

Information and communication technology-based cardiac rehabilitation homecare programs

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Abstract: Cardiac rehabilitation (CR) has, for many years, been a highly recommended approach to secondary prevention for patients recovering after a heart attack or heart surgery. These programs are traditionally delivered from a hospital outpatient center. Despite demonstrated benefits and guideline recommendations, CR utilization has been poor, particularly in women, older patients, and ethnic minority groups. To overcome some of the barriers to the traditional delivery of CR, different delivery platforms and approaches have been developed in recent years. In general, Telehealth solutions which have been used to address the delivery of CR services remotely include: 1) patient-provider contact delivered by telephone systems; 2) the Internet, with the majority of patient-provider contact for risk factor management taking place online; and 3) interventions using Smartphones as tools to deliver CR through (independently or in combination with) short message service messaging, journaling applications, connected measurement devices, and remote coaching. These solutions have been shown to overcome some of the barriers in CR participation and show potential as alternative or complementary options for individuals that find traditional center-based CR programs difficult to commit to. The major benefits of remote platforms for CR delivery are the ability to deliver these interventions without ongoing face-to-face contact, which provides an opportunity to reach large numbers of people, and the convenience of selecting the timing of cardiovascular disease management sessions. Furthermore, technologies have the potential to deliver long-term follow-up, which programs delivered by health professionals cannot afford to do due to staff shortages and budget restrictions. However, change in the existing CR services is not without challenges. There is a need to identify development issues that can hamper the implementation of the interventions outside controlled trial settings systems, which may require new computing infrastructures, specific clinical responsibilities, time for training, and development and openness to new ways of doing things.

Keywords: cardiovascular disease, Telehealth, telephone, Internet, mobile phones

Background

In developed countries, cardiovascular disease (CVD) remains the leading cause of death and disability, despite the gradual decline in disease rates experienced over the last few decades. In 2000, 48.6% of deaths in developed countries were attributed to CVD, which is not expected to change by 2020, with 46.4% of all deaths in developed countries still expected to be attributable to CVD.¹

The way in which CVD is treated has huge implications for patients, health professionals, and policymakers. Once a person has a cardiac event such as a heart attack, the prevention of further heart attacks, stroke, or death is crucial. Secondary prevention through cardiac rehabilitation (CR) is a key component of the ongoing

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care of these patients, immediately following discharge from hospitals.² Today, CR is widely accepted as a proven program that provides health benefits and long-term management of cardiac conditions. CR programs offer a cost-effective, multidisciplinary, and comprehensive approach to address risk factors and to restore individuals to their optimal physiological, psychosocial, nutritional, and functional status, thereby reducing morbidity and mortality.³⁻⁵

Since the introduction of CR programs, the traditional mode of delivery has been mainly from hospital- or community center-based settings. Traditional hospital- or community center-based CR is considered to be a long-term program that consists of multiple phases.^{6,7} While delivery of CR in the United Kingdom (UK) and United States (US) consists of four phases, in Australia, the delivery is generally performed in three phases,⁸ as shown in Figure 1. Inpatient rehabilitation (phase 1) is an early intervention during the stay in hospital and is mostly undertaken on an individual basis, whereas ambulatory CR programs after discharge from hospital, phase 2, are usually conducted with groups of patients and are generally based upon supervised ambulatory programs conducted in a suitable outpatient setting of the treating hospital.⁸ The more immediate objectives of phase 2 are to achieve clinical stability, limit the physiological and psychological effects of cardiac illness, improve the functional status, and maintain independence with an emphasis on quality of life (QoL). The program is individually designed and the sessions typically occur once or twice a week for 6–8 weeks. Formal outpatient CR programs vary widely in content, but almost all include an element of structured group exercise. Education is usually also delivered. The longer-

term objectives, outlined in phase 3 of the CR program, are to reduce the risk of future coronary events, slow the progression of the underlying atherosclerotic process and clinical deterioration, and ultimately reduce morbidity and mortality.⁸ Phase 3 is thus an ongoing maintenance phase beyond inpatient and outpatient rehabilitation, which involves sustained activities and behavior to reduce CVD risk factors through self-management.

