

World Journal of *Clinical Cases*

World J Clin Cases 2020 May 26; 8(10): 1756-2065



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The WJCC is now indexed in PubMed, PubMed Central, Science Citation Index Expanded (also known as SciSearch®), and Journal Citation Reports/Science Edition. The 2019 Edition of Journal Citation Reports cites the 2018 impact factor for WJCC as 1.153 (5-year impact factor: N/A), ranking WJCC as 99 among 160 journals in Medicine, General and Internal (quartile in category Q3).

RESPONSIBLE EDITORS FOR THIS ISSUE

Responsible Electronic Editor: Ji-Hong Liu

Proofing Production Department Director: Xiang Li

Responsible Editorial Office Director: Jin-Lai Wang

NAME OF JOURNAL

World Journal of Clinical Cases

ISSN

ISSN 2307-8960 (online)

LAUNCH DATE

April 16, 2013

FREQUENCY

Semimonthly

EDITORS-IN-CHIEF

Dennis A Bloomfield, Bao-Gan Peng, Sandro Vento

EDITORIAL BOARD MEMBERS

<https://www.wjgnet.com/2307-8960/editorialboard.htm>

PUBLICATION DATE

May 26, 2020

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<https://www.wjgnet.com/bpg/GerInfo/239>

ONLINE SUBMISSION

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Remotely monitored telerehabilitation for cardiac patients: A review of the current situation

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Author contributions: Batalik L and Filakova K designed the research; Batalik L, Filakova K, and Dosbaba F analyzed the data; Batalik L, Batalikova K, and Dosbaba F conducted the data interpretation; Batalik L and Filakova K wrote the paper; Batalikova K and Dosbaba F revised the text; all authors approved the final version of the article.

Supported by Ministry of Health, Czech Republic - Conceptual Development of Research Organization FNBr, No. 65269705.

Conflict-of-interest statement: The authors declare no conflict of interest for this article.

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Manuscript source: Invited manuscript

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Abstract

Cardiac rehabilitation through center-based programs is an effective multicomponent intervention for the secondary prevention of cardiovascular diseases. Despite the benefits it brings, patients' participation in rehabilitation programs remains low. In this work, the latest relevant literature regarding remotely monitored cardiac telerehabilitation (TR) was reviewed considering its efficiency and utilization. The main objective was to assess whether TR has the potential to be an appropriate alternative form of rehabilitation. A total of 105 publications on this topic were screened out of 747 full-text articles that were read and evaluated, of which 12 were considered suitable for inclusion in the final review. Feasibility, efficiency, and safety were assessed for each TR intervention. The results of our evaluation indicate that TR seems to be a usable, effective, and safe alternative rehabilitation for patients with heart disease. Most of the currently published articles have studied remotely monitored TR intervention offering a comprehensive approach, which indicates the significant development and steps forward in this field of study. Our research evidence supports the implementation of TR, which could positively influence barriers in participating in cardiac rehabilitation programs.

Key words: Telerehabilitation; Cardiac rehabilitation; Wearable devices; Cardiovascular diseases; Telemonitoring; Telecoaching; Telemedicine

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Core tip: Telerehabilitation (TR) and mobile technologies are becoming potentially suitable alternatives through which it is possible to fill the gap over barriers in participation in cardiac rehabilitation programs. Based on this review, it is estimated that TR may be an effective and safe alternative rehabilitation for patients with heart disease. Most of the TR interventions currently published provide a comprehensive approach,

Received: February 21, 2020
Peer-review started: February 21, 2020
First decision: March 18, 2020
Revised: April 5, 2020
Accepted: April 28, 2020
Article in press: April 28, 2020
Published online: May 26, 2020

P-Reviewer: Barik R, Boussuges A, Dai XM, Karatza AA, Kaypakli O, Kharlamov AN, Tzamaloukas AHH, Ueda H
S-Editor: Zhang L
L-Editor: A
E-Editor: Zhang YL



indicating the significant development and step-forward in this field of study.

Citation: Batalik L, Filakova K, Batalikova K, Dosbaba F. Remotely monitored telerehabilitation for cardiac patients: A review of the current situation. *World J Clin Cases* 2020; 8(10): 1818-1831

URL: <https://www.wjnet.com/2307-8960/full/v8/i10/1818.htm>

DOI: <https://dx.doi.org/10.12998/wjcc.v8.i10.1818>

INTRODUCTION

Cardiovascular diseases remain significant causes of death worldwide, which represents a substantial economic burden on health care systems^[1]. Guidelines for cardiovascular disease prevention focus on a multifaceted approach in controlling cardiovascular risks, including patient participation in cardiac rehabilitation programs^[2,3]. Cardiac rehabilitation is strongly recommended as an effective multicomponent intervention, which includes systematic support and consultancy in achieving key preventative components (Figure 1) and which helps reduce mortality and numbers of rehospitalization in patients after acute coronary syndrome, coronary revascularization, or heart failure^[4,5]. Exercise training is one of the essential components of cardiac rehabilitation. Despite the benefits it brings, the attendance of patients in cardiac rehabilitation programs remains low (about 20%-30%). There are numerous barriers that prevent patients from enrolling in cardiac rehabilitation, such as transportation problems and distance to rehabilitation centers, time, and financial costs^[6,7]. The home-based model of cardiac rehabilitation copes with a few of these barriers regarding possibilities to take part in outpatient or center-based programs. Comparable effects of home-based and center-based approaches are very encouraging^[8].

