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Behaviour change techniques and intervention characteristics in digital cardiac rehabilitation: a systematic review and meta-analysis of randomised controlled trials

Eanna Kenny [a], Rory Coyne [b], John W. McEvoy [c], Jenny McSharry [a], Rod S. Taylor [d] and Molly Byrne [a]

[a]Health Behaviour Change Research Group, School of Psychology, University of Galway, Galway, Republic of Ireland; [b]School of Psychology, University of Galway, Galway, Republic of Ireland; [c]National Institute for Prevention and Cardiovascular Health, School of Medicine, University of Galway, Galway, Republic of Ireland; [d]MRC/CSO Social and Public Health Sciences Unit & Robertson Centre for Biostatistics, Institute of Health and Well Being, University of Glasgow, Glasgow, UK

ABSTRACT

Evidence suggests that digitally delivered cardiac rehabilitation (CR) is likely to be an effective alternative to centre-based CR. However, there is limited understanding of the behaviour change techniques (BCTs) and intervention characteristics included in digital CR programmes. This systematic review aimed to identify the BCTs and intervention characteristics that have been used in digital CR programmes, and to study those associated with effective programmes. Twenty-five randomised controlled trials were included in the review. Digital CR was associated with significant improvements in daily steps, light physical activity, medication adherence, functional capacity, and low-density lipoprotein-cholesterol when compared to usual care, and produced effects on these outcomes comparable to centre-based CR. The evidence for improved quality of life was mixed. Interventions that were effective at improving behavioural outcomes frequently employed BCTs relating to feedback and monitoring, goals and planning, natural consequences, and social support. Completeness of reporting on the TIDieR checklist across studies ranged from 42% to 92%, with intervention material descriptions being the most poorly reported item. Digital CR appears effective at improving outcomes for patients with cardiovascular disease. The integration of certain BCTs and intervention characteristics may lead to more effective interventions, however better intervention reporting is required.

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Cardiovascular disease; cardiac rehabilitation; digital; behaviour change; systematic review; meta-analysis

Introduction

Cardiovascular disease (CVD) is the leading cause of death worldwide, responsible for an estimated 17.9 million deaths in 2019 (WHO, 2021). Cardiac rehabilitation (CR) is a multidisciplinary secondary prevention programme designed to slow, stabilise or reverse the progression of CVD, thereby improving health outcomes (Balady et al., 2007). It is a multifaceted intervention that includes patient assessment, exercise training, nutritional counselling, risk factor management, and

CONTACT Eanna Kenny e.kenny9@universityofgalway.ie
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psychosocial support (Thomas et al., 2019). There is strong evidence that CR can lead to reductions in all-cause and cardiovascular mortality, and hospital re-admissions while improving health-related quality of life (QoL), depression, and anxiety in coronary heart disease (CHD) and heart failure populations (Dibben et al., 2021; Zheng et al., 2019). Based on this evidence, national and international guidelines including the European Society of Cardiology, the American Heart Association, and the American College of Cardiology strongly recommend CR referral for all patients following hospital admission for acute coronary syndrome, revascularisation procedures, chronic stable angina, and heart failure (Piepoli et al., 2016; Smith et al., 2011). Despite these recommendations, participation rates at CR are suboptimal, with less than half of eligible patients attending and even fewer completing a programme (Kotseva & Wood, 2018; Turk-Adawi & Grace, 2014). This is due to a range of factors including distance from the CR centre, lack of time, and the cost of rehabilitation (De Vos et al., 2013). Participation at CR has been further impacted by the COVID-19 pandemic, as many services were suspended or stopped completely (Ghisi et al., 2021). The poor uptake of CR, coupled with the impact of the pandemic, has heightened the need to consider alternative models of delivering CR.

The proliferation of information communication technologies has enabled CR to be delivered through digital means such as smartphones, web-based applications, and wearable devices. This model of delivery allows for the remote provision of CR, while also widening access and increasing participation in services. Several recent systematic reviews have sought to establish evidence for the efficacy of digitally delivered CR. Overall, they have concluded that digital CR can lead to significant improvements in many outcomes including physical activity, daily steps, medication adherence, smoking, functional capacity, QoL, and cardiac-related re-hospitalisation (Anderson et al., 2017; Chong et al., 2021; Ramachandran et al., 2021; Su et al., 2020). These findings demonstrate that digital CR can produce positive outcomes for patients, equivalent, and potentially in some cases superior, to those produced by centre-based CR. However, the conclusions of these reviews are based on the findings of relatively few studies, and as evidence on this topic is rapidly accumulating, further examination is required. While the evidence for digital CR is promising, it is important to note that the interventions included in these reviews vary significantly in terms of features such as intervention materials, modes of delivery, intensity and personnel involved. Furthermore, the most effective components or 'active ingredients' of digital and traditional in-person CR remain unclear. A previous systematic review of CR concluded that defining the content of interventions and the active components of CR is a major challenge (Goodwin et al., 2016). Our lack of understanding of the core components, optimal dose of each component, and combination of components severely limits any attempts to maximise the effectiveness of CR and the efficiency of its delivery.

Studying the content and context of effective interventions is essential to uncovering how an intervention achieves its effects. This is especially true in the case of complex interventions such as CR, where multiple components can render interventions into 'black boxes' (Abell et al., 2015). This uncertainty about the most effective components of complex interventions can have the effect of limiting the application of research evidence in practice, creating difficulties in efficiently delivering interventions at scale or adapting an intervention to different contexts. The behaviour change technique (BCT) taxonomy (v1) (Michie et al., 2013) is a comprehensive list of 93 BCTs that allows the components of complex interventions to be systematically described and replicated. Furthermore, the Template for Intervention Description and Replication (TIDieR) (Hoffmann et al., 2014) checklist allows for a systematic description of the replicable aspects of an intervention including items such as theoretical framework, materials and procedures, mode of delivery, frequency, duration, and intervention adherence. A detailed exploration of these core elements of an intervention is crucial for determining the characteristics of effective interventions and for enabling future replication.

