Effects of Home-based Remote Cardiac Rehabilitation on Left Ventricular Function and Fear of Exercise in Patients after Percutaneous Coronary Intervention (PCI): A Retrospective Cohort Study

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Abstract

Aim: This study aims to explore the effects of home-based remote cardiac rehabilitation on left ventricular function and exercise fear in patients after percutaneous coronary intervention (PCI). Methods: A total of 232 patients with coronary heart disease after PCI treated in Tianshan Traditional Chinese Medicine Hospital from January 2020 to December 2022 were retrospectively analyzed. The patients were divided into the remote rehabilitation group (169 cases) and the routine group (63 cases) according to the exposure factor (home-based remote cardiac rehabilitation). Changes in left ventricular function and sportsophobia Tampa Scale in patients with coronary heart disease after PCI were compared using propensity score matching to reduce selection bias and confounding factors. Results: After the intervention, the scores of patients in the tele-rehabilitation group were significantly higher than those in the conventional group in terms of fear of movement, perception of danger, fear of movement, avoidance of movement, and dysfunction (p-value < 0.05). Left heart function was compared between the tele-rehabilitation group and the conventional group. Patients in the tele-rehabilitation group had significantly higher peak mitral valve blood flow in the early diastolic period (E), peak mitral valve blood flow in the late diastolic period (A), six-minute walk test (6MWT), and ratio of the peak mitral valve blood flow in the early diastolic period to the peak mitral valve blood flow in the late diastolic period (E/A) than those in the conventional group (p-value < 0.05). However, the peak deceleration time and isovolumic diastolic time in the early mitral valve diastolic period were significantly higher in the tele-rehabilitation group than in the conventional group (p-value < 0.05). Conclusions: Home-based remote cardiac rehabilitation instruction can improve the heart function and exercise fear state of patients after PCI.

Keywords

home remote; cardiac rehabilitation; percutaneous coronary intervention; left ventricular function; kinesophobia

Background

With the improvement of people’s living standards, the risk factors of coronary heart disease continue to increase. The number of cardiovascular patients in China has exceeded 290 million, of which 11 million have coronary heart disease, and the rate of increase is 20% every year [1]. Percutaneous coronary intervention (PCI) is used to treat coronary heart disease and revascularization and has given patients with coronary heart disease a new life; however, PCI cannot reverse or delay the biological process of atherosclerosis. The possibility of restenosis or thrombus cannot be ruled out after surgery [2].

The probability of intrastent restenosis in patients with coronary heart disease within six months after PCI is 10% to 20%, which has a serious effect on the long-term efficacy of the treatment [3]. Therefore, cardiac rehabilitation is the key to prevent the recurrence of coronary heart disease and improve the quality of life of patients after PCI [4]. Developing a complete rehabilitation system is difficult due to China’s unbalanced economic development, and the existing rehabilitation mode is dominated by cardiac rehabilitation in hospitals [5]. Although studies have confirmed the benefits of cardiac rehabilitation for patients with coronary heart disease, its use is limited by various reasons, such as time, transportation conditions, and medical insurance policies [6]. Patient compliance with hospital cardiac rehabilitation treatment is generally low, resulting in an increasing rate of rehospitalization and recurrence of adverse cardiovascular events after PCI and, consequently,
heavy economic and mental burden to the country and pa-

tient families [7]. Home-based remote cardiac rehabilita-

tion is a new form of out-of-hospital rehabilitation and uses

modern medical technology, computer network technology,

and remote communication technology to collect patient’s

physiological parameters; data are then displayed on a mo-

bile phone and sent to the patient’s electronic health system

through wireless network so the service center can record

the user’s health status in time and dynamically track the

patient’s physical condition for rapid communication and

feedback between doctors and patients [8]. Home-based

cardiac rehabilitation is inexpensive and has been carried

out in developed countries, but it has not been widely pro-

moted and popularized in China. Home-based cardiac reha-

bilitation has different specific intervention measures and

monitoring methods, and its training effect should be fur-

ther verified [9]. Therefore, we used sports bracelet appli-

cation (APP) to carry out home-based remote cardiac reha-

bilitation in patients with coronary heart disease after PCI
to explore influencing factors on improving left ventricular

function and exercise fear.