Nevertheless, a lot of home-based programs are unable to include specialist supervision over patients' performance. Multinational cardiological societies support research studies to increase patients' attendance in cardiac rehabilitation programs according to their preferences and needs^[8-10]. Telerehabilitation (TR) and mobile technologies are becoming potentially suitable alternatives through which it is possible to fill the gap over limited participation. The concept of TR relies on information and communication technologies, such as the internet, telephone, or videoconferencing, to expand home-based cardiac rehabilitation programs and enables enough feedback, coaching, and specialist consultancy to be provided^[11] (Figure 2). Thanks to TR, patients do not necessarily have to commute to hospitals and health care centers to take part in cardiac rehabilitation, but they can perform the rehabilitation program in their home environment.

The availability of mobile phones and smartphones is still increasing globally. In many developed countries, almost 75% of the population owns mobile devices and nearly 80% can easily connect to the Internet. Furthermore, mobile Internet connection coverage and the Internet subscriptions reach high rates, nearly 80%, and it becomes almost ubiquitous^[12,13]. Such a high rate of the Internet and mobile phone accessibility suggests that it is appropriate to start implementing sophisticated telemedicine and mobile health methods that can optimize accessibility, individualization, and utilization of cardiac rehabilitation programs. Using remote technologies and wearable sensors enables monitoring patient performance and exercise information, such as intensity, time, distance, heart rate, and many other relevant factors. Medical staff can provide regular feedback and guidance to patients. The integration of wearable sensors and mobile telecommunication technologies have not been appropriately explored in home-based cardiac rehabilitation programs so far.

Nevertheless, many benefits are expected. Wireless devices are adaptive and enable providing intervention to broader environment. This review examines recent literature on the use of remotely monitored cardiac TR and evaluates its efficiency and utilization, and the safety of these interventions.

LITERATURE SEARCH

We searched for articles on MEDLINE and Web of Science from January 2012 to October 2019, while using a combination of key words as a searching process. The key



Figure 1 Key preventive components of cardiac rehabilitation. Providing secondary prevention programs of cardiac rehabilitation supports patients in setting goals of increasing levels of physical activity, healthy nutrition, optimal adherence to medication, bodyweight management, smoking cessation, and optimal psychosocial well-being, thereby helping them reduce their risk of a future cardiovascular disease event.

words were the following: “telerehabilitation”, “telemonitoring”, “home-based”, or “training” or “Internet” or “smartphone” or “mobile” or “remote” and (“cardiac” or “cardiovascular” or “heart”). Initially, the relevant articles were independently selected and evaluated by two reviewers based on their abstracts. In the next step, the full text was assessed for those articles which met the inclusion criteria. The available publications had to be written in English, to have included TR with a wearable sensor in cardiac patients, to be randomized controlled studies with an active or usual care group, to have involved telemedicine surveillance, and to have at least 6 wk for the intervention period.

Studies included in both publication databases as duplicates, describing alternative methods of cardiac rehabilitation without using remote telemonitoring, were excluded from the review. Systematic reviews, meta-analyses, or expert commentaries were excluded as well, but their appropriate references and studies that met the inclusion criteria were evaluated. The selected studies underwent a full evaluation. If there was a disagreement between the two reviewers, the lead author decided on suitability for the analysis.

PATIENT DISTRIBUTION AND INTERVENTION DESCRIPTION

We identified two groups of patients with heart disease divided into ischemic heart disease and heart failure groups. The first group was patients with myocardial infarction, angina pectoris, aortocoronary bypass, and coronary revascularization. The second group consisted of patients with chronic heart failure with preserved or reduced left ventricular ejection fraction. In the next step, we described the phase of cardiac rehabilitation (Phase II, Phase III, or heart failure) and the distribution of intervention participants according to the risk of cardiovascular events.

The two main areas of TR intervention were telemonitoring and telecoaching. Each of the evaluated studies monitored whether TR intervention contains one or both areas of focus. Description of TR intervention with remote monitoring of physical fitness consisted of identifying the component of telemonitoring, through which the data were collected and analyzed from sensors in order to obtain precise and complete patient data. That concretely meant intensity description and duration of physical fitness while using wearable sensors (heart rate monitors, accelerometers, pedometers). In another area of telecoaching focus, we evaluated the variability of techniques that control, educate, and motivate patients to do exercises and the principles of secondary prevention. At the same time, it was necessary to specify all possible ways of how often the information was transmitted from patients to specialists in medical centers. Telecommunication channels allowed providing patients with feedback in real-time or after performance.

