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Review Article

A Review of the Digital Era of Cardiac Rehabilitation: From Centres to Screens

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ABSTRACT

Introduction: Cardiac rehabilitation (CR) is a vital measure aimed at improving the quality of life (QoL) and preventing secondary complications and recurrence in individuals with a high cardiac risk profile. As an alternative to traditional CR, e-rehabilitation (e-rehab) using smartphones or web-based platforms is a modern solution for effective CR. This study aimed to identify its implementation and evaluate its effectiveness on functional capacity, adherence, and QoL.

Materials and Methods: A systematic search of randomized controlled trials (RCTs) was conducted in electronic databases, such as Medline, Embase, and Cochrane Central Register of Controlled Trials, between January 2015 and January 2025. The selected studies included e-rehab as an intervention, implemented through a hybrid model, among a heart disease population. A total of 210 studies were identified, of which 13 with higher-quality evidence were selected as appropriate to our scope.

Results: CR using the e-rehab protocol improved functional capacity and QoL. Participants' follow-up rates and interest were noticeably lower in traditional CR compared to e-rehab.

Conclusion: Overall, e-rehab-based CR was effective, but when implemented alongside telemonitoring devices, it may reduce the risk of physical activity-induced adverse reactions. Such a model enhances patients' willingness to enroll in exercise-based CR.

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Introduction

The World Health Organization (WHO) states that 1 in 3 deaths are due to cardiovascular diseases (CVD), with 17.9 million deaths worldwide annually, and over 197.2 million deaths globally in the past three decades [1, 2]. Cardiac rehabilitation (CR) is the core domain of management to prevent secondary complications in patients with cardiovascular disease, with artificial intelligence (AI) recommendations from the American and European societies of cardiology [3, 4]. Despite stronger evidence for using CR as a vital tool for preventing secondary complications and prognosis severity, the availability of CR centers is low [5].

A precise alternative to traditional CR is e-rehabilitation (e-rehab), using a smartphone or web-based platform [6, 7]. A recent advancement that has gained closer attention in the field of rehabilitation is e-rehab among the cardiovascular disease population, which has been persistently delivered higher benefits than the traditional method of CR [8, 9]. Patients with cardiovascular disease undergoing hybrid models of CR have been shown to have significant increases in disease-related knowledge, health behaviour, and clinical outcomes [10-12].

Participant adherence is directly related to the resultant benefits of CR; people often discontinue the program due to various factors, such as physical, health-related, demographic, and mental factors, which require immediate action to incorporate specific strategies for effective enabling [13, 14]. Digital health interventions in the CR domain have a greater impact on adherence among participants, leading to the prevention of secondary complications [15]. This study aimed to review the impact of e-rehab on CR, focusing on its efficacy and clinical outcomes, and to identify research gaps for future studies.

Research questions:

What factors were associated with enhanced outcomes among e-rehab participants? What were the pros and cons of implementing e-rehab among patients with cardiac disease?

What factors are associated with e-Rehab and adherence among the participants?

Materials and Methods

The preferred reporting items for systematic reviews and meta-analyses (PRISMA) extension for Scoping Reviews was followed. The eligibility criteria primarily focused on identifying studies of cardiac diseases that used tele-monitoring, e-rehab, and hybrid, remote, and virtual CR methods. This scoping review aimed to evaluate the availability of e-rehab, which facilitated the identification of research gaps.

Search strategy:

For the extensive literature search, electronic databases, such as Medline, Embase, and the Cochrane Central Register of Controlled Trials (CENTRAL), were used. The search strategy used the following keywords: "e-rehabilitation OR tele-rehabilitation OR hybrid model of CR OR virtual rehabilitation OR rehabilitation with smartphone application AND CR AND cardiovascular disease".

Eligibility criteria:

Study designs were restricted to randomized controlled trials (RCTs) and experimental studies on cardiac diseases utilising e-rehab as an intervention, with no restrictions on the duration of follow-up for participants. Full-text articles in the English language published between July 2015 and January 2025 were searched.

Study designs were analysed based on populations, interventions, comparisons, and outcomes that had e-rehab or a hybrid model of CR, tele-rehab, or remote rehabilitation, virtual rehabilitation or rehabilitation using a smartphone application or web-based platform as the intervention.

Data analysis and segregation:

Studies following the hybrid model of CR and e-rehab with e-media were grouped for analysis of the design, population, protocol, duration, outcome measures, results, summary, and limitations. The results obtained from each study on the implementation of e-rehab were summarized and tabulated.