Materials and Methods

Survey Subjects

A total of 232 patients with coronary heart disease af-
ter PCI treated in Tianshan Traditional Chinese Medicine
Hospital from January 2020 to December 2022 were retro-
spectively analyzed. The patients were divided into the tele-
rehabilitation group (169 cases) and the routine group (63
cases) according to the exposure factor (home tele-cardiac
rehabilitation). Our study has been approved by the Ethics
Committee of Tianshan Traditional Chinese Medicine Hos-
pital and is in line with the relevant provisions of the Dec-
claration of Helsinki. The inclusion criteria of the subjects
were as follows: (1) complete clinical medical records of
the patients and diagnosis based on the requirements of the
Association of Acute Cardiovascular Care (ACVC) of the
European Society of Cardiology [10]; and (2) patients aged
18–75 years with coronary heart disease who underwent
PCI by radial artery puncture for the first time and were
successfully operated. The exclusion criteria included the
following: (1) high-risk patients, such as those with mas-
sive myocardial infarction, malignant arrhythmia, cardio-

genic shock, etc.; patients who have undergone coronary
bypass surgery; patients who had a recent acute infection;
people with frequent resting pain; (2) patients with mali-
gnant tumors, severe renal insufficiency, anemia, and severe
lung disease; a bone and joint disease that interferes with
movement; severe neurological, mental illness, or speech
and cognitive dysfunction or cannot cooperate with the ex-
amination and treatment; and (3) patients with no one to
care for them at home or who are far away from the rehabil-
itation hospital (more than 1 hour by car) and those with se-
vere coronary artery lesions requiring rehospitalization for
PCI during the intervention period.

Retrospective Cohort Investigation

Routine group: A nursing staff observed and doc-
umented patients’ condition, provided guidance for their
activities, and maintained weekly contact following their
discharge. Cardiologists evaluated patients’ conditions
by conducting cardiopulmonary exercise tests, formulating
comprehensive cardiac rehabilitation plans encompassing
exercise, nutrition, and psychology, and overseeing safety
measures throughout the rehabilitation process. Nutrition
prescriptionists elucidated the correlation between nutrition
disease to patients through various channels, including
online platforms, offline venues, such as rehabilitation clin-
ics and lectures, and WeChat groups, thereby offering tai-
lored guidance to patients. Patients who were diagnosed
with dual heart conditions underwent psychological scale
assessments at the rehabilitation clinic, followed by drug
therapy and psychological counseling. Remote rehabilita-
tion group: Patients were advised to wear a Huawei TER-
B09 sports bracelet (Huawei Technologies Co, Ltd, Shen-
zhen, China) on their wrist while engaging in physical ac-
tivity for real-time monitoring of heart rate, blood pressure,
and metabolic equivalent and recording of movement tra-
jectory. Data were transmitted to smartphone applications
via Bluetooth smart technology during the exercise session.
In the event of an electrocardiogram anomaly, such as ar-

rhythmia, arising during physical exertion, the system will
prompt a message to the patient to cease or temporarily
suspend the exercise or modify its intensity. The system
will transmit the collected data to the data center in real-
time for expert analysis. In this regard, adjustments are
made promptly to the patient’s remote cardiac rehabilita-
tion guidance plan, thereby ensuring timely modifications
to their home-based rehabilitation program. Prior to dis-
charge, the patient was instructed on the proper utilization
of the bracelet, including the downloading and installation
of the bracelet application on their smartphone, account
binding, and inputting pertinent patient information, such as
age, height, gender, body mass index, and pre-set exercise
goals. The patient was also guided on the correct wearing
of the bracelet and encouraged to walk within the ward to
demonstrate the successful acquisition of data pertaining
to the patient’s heart rate, exercise steps, and duration of phys-
ical activity. After guiding the patient to exercise, the data
will be uploaded to the mobile APP cloud, shared through
a mobile phone, and transmitted to the rehabilitation team
members for real-time monitoring.
Heart Surgery Forum