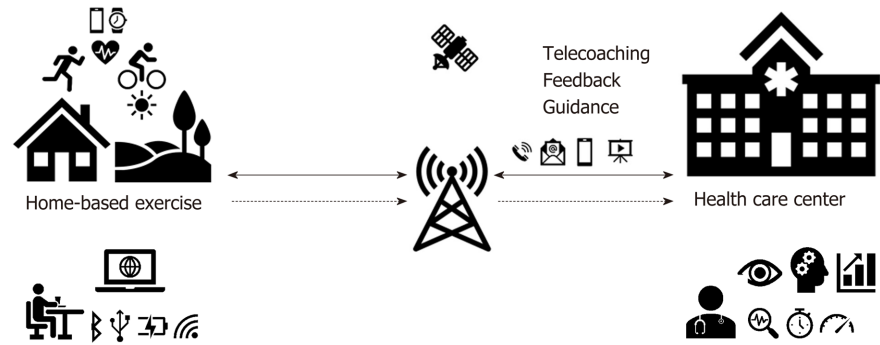


Figure 2 Scheme of remotely monitored telerehabilitation. The diagram shows remotely monitored home-based exercises from the health care center through telemonitoring and telecoaching. Images and icons are depicted as telerehabilitation form using telemedicine technologies.

STUDY AND REPORTING QUALITY

The quality of the described studies was evaluated by the Tool for the assEssment of Study qualiTy and reporting in EXercise (TESTEX), which is used for the assessment of study quality and reporting in exercise training studies^[14]. The TESTEX tool was chosen due to its reliability for exercise scientists, which facilitates a comprehensive review of exercise training trials. The advantage of this scale, compared to traditional study quality criteria, is that it considers criteria such as participant or researcher blinding, which is extremely difficult to be implemented in these study types. The scale includes 12 criteria, some of which are given more than one possible point, allowing a maximum of 15 points, whereby 5 points can be earned for the quality of the study, while 10 points can be earned for reporting. Higher scores reflect better study quality and reporting. Here, we have classified average score studies as "High Quality" for 12 points or more, "Good Quality" for 7 to 11 points, and "Low Quality" for 6 points or less.

High intervention quality was defined as highly relevant, reproducible, and very well methodically-described with precise results reporting. Good intervention quality was defined as medium relevant and with valuable reproduction possibilities in further studies but with limitations in results reporting. Low intervention quality was defined as having substantial limitations regarding relevance, poor reproducing possibilities, and insufficient results reporting. This self-approach was chosen because validated scales of marginal results are not recommended.

OUTCOMES DESCRIPTION AND EVALUATION

All eligible studies were assessed regarding primary and secondary outcomes used in TR intervention publications. Primarily, studies described TR efficiency as an exercise capacity before and after intervention (at the baseline and after intervention). Second, the feasibility of TR has been described by the percentage of completion, and the safety assessment focused on the occurrence of adverse events and mortality. Adverse events were identified as mild, moderate events that require medical help or treatment and could lead to further hospitalization. Mortality was defined as a severe adverse event.

In this review, the focus of TR interventions on key preventive components of cardiac rehabilitation has also been assessed. As recommended by multinational cardiology societies, it is essential to include a combination of these preventive components of cardiac rehabilitation to reduce the burden of the disease^[2,3]. We assessed whether TR interventions considered only one, two, or more key preventative components for cardiac rehabilitation. We also focused on methods and forms of delivery for comprehensive cardiac TR.

LITERATURE SEARCH RESULTS

We identified 1425 unique publications through the MEDLINE and Web of Science databases searching and 22 publications from other sources. A total of 700 duplicates were recognized and excluded from the review. We screened the abstracts and titles

of the remaining 747 publications and found 652 inappropriate works (other study focus); the 105 publications left were studied in detail as full texts and another 93 works were excluded. The main reasons to exclude these works were lack of remote monitoring (54 publications), insufficient TR description (30 publications), and not including exercise effectivity (9 publications). Finally, 12 eligible randomized controlled studies were accepted, including 9 that were cardiovascular disease TR studies^[15-23] and 3 heart failure TR studies^[24-26]. An overview of the search and publication selection process is shown in **Figure 3**.

Two each from among the twelve studies were conducted in Australia^[23,24], Belgium^[15,18], and China^[17,25]; one each was conducted in Korea^[20], the Netherlands^[19], New Zealand^[21], Poland^[26], and Spain^[16], and one was multi-centrally conducted in Germany, the United Kingdom and Spain^[22]. Five of the eligible studies were published between 2012 and 2016, and the other seven works between 2016 and 2020. The sample size of TR interventions ranged from 14 patients to 82 patients (total sample 545) followed by an intervention period ranging from 6 wk to 24 wk (most commonly, a 12-wk follow-up was used). Six studies included the active control group of patients in center-based cardiac rehabilitation, and another six studies included a control group of patients with usual care. Most studies included patients with an uncomplicated myocardial infarction or after coronary revascularization in phase II of cardiac rehabilitation with a low or medium risk of cardiovascular complications. Only three studies included patients with heart failure (**Table 1**).