The evaluated studies compared two approaches: traditional center-based CR (control group) and e-media-supported remote CR (intervention group).

Outcomes and outcome measures:

The evaluated studies were stratified by the following outcomes, which directly imply the recovery of individuals with CVD. Physical activity status and functional capacity are the core components of recovery in the post-operative period and post-cardiac incidents. The health-

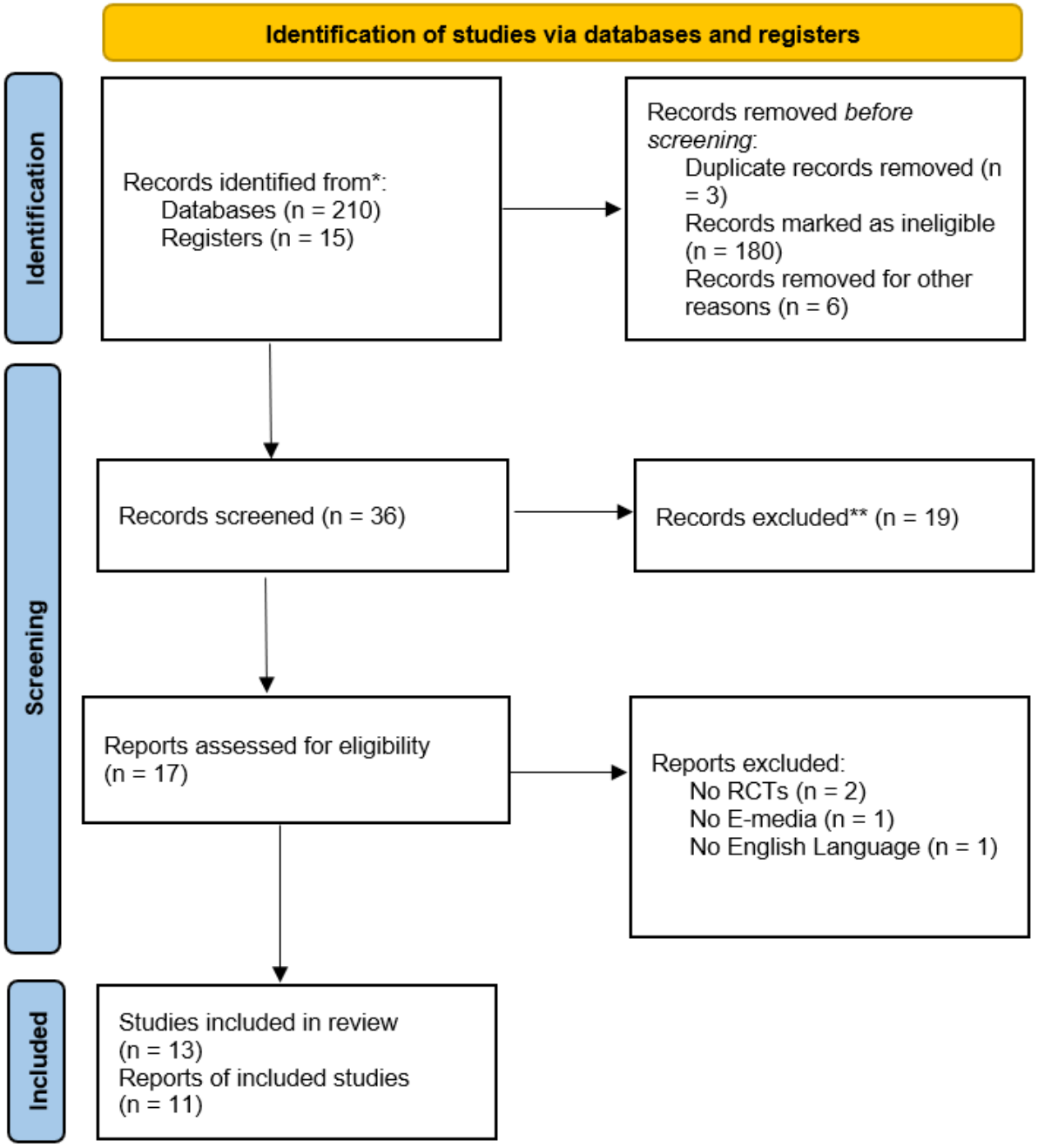

Figure 1. PRISMA chart-study selection

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related quality of life (QoL) is the primary outcome for evaluating the patient's psycho-motive approach in daily life participation and approaching society. The six-minute walk test, International physical activity readiness questionnaire, treadmill testing, and VO_2 peak are outcome measures used to evaluate functional capacity and physical activity status.