Evaluation Tools

6MWT: Six-minute walk test (6MWT) mainly measures distance walked within 6 minutes and is an important index used to evaluate the exercise endurance of patients [10]. The interventionist delimited the range of distance to 30 m, made marks at both ends, let the patient be familiar with the site before the experiment, and informed the participants of the purpose, method, and precautions of the experiment. The patient was also instructed to avoid strenuous exercise within 2 hours before the experiment, walk back and forth within the delimited range, and attempt to walk farther within 6 minutes according to their physical strength, but not to run. If the physical strength is insufficient, then the patient will be advised to slow down the walking speed or stop to rest properly and continue to move forward as soon as possible after the physical strength recovers. Before the test, the patient’s condition was strictly assessed by a professional physician, and emergency supplies (oxygen, nitroglycerin, salbutamol, etc.) were prepared. During the trial, the investigator closely observed the patient’s physical condition. If the patient develops chest pain, sweating, pale face, intolerable dyspnea, walking instability, and malignant arrhythmia, then the trial should be terminated. The distance walked by the patients within six minutes was recorded at the end of the trial. The 6-minute walking distance results were interpreted as follows: <150 m indicates severe cardiac insufficiency, 150–425 m indicates moderate cardiac insufficiency, and 426–550 m indicates mild cardiac insufficiency.

Left ventricular function index: GEVivid-7 color Doppler ultrasonic diagnostic instrument (General Electric Company, Boston, MA, US) was used, and the probe frequency was 1.7–3.4 MHz. The patient was placed on the left side of the bed by a special person. Two-Dimensional (2D), M-type, color Doppler, and electrocardiogram were routinely performed, and the patient was asked to breathe peacefully. The peak of R-wave was regarded as the pre-diastolic period, and the end of T-wave was regarded as the pre-systolic period. The measurements included M-type of aorta, left ventricular anterior–posterior diameter, interventricular septum, and left ventricular wall thickness. A volume sampler was placed 1 cm above the mitral valve orifice to measure the peak value of mitral blood flow in the early diastolic period (E), the peak value of mitral blood flow in the late diastolic period (A), the ratio of E/A, and the peak deceleration time of E (DT). The apical five-chamber section of the heart was taken, and the pulsed Doppler volume sampler was placed between the left ventricular outflow tract and the anterior mitral valve to measure isovolumic relaxation time (IVRT). All indices were measured for three consecutive times and averaged.

Fear of exercise of patients with heart disease: The Tampa Scale for Kinesiophobia (TSK) is used to evaluate exercise fear among patients with heart disease [11]. TSK was developed by Dr. Back in 2012. The scale initially assessed patients with coronary heart disease in terms of risk perception (items 3, 8, 11, 16), exercise fear (items 1, 7, 9, 13), exercise avoidance (items 2, 4, 12, 14, 17), and dysfunction (items 5, 6, 10, 15), with a total of 17 items; these dimensions represent the disease risk perception of heart disease, fear of adverse outcomes from exercise, avoidance of exercise due to heart problems, and physical, psychological, and social disorders caused by fear exercise. Likert 4 scores were used for each item of the scale, with 1 point representing “strongly disagree”, 2 points representing “disagree”, 3 points representing “agree”, and 4 points representing “strongly agree”. The total score was between 17 and 68 points, among which items 4, 8, 12, and 16 were reverse scoring items. High scores indicate a high level of sports fear. The Cronbach’s α coefficient of the scale was 0.78, which showed good temporal stability (intra-group correlation coefficient 0.83). Since its development in 2012, the scale has been introduced in Portugal, Turkey, and other countries for studies on patients with pulmonary hypertension and heart failure and shown good reliability and validity.

Follow-up Patients

A rehabilitation therapist conducted a telephone follow-up of the patients once a week to understand each patient’s diet, medication, rehabilitation program implementation status, and emotional state and timely answered the problems of the patients and recorded them. Home visits were conducted by rehabilitation therapists and caregivers every Friday from 6:00 pm–8:00 pm. At each visit, patients’ vital signs, disease recovery, and exercise compliance were assessed, and they were given exercise, medication, diet guidance, and psychological counseling. During each subsequent visit, potential issues were collected through the assessment of left ventricular function index and exercise fear score of patients in relation to their heart disease. Furthermore, patients were provided with an explanation regarding the effect of adverse mental states on their condition and given positive psychological suggestions. By considering emotional circumstances at the individual patient level, individuals are empowered to devise effective coping strategies for managing daily stressors. At the same time, we should mobilize family members to actively exert their subjective initiative, improve their ability to cope with diseases, guide other family members to carry out family self-rescue, improve the ability of caregivers to prevent and intervene, and help family members establish and use an effective social support system. Before the start of the study, rehabilitation therapists and nurses were given unified training on follow-up calls and visits, and unified guidance was required. Telephone and home visits were initiated one week after the start of the home cardiac rehabilitation program and were completed within four months.
Statistical Methods