All TR studies we investigated contained physical exercise. The prescription of TR physical activity was determined in the frequency range from 2 sessions to 5 sessions per wk, with a duration from 30 min to 300 min per week. Physical activity prescription was set from 45 min to 60 min per one session, including a warming up phase and cooling down phase with the modality of physical fitness activities (walking, Nordic walking, jogging, cycling).

In most rehabilitation interventions, all participants started the program under the direct supervision of a specialist in a hospital center (the number of sessions varied in each study), followed by a remotely monitored TR exercise. The intensity of physical exercise ranged from 40% to 80% heart rate reserve or from 9 to 13 ratings of perceived exertion. In some cases, intensity or modality was not reported.

Furthermore, in most TR studies, the intensity of physical activity was monitored by electrocardiogram telemetry ($n = 5$) or through wearable monitor or heart rate sensor with chest strap fixing. In half of the study trials, the telemonitoring was done in real-time. Exercise protocols included telecoaching with feedback provided *via* telephone calls ($n = 7$), videoconferences ($n = 2$), text messages, emails or short message services (commonly known as SMSs) ($n = 2$). In one case, the feedback was provided by the specialist ($n = 1$) (**Table 1**).

In six studies, post-exercise telecoaching was done once a week, with the Internet as a tool for data transmission. In the other six studies, real-time telecoaching was used. In these cases, the physical activity data and communication with patients were provided through videoconferences or mobile phones.

Evaluation of studied publications showed that most of the TR interventions (8 studies, 67%) included a combination of key preventive components (**Figure 4**). Only three published studies included only one component of physical activity. Also, the physical activity was the most evaluated cardiac rehabilitation component. Comprehensive TR interventions delivered preventive components to participants at the beginning of the intervention by the initial examinations or during the intervention period by telecoaching.

Feedback methods used in the studies were: Group educative session^[16]; individual educative session^[19-21,25]; educational brochure/booklet^[17,25]; telecoaching: Regular consultations *via* email/SMS^[18]; motivational telephone call^[19]; audiovisual electronic presentation with possible chat^[24]; and health smartphone applications for delivering motivational and educational materials to participants (messages and audio-visual files)^[23].

STUDY AND REPORTING QUALITY

Results of the study quality assessment showed that total study and reporting quality were good, with an average score of 11 points (range: 5-15 points). The study quality was mainly evaluated as high, being 4 points on average (range: 2-5 points) and reporting of the study results was rated as good, being 7 points on average (range: 3-10 points). Only two studies were evaluated for low overall intervention quality (**Table 2**).

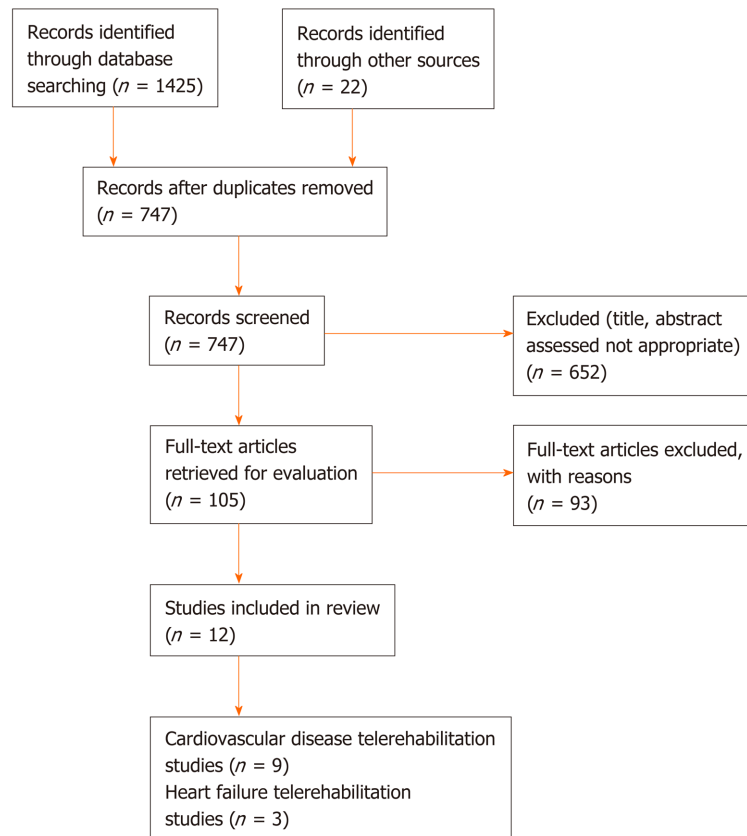


Figure 3 Flowchart of the publication selection process.