Despite the clear benefits of CR programs, studies continue to demonstrate that the participation rates of eligible patients in CR programs remain alarmingly low.^{9,10} In Australia, only 19%–36% of patients completed a CR program in New South Wales,¹¹⁻¹³ <20% in Queensland,¹⁴ and remote Indigenous patients are even less likely to participate in CR programs.¹⁵ The low CR participation rate in Australia is reflective of other developed countries. Large UK studies showed low rates of participation (24%–40%) by eligible patients.^{6,16} Furthermore, similar low rates of CR participation have been demonstrated in the US (19%–64%),^{9,17-19} Canada (45%–49%),^{20,21} and the Netherlands (11%).²²

Current delivery models of CR, specifically during phase 2, are marred by barriers to participation related to referral, patient, and systemic factors. Barriers include limited referrals by physicians to CR,^{23,24} because of skepticism regarding the benefits of CR programs, doubts about the likelihood of lifestyle changes resulting in the desired outcomes,^{25,26} and logistic reasons such as site locations and a lack of standardized referral forms.²⁷ Systemic factors relate to a lack of availability and often to geographical inaccessibility^{28,29} and, furthermore, to limited transportation and a lack of parking,^{29,30} course content and inconvenient program

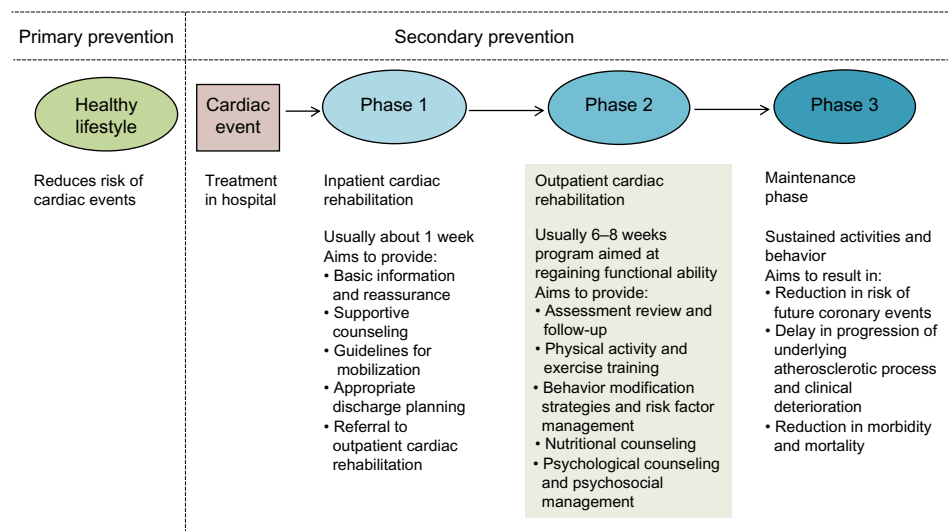


Figure 1 The three phases in the traditional secondary prevention of cardiovascular disease in the Australian cardiac rehabilitation service delivery model.

scheduling,³¹ and financial costs.²⁹ Patient barriers include limited participation by females,^{9,32} older age,³² a dislike of group-based classes,²⁹ a lack of personalization of exercise programs,³³ competing demands of returning to work,^{31,34} family commitments (particularly among females),^{17,19} and a lack of motivation.²⁴ Further patient predictors of poor participation in CR are racial/ethnic minority groups,¹⁵ low socioeconomic status and educational attainment,¹⁷ low self-efficacy and literacy, and a lack of perceived need for CR.²⁹

Attempts to improve access to CR have led to the design and development of various alternative delivery models of CR, and many have focused on extending CR delivery from traditional center- and hospital-based CR to the patient's home and community.³⁵ Over the last decade, these delivery models have increasingly focused on utilizing the advances made in information and communication technologies (ICT). In this paper, we present a review of studies that feature a variety of ICT intervention platforms for the delivery of alternative models of CR. We summarize the research findings and finally discuss the future perspectives of ICT-based CR programs.

Methods

Published literature that addressed the use of ICT for CR programs at home was identified through a careful search of PubMed, Web of Science, and the Cochrane Library, and other sources of literature were gathered from references included in reviews. No beginning time limit was employed for the search, as studies involving ICT technology in CR were expected to be relatively current and the authors intended to portray the progression of these technologies since their introduction in home-based CR in the late 1990s. Only patients with coronary artery disease were considered for this review. Included studies described patients as having either an acute myocardial infarction (MI), a diagnosis of acute coronary syndrome, or they had undergone a revascularization procedure.