The data of all patients with coronary heart disease after PCI were evaluated and organized into a database by using Excel software (Microsoft Excel 2013 version 15.19.1; Microsoft, Redmond, WA, USA). After logical verification, the data were imported into SPSS26.0 software (IBM Corp., Armonk, NY, USA) for data analysis. Count data were expressed as integers or percentages, and $\chi^2$ test was used for comparison between groups. Measured data were represented by mean ± standard deviation, and $t$ test was applied when the left ventricular function index and Tampa Scale for Kinesiophobia (TSK) score of patients after PCI followed normal distribution. Values with $p$-value < 0.05 indicated significant statistical difference.

Results

General Comparison of Survey Results

Propensity score matching was performed on patients after PCI to minimize the effects of selection bias on drug allocation and confounding factors, and baseline characteristics with significant differences in the two groups of patients were strictly adjusted. The propensity score was estimated by multiple Logistic regression model, and the groups were input into the regression model as dependent variables. Baseline features with significant differences were used as covariates. In 1:1 nearest neighbor matching without replacement, the caliper value was set to 0.02. Finally, 50 cases were successfully matched between the remote rehabilitation group and the conventional group.

The clinical data of the two groups were not comparable. Subsequently, 74 patients in the tele-rehabilitation group and 74 patients in the conventional group were successfully matched. No statistically significant differences were found between the two groups in terms of gender, age, payment method, comorbidities, medication history, high-density lipoprotein, low-density lipoprotein, fasting blood glucose, surgical method, number of stents, occupation, and residence area ($p$-value > 0.05, Table 1).

Comparison of Sports Fear Scores

Before intervention, the differences in exercise fear scores were not statistically significant between the two groups ($p$-value > 0.05). After the intervention, the scores of exercise fear, risk perception, sports avoidance, and dysfunction in the tele-rehabilitation group were higher than those in the conventional group, and the difference was statistically significant ($p$-value < 0.05, Table 2).

Discussion

The primary approach to family cardiac rehabilitation involved encouraging patients to engage in timely rehabilitation training through telephone follow-up. To mitigate potential inaccurate findings resulting from patients’ inaccurate or incomplete reports, we implemented remote monitoring of patients’ physical activity by using sports bracelets. The bracelet application on the server and mobile phone can continuously track patients’ exercise status and intensity, thereby minimizing any discrepancies arising from patients’ unreliable self-reports. Therefore, the effect of using this remote rehabilitation model is discussed. Our results show that the use of home tele-rehabilitation mode such as tele-rehabilitation exercise training intervention in patients with coronary heart disease after PCI can improve the cardiac function indicators of patients and reduce the occurrence of end events.

A sports bracelet was employed to monitor the implementation of home-based remote cardiac rehabilitation for patients following PCI to facilitate prompt communication and feedback between healthcare professionals and patients. This approach resulted in a more pronounced improvement in cardiac function and psychological well-being during the rehabilitation process. The possible reasons are as follows. (1) Before the intervention and after the preliminary investigation of the exercise conditions of the two groups, home-based remote cardiac rehabilitation training was implemented not only to establish collateral circulation but also to improve the function of vascular endothelial cells to slow down the development of atherosclerosis [12]. Patients with coronary heart disease who received home-based remote cardiac rehabilitation for 3 to 6 months had 11%–36% increase in peak oxygen uptake [13]. (2) The sports bracelet was used to implement...
Table 1. General comparison of survey results (n).

