicability of the smartwatch-facilitated home-based cardiac rehabilitation (HBCR) model in more diverse settings. Future multi-center studies involving diverse populations would help validate the applicability of the smartwatch-facilitated home-based cardiac rehabilitation (HBCR) model across different settings. Second, the sample size of the study ($n=32$) is relatively small, which limits statistical power and increases the risk of type II errors, meaning that potentially

meaningful effects may not have been detected. A larger cohort would strengthen the reliability of the results and allow for more robust subgroup analyses to identify factors influencing adherence and intervention efficacy. Third, the study did not account for potential confounding factors that could have influenced the outcomes, such as patients' prior experience with digital health technologies, socio-economic status, or comorbidities. These factors may affect both adherence to the HBCR program and the patient's overall health outcomes. A more comprehensive analysis considering such confounders could offer deeper insights into the factors influencing the success of smartwatch-based rehabilitation. Fourth, in China, family involvement in healthcare decisions is often more pronounced than in many Western countries, which could have influenced patient adherence to the intervention. Furthermore, the acceptance and familiarity with digital health technologies vary across cultures. While digital health solutions are increasingly popular in urban areas of China, older adults or those in rural regions may face challenges in using such technologies. These factors may limit the generalizability of our findings to other populations. Lastly, the duration of the intervention (3 months) may be too short to fully evaluate the long-term benefits of the smartwatch-based HBCR program. Further research with extended follow-up periods is needed to assess the sustainability of the observed improvements in cardiopulmonary function, anxiety, depression, and quality of life beyond the immediate post-intervention period.

Conclusions

In conclusion, our study demonstrates that a smartwatch-facilitated home-based cardiac rehabilitation (HBCR) model is both feasible and effective for patients with coronary heart disease (CHD). The intervention significantly improved exercise adherence, cardiopulmonary function, and psychosocial health outcomes, highlighting its potential as an accessible and scalable alternative to traditional center-based cardiac rehabilitation programs. These findings underscore the value of mHealth technologies in overcoming barriers to rehabilitation participation, promoting patient engagement, and improving overall health outcomes. Future studies with larger sample sizes and longer follow-up periods are warranted to further validate these results and explore the broader implications of digital health interventions in cardiac care.

Conflicts of Interest: None declared.

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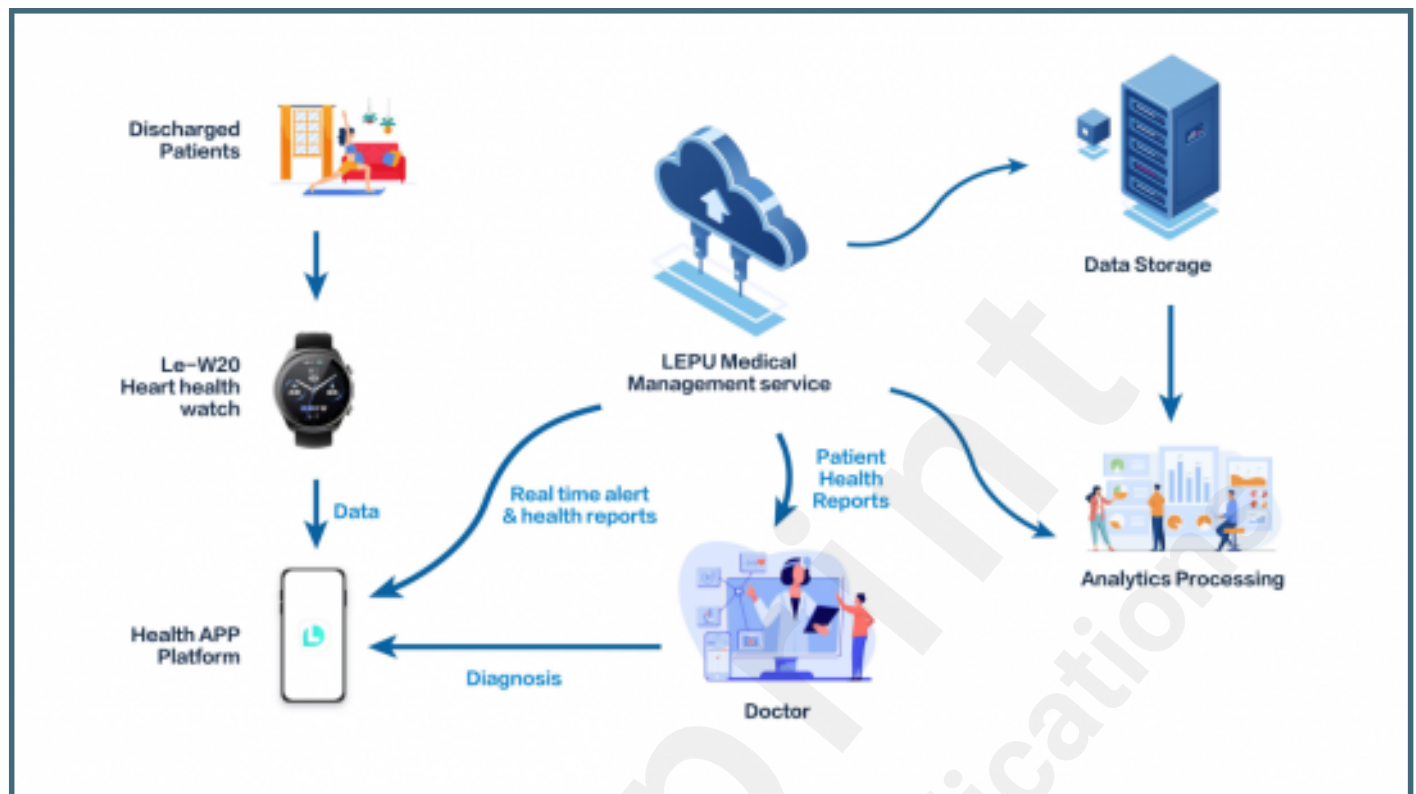
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Supplementary Files

Figures

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