Results

Studies extracted: An extensive search of electronic databases found 210 published articles from Medline, Embase, and Cochrane, of which 36 relevant abstracts were screened with an appropriate title, and 189 articles were excluded that did not meet the eligibility criteria of the search for this study. Of 36 published articles, 13 full-text articles were found to include e-rehab interventions for the cardiovascular disease population and were

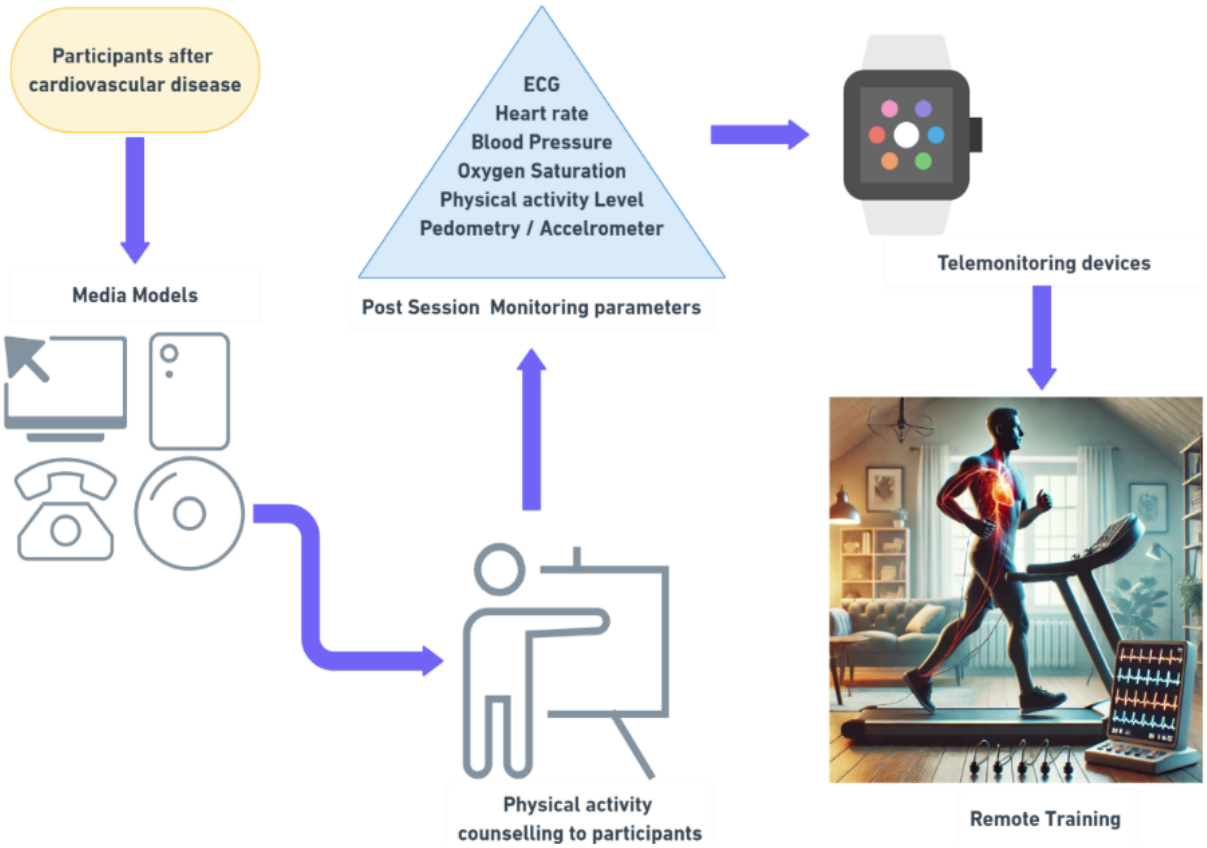

Figure 2. Participants receiving protocol of home-based CR using e-media platforms

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assessed for full-text review (Figure 1). The total number of participants recruited for the study was 1605, and the overall number of participants recruited for analysis was 1398. A total of 709 participants received hybrid model CR, and 689 received traditional model CR. The mean age of all participants was 61.92±7 years (Table 1). The evaluated studies followed a standardized protocol for a hybrid model of CR with e-media support. Telemonitoring support was provided to participants for their remote setups (Figure 2). Dropout and loss-to-follow-up rates were also significantly higher in the traditional group compared with the e-media CR group (Figures 3 and 4).