The keywords “cardiac rehabilitation”, “secondary prevention”, “heart disease”, and “cardiovascular disease”, were combined with “home-based”, “homecare”, “Telehealth”, “technology”, “information and communication technologies”, “telephone”, “Internet”, “mobile phone”, and “Smartphone”. As this is not a systematic review, the authors included selected exemplary studies that involved technologies such as the telephone, Internet, and/or mobile technology interventions to support home-based CR or secondary prevention programs. Figure 2 shows the search

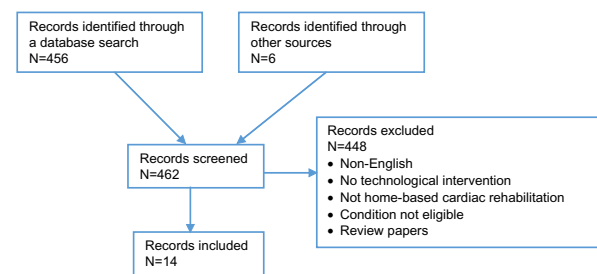


Figure 2 Flow diagram of the literature search and the selection of studies.

results from keywords database searches and other sources, such as references from previous reviews. The results were then screened and excluded, as shown in Figure 2, to specifically include studies in the English language relating to the technology-based homecare delivery of CR.

Application of technology in the delivery of cardiac rehabilitation homecare programs

Since the 1960s, researchers have been preoccupied with improving CR program delivery into patients' homes through remote monitoring, but these have been limited to the exercise component and not to a comprehensive approach to CR. Recent advances in ICT, however, have shown potential to overcome this limitation by providing the capacity for health ambulatory monitoring and enabling remote coordinated care by the health service provider. The extent of advanced monitoring not only includes electronic weight scales, blood pressure (BP) meters, and thermometers, but also advanced devices such as accelerometers for activity monitoring and sleep-monitoring devices, with many of these becoming wireless and more ambulatory. In addition, the explosive growth of the Internet, personal computers and other digital devices, smart mobile phones, and associated technologies continues unabated. An important component of this growth has been a decrease in the cost to adopt these technologies to one's lifestyle. Hardware and computer processing power, network bandwidth, Internet access, and software costs have all decreased as new technologies become commodities. With these rapid advances made in ICT, opportunities exist to augment homecare, including the provision of remote comprehensive CR programs.

In general, technologies used to address the delivery of remote CR services progressively include: 1) multifactorial Telehealth delivery, with the majority of patient-provider contact delivered by telephone systems; 2) Internet-based delivery of CR with the majority of patient-provider

contact online; and 3) interventions using Smartphones as tools to deliver CR through employing, independently or in combination, short message services (SMS) messaging, journaling applications, connected measurement devices, and remote coaching. This paper will review studies that describe interventions in all three categories mentioned earlier, outlined in Table 1. While these studies vary in terms of the intervention used, there was one common objective, which was to improve the uptake and completion of CR programs, while not compromising the quality of care. Figure 3 presents examples of user interfaces used in home-based CR delivery through the 1) Internet and 2) mobile phone applications and the Internet.

Cardiac rehabilitation with telephone support

The early form of communication technology, being the “traditional” landline telephone, has been used to deliver home-based CR services live by nurse/caregiver visits that were supported by telephone calls and computer-generated mailings;^{36–38} more recently, self-monitoring handbooks and logs,^{34,39–41} and also telephonically transmitted electrocardiogram (ECG)^{42,43} have been utilized to augment such services. “Tele-rehabilitation” began in the mid-1990s, and since then, initiatives in “tele-rehabilitation” programs have been steadily growing.

In 1996, DeBusk³⁶ pioneered the delivery of home-based CR using telephone calls and computer-generated progress reports to remotely support patients to manage their CVD risk (MULTIFIT system). DeBusk compared patients with postacute MI undergoing the MULTIFIT home-based CR program (nurse-initiated and supported exercise training, smoking cessation, dietary, and lipid-lowering drug therapy counseling) to those with usual medical care, over 1 year. The MULTIFIT program showed greater improvement than the usual care group in exercise capacity at 6 months, and smoking cessation rates, total cholesterol, and low-density lipoprotein (LDL) cholesterol reductions at 12 months. Subsequent studies that used similar models as the MULTIFIT telephone-supported home-based CR confirmed the improvement in exercise capacity and lipid profiles, but further demonstrated increased social support, health-related quality of life (HRQoL), reduced nurse intervention time, and a twofold capacity to manage CR patients.^{37,39}

Another intervention called Coaching patients On Achieving Cardiovascular Health (COACH)^{38,44} employed a comparable home-based model to assist patients with

managing coronary risk factors through the management of their medications with their physicians, so as to reach the target levels for their particular risk factors. COACH incorporated computer-generated mailings and coaching sessions delivered by telephone over a 6-month period. While this was provided as somewhat optional to CR, where lifestyle behavioral changes were addressed, it did not center on improving physical activity. Through a randomized controlled trial (RCT), COACH showed a significant reduction in total cholesterol and improvements in LDL cholesterol, body mass index (BMI), dietary intake of saturated fat, and general well-being,³⁸ but despite a greater proportion of COACH program participants reporting taking up regular walking compared to the usual care group, the trial was not effective in improving their physical activity, which is questionable as an outcome of a CR program.