We know of no systematic review to date that has evaluated digital CR using the BCT taxonomy and the TIDieR checklist. Therefore, this systematic review aims to: (1) determine the effectiveness of digital CR on behavioural, clinical and physiological outcomes compared to centre-based CR or usual care, (2) identify the BCTs that have been used in digital CR programmes, (3) examine the BCTs and intervention characteristics and components that are associated with effective digital CR programmes.

Methods

This systematic review was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021) (Supplementary Figure 1). The review protocol has been published (Kenny et al., 2021) and registered on PROSPERO (CRD42021256055).

Eligibility criteria

Studies were eligible if they included: (a) adults (≥18 years old) with any form of heart disease (coronary heart disease, acute coronary syndrome, congenital heart disease, heart failure, valvular heart disease); (b) a CR intervention delivered at least in part via the internet or a smartphone application; (c) compared the intervention to usual care or centre-based CR; (d) reported a behavioural outcome (e.g., physical activity, diet, smoking, alcohol use, medication adherence) as either the primary or secondary outcome; (e) used a randomised controlled trial (RCT) design; and (f) full publication in a peer-reviewed journal in English. Studies were excluded if the intervention consisted exclusively of text messaging, phone calls or participant monitoring as the focus of this review was on interventions where the core intervention content was delivered using digital technology (e.g., internet or smartphone application).

Information sources

The following databases were searched from inception to 11 November 2021: PubMed (1996), MEDLINE (Ovid; 1946), EMBASE (Elsevier; 1966), CINAHL (EBSCOhost; 1957), PsycINFO (Ovid; 1806) and Cochrane Central Register of Controlled Trials (Wiley; 1996). Included publications were forward and backward reference searched to identify additional relevant studies. Study authors were contacted if the full-text article was not available.

Search strategy

The search strategy was developed based on previous systematic reviews (Pfaeffli Dale et al., 2016; Su et al., 2020; Widmer et al., 2015) and in consultation with a specialist librarian. It included a combination of medical subject headings (or equivalent) and free-text terms. The search strategy for MEDLINE (Ovid) is provided as an example in the supplementary files (Supplementary Table 1). The search strategy was modified for each database.

Selection process

The results from all database searches were imported into EndNote X20. Duplicates were removed first by the software and then manually by the main reviewer (EK). Articles were then exported to Rayyan (Ouzzani et al., 2016) for screening. Studies were screened by abstract and full text by one reviewer (EK), and a second reviewer (RC) screened a random 20% at both abstract and full-text stages. Any disagreement regarding eligibility was resolved through discussion or in consultation with a third reviewer (JMS).

Data extraction

Data extraction was completed by one reviewer (EK) using a pre-piloted data extraction form. A second reviewer (RC) independently verified a random 20% of the extracted data. Any identified discrepancies in the data were resolved via discussion. General study characteristics (e.g., author, year, country), participant characteristics (e.g., sample, age, sex, diagnosis), and outcomes (e.g.,

behavioural, clinical, physiological) were extracted from the included studies. The TIDieR checklist was used to describe the: Why (theoretical framework), What (materials, procedures, core components home-based CR programmes (Thomas et al., 2019)), Who (intervention provider), How (mode of delivery), Where (location of intervention), When and How much (duration and number of sessions), Tailoring (e.g., individualised exercise training), Modifications, and How well (adherence and attrition) for each intervention. The checklist was also used to assess the completeness of reporting for each intervention, with items rated as either 'present', 'absent' or 'unclear'. Source material for the intervention descriptions included all publications related to the trial (e.g., trial result publication, study protocol) and supplementary files. Interventions were coded for BCTs using the BCT taxonomy (v1) (Michie et al., 2013) by one reviewer (EK), and a second reviewer (RC) double-coded a random 20% of interventions to check for reliability. Both reviewers had completed an online training course in using the taxonomy (https://www.bct-taxonomy.com/). A BCT had to be explicitly present to be coded as included. Coding differences were resolved through discussion and if agreement could not be reached, the views of a third reviewer (JMS) were sought.

Outcomes and effectiveness assessment

The primary outcomes of interest in this review were changes in health-related behaviours (e.g., physical activity, diet, smoking, and medication adherence). These outcomes were chosen as CR is an intervention aimed primarily at improving modifiable CVD risk factors. Secondary outcomes included clinical and physiological outcomes. For the purpose of this review, an intervention was classified as 'effective' where there was a statistically significant difference between intervention and comparator in a behavioural outcome. The frequency of BCTs and intervention characteristics in effective and non-effective interventions were compared to allow the differences between these interventions to be examined.

Study risk of bias assessment

Included studies were critically appraised using the Cochrane Risk of Bias Tool for Randomised Trials (RoB 2.0) (Sterne et al., 2019). This tool assesses bias arising from the randomisation process, deviations from intended intervention, missing outcome data, measurement of the outcome, and selective reporting. The risk of bias appraisal was conducted on primary outcomes. Where no primary outcome was specified, the first outcome reported in the results was chosen. The overall level of bias was rated as 'high', 'low' or 'some concerns'. One reviewer (EK) appraised all the studies, while a second (RC) independently appraised a random 20% of the included studies. Any discrepancies that arose were resolved through discussion or in consultation with a third reviewer (JMS).