The use of e-media-supported CR in the intervention group resulted in notable changes in functional capacity and QoL, with improvements of 87.5% and 60%, respectively (Table 2). Our analysis revealed that 68.75% of studies utilized telemonitoring, which plays a crucial role in e-media-supported rehabilitation, enabling proactive management and helping prevent secondary complications. For effective communication at remote setups 18.75% of studies used telephone calls and text messages for participants, and 81.25% used advanced tech support, such as mobile software, gadgets, virtual reality (VR), webpages, communicating software (WeChat, WhatsApp), and DVDs (Table 3). E-rehab lacks technological advancements in enhancing safety measures and precautions during the implementation of home-based CR, despite the current advanced technology in health care.

The control group received the traditional CR method. Usual care, emphasizing lifestyle modifications, physical activity promotion, education about diet and smoking, and regular medications, was used in six studies. Four studies involved center-based supervised CR programs, such as traditional model of structured exercise program with routine workouts and cycle aerobics training. Three studies adhered to locally defined standard care guidelines.

Among the evaluated studies, five studies did not include telemonitoring to assess the vital parameters during hybrid model CR. Studies were summarised into telemonitoring with and without a telemonitoring device, and into e-media content with and without e-media

Table 1. Study characteristics of evaluated studies

Author(s), Year	Subjects	Drop Outs	Mean±SD
			Age (y)
Widmer et al. 2017 [15]	IG:40 CG: 40	3 6	62.5±10.9
Bernocchi et al. 2018 [16]	IG: 56 CG: 56	11 21	70±9
Snoek et al. 2021 [17]	IG: 88 CG: 90	16 12	76±11
Vieira et al. 2018 [18]	IG 1: 15 IG 2: 15 CG: 16	4 4 5	55±11.3
Lunde et al. 2020 [19]	IG: 57 CG: 56	9 2	59.0±8.7
Dalli Peydró et al. 2022 [20]	IG: 34 CG: 33	1 2	54.7±9.9
Su & Yu 2021 [21]	IG: 73 CG: 73	7 15	55.78±7.14
Bravo-Escobar et al. 2017 [22]	IG:14 CG:14	1 0	56.07±8.92
Dibben et al. 2023 [23]	IG: 132 CG: 134	0 0	70.9±10.3
Su et al. 2023 [24]	IG: 39 CG: 39	5 10	55.73±7.17
Dorje et al. 2019 [25]	IG: 156 CG: 156	2 4	60.5±9.02
Claes et al. 2020 [26]	IG: 60 CG: 60	3 2	61.4±13.5
Lahtio et al. 2023 [27]	IG: 29 CG:30	2 3	60±6

IG: Intervention group; CG: Control group.

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content, implemented in the intervention group (Table 3). Evaluated studies included e-media content as the primary source of material for participants' education in the hybrid model of CR. One study utilized a handbook/manual for exercise education and a diary or booklet to schedule the exercise focus [16]. One study encouraged participants through telephone interviews regarding exercise schedules, motivation, and types of exercise [17].

Functional outcomes, including physical activity status and QoL, were significant across studies.

Significant changes were observed with enhanced physical activity level in seven of the studies reviewed (Table 4). The physical activity level of the participants was also improved with e-media-supported rehabilitation among overall participants in the evaluated studies.

The traditional CR group exhibited higher dropout rates and a greater number of participants lost to follow-up than the e-media group (Figures 3 and 4).

Discussion

Technology-based rehabilitation for cardiac diseases was an evolving trend that requires close attention for successful implementation of CR, especially in low-income countries [28]. A global implementation of CR has been haphazard, with poor adherence to centre-based approaches due to economic constraints and various conflicting factors. The majority of the evidence belonged to European countries, including Italy, Spain, Portugal, Finland, Ireland, and Norway, providing insight into the highest interventional aspects of existence among these territories. Studies from China, Canada, and the USA also showed the highest support for telerehabilitation in cardiac diseases.