A noteworthy RCT by Dalal et al,³⁴ the Cornwall Heart Attack Rehabilitation Management Study (CHARMS), which introduced a self-help manual (“Heart Manual”) to a 6-week exercise, stress management, and education with telephone-supported home-based CR, observed changes in anxiety and depression in CR participants following CR at a 9-month follow-up. In this study, 104 patients were randomized to an 8-week hospital-based CR program or a home-based program, and another 126 were given the option to choose either of these CR programs. The home-based program was supported by a CR nurse who made a home visit on the first week after discharge, followed up by typically 4 telephone calls over 6 weeks. The outcomes showed similar improvements on depression or anxiety scores, HRQoL, and total cholesterol levels between the groups, concluding that home-based CR is a viable alternative to a hospital-based program.

In another approach, scripted telephone health coaching sessions (10×30 minutes), supported by a handbook and educational resources (ProActive Heart program), were introduced to modify coronary heart disease risk factors.^{40,45} Results of the ProActive program not only demonstrated compliance to recommended levels of physical activity, BMI, vegetable intake, and alcohol consumption, but they also found significant improvements in HRQoL (mental component), social functioning, and role–emotional subscales,⁴⁰ as well as reductions in anxiety.⁴⁵ Although the ProActive program was associated with higher costs compared to usual care,⁴⁶ it was unrelated to the intervention or cardiac-related hospitalization.

Remote physiological monitoring to home-based CR patients became feasible with the introduction of ECG transmission via fixed-line telephone communication.

Table 1 Summary of the studies included in this review

Study	Type of trial, N, cardiac event/s	Intervention	Improved primary and/or secondary outcomes through ICT intervention
Multifactorial Telehealth delivery of home-based CR, with the majority of patient-provider contact delivered by telephone			
DeBusk ³⁶ (MULTIFIT)	RCT, 585, post-MI	Nurse-initiated phone contacts Computer-generated progress reports mailed to patients	At the end of 12 months, the intervention group showed significantly greater: smoking cessation rates; total cholesterol and LDL cholesterol reductions; functional capacity.
Kodis et al ³⁷	Retrospective review, 1,042 post-CABG	Prescription and detailed guidelines for home-based exercise Telephone calls to home-based groups two to three times over 6 months	Substantial improvements at 6 months in: VO ₂ ; peak workload and metabolic equivalents; HDL cholesterol.
Vale et al ³⁸ (COACH)	RCT, 792, CABG, PCI, AMI, UA	Patient contacted by telephone within 2 weeks after randomization Three telephone coaching sessions at 6-week intervals for 6 months Patients invited to contact coach if required Progress reports mailed to participants	Intervention group showed: significant improvement in total cholesterol; substantial improvements in coronary risk factors and in patient HRQoL.
Arthur et al ³⁹	RCT, 242 post-CABG	A total of 6 months of monitored, home-based exercise training Telephoned every 2 weeks Exercise logs monitored monthly	Significant improvement in peak oxygen in both groups at 6 weeks. Home group greater total social support at 3 months and 6 months, and greater improvement in HRQoL (physical) at 6 months.
Dalal et al ³⁴ (CHARMS)	RCT and preference arms, 230, MI	Nurse support typically provided by four calls over 6 weeks Self-help package (the "Heart" manual)	At 9 months, similar results to hospital-based CR in: depression and anxiety score; HRQoL and; total cholesterol levels.
Hawkes et al ⁴⁰ O'Neil et al ⁴⁵ (ProActive Heart)	RCT, 430, MI	A total of 10x30-minute scripted telephone health coaching sessions over 6 months Handbook for patients and educational resource to use during health sessions	Significant improvement in health status in both groups, difference between groups not significant. Intervention showed a significant reduction in anxiety.
Telehealth delivery of home-based CR, with the patient-provider contact delivered by telephone augmented by ECG monitoring			
Ades et al ⁴²	Controlled study, 133, CABG, MI, PCI	For 3 months, participants exercised three times per week with a stationary cycle ergometer with direct communication to the nurse Simultaneous conference calls with other CR patients	The home-based group increased peak aerobic capacity to a similar degree to that of on-site CR patients. Similar HRQoL outcomes.
Körtke et al ⁴³	Open clinical study, 170, CABG, PCI	A 3-month ambulant CR Cardiovascular function recorded by a mobile telemedicine unit (ECG and heart rate monitor) and transmitted telephonically	The intervention showed significant improvement in maximal physical performance, physical and psychological HRQoL, lower cost.
Delivery of home-based CR with the majority of patient-provider contact for risk factor modification via the Internet			
Lear et al ⁴⁷ (vCRP)	RCT, 78, ACS or PCI	A 4-month Internet-based program to mimic a standard hospital-based CR (vCRP) Recordable heart rate monitor Data capture for test results, education sessions, progress notes, monthly ask-an-expert group chat sessions, and private online chat sessions	The vCRP group showed significantly higher exercise capacity and dietary quality, with reductions in cholesterol levels. No differences in lipids, blood pressure, and physical activity were noted between the two study groups.
Clark et al ⁴⁸ (eOCR)	Pilot study, 16 health professionals and 24 patients, post-MI or angioplasty	Internet-based self-management Website system Cardiac case manager delivers education, tracks patient progress, and contacts patients and/or their caregivers via Web-based email and discussion boards or by telephone	The Website increased the reach of CR program within regions. Profiled the potential users of this type of health care (ie, active Internet users). Online discussion rooms and workbooks were not used.
Interventions using Smartphones as tools to deliver CR remotely through SMS messaging and/or journaling applications, connected measurement devices, and remote coaching			
Lounsbury et al ⁴⁹	Retrospective analysis, 237, patients enrolled in CR	Five to seven SMS messages/week consisting of heart-healthy tips, requests for weight, minutes of exercise, blood pressure, and medication adherence	Intervention participants attended significantly more CR sessions and were significantly more likely to complete CR than patients not participating in texting.