ENDPOINT ASSESSMENT

In most TR studies ($n = 10$, 83%), the primary outcome was to compare the effect of the intervention in exercise capacity. A large portion of these studies used peak oxygen uptake to describe exercise capacity effect. Besides using peak oxygen uptake, some other studies explored other measurements, such as a 6-min walking test or exercise stress test, with peak metabolic equivalents improvement.

Almost all of the studies evaluating TR intervention in a group of patients reached a statistically significant change in exercise capacity ($P < 0.05$). In six studies we identified similar improvements in comparison to the active control group undergoing their training in medical center. On the contrary, six studies showed a statistically significant improvement in exercise capacity in the TR group in comparison to the usual care group (Table 3).

These data are supported by the high percentage of completion rate of all TR interventions, having 86% on average (range: 35%-100%) in comparison to control group, having 89% on average (range: 67%-100%).

Adverse events were assessed in most of the studies; only three studies did not include them in their report. No cardiovascular severe complications or deaths were recorded during interventions described in the studies. Only mild to moderate cardiovascular events occurred in six studies but were not reported as a complication during TR exercise (Table 3).

Secondary outcome measures included modifiable lifestyle, biomedical cardiovascular risk factors (daily physical activity levels and energy expenditure, dietary habits, nicotine dependence, psychosocial functioning, blood pressure, heart rate, body weight, body mass index, waist circumference, fasted blood lipids, glucose concentrations, exercise-related motivation, acceptance and satisfaction of the TR intervention, health-related quality of life), cost efficiency through questionnaires, clinical assessments, evaluations, and blood sample testing. Comparing secondary outcomes was difficult due to various measurement methods and monitoring devices. Nevertheless, comparing secondary outcomes was not our research aim.

Table 1 Description of telerehabilitation studies

Ref.	Design	TR group patients	TR intervention			Outcomes
			Remote monitoring	Exercise prescription	Feedback	I-primary II-secondary
Avila <i>et al</i> ^[15] , 2018	RCT, 12-wk III-phase CR active CBCR	<i>n</i> = 30 age 59 I-II CVR	Post-exercise, chest strap HR monitor, internet connection	Target HR zone 70%-80% HRR, 150 min/wk	Phone call or email 1/wk	I-exercise capacity II-daily PA, strength CVR factors
Bravo-Escobar <i>et al</i> ^[16] , 2017	RCT, 8-wk II-phase CR active CBCR	<i>n</i> = 14 age 56 II - CVR	Post-exercise, ECG, biometric vest, smartphone internet	Target HR zone 70%-80% HRR, 60 min > 2/wk	Supervised CR in center 1/wk	I-exercise capacity II-CVR factors, HRQL, adherence
Fang <i>et al</i> ^[17] , 2018	RCT, 6-wk II-phase CR usual care CG	<i>n</i> = 40 age 60 I - CVR	Real-time belt strap sensor, smartphone internet connection	Physical activity booklet, walking 3/wk	Phone call 1/wk	Exercise capacity, anxiety, depression CVR factors
Frederix <i>et al</i> ^[18] , 2015	RCT, 24-wk II-III phase CR usual care CG	<i>n</i> = 70 age 61	Post-exercise accelerometer, webservice, internet	Target HR zone 1VT, 45-60 min 2/wk	Email or SMS 1/wk	I-exercise capacity II-daily PA, HRQL, CVR factors
Hwang <i>et al</i> ^[24] , 2017	RCT, 12-wk HF-CR active CBCR	<i>n</i> = 24 age 68	Real-time video platform <i>via</i> internet, educational lectures	Target RPE zone 9-13 RPE, 60 min 2/wk	15 min real-time video feedback	I-walking distance II-balance, strength, HRQL
Kraal <i>et al</i> ^[19] , 2014	RCT, 12-wk II-phase CR active CBCR	<i>n</i> = 25 age 59 I-II CVR	Post-exercise, chest strap HR monitor, internet platform	Target HR zone 70%-85% HRmax 45%-60% min > 2/wk	Weekly coaching <i>via</i> telephone	I-exercise capacity II-HRQL, training adherence
Lee <i>et al</i> ^[20] , 2013	RCT, 12-wk II-phase CR usual care CG	<i>n</i> = 26 age 54 I-II CVR	Wearable ECG equipment <i>via</i> mobile phone	Target HR zone 40%-80% HRR, 50 min, 4-5/wk	Phone call 1/wk	I-exercise capacity II-HRQL
Maddison <i>et al</i> ^[21] , 2019	RCT, 12-wk II-phase CR active CBCR	<i>n</i> = 82 age 61	Chest-worn wearable ECG sensor, internet smartphone app, accelerometry	Target HR and RPE zone 40%-65% HRR, 11-13 RPE 30-60 min, 3/wk	Real-time audio service <i>via</i> earphones	I-exercise capacity II-daily PA, HRQL, CVR factors, costs
Peng <i>et al</i> ^[25] , 2018	RCT, 8-wk HF-CR usual care CG	<i>n</i> = 49 age 66	Real-time, HR monitor smartphone, internet platform	Target HR zone 40%-70% HRR 20 min, 3/wk	Text, audio service <i>via</i> webcam	I-HRQL II-walking distance, anxiety, depression
Piotrowicz <i>et al</i> ^[26] , 2014	RCT, 8-wk HF-CR usual care CG	<i>n</i> = 77 age 54	Real-time, ECG, BP and BW monitor, mobile phone	Target HR zone 40%-70% HRR 45-60 min 5/wk	Real-time telephone call	I-exercise capacity II-walking distance HRQL, adherence
Skobel <i>et al</i> ^[22] , 2017	RCT, 24-wk III-phase CR usual care CG	<i>n</i> = 55 age 60	Real-time, ECG sensor vest, smartphone, internet platform	Target RPE zone 11-13 RPE, 10-60 min 3/wk	Real-time <i>via</i> smartphone	I-exercise capacity II-HRQL, CVR factors, anxiety
Varnfield <i>et al</i> ^[23] , 2014	RCT, 24-wk II-phase CR active CBCR	<i>n</i> = 53 age 56	Post-exercise, step-counter, BP and BW monitor, web portal, internet	Target RPE zone 11-13 RPE, > 30 min most d/wk	Text message telephone consultation first 6 wk	I-uptake, adherence II-HRQL, CVR factors, functional capacity