Telemonitoring implications on physical activity:

The effects of using technology in the field of rehabilitation were promising, and among the assessed evidence, they utilised technology as a tool to enhance participa-

Table 2. E-media-based rehabilitation effects on functional outcomes

Author(s), Year	Duration	Functional Capacity	Changes	QoL	Changes
Widmer et al. 2017 [15]	3 m	VO_2 peak	ⓧ	Dartmouth QoL	↑
Bernocchi et al. 2018 [16]	4 m	6 MWT	↑	MLHFQ	ⓧ
Snoek et al. 2021[17]	6 m	VO_2 peak	↑	SF-36	ⓧ
Vieira et al. 2018 [18]	6 m	TMT	↑	MacNew-HR QoL	↑
Lunde et al. 2020 [19]	12 m	VO_2 peak	↑	Heart QoL	↑
Dalli Peydró et al. 2022 [20]	10 m	VO_2 max	↑	EQ-5D-5L	↑
Su & Yu 2021 [21]	12 w	MET	↑	MacNew-HR QoL	↑
Bravo-Escobar et al. 2017 [22]	6 m	TMT	↑	SF-36	↑
Dibben Hillsdon et al. 2023 [23]	12 m	ISWT	↑	EURO QoL	↑
Su et al. 2023 [24]	12 w	IPAQ	↑	MacNew-HR QoL	ⓧ
Dorje et al. 2019 [25]	12 m	6MWD	↑	SF-12 (mental, physical) –	ⓧ
Claes et al. 2020 [26]	6 m	VO2 peak	↑	SF-36	ⓧ
Lahtio et al. 2023 [27]	12 m	6MWT	ⓧ	WHOQOL BREF question-naires	ⓧ

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Abbreviations: QoL: Quality of life; SF-36: Short form 36; 6MWT: Six minute walk test; MLHFQ: Minnesota living with heart failure questionnaire; ISWT: Incremental shuttle walk test; IPAQ: International physical activity questionnaire; PA: Physical activity; TMT: Treadmill testing; ↑: Improved; ⓧ: No change; M: Month; W: Week; MET: Metabolic equivalent.

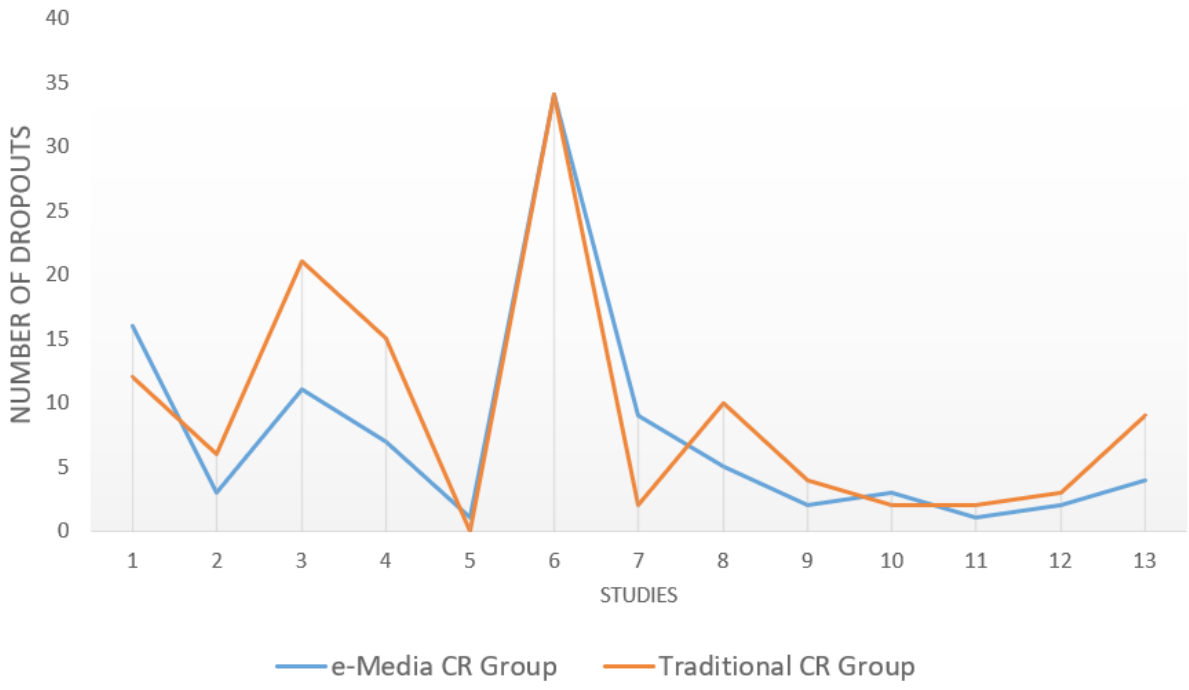

Figure 3. Dropout comparison between e-media CR group and traditional CR group

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Table 3. Model of e-media for rehabilitation and type of telemonitoring technology availed