Synthesis methods

BCTs and TIDieR findings were synthesised narratively, with frequencies and percentages presented in summary tables. Outcome data were quantitatively synthesised in a series of meta-analyses by outcome using Review Manager (RevMan) version 5.425. In studies that measured outcomes at multiple time points, the outcome time point immediately after the intervention was included in the meta-analysis. Continuous outcomes were analysed using the inverse variance statistical method with mean differences (MD) (with 95% CIs) as the effect measure, or standardised mean difference (SMD) if different outcome measures were used. Dichotomous outcomes were analysed using risk ratios (with 95% CIs) via the Mantel-Haenszel method. Statistical heterogeneity was assessed using the Higgins I^2 statistic, with I^2 values of 25%, 50%, and 75% indicating low, moderate, and high heterogeneity, respectively (Higgins et al., 2003). A random-effects model was adopted as there was likely a high level of clinical heterogeneity in the included trials. If a study did not report mean and standard deviation units, an estimate was calculated using methods outlined by

Wan et al. (Wan et al., 2014), or the Cochrane SD calculator. Where these values could not be estimated or if heterogeneity was high (I^2 >75%), a narrative synthesis was performed. Meta-analyses were stratified by type of comparison group (e.g., usual care, centre-based CR) to differentiate between active and passively controlled studies. Four studies (Claes et al., 2020; Lunde et al., 2020; Park et al., 2021; Skobel et al., 2017) comparing digital CR to usual care recruited patients who had previously attended a CR programme. Therefore, a sensitivity analysis was conducted where the 'usual care' comparison group was defined as having never previously attended a CR programme. A meta-regression was not performed as the meta-analysis did not contain a sufficient number of studies.

Results

The initial search identified 13,274 articles. After the removal of duplicates and screening of titles and abstracts, 55 articles were considered eligible for inclusion and were screened by full text. In total, 25 articles reporting 25 RCTs met the eligibility criteria and were included in the review. The PRISMA flow diagram (Figure 1) summarises the study selection process.

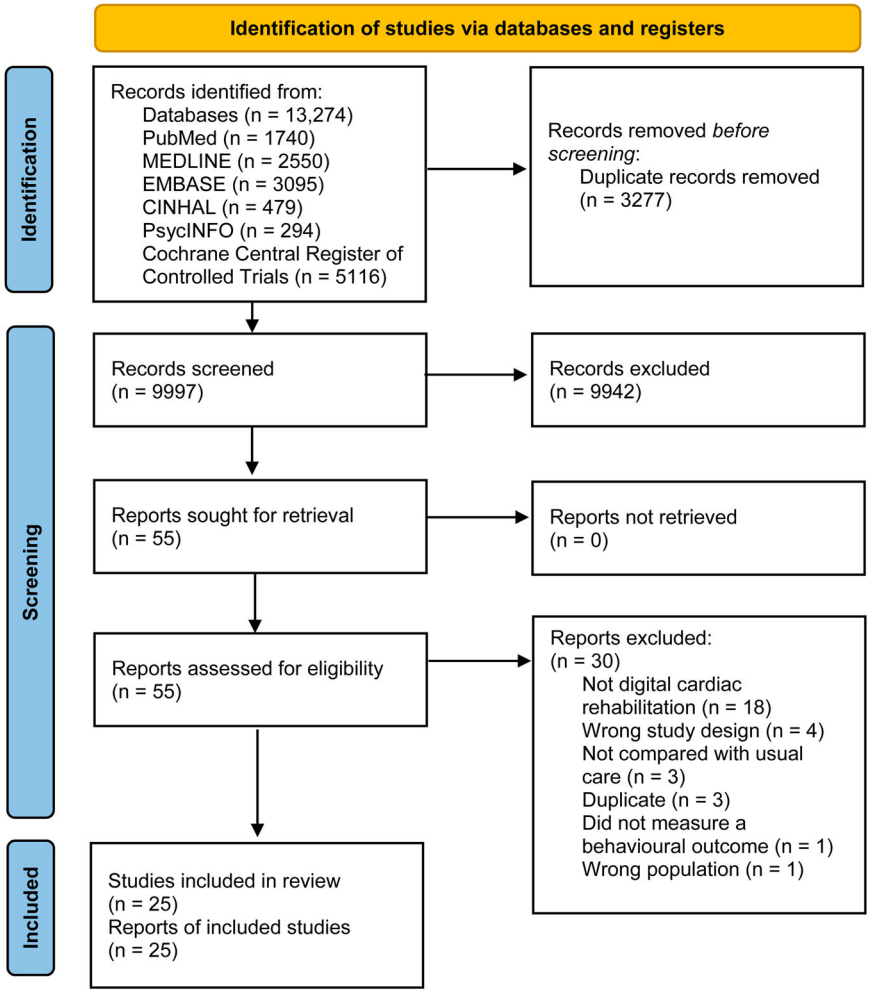


Figure 1. Prisma 2020 flow diagram showing study selection process.