(Continued)

Table 1 (Continued)

Study	Type of trial, N, cardiac event/s	Intervention	Improved primary and/or secondary outcomes through ICT intervention
Dale et al ⁵⁰ (Text4Heart)	RCT protocol, 120 (estimate), MI, angina, or PCI	mHealth intervention group receive the core components of CR delivered via text messages (SMS) from a library of 503 messages and a supporting Website over the course of 24 weeks (5–7 messages per week)	Adherence to healthy behaviors at 6 months, overall CVD risk, body composition, illness perceptions, self-efficacy, anxiety/depression, and medication adherence.
Varnfield et al ⁵¹ (CAP)	RCT, 120, MI	Smartphone application with accelerometer and health diary, visual feedback, text message reminders, educational videos, and Web portal; goal setting and education provided through weekly telephonic mentoring sessions	Significant higher uptake, adherence, and completion rates. Significant improvements on the 6-Minute Walk Test for both groups from baseline to 6 weeks. Slight weight reduction and significant improvements in emotional state and HRQoL.

Abbreviations: CR, cardiac rehabilitation; N, number; ICT, information and communication technology; RCT, randomized controlled trial; MI, myocardial infarction; LDL, low-density lipoprotein; CABG, coronary artery bypass surgery; VO₂, peak oxygen uptake; HDL, high-density lipoprotein; HRQoL, health-related quality of life; COACH, Coaching patients On Achieving Cardiovascular Health; PCI, percutaneous coronary intervention; AMI, acute myocardial infarction; UA, unstable angina; CHARMS, Cornwall Heart Attack Rehabilitation Management Study; ECG, electrocardiogram; vCRP, virtual cardiac rehabilitation program; vCRP, virtual cardiac rehabilitation program; ACS, acute coronary syndrome; eOCR, electronic outpatient cardiac rehabilitation; SMS, short message system; mHealth, mobile health; CVD, cardiovascular disease; CAP, Care Assessment Platform; CAP-CR, Care Assessment Platform cardiac rehabilitation.

This provided the capacity to monitor home-based exercise programs with ECG recordings sent to care centers for support. Studies were able to demonstrate similar significant improvements in exercise capacity in home-based CR as that of the center-based CR programs.^{42,43}

A recent systematic review and meta-analysis,⁵² however, showed that telephone-supported CR interventions for coronary heart disease patients was limited to reducing certain risk factors such as anxiety and depression, while improving systolic BP and the likelihood of smoking cessation.