Author(s), Year	Mode of e-Media	Telemonitoring Technology
Widmer et al. 2017 [15]	Mobile and web application	No information
Bernocchi et al. 2018 [16]	Phone calls, dairy	Oximeter, card guard scientific Ltd – ECG
Snoek et al. 2021 [17]	Smartphone	Heart rate belt
Vieira et al. 2018 [18]	Virtual reality (Kinect)	A Polar wearlink coded cardiofrequencemetre model FT7 - HR
Lunde et al. 2020 [19]	Mobile application	No information
Dalli Peydró et al. 2022 [20]	Webpage, smartphone	Polar H7 - HR
Su & Yu 2021 [21]	WeChat.	Pedometer
Bravo-Escobar et al. 2017 [22]	Mobile application -NUUBO	ECG- NUUBO
Dibben et al. 2023 [23]	DVD	No information
Su et al. 2023 [24]	Website	Smart watch (Mi watch)
Dorje et al. 2019 [25]	WeChat and videos	Pedometer and C-health XY-10 sky innovation tech - BP, HR
Claes et al. 2020 [26]	Gadget PATHway system- Exerclass, Exergame.	Actigraph GT9X Link
Lahtio et al. 2023 [27]	WhatsApp (meta) and Web software (Movendos)	Fit bit Accelerometer

Abbreviations: DVD: Digital versatile disc; ECG: Electrocardiography; HR: Heart rate; BP: Blood pressure.

Table 4. Hybrid CR and exercise capacity

Author(s), Year	Outcomes	Control Group	Mean±SD/Median (IQR)	P
			Experimental Group	
Widmer et al. 2017 [15]	VO_2 peak (mL/min/kg)	0.6±1.1	1.1±2.9	0.67
Lunde et al. 2020 [19]	VO_2 peak (mL/min/kg)	–0.8±3.3	1.4±3.5	<0.001
Dalli Peydró et al. 2022 [20]	VO_2 max (mL/min/kg)	24.3(5.5)	25.6(5.6)	0.004
Claes et al. 2020 [26]	VO_2 peak (mL/min/kg)	-	24.1(5.82)	-
Snoek et al. 2021 [17]	VO_2 peak (mL/min/kg)	0.2	1.6	<0.001
Bravo-Escobar et al. 2017 [22]	TMT (min)	6.87(1.67)	6.38(1.8)	0.32
Bernocchi et al. 2018 [16]	6 MWT (P)	0.2543	0.9573	0.0040
Dorje et al. 2019 [25]	6 MWT (m)	523.5(60.2)	543.4(67.5)	0·027
Lahtio et al. 2023 [27]	6 MWT (m)	20.3(42.5)	28.6 (44.3)	0.01
Su & Yu 2021 [21]	MET	1833(2324.25)	2796(29.448)	<0.001
Dibben et al. 2023 [23]	ISWT	-	-	0.008

Abbreviations: 6MWT: Six-minute walk test; ISWT: Incremental shuttle walk test; TMT: Treadmill testing.