BP: Blood pressure; BW: Body weight; CBCR: Center-based cardiac rehabilitation; CG: Control group; CR: Cardiac rehabilitation; CVR: Cardiovascular risk; ECG: Electrocardiogram; HF: Heart failure; HR: Heart rate; HRQL: Health-related quality of life; HRR: Heart rate reserve; *n*: Number of participants; PA: Physical activity; RCT: Randomized controlled trial; RPE: Ratings of perceived exertion; SMS: Short message service; TR: Telerehabilitation.

DISCUSSION

This review brings the newest insight into relevant literary sources regarding TR intervention in cardiac patients. The purpose of this work was to explore whether remotely monitored TR can be an adequate form of rehabilitation compared to traditional center-based cardiac rehabilitation.

The main findings of the review were that TR appears to be at least as effective in improving cardiovascular risk factors and exercise capacity as traditional center-based cardiac rehabilitation. Study results significantly correspond with previous publications comparing intervention between home-based and center-based cardiac rehabilitation^[8,27,28]. TR studies included in this review mention completion rates comparable to those monitored in center-based cardiac rehabilitation. The total incompleteness intervention rate followed by exclusion from the study, which is mentioned in the final review, is comparable to that in previous studies^[29,30]. Study outcomes support our assumption that remotely monitored cardiac TR can be an

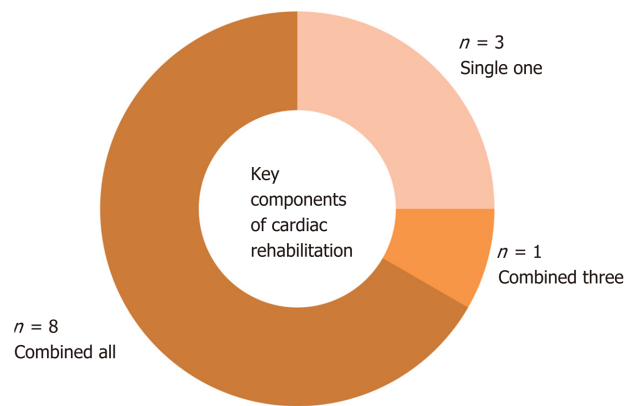


Figure 4 Use of key components in telerehabilitation interventions. The number of studies that evaluated one, three, or all key preventive components of cardiac rehabilitation are shown. Blue represents the use of a single component (physical activity); Red represents the combination of three components; Green represents the use of all preventive components in the telerehabilitation intervention.

effective alternative method that is suitable, especially for those participants who face some barriers or limitations and are not able to take part in center-based programs. As already proved in many previous cardiac rehabilitation studies, improving exercise capacity corresponded with the following prognosis, mortality included^[5,31,32].

The fact that participants of remotely monitored TR also had similar results to participants of center-based cardiac rehabilitation speaks well of the potential of this effective intervention in improving long-term prognosis after significant heart events. The quality evaluation of the studies showed an above-average level of study design and reporting. Only two of thirteen studies were below average, indicating this collection of studies a good sample with strong research basics and likelihood to be well-reproduced. This finding shows that the studies' quality levels in this review are better than those assessed in previous research^[33].

Besides monitoring physical activity, most TR interventions included some other key components of cardiac rehabilitation. A combination of telemonitoring and telecoaching was the most common TR form. This process is in line with recommendations of the American and European Preventive Societies to a multidisciplinary approach in cardiac rehabilitation, and there is no reason to underestimate TR intervention, which can deliver highly relevant practice^[34-36].