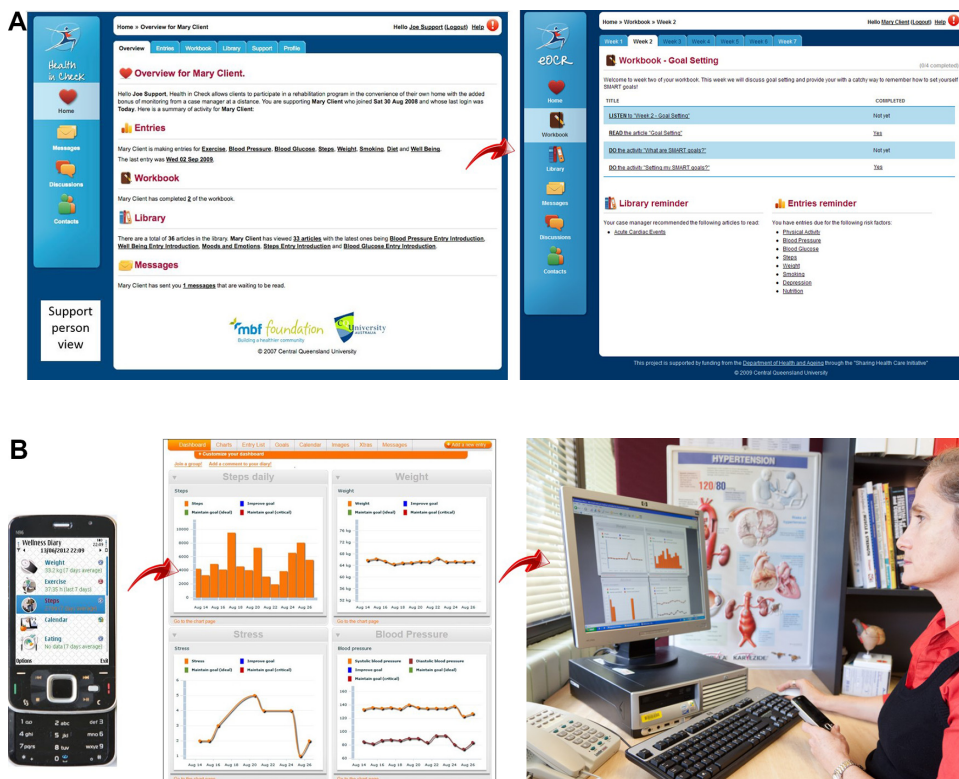


Figure 3 Examples of user interfaces for delivering cardiac rehabilitation through the Internet (A) and a journaling application on a mobile phone combined with portal (B). Figure 3A courtesy of Professors Kerry Mummery and Robyn Clark. **Abbreviation:** eOCR, electronic outpatient cardiac rehabilitation.

Furthermore, telephone-supported CR interventions also have their drawbacks, as possible labor-intensive conversations are expensive; this is supported by less conclusive cost-effectiveness reports of such programs than by reports that are focused on clinical effectiveness.⁵³

Cardiac rehabilitation delivery via the Internet and mobile technologies

The Internet has been used as tool for a range of health interventions, including delivering CR programs. Munro et al⁵⁴ reviewed the evidence for patient-focused Internet-based approaches to CR. In total, nine studies involving 830 patients with heart disease that compared Internet-based CR to usual care were identified in their study. Outcome data were pooled under four subheadings: compliance; physical activity outcomes; clinical outcomes; and psychosocial outcomes. Although uptake rates with the Internet interventions were mostly high (ranging from 36%–97%), adherence was low. Physical activity measures were found to generally improve, as were clinical outcomes. Changes in psychosocial measures such as QoL, anxiety and depression, self-efficacy, and functional emotion were positive in most of these the studies included in the review. None of the interventions noted a negative effect on outcomes.

Two more recent Internet-based CR studies were not included in Munro et al's review.⁵⁴ One of the studies was a virtual CR program (vCRP)⁴⁷, delivered through the Internet, that mimicked standard hospital-based CR delivery. It included a recordable heart rate monitor that connected with the vCRP Website; data capture for exercise stress test and blood test results; education sessions; progress notes; monthly ask-an-expert group chat sessions; and private online chat sessions with clinicians. The vCRP group showed significantly higher exercise capacity and dietary quality. Although there were no differences observed in lipids and blood pressure, this was ascribed to the baseline values being already in the healthy range. The second study, although a pilot study (number [n] =27), included an Internet-based self-management Website system, called electronic outpatient cardiac rehabilitation (eOCR), through which cardiac case manager(s) could deliver education, track patient progress, and have contact with the patient and/or their caregiver via Web-based email and discussion boards, or by telephone.⁴⁸ An online workbook guided the patients week-by-week through their self-managed, individualized CR program, in which case managers monitored their progress weekly. The eOCR system was able to increase the reach of a CR and secondary prevention program within regions where previously limited

services had been available. The validity of eOCR to demonstrate clinical improvements has yet to be reported.

Recently, researchers have taken advantage of Smartphone capabilities and features to develop and investigate novel models for home-based CR delivery.⁵⁵ The features that have particularly attracted the use of the homecare delivery of CR include SMS-based interventions, journaling applications, built-in and connected measurement devices, and remote coaching.