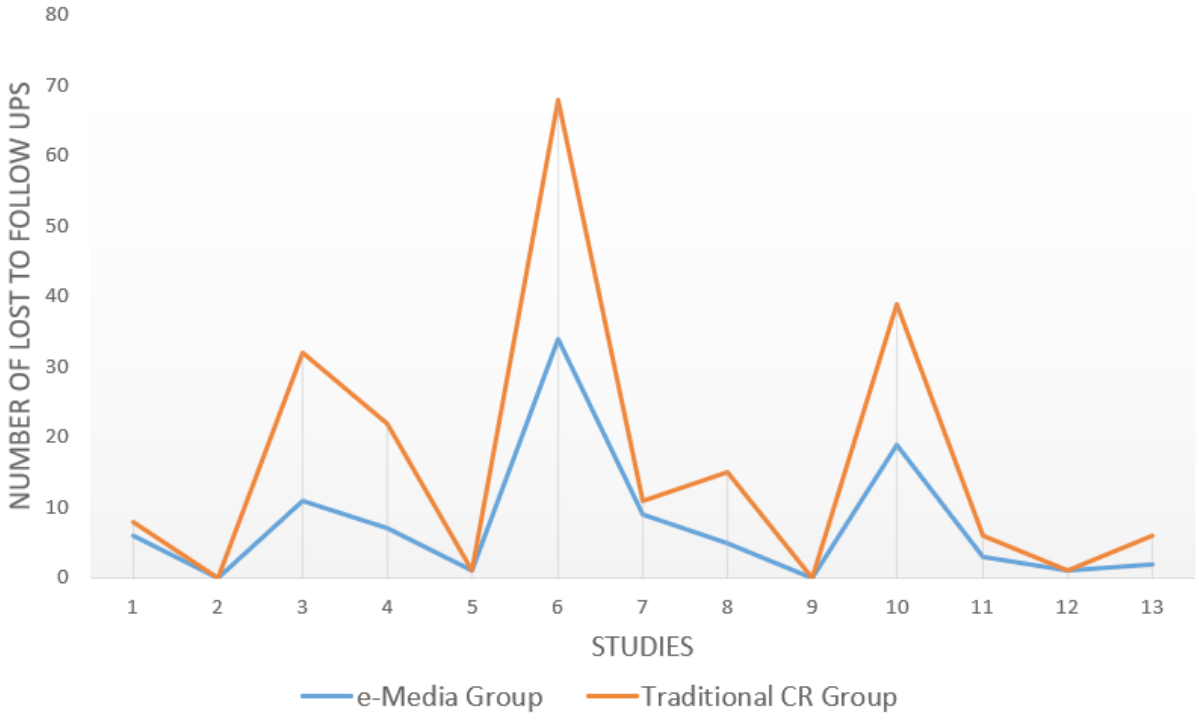

Figure 4. Lost to follow-ups between e-media CR group and traditional CR group

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tion in the hybrid model CR (Table 3). They also utilised the pedometer as a telemonitoring tool in the evaluation of physical activity level, but it was evident that the essential domain for telemonitoring is vital. Heart rate and ECG were measured in seven studies and two studies, respectively. A similar study by Vieira et al. (2018) included real-time feedback via a telemonitoring device for the evaluation of participants, which was successful in measuring vitals [18]. Telemonitoring helps enhance the safety of participants during practice and prevents unnecessary secondary complications.

Effects on physical activity status

Among the assessed studies, 11 included functional capacity as an outcome measure for evaluating post-intervention effects on physical activity level. Seven studies showed a significant change in the patient's functional capacity, and the other studies showed improved functional capacity over baseline that was not significantly different from the control. Overall, the functional capacity was improved after the hybrid model CR than in participants who received usual care. Data from articles indicated that physical activity levels and participation were enhanced in both the traditional and hybrid models; however, the e-media-supported rehabilitation enhanced participant's interest and adherence.

Effects on QoL

Studies measured the QoL among the participants with various domains, primarily including physical composite measures. QoL at post-intervention improved in seven studies, and six studies reported no significant differences observed between the control and intervention groups. However, the existing literature supports that QoL improves over time post-CR irrespective of the type of CR intervention model used. A study attempting to implement VR therapeutic support (VRTierOne – VR HTC VIVE goggles) following the standard CR protocol, twice a week for 4 weeks/ 30 minutes duration, showed improved mental health for adults at a mean age of 68.91 +/- 6.26 [29] and improved QoL. All participants following the standard intervention also showed a significant improvement in QoL from baseline.

Adherence to CR

Long-term adherence had a greater impact on functional outcomes, and a trial of long-term follow-up proved significant in improving exercise capacity relative to VO_2 peak of 2.2 mL/kg/min after effective CR [30]. According to Lunde et al. (2020), participants who did not undergo CR experienced a decline in exercise capacity over time, reaching 1.8 mL/kg/min [19]. Another study reported a significant increase in physical activity,

measured in metabolic equivalents, with the intervention group reaching 1726 MET-min/week compared to 636 MET-min/week in the center-based CR group (P=0.045). After a 10-month follow-up, Dalli Peydró et al. (2022) observed a VO_2 max of 1.62 mL/kg/min [20].

Adherence rate for the hybrid model of CR was 79.14%, which was significant when compared with 61.46% of the traditional model of CR (P<0.001) [31]. Su and Yu (2021) reported an adherence rate of 76.7%, demonstrating increased intervention engagement [21]. Many studies reported poorer long-term follow-ups among control groups than the intervention group, where the newer technological platform implementation for rehabilitation encouraged participants' adherence to CR. Overall loss to follow-ups among assessed studies for primary analysis was 246; the intervention group lost 112, whereas the control group lost 134. Many low-income countries lack implementation of CR, with poor adherence rates due to poor social support, low education, and familial constraints [32, 33].

The implementation of e-media in rehabilitation requires standardization; from the evaluated studies, diverse applications of e-media content were utilized based on applicability. The minimum study duration used among the evaluated studies was 12 weeks, and it has proven to be effective.