Study characteristics

Table 1 presents a summary of the study characteristics. Of the included studies, four were conducted in Asia (Dorje et al., 2019; Duan et al., 2018; Su & Yu, 2021; Wong et al., 2020), nine in Europe (Brouwers et al., 2021; Claes et al., 2020; Devi et al., 2014; Frederix et al., 2015; Hakala et al., 2021; Lunde et al., 2020; Sankaran et al., 2019; Skobel et al., 2017; Vernooij et al., 2012), seven in North America (Lear et al., 2014; Park et al., 2021; Reid et al., 2012; Southard et al., 2003; Thomas et al., 2019; Widmer et al., 2017; Zutz et al., 2007), and five in Oceania (Maddison et al., 2015; Maddison et al., 2019; Pfaeffli Dale et al., 2015; Varnfield et al., 2014; Yudi et al., 2021). Most of the studies were parallel two-arm RCTs (n = 22, 88%). Other designs included a two-arm cluster RCT (Hakala et al., 2021), a pragmatic RCT (Lunde et al., 2020) and a crossover study (Sankaran et al., 2019). The total number of participants included in all the studies was 3,667 (mean age 60.06), with the sample size ranging from 15 to 438. Males accounted for 75% (n = 2,752) of the overall sample. Participants included in the studies were primarily diagnosed with: CHD (Duan et al., 2018; Su & Yu, 2021; Wong et al., 2020; Southard et al., 2003; Maddison et al., 2019; Pfaeffli Dale et al., 2015; Yudi et al., 2021), acute coronary syndrome (Lear et al., 2014; Lunde et al., 2020; Reid et al., 2012; Vernooij et al., 2012; Widmer et al., 2017), coronary artery disease (Brouwers et al., 2021; Frederix et al., 2015; Lunde et al., 2020; Sankaran et al., 2019; Skobel et al., 2017), CVD (Claes et al., 2020; Hakala et al., 2021; Park et al., 2021), myocardial infarction (Dorje et al., 2019; Varnfield et al., 2014; Zutz et al., 2007), percutaneous coronary intervention (Dorje et al., 2019; Zutz et al., 2007), coronary artery bypass graft (Frederix et al., 2015; Zutz et al., 2007), stable angina (Devi et al., 2014; Dorje et al., 2019), ischemic heart disease (Maddison et al., 2015), chronic heart failure (Frederix et al., 2015), coronary revascularization (Lear et al., 2014) and heart failure (Tomita, 2009).

Intervention characteristics according to the TIDieR checklist

A summary of the intervention characteristics ('why', 'how', 'how long', 'tailoring', and 'how well') is displayed in Table 2. Characteristics relevant to 'what' are described briefly below and are summarised in Table 1.

Theoretical framework (why)

Approximately half of the studies reported using a theoretical framework (n = 13, 52%) (Claes et al., 2020; Duan et al., 2018; Lunde et al., 2020; Maddison et al., 2015; Maddison et al., 2019; Park et al., 2021; Pfaeffli Dale et al., 2015; Sankaran et al., 2019; Skobel et al., 2017; Su & Yu, 2021; Tomita, 2009; Wong et al., 2020; Yudi et al., 2021), with six studies reporting the use of two or more theories (Claes et al., 2020; Maddison et al., 2019; Pfaeffli Dale et al., 2015; Sankaran et al., 2019; Skobel et al., 2017; Tomita, 2009). Social cognitive theory was the most commonly used (n = 5), followed by Fogg's behaviour model, the health belief model, self-efficacy theory and the transtheoretical stages of change model which were each used in two studies.

Materials, procedures, and intervention content (what)

The majority of interventions provided participants with health and lifestyle information (n = 21, 84%), enabled the recording of health behaviours (n = 23, 92%) and goal-setting (n = 18, 72%). Other common intervention features included personalised feedback (n = 17, 68%), reminders and prompts (n = 12, 48%), and the ability to ask questions to the intervention provider (n = 11, 44%). Five interventions (Dorje et al., 2019; Pfaeffli Dale et al., 2015; Tomita, 2009; Varnfield et al., 2014; Yudi et al., 2021) delivered all the core components of home-based CR programmes as described by Thomas et al. (Thomas et al., 2019) (patient assessment, exercise training, diet management, psychosocial support, medication adherence and risk factor management). Exercise training was the most common component, included in all studies except one (Vernooij et al., 2012), which

Table 1. Characteristics of the included studies.

Author (year), country	Sample, Mean age (SD)	Men (%)	Diagnosis	Intervention components	Mode of delivery	Intervention	Control	Outcomes
Brouwers et al. (2021) Netherlands	300 IG: 60.8 (9.3) CG: 60.5 (9.8)	266 (89%)	CAD	PAs, ET	Face-to-face (6 six supervised group-based sessions), website, tele-monitoring	Supervised training sessions to determine individual exercise prescription. ET and PA targets recorded in the web-based app. Weekly video consultation with physical therapist to assess symptoms, injuries or adverse events, adherence and PA data review. Motivational interviewing used to address motivational issues.	CBCR (group-based exercise and additional content depending on needs)	Behavioural: PA Physiological: BMI, BP Clinical: HRQoL, anxiety, depression
Claes et al. (2020) Belgium, Ireland	120 IG: 61.7 (14.5) CG: 59.6 (13.2)	98 (82%)	CVD	PAs, ET, RFM	Face-to-face (4 familiarisation sessions) website, tele-monitoring, email, SMS	Four familiarisation classes conducted with user during week 4–6 of phase 2 CBCR. PATHway system provides individualised exercise prescription, monitoring of exercise and personalised feedback via a virtual 'avatar' coach. Remote communication via headsets, messages, and a live chat function during exercise. Behaviour change module with behavioural goal setting. e-learning platform with information on reducing lifestyle-related risk factors for CVD.	Usual care (verbal advice on how to best maintain PA and a heart-healthy lifestyle post CBCR)	Behavioural: PA, MA, alcohol, smoking status, diet Physiological: CVD risk profile and vascular function Clinical: HRQoL, depression, stress, social support, exercise self-efficacy, exercise barriers, exercise intentions, illness perceptions, mental wellbeing, exercise capacity, adverse events
Devi et al. (2014) United Kingdom	94 IG: 66.27 (8.35) CG: 66.20 (10.06)	70 (74%)	Stable angina	PAs, ET, DM, PS, RFM	Face-to-face (1 familiarisation session), website, tele-monitoring, email	Access to 'ActivateYourHeart' website and Sensewear Pro3 accelerometer.. Individualised goals on exercise, diet, emotions and smoking. Online exercise diary. Feedback on PA and smoking. Information on CHD-related risk factors. Advice and support from CR nurses via email link or at weekly scheduled synchronised chat rooms.	Usual care (annual check of RFM)	Behavioural: PA, diet Physiological: Weight, BP, body fat percentage Clinical: Anxiety, depression, self-efficacy, HRQoL

(*Continued*)

Table 1. Continued.