Lounsbury et al⁴⁹ examined the effect of a SMS text-messaging program on the number of sessions completed in outpatient CR, together with other outcomes. Text messages sent 5–7 times per week consisted of heart-healthy tips, requests for weight, minutes of exercise, BP, and medication adherence. The study demonstrated that patients who participated in the text-messaging program attended significantly more sessions and were more likely to complete outpatient CR than patients who did not.

An innovative text message and Internet-based delivery of CR (mHealth) was recently developed by Pfaeffli et al⁵⁶ to improve adherence to lifestyle changes. Following a successful pilot study,⁵⁶ which indicated the mHealth program to be an effective way to deliver exercise-based CR, an intervention was introduced (Text4Heart), which is currently being evaluated in a RCT.⁵⁰ Participants receive a tailored program of SMS text messages via their mobile phone with evidence-based information on actions that will reduce the risk of subsequent events. The results from these research studies could aid in understanding the effectiveness of mobile phone applications, combined with health coaching, used in long-term interventions requiring a degree of self-management.

Walters et al⁵⁷ designed and developed a Smartphone- and Internet-based homecare delivery model in alignment with an Australian (Queensland) state health service delivery of center-based CR, called the Care Assessment Platform (CAP). The CAP-CR model was the first to employ new-generation Smartphones with built-in sensors, mobile health diary applications, and a corresponding connected Internet portal to deliver components of a comprehensive CR program at home.⁵⁷ The mobile applications included the processing of physical activity measurement from a built-in accelerometer and a journaling application (WellnessDiary [Nokia Research Centre, Media Technologies Lab, Tampere, Finland]),⁵⁸ which supported logging a wide range of health-related states and activities. Home-based CR participants were able to view their own recorded data on a daily, weekly, or monthly basis, displayed as text and/or graphs on the Smartphone provided. The CAP-CR model also employed remote coaching by

a dedicated mentor, specifically trained for the delivery of the program, to provide weekly scheduled telephone consultations with patients at home after reviewing the patients' updated data.⁵⁷ The results of a RCT validating CAP-CR home-based CR delivery were published recently.⁵¹ The findings were remarkable in demonstrating not only improved uptake, but an adherence of 94% among CAP-CR participants, which resulted in completion rates of >30% when compared to those attending center-based CR programs.⁵¹ Moreover, CAP-CR participants demonstrated similar improvements in physical activity, nutrition, and the lowering of depression as those of the center-based CR group. CAP-CR was also effective in significantly reducing anxiety and increasing HRQoL.

Discussion

In developed countries, CVD remains the first cause of death and disability.⁵⁹ Over the last few decades, evidence has shown CR to be highly effective as a secondary prevention for patients recovering after a heart attack or heart surgery, and it is known to decrease the subsequent risk of total mortality, cardiovascular mortality, and cardiovascular morbidity.^{60,61} Despite the clear health benefits of CR programs, studies have shown that referral and participation rates of traditional center-based CR programs remain alarmingly low.^{9,29,62} To overcome some of the barriers to the traditional delivery of CR, alternative delivery approaches have been developed over the last 20 years.

Cardiac rehabilitation with telephone support

In the 1990s, CR programs evolved to become nurse-managed, telephone-supported, home-based CR programs. The MULTIFIT was the pioneer of such programs³⁶ and showed positive results in addressing the majority of CVD risk factors (physical capacity, lifestyle, and biomedical factors) at home. Subsequent comparable studies confirmed the potential of these programs to demonstrate further improvements in mental health outcomes and QoL.^{37,39} Another approach has been to include structured or scripted coaching sessions^{38,40} and a self-help manual,³⁴ which have also been effective in improving mental health outcomes and QoL. Although telephone-supported CR programs have been effective, there was still a constant need for clinical staff to have verbal communication with CR clients to monitor their progress. This was found not only to be labor intensive and expensive,⁴⁰ but it sometimes narrowed telephone-supported home CR to low-intensity exercise programs due to the unsupervised nature of the delivery.

The introduction of the simultaneous transmission of ECG and voice during CR sessions has facilitated remote

performance monitoring of ambulant rehabilitation without compromising the safety of exercise sessions.^{42,43} Access to telephones became standard to most households, which makes transtelephonic ECG monitoring a feasible technology solution for unmonitored or intermittently-monitored exercise sessions for home-based CR. However, while transtelephonic ECG monitoring may improve patient adherence to exercise and allow for home monitoring, it somewhat restricts the patient's lifestyle because it requires them to be equipped and confined to a specific location of the home to be monitored.