Effectiveness in user engagement and cost

The credibility of the hybrid model or e-media-based exercise CR is fun, and the feasibility of the user interface. Encouraging users to become more involved in such a platform requires an extreme understanding of people's attitudes towards CR. The focus of CR using the e-media platform must be on user engagement and cost effectiveness. Multiple routes can be used to attain user interest, including VR embedded games and exercises, videography demonstrations, pictorial demonstration (JPEG or GIF), and scripts. Apart from the featured user interface, there is a requirement for regular reminders of such practice every day at specific periods for users. Considering frailty of the cardiovascular disease, their interest in participating in physical activity is anticipated to be low. Another factor that influences the user engagement in adapting to e-media platforms is cost. CR using traditional methods is not successful worldwide due to economic constraints faced by patients for sustained participation [34, 35].

Cost-effective discoveries in the e-media-based rehabilitation in the field of CR are more encouraged and welcomed. Futuristic approaches are expected to be more economical for effective implementation, even in remote set-ups. The core concept behind such discoveries is to effectively implement CR in rural areas for people who have failed to participate in CR. Hence, mobile or web-based software must be more feasible and economical. VR-aided games and exercises are an emerging field with high applicability in rehabilitation. Future directions for implementing such a system must be available to rural people and economically weaker populations [36].

The limitation of the current study is that the database was restricted to two sources, and a more extensive search may yield additional articles supporting the use of e-media in CR. This study mainly focused on e-media use among patients with cardiac diseases; a validated protocol for media content is required to assess its feasibility [37]. As the study included RCTs only, for a clearer understanding of the utility worldwide, other designs may also need to be evaluated.

Limitations of e-media supported rehabilitation: The major limitation of implementing tele-rehabilitation using e-media support is the lack of supporting measurement tools, such as tele-monitoring devices. Such a telemonitoring tool paves a route towards the attainment of confidence among the participants, considering their unstable vitals. Vital signs must be closely monitored, especially during the acute phase. Most rehabilitation settings, especially in low-income countries, are unable to use such monitoring devices effectively. Hence, such scenarios make telemonitoring-supported e-media-based telerehabilitation a difficult model.

Evaluated studies report difficulties in implementing e-media-supported telerehabilitation in the field of CR due to various constraints, including cost, applicability, smartphone availability, literacy, and most importantly, participants' interest. Patients who fall under the high-risk or moderate-to-high-risk category still require close monitoring, including heart rate variability and electrophysiological changes during the prescribed exercises. This would be a major limitation for implementing the e-media-supported tele-rehabilitation among these people. Even with telemonitoring support during the exercise session at remote settings, supervision by a healthcare professional is required for immediate action in case of emergencies. Hence, these limitations make it a difficult model for high-risk patients due to safety concerns.

Telerehabilitation: A valid solution for preventing dropouts

Postoperatively, exercise protocols and patient enrollment in CR have become challenging. To engage patients in exercise-based CR, frequent sensitization programs for patients, caregivers, or guidelines are required, along with awareness of the importance of physical activity in managing their condition. Such intricacy is not reflected in telerehabilitation due to its fun nature, regular follow-up, and reminders. A safer environment and safety measures are mandatory precautionsto avoid secondary complications. Utilization of telemonitoring technology in a remote setup might increase participants' confidence. Core disadvantages for patients after cardiac incidents include low self-esteem and a fear-avoidance factor that inhibits participation in physical activity [28, 38, 39].

Conclusion

The applicability of e-rehab within the CVD population is hindered by the lack of robust, comprehensive telemonitoring platforms. This gap reveals the cause of poor implementation of e-rehab CR in low-income countries, where economic constraints limit access to centre-based CR. Our findings highlight the need for future research to address these technological and accessibility gaps. Future directions in CR utilizing such virtual platforms to enhance functional capacity, support early recovery, and prevent rehospitalization are promising in rehabilitation. An economical and feasible model would make implementation more accessible for individuals with CVD. It is imperative to focus on future studies towards e-rehab trials to formulate an appropriate protocol for e-media-supported rehabilitation among the CVD population.

Ethical Considerations

Compliance with ethical guidelines

This review is a part of a project called the "SRCardioCare" app for adult surgical revascularization patients. A Registered trial; IEC/24/AUG/187/26 from the Sri Ramachandra Institute of Higher Education and Research (DU), Chennai.

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Authors' contributions

All authors equally contributed to preparing this article.

Conflict of interest

The authors declared no conflict of interest.

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