Author (year), country	Sample, Mean age (SD)	Men (%)	Diagnosis	Intervention components	Mode of delivery	Intervention	Control	Outcomes
Dorje et al. (2019) China	312 IG: 59.1 (9.4) CG: 61.9 (8.7)	254 (81%)	Post-PCI (MI; unstable/ stable angina)	PAs, ET, DM, PS, MA, RFM	Smartphone app, tele-monitoring, SMS	Smartphone app delivered via WeChat. WeChat-interfaced pedometer, BP and HR monitor for remote monitoring and management. 32 cartoon format CHD educational modules. Individualised walking programme. Remote supervision and feedback after data review. WeChat-based consultations on RFM and medication adherence.	Usual care (brief inpatient health education, medication management, ad-hoc follow-up visits to a cardiologist or other HCP)	Behavioural: MA, smoking status, diet, PA Physiological: Resting HR, BP, lipid profile, plasma glucose, BMI, waist-to-hip ratio Clinical: Major adverse cardiac events, psychosocial wellbeing, QoL
Duan et al. (2018) China	114 IG: 45.8 (14.68) CG: 51.57 (11.57)	35 (43%)	CHD	PAs, ET, DM	Website	Web-based modules on PA in the first 4 weeks, followed by content on fruit and vegetable consumption in the next 4 weeks.	Usual care and waiting-group control	Behavioural: PA, fruit and vegetable consumption Physiological: BMI Clinical: Intentions, self-efficacy, social support, QoL, depression
Frederix et al. (2015) Belgium	139 IG: 61 (9) CG: 61 (8)	114 (81%)	CAD treated with a PCI or CABG, CHF	PAs, ET, DM, PS, RFM	Face-to-face (1 familiarisation session) website, tele-monitoring, email, SMS	Individualised ET protocols. Semiautomatic tele-coaching feedback via email and SMS encouraged achievement of ET goals, and provided tailored dietary and smoking cessation recommendations.	CBCR	Behavioural: PA Physiological: Hemoglobin A1c (HbA1c), glycemic control, lipid profile Clinical: Peak aerobic capacity, HRQoL
Hakala et al. (2021) Finland	59 IG: 59.7 (6.0) CG: 59.2 (6.1)	49 (83%)	CVD	PAs, ET, DM, RFM	Face-to-face (three 5-day inpatient sessions at beginning, month 6, month 12), website, tele-monitoring	Provided with Fitbit Charge HR and Movendos mCoach. 1.5-hours face-to-face support on the use of activity monitoring technologies. Goal-setting and instructions on how to perform exercises. Automatic prompts to engage in PA and feedback on activity.	Conventional CR	Behavioural: PA Clinical: Adherence to treatment
Lear et al. (2014) Canada	78 IG: 61.7 (51.3, 65.2) CG: 58.4 (52.8, 64.7)	66 (85%)	ACS, CRV	PAs, ET, DM, RFM	Face-to-face (1 familiarisation session), website, tele-monitoring	vCRP website with weekly educational content, one-on-one chat sessions with program nurse case manager, exercise specialist and dietician. Participants wore HR monitors when exercising and uploaded exercise, weight, BP and glucose to the vCRP twice weekly.	Usual care (guidelines on exercise and healthy eating, list of internet-based resources)	Behavioural: PA, diet, smoking status Physiological: Total cholesterol, HDL-C, triglycerides, blood glucose, BP, BMI, weight, waist circumference Clinical: Exercise capacity, hospital admissions, ED visits
			ACS, CAD	PAs, ET, DM			Usual care	