Cardiac rehabilitation delivery via the Internet and mobile technologies

Despite the increasing accessibility of the Internet to homes, take-up of Internet-based health interventions has been somewhat slow. Studies in homecare CR delivery have recently leveraged these.^{47,48} Although previous studies have reported Internet-based homecare CR delivery to be effective in improving compliance rates^{47,54,63} and physical activity,⁶⁴ many of these have been developmental and pilot studies. A previous RCT study by Southard et al⁶⁵ used an Internet case management system to deliver home-based CR to clients through online chats to clinicians with online educational material. Although the Internet-based intervention showed a reduction in body weight, it did not significantly change the patients' exercise capacity or other risk factors (lipids, depression, or diet). Unlike the Southard et al study, a more recent RCT study by Lear et al,⁴⁷ mentioned earlier, included a structured exercise program (via treadmill) for their innovative Web-based heart rate monitoring. While the results were positive in addressing accessibility to CR in remote geographic locations, as well as to health care and improvement in exercise capacity, changes in other key risk factors were limited, despite the provision of behavioral counseling. In the vCRP study, the level of engagement with the website varied noticeably. This supports previous studies where compliance to adhere to Internet-based CR interventions has been questionable.^{48,54} Hence, the design of Internet-based delivery CR warrants further improvement to afford CR participants the flexibility to adhere to their CR program, such as attending to exercises and monitoring health parameters. The advent of the provision of Internet services and accessibility through recent advances made in mobile phone handsets and tablets could make this flexibility possible.

Advances in mobile phones have become particularly attractive for the delivery of health interventions because of: 1) the widespread adoption of phones; 2) the fact that they form

part of one's lifestyle as a communication tool for voice and text messaging; and, more recently, 3) smarter features with in-built sensors are available that enable geolocation (global positioning systems), activity measurement (accelerometers), storage, and connectivity to computer (Internet) applications via the mobile network (hence, termed the Smartphone). Recently, Smartphones, have employed wireless connectivity features to connect to health devices such as BP and glucose level monitors, thereby enabling the automated and accurate capture of measurements as they are performed.

With these capabilities offered by Smartphones, the technology is well placed to provide lifestyle flexibility for participants to monitor their exercise and other key cardiovascular risk factors. Through this, the CR participant could share monitored data of his or her progress from his or her Smartphone to a clinical portal, where guidance can be offered remotely by a care provider; it also enables the participant to self-manage in between clinical consultations. The advanced capabilities of Smartphones, as well as connectivity to remote Internet services, served as the impetus to design the homecare delivery model of the CAP by Walters et al, to deliver a comprehensive CR program remotely.⁵⁷ That is, ensuring CR provision includes the monitoring of a participant's lifestyle and biomedical risk factor modifications through close guidance and counseling by care providers or coordinators, particularly to achieve individualized goals according to the participant's cardiac health profile. The RCT of this model was the first mobile phone delivery of home-based CR to be clinically validated, and to demonstrate its potential to overcome the service issue of low completion currently faced by the traditional delivery of CR.⁵¹

Challenges and future perspectives

While the clinical validation of innovative CR interventions are being researched to contribute toward proving improved health outcomes, effective implementation and adoption require translation into policy and action. Care systems have not accepted technology solutions as eagerly as might have been anticipated, and obstacles to uptake have been identified as a lack of reimbursement for physicians offering remote medical treatment, regulatory and professional liability concerns, and the accuracy of data.⁶⁶ An important issue to consider in the development and implementation of effective technological interventions for home-based CR is that these interventions could be perceived as undermining important aspects of care, with some professionals fearing that new technology will replace them and take away direct human contact.⁶⁷ Implementing a technology-supported CR program should comply with measures of technology

acceptance, particularly in terms of ease of use, compatibility of programs with the patients' needs and practices, and relative advantages offered to the patient.⁶⁸ This highlights the importance of users' perspectives when designing, implementing, and evaluating such interventions, and the need for programs to meet patient and clinician requirements. Changes in the existing CR services and systems may require new clinical responsibilities, time for training, and the development and openness to new ways of doing things. From a change management perspective, the clinicians' roles have to be defined and implemented to align with current practices without negatively impacting on existing staff and services in new care models.

As more evidence emerges about its efficacy and challenges (such as data management, privacy issues, and technology interoperability), and as reliability and governance are addressed, ICT has the potential to revolutionize the way in which CR programs are delivered, as well as to address some of the barriers faced by center-based programs. Instead of providing one uniform intervention for all, irrespective of the patient's condition, it is appropriate to provide a set of choices of interventions or components thereof from which individuals can then self-tailor an intervention that best suits their personal needs and circumstances.

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Disclosure

The authors report no conflicts of interest in this work.

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