In addition to monitoring and coaching, comprehensive programs can support cardiac patients in their rehabilitation process through social networks and e-learning. Social networks support and setting goals through e-learning can help individuals who lack motivation or interest in participating in TR programs. E-learning tools can provide patients with important medical and scientific information to improve knowledge of their condition and eventually lead to better compliance with therapy. Comprehensive TR programs, including all the above areas of key preventive components, can have an even greater impact on patient health^[37]. The next part of our review deals with the question of TR intervention safety. As patients rehabilitate without "face-to-face" surveillance, as is common in traditional center-based models, there are some concerns and doubts about the safety of such interventions. Not much about this topic has been published so far, particularly for high-risk patients, such as those with heart failure. Our review includes nine studies that considered the question of safety. Of the total number of participating patients ($n = 545$), there was no cause of death or serious complications associated with TR intervention. Three of these studies included patients ($n = 150$) with heart failure^[24-26].

Although these results support the implementation of TR intervention in all risk groups of patients with heart disease, more extensive research in this area is needed to decide on the level of control. The ongoing "TELEREH-HF" study provides new data on TR effects on hospitalization and mortality in patients with heart failure. A total of 850 patients with TR intervention period of 8 wk, followed by a 24-mo follow-up, may provide more substantial evidence in this field^[38].

The cost-effectiveness of remotely monitored TR was examined in a study by Maddison *et al*^[21] and indicated that the intervention reduced the total cost of rehabilitation by 70% compared to a traditional center-based program. The FIT@home study confirmed that a TR program of the same duration as a center-based program could be a cost effective alternative^[39]. Finally, this promising assumption is supported by a study from Belgium, which showed that if the patients' participation in TR

Table 2 Study quality using Tool for the assessment of Study quality and reporting in EXercise scale

Ref.	Study quality, Max 5	Study reporting, Max 10	Total score, Max 15
Avila <i>et al</i> ^[15] , 2018	4	9	13
Bravo-Escobar <i>et al</i> ^[16] , 2017	4	7	11
Fang <i>et al</i> ^[17] , 2018	2	3	5
Frederix <i>et al</i> ^[18] , 2015	5	8	13
Hwang <i>et al</i> ^[24] , 2017	5	10	15
Kraal <i>et al</i> ^[19] , 2014	4	8	12
Lee <i>et al</i> ^[20] , 2013	2	3	5
Maddison <i>et al</i> ^[21] , 2019	4	6	10
Peng <i>et al</i> ^[25] , 2018	4	7	11
Piotrowicz <i>et al</i> ^[26] , 2014	4	6	10
Skobel <i>et al</i> ^[22] , 2017	5	5	10
Varnfield <i>et al</i> ^[23] , 2014	4	9	13

Max: Maximum.

cardiac program increases, it can reduce the burden of disease and the results will overtop the costs^[40]. This research describes TR as a cost-effective complement, particularly for those patients who cannot undergo center-based cardiac rehabilitation.

Long-term maintenance after the adaptation phase of cardiac rehabilitation is a critically important issue, and there were only two studies in our review, which monitored long-term effects 1 year after the intervention^[39,41]. Although it is reasonable to presume that TR interventions (in case they were effective) lead to improving clinical outcomes, further studies are needed to see the long-time impact of this intervention. However, promising results from individual studies suggest that TR is at least as effective in maintaining multiple intervention outcomes as center-based programs.

Besides, it is not clear how much the use of TR can fill the gap in participation in cardiac rehabilitation programs. An important potential benefit of TR is its flexibility, which can help improve the low level of cardiac rehabilitation participation and compliance reported in studies at center-based programs^[42,43]. At the same time, strategies based on improving participation in cardiac rehabilitation, such as a systematic or automatic enrollment may also be successful in cardiac TR models^[44,45]. For example, it is interesting that when the patients could choose from participating in a home-based or center-based program, almost one-half of eligible patients preferred a home-based approach^[46]. It can also indicate TR preference, which extends current home intervention and enables remotely monitored supervision in order to fill many patients' needs. At the same time, we estimate that TR can increase the number of participating patients who have difficulties commuting to rehabilitation, have personal reasons for non-participation, or have inflexible working hours^[7,47].

Usage and optimization of the TR tool offered through telemedical platforms can lead to enhancing their attractiveness and usefulness. The fact that our review includes patients who are 60-years-old on average (in half of the studies, being even more than 60-years-old in age) reflects the attractiveness and willingness of older people to engage in using new technologies.

However, acceptance and usefulness of the application can be limited by some other factors. Smartphone-based heart rate monitors may produce mixed results in accuracy between applications^[48]. This unreliability of data may limit the use of mobile health applications for telemonitoring purposes. On the other hand, the validity of heart rate monitors (wrist or chest strap sensors) has produced satisfactory results in accuracy^[49]. This fast-developing technological field of wearable sensors will probably provide more opportunities to be more precise and to optimize remotely monitored TR possibilities^[50].