Lunde et al. (2020) Norway	113 IG: 59.5 (9.1) CG: 58.4 (8.2)	88 (78%)			Face-to-face (1 familiarisation session), smartphone app, tele-monitoring, email	Post CBCR individualised follow-up via smartphone app with goals-setting, tasks and reminders. Short, tailored and individualised motivational feedback provided through the app 1–3 times per week. Comprehensive individual feedback via email.		Behavioural: Exercise habits Physiological: Body weight, resting BP, lipid profile, triglycerides Clinical: Difference in VO_2 peak, peak incline (%), peak velocity (km/h), HRQoL, health status
Maddison et al. (2015) New Zealand	171 IG: 61.4 (8.9) CG: 59.0 (9.5)	139 (81%)	IHD	PAs, ET	Website, SMS	3–5 behavioural support SMS messages per week. Secure website with messages received, video messages, motivational messages, and weekly health and exercise tips.	Usual community-based CR	Behavioural: PA Clinical: Change in peak VO_2, self-efficacy and motivation to exercise, HRQoL
Maddison et al. (2019) New Zealand	162 IG: 61.0 (13.2) CG: 61.5 (12.2)	139 (86%)	CHD	PAs, ET	Smartphone app, website, tele-monitoring, SMS	Provided with a smartphone, a mobile data subscription and chest-worn wearable sensor. Real-time exercise monitoring and remote coaching. Behaviour change education via direct messaging. Website allows individualised goal-setting performance data to be reviewed.	Centre-based exercise CR	Behavioural: Exercise adherence, PA Physiological: Fasted blood lipid, glucose concentrations, height, weight, BMI, waist/hip circumference, BP Clinical: Between-group difference in V̇O2max, exercise-related motivation, adverse events, HRQoL
Park et al. (2021) USA	60 IG: 66.7 (8.6) CG: 66.8 (8.7)	46 (77%)	CVD	PAs, ET, DM, RFM	Smartphone app, tele-monitoring, SMS	Post CBCR participants received a Fitbit Charge 2 and Movn mobile app to record step counts and exercise. Motivational PA prompts and educational messages related to CVD management.	Usual care (given a pedometer and diary of daily steps)	Behavioural: PA Clinical: Functional capacity, exercise self-efficacy, depression
Pfaeffli Dale et al. (2015) New Zealand	123 IG: 59.0 (10.5) CG: 59.9 (11.8)	100 (81%)	CHD	PAs, ET, DM, PS, MA, RFM	Website, tele-monitoring, SMS	Participants received a pedometer for PA monitoring and 5–7 automated SMS messages per week. Personalised feedback was available within 48 h upon request. Supporting website with a blog, self-monitoring function and information.	Usual Care	Behavioural: Adherence to health guidelines, MA Physiological: BP, lipid profile, weight, BMI, waist-to-hip ratio, CHD risk probability Clinical: Self-efficacy, illness perceptions, anxiety, depression, serious adverse events
Reid et al. (2012) Canada	223 IG: 56.7 (9.0) CG: 56.0 (9.0)	188 (84%)	ACS post successful PCI	PAs, ET	Face-to-face (1 familiarisation session), website, tele-monitoring, email	PA plan and access to CardioFit website to log activity daily and complete online tutorials. Exercise specialist answered questions and gave motivational feedback on progress via email.	Usual care (received PA guidance from their attending cardiologist and an education booklet)	Behavioural: PA Clinical: Heart disease HRQoL

(*Continued*)

Table 1. Continued.

Author (year), country	Sample, Mean age (SD)	Men (%)	Diagnosis	Intervention components	Mode of delivery	Intervention	Control	Outcomes
Sankaran et al. (2019) Belgium	28 60.9 (8.2)	24 (86%)	CAD	PAs, ET, MA, RFM	Smartphone app	HeartHab smartphone app with monitoring of risk factors, medication management, PA, e-coaching and symptom monitoring. Caregivers can remotely monitor patient risk factors and PA progress, tailor targets and prescribe medication.	Usual care (self-management)	Behavioural: PA Physiological: Weight, BP, heart rhythm, exercise capacity, glucose, lipid profile Clinical: HRQoL
Skobel et al. (2017) Germany, Spain, United Kingdom	118 IG: 60 (50, 65) CG: 58 (52, 67)	105 (89%)	CAD post MI	PAs, ET	Smartphone app, tele-monitoring	Phase 3 follow-up internet-based training. Mobile station - a wearable sensor and a smartphone app for use during exercise. Patient station - a tablet PC for synchronising data, delivering educational content, and messages from HCP. The Professional System - a Web-based tool with patient data and information.	Usual care (as provided in each country)	Behavioural: Exercise time Physiological: Total cholesterol, LDL-C, HDL-C, fasting glucose, BMI Clinical: Exercise capacity, QoL, anxiety, depression
Southard et al. (2003) USA	104 IG: 61.8 (10.6) CG: 62.8 (10.6)	78 (75%)	CHD	PAs, ET, DM, RFM	Website, email	Website with educational modules and links to related sites. Track progress using online graphs, online discussion group for support. Dietician provides feedback on daily dietary intake.	Usual care	Behavioural: PA, diet, smoking status Physiological: Height, weight, BP Clinical: Functional status, QoL, depression
Su and Yu (2021) China	146 IG: 55.53 (7.30) CG: 56.03 (7.02)	122 (84%)	CHD	PAs, ET, DM, PS, RFM	Face-to-face (1 familiarisation session, 1 group-based session), smartphone app, website, tele-monitoring, email	In-person individualised health counselling to identify patients' self-care needs, develop client-centred goals and action plans. Group-based engagement session to orientate participants to platform and to form a cohesive peer support group. Web-based platform with self-monitoring of behavioural goals and motivational feedback; experiential learning platform; and health dialogue forum.	Usual care (10 min didactic session on medication usage and lifestyle changes)	Behavioural: PA, health behaviours, smoking cessation Physiological: BP, BMI, waist circumference Clinical: Cardiac self- efficacy, HRQoL, psychological wellbeing, cardiac-related hospital readmissions, re-vascularisation, ED visits