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Home-based remote cardiac rehabilitation for patients after PCI. The bracelet APP was used to check the implementation of home-based remote cardiac rehabilitation at any time, and data on misunderstandings and emotional disorders of patients in home-based remote cardiac rehabilitation were collected through regular home visit and telephone follow-up [14]. The home-based remote cardiac rehabilitation program should be timely adjusted according to the patients’ physical condition, and corresponding psychological counseling should be given [15]. Patients in the routine group may gradually lose understanding of the importance of home cardiac rehabilitation due to the absence of supervision and guidance from medical staff after discharge [16]. The present results showed that E, A, and E/A in the tele-rehabilitation group were significantly higher than those in the conventional group, while DT and IVRT in the tele-rehabilitation group were significantly higher than those in the conventional group. This finding differs from the results of Thomas et al. [17]. Several studies demonstrated the positive effect of elevated levels of E, A, and E/A on coronary blood flow and myocardial oxygen supply, thereby enhancing the coronary blood flow reserve ca-
capacity and heart function. However, other works reported that tele-rehabilitation does not exert significant short-term improvements in patients’ heart function [18].

Reducing exercise fear is of great significance to the prognosis of patients. After PCI, patients with coronary heart disease will have exercise fear due to many factors, which will reduce their exercise compliance and affect their rehabilitation progress. The results of our study showed that patients in the tele-rehabilitation group had higher scores on the dimensions of fear of movement, risk perception, avoidance of movement, and dysfunction than those in the conventional group [19].

The reasons may lie in the following aspects. (1) The tele-rehabilitation group makes personalized home telecardiac rehabilitation guidance program for patients, and rehabilitation exercise has a certain preventive effect on factors that induced patients’ diseases. It cannot only promote the recovery of patients’ physical activity ability but also contribute to the enhancement of heart function and the release of pressure [20]. In addition, exercise may improve the exercise fear state of patients by increasing the levels of β-endorphins and brain neurotransmitters in the body, thereby improving the quality of life of the patients [21]. (2) The tele-rehabilitation group provides patients with all-round care of psychological, physiological, and social function, so they can continue to feel the care and guidance of the hospital after discharge; as such, their fear of sports will greatly improve [22]. (3) Hospital cardiac rehabilitation projects require direct face-to-face observation of patients, while home-based remote cardiac rehabilitation projects transmit patients’ vital signs and physical and mental state on demand through intelligent monitoring systems to ensure completion of optimal exercise training and improvement of exercise fear [23]. This rehabilitation model aims to encourage patients to complete scheduled activities according to the home-based remote cardiac rehabilitation guidance plan formulated by rehabilitation doctors for rapid communication and feedback between doctors and patients [24]. Therefore, home-based remote cardiac rehabilitation mode is easy to integrate into patients’ lives and can guide patients to adhere to long-term exercise to improve their fear of exercise [25]. (4) Our wearable sports bracelet can assess whether the exercise intensity of patients is up to the standard by heart rate, ensure that the exercise intensity is within the range specified in the home-based remote cardiac rehabilitation guidance program, provide guarantee for the exercise safety of patients, and encourage patients to overcome their fear and insist on exercise [26]. (5) In addition,
rehabilitation training can reduce the use of related drugs and the occurrence of exercise fear in patients after PCI and improve the quality of life.

We have encountered some problems in the implementation process. Patient compliance with the home-based remote cardiac rehabilitation guidance program is poor. Many patients will arbitrarily increase the amount of exercise during the implementation process, mistakenly believing that the greater the amount of exercise, the more conducive to the recovery of heart function. The benefit of cardiac rehabilitation is a long-term process, so some patients may not have significant rehabilitation effect in the short term; these patients lost their confidence and courage to continue to participate in rehabilitation treatment. In this regard, medical personnel should actively communicate with patients during follow-up and door-to-door visits, clarify their psychological misunderstandings, and provide psychological counseling. Patients should be informed of the significance and necessity of long-term cardiac rehabilitation.

Conclusions
We used a retrospective cohort study to collect data of patients with coronary heart disease after PCI and found that the application of home-based remote cardiac rehabilitation guidance could improve their heart function and exercise fear.

Availability of Data and Materials
The original contributions presented in the study are included in the article. Further inquiries can be directed to the corresponding authors.

Author Contributions
XG and LZ designed the research study. LZ and ZC performed the research. XG and ZC analyzed the data. All authors contributed to 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 Tianshan Traditional Chinese Medicine Hospital (Approval number: 20190713). All patients or their families had informed consent and signed an informed consent form.

Acknowledgment
Not applicable.

Funding
This research was 2021 Xuhui District Medical Research General Project, grant No. SHXH202116.

Conflict of Interest
The authors declare no conflict of interest.

References