LIMITATIONS

Some limitations of this review result from heterogeneity and lack of details in the publications we analyzed. Most studies included heterogenous study population, used various TR forms, modalities of physical fitness, monitoring times, and

Table 3 Studies outcomes

Ref.	Follow-up, in week	Completion rate, %		Adverse events, <i>n</i>	Exercise capacity between group differences ^a
		TR	CG		
Avila <i>et al</i> ^[15] , 2018	12	94	100 ¹	No adverse events	TR = CBCR
Bravo-Escobar <i>et al</i> ^[16] , 2017	8	93	100 ¹	3 angina type pain during TR, no ECG changes; no serious CV events	TR = CBCR
Fang <i>et al</i> ^[17] , 2018	6	83	85	Not reported	TR > UC
Frederix <i>et al</i> ^[18] , 2015	24	89	91	Not reported	TR > UC
Hwang <i>et al</i> ^[24] , 2017	12	100	90 ¹	Minor adverse events: 3 angina, 2 palpitation, 3 diaphoresis; no serious CV events	TR = CBCR
Kraal <i>et al</i> ^[19] , 2014	12	86	96 ¹	No adverse events	TR = CBCR
Lee <i>et al</i> ^[20] , 2013	12	87	97	Not reported	TR > UC
Maddison <i>et al</i> ^[21] , 2019	12	88	92 ¹	Mild: 12 non-serious; moderate: 6 medically important event, hospitalization; no serious CV complications	TR = CBCR
Peng <i>et al</i> ^[25] , 2018	8	86	84	No adverse events	TR > UC
Piotrowicz <i>et al</i> ^[26] , 2014	8	97	94	Minor: 4 skin reactions due to the ECG electrodes; no serious CV events	TR > UC
Skobel <i>et al</i> ^[22] , 2017	24	35	67	No CV events associated to CR adverse events: 9; 2 chest infection, 3 angina, 2 chest pain before training, 1 atrial fibrillation, 1 palpitation	TR > UC
Varnfield <i>et al</i> ^[23] , 2014	6	91	68 ¹	10 deterioration in health and/or medical care needs unrelated to CR; no serious CV events	TR = CBCR

^a*P* < 0.05.¹Center-based cardiac rehabilitation. CBCR: Center-based cardiac rehabilitation; CG: Control group; CR: Cardiac rehabilitation; CV: Cardiovascular; ECG: Electrocardiogram; TR: Telerehabilitation; UC: Usual care.

evaluations of intervention effect. Various methodologies used in the studies limited us from comparing them in detail.

Another limitation is the disunity among the studies regarding the cardiac rehabilitation phase. The studies mention the adaptation phase (II), stabilization, and maintenance phase (III), and a combination of both, and some studies did not provide information about phases, which limits us from providing a better comparison. It is difficult to be transparent in results' interpretation. Further problems might occur in developed countries, where the elderly are not capable of using high-tech technology.

Regardless of these limitations, the results show improvement and offer the possibility to find a place for TR in preventing heart disease.

OPPORTUNITIES FOR FUTURE DEVELOPMENT

Although TR has been explored from many points of views, there are some more key questions, which are necessary to be answered in further investigations in this field of study. Concretely, TR studies published do not include enough women in order to decide about specific sex-related differences as an intervention factor. What is more, we have not found any study exploring implementation of TR in patients with low socioeconomic status. In these cases, the intervention might decrease barriers in attendance and bring more essential advantages. At the same time, we need to study

TR impact on various age groups, especially for the elderly, who often have individual needs that can limit them from reaching optimal intervention effect^[51].

The future requires more studies that will implement TR tools for a various spectrum of eligible patients, including those who have more difficult life conditions (rural living, comorbidity, low socioeconomic status, older age) and who may not achieve similar safety outcomes or effectiveness of TR intervention. The challenge for further development and implementation of TR can be keeping and securing the data regarding the personal information of participants and providers. It is necessary to think about the area of cybernetic security as well.

Previous data have indicated that inclusion of other training modalities, such as interval training with high intensity, can bring further health benefits and shorter time of physical performance^[52]. On the other hand, implementing this new method in the home environment can be more difficult and less precise in comparison to possibilities in medical centers under supervision. The use of such a form in the TR model provides space for further studies.

The current overview of remotely monitored TR was designed for cardiology patients. However, it has potential for use in other groups of patients with different diseases (for example, cardio-oncology, cardiopulmonary, neurology, metabolic syndrome, and many others.). Also, these patients could benefit from this form in which the program is tailored to their individual needs and health condition.

CONCLUSION

According to this review, it is estimated that TR could (compared to traditional center-based program of cardiac rehabilitation) represent usable, effective, and safe alternative forms of rehabilitation for patients with heart disease. Most of the currently published works studied remotely monitored TR interventions offering a comprehensive approach, which indicates significant development and steps forward in this field of study.

Our research evidence supports the effectiveness of TR, which could positively influence barriers to participation in cardiac rehabilitation programs. TR seems to be a great possibility to facilitate taking part in programs for those individuals who cannot decide any other way. These encouraging findings should be supported by additional studies but already present a strong reason for implementing TR in existing secondary preventive therapies of cardiac rehabilitation.

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