Tomita (2009) USA	40 IG: 74.2 (9.7) CG: 77.5 (7.4)	13 (33%)	HF	PAs, ET, DM, PS, MA, RFM	Face-to-face (1 familiarisation session), website	Computer and internet provided. Daily recording of vital signs and health behaviours on website. Webpage containing information on health-related topics, past records and an automatic alerts for sudden weight gain. Exercise instruction delivered via streaming video. Monthly appraisal support provided via email.	Usual care (3 month regular check up with physician for home-based patients in the US)	Behavioural: PA Clinical: QoL
Varnfield et al. (2014) Australia	94 IG: 54.9(9.6) CG: 56.2 (10.1)	82 (87%)	Post-MI	PAs, ET, DM, PS, MA, RFM	Face-to-face (1 familiarisation session), smartphone app, tele-monitoring, SMS	Smartphone app used for mentoring and goal setting, daily motivational messages, educational videos and relaxation audio, and recording of self-observations and measurements via in-build applications (pedometer and BP monitor). Mentors review patient data and provide personalised feedback and goal setting during weekly phone consultations.	CBCR (two supervised exercise and 1 h educational sessions per week)	Behavioural: CR uptake, adherence and completion, PA, diet Physiological: BP, HR, weight, BMI, waist circumference, lipid profile, functional capacity Clinical: Psychosocial functioning, depression, anxiety, HRQoL
Vernooij et al. (2012) Netherlands	330 IG: 60.7 (7.8) CG: 59.2 (8.9)	246 (75%)	ACS	PAs, RFM	Face-to-face (1 familiarisation session), website, email	Personalised website allowed risk factor measurements, drug use, treatment goal, advice from the nurse, correspondence between nurse and patient, and news items for particular risk factors.	Usual care	Behavioural: Smoking status Physiological: SBP, LDL-C, HDL-C, triglycerides, BMI, waist circumference, type 2 diabetes mellitus, fasting glucose, glucose lowering drugs Clinical: Relative change in Framingham heart risk score, adverse events
Widmer et al. (2017) USA	80 IG: 62.5 (10.7) CG: 63.6 (10.9)	58 (73%)	ACS post PCI	PAs, ET, DM	Face-to-face (1 familiarisation session), smartphone app, website, email	Standard CR and smartphone app/ web-based portal to track health vitals, complete recommended daily activities and view educational modules. Reminders to complete educational content or log information. Could contact the study team via the online program.	CBCR	Behavioural: PA, diet, smoking status Physiological: Weight, BP, HR, glucose/HbA1c, lipid profile Clinical: CVD re-hospitalisations and ED visits, QoL stress
Wong et al. (2020) China	438 IG: 52.22 (5.07) CG: 52.46 (4.72)	289 (66%)	CHD	PAs, ET, RFM	Face-to-face (1 familiarisation session), website	Website learning platform with facts about CHD. Participants could view educational material, self-monitor behaviour and vitals, and receive reminders to log information.	Usual care (routine medical visit by physician, educational leaflet, and recommendation to be physically active)	Behavioural: PA Physiological: Total cholesterol, LDL-C, HDL-C, triglyceride levels, body weight, BP, BMI Clinical: Exercise self-efficacy

(*Continued*)

Table 1. Continued.

Author (year), country	Sample, Mean age (SD)	Men (%)	Diagnosis	Intervention components	Mode of delivery	Intervention	Control	Outcomes
Yudi et al. (2021) Australia	206 IG: 56.8 (9.9) CG: 56.2 (10.2)	71 (84%)	CHD	PAs, ET, DM, PS, MA, RFM	Face-to-face (1 familiarisation session), smartphone app	Smartphone app provides exercise prescription, tracking of risk factors, dietary habits and medications, cardiac education, personalised feedback and support.	Usual care (inpatient cardiology review, pre-discharge planning, referral to CBCR, promotion of self-care and a chest pain action plan)	Behavioural: Smoking status Physiological: Fasting lipid levels, fasting glucose, Resting BP, weight, BMI, waist circumference Clinical: Change in 6MWT, uptake, adherence and completion of CR, depression, anxiety, QoL, time to return to work, major adverse CVD events, CVD hospital re-admissions
Zutz et al. (2007) Canada	15 IG: 58 (4) CG: 59 (12)	12 (80%)	MI, PCI, CABG	PAs, ET, DM, RFM	Face-to-face (1 familiarisation session), website, tele-monitoring, email	vCRP website with weekly educational content, one-on-one chat sessions with program nurse case manager, exercise specialist and dietician. Participants wore HR monitors when exercising and uploaded exercise, weight, BP and glucose to the vCRP twice weekly.	Usual care	Behavioural: PA Physiological: Lipid profile, LDL-C, BP, BMI, waist circumference Clinical: Exercise capacity, self-efficacy, exercise self-efficacy

Abbreviations: 6MWT, 6-min walk test; ACS, acute coronary syndrome; BMI, body mass index; BP, blood pressure; CABG, coronary artery bypass graft; CAD, coronary artery disease; CBCR, centre-based cardiac rehabilitation; CG, control group; CHD, coronary heart disease; CHF, chronic heart failure; CPET, cardiopulmonary exercise testing; CR, cardiac rehabilitation; CRV, coronary revascularization; CVD, cardiovascular disease; DM, diet management; ECG, electrocardiogram; ET, exercise training; HF, heart failure; HCP, healthcare professional; HDL-C, high-density lipoprotein cholesterol; HR, heart rate; HRQoL, health-related quality of life; IG, intervention group; IHD, ischemic heart disease, LDL-C, low-density lipoprotein cholesterol; MA, medication adherence; MI, myocardial infarction; PA, physical activity; PAs, patient assessment; PATHway, physical activity toward health; PCI, percutaneous coronary intervention; PS, psychosocial support; QoL, quality of life; RCT, randomised controlled trial; RFM, risk factor management; SBP, systolic blood pressure; SD, standard deviation; vCRP, virtual cardiac rehabilitation programme; VO2, oxygen consumption.

Table 2. Intervention characteristics with TIDieR headings.

Author (year)	Why?	How?							Duration			Tailoring	How well? Attrition			Primary outcome		
	Theory	Face to face	Smart phone app	Web site	Telemonitoring	Email	SMS	Phone call	Short: ≤3 mths	Med: >3 mths	Long: ≥12 mths		Low: 0 -12.99%	Med: 13 - 26%	High: >26%	PA	FC	Other
Brouwers et al. (2021)		✓		✓	✓				✓			✓	✓			–		
Claes et al. (2020)	BCW, SCT	✓		✓	✓	✓	✓			✓		✓		✓		+		
Devi et al. (2014)		✓		✓	✓	✓			✓			✓	✓			+		
Dorje et al. (2019)			✓		✓		✓			✓		✓		✓			+	
Duan et al. (2018)	HAPA			✓					✓						✓	+		
Frederix et al. (2015)		✓		✓	✓	✓	✓		✓			✓	✓				+	
Hakala et al. (2021)		✓		✓	✓						✓		✓			–		
Lear et al. (2014)		✓		✓	✓						✓	✓	✓				+	
Lunde et al. (2020)	TTM	✓	✓		✓	✓					✓	✓	✓				+	
Maddison et al. (2015)	SET			✓			✓			✓		✓	✓				–	
Maddison et al. (2019)	SET, SDT		✓	✓	✓		✓		✓			✓		✓			–	
Park et al. (2021)	SCT		✓		✓		✓		✓			?		✓		+		
Pfaeffli Dale et al. (2015)	CSM, SCT			✓	✓		✓		✓			✓	✓					AHG–
Reid et al. (2012)		✓		✓	✓	✓				✓		✓			✓	+		
			✓						✓			✓		✓			–	

(*Continued*)

Table 2. Continued.

Author (year)	Why?	How?							Duration			Tailoring	How well? Attrition			Primary outcome		
	Theory	Face to face	Smart phone app	Web site	Telemonitoring	Email	SMS	Phone call	Short: ≤3 mths	Med: >3 mths	Long: ≥12 mths		Low: 0 -12.99%	Med: 13 - 26%	High: >26%	PA	FC	Other
Sankaran et al. (2019)	FBM, PSD, BH																	
Skobel et al. (2017)	HBM, FFT		✓		✓					✓		✓			✓		+	
Southard et al. (2003)				✓		✓		✓		✓		✓	✓			–[†]		
Su and Yu (2021)	SCT	✓	✓	✓	✓				✓			✓		✓		+		
Tomita (2009)	TTM, SST	✓		✓		✓					✓	?		✓		+[†]		
Varnfield et al. (2014)		✓	✓		✓		✓	✓	✓			✓			✓			CR UAC +
Vernooij et al. (2012)		✓		✓		✓					✓	✓	✓					FRAM +
Widmer et al. (2017)		✓	✓	✓		✓			✓				✓					RH –
Wong et al. (2020)	HBM	✓		✓						✓		✓		✓		–		
Yudi et al. (2021)	SCT	✓	✓						✓			✓		✓			+	
Zutz et al. (2007)		✓		✓	✓	✓			✓			✓		✓		+[†]		
Total $N = 25$ (100%)	13 (52%)	16 (64%)	10 (40%)	18 (72%)	16 (64%)	10 (40%)	8 (32%)	2 (8%)	13 (52%)	7 (28%)	5 (20%)	20 (80%)	11 (44%)	10 (40%)	4 (16%)			

[†]No primary outcome specified

Abbreviations: AHG, adherence to healthy guidelines; BCW, behaviour change wheel; BH, behaviour wizard; CR UAC, cardiac rehabilitation uptake, adherence and completion; CSM, common sense model; FBM, Fogg's behaviour model; FC, functional capacity; FFT, Fogg's functional triad; FRAM, Framingham heart risk score; HAPA, health action process approach; HBM, health belief model; PA, physical activity; PSD, persuasive systems design model; RH, re-hospitalisations; SCT, social cognitive theory; SDT, self-determination theory; SET, self-efficacy theory; SST, social support theory; TTM, transtheoretical Model; ✓, present;?, unclear; +, statistically significant difference between groups at study endpoint; –, no statistically significant difference between groups at study endpoint.

focused on risk factor management. Risk factor management was a component in 17 studies, diet management in 16 studies, psychosocial support in eight studies, and medication adherence in six studies. The control group in the studies included usual care (Claes et al., 2020; Lunde et al., 2020; Park et al., 2021; Skobel et al., 2017; Dorje et al., 2019; Su & Yu, 2021; Devi et al., 2014; Sankaran et al., 2019; Vernooij et al., 2012; Reid et al., 2012; Southard et al., 2003; Zutz et al., 2007; Tomita, 2009; Lear et al., 2014; Yudi et al., 2021), centre-based CR (Brouwers et al., 2021; Frederix et al., 2015; Hakala et al., 2021; Maddison et al., 2015; Maddison et al., 2019; Pfaeffli Dale et al., 2015; Varnfield et al., 2014; Widmer et al., 2017; Wong et al., 2020), and usual care followed by a waiting control group (Duan et al., 2018).

Intervention provider (who)

Sixteen interventions were delivered by healthcare professionals such as nurses (n = 10) (Vernooij et al., 2012; Duan et al., 2018; Su & Yu, 2021; Wong et al., 2020; Devi et al., 2014; Hakala et al., 2021; Sankaran et al., 2019; Southard et al., 2003; Zutz et al., 2007; Lear et al., 2014), cardiologists (n = 4) (Brouwers et al., 2021; Dorje et al., 2019; Frederix et al., 2015; Sankaran et al., 2019), dieticians (n = 4) (Lear et al., 2014; Hakala et al., 2021; Southard et al., 2003; Zutz et al., 2007), psychologists (n = 2) (Brouwers et al., 2021; Hakala et al., 2021), physiotherapists (n = 3) (Lunde et al., 2020; Brouwers et al., 2021; Sankaran et al., 2019), and general practitioners (n = 1) (Brouwers et al., 2021). Interventions were also delivered by non-healthcare professionals including members of the research team (n = 4) (Claes et al., 2020; Park et al., 2021; Pfaeffli Dale et al., 2015; Widmer et al., 2017), exercise specialists (n = 4) (Hakala et al., 2021; Maddison et al., 2019; Reid et al., 2012; Zutz et al., 2007), IT specialists (n = 2) (Frederix et al., 2015; Hakala et al., 2021), and mentors (n = 1) (Varnfield et al., 2014). One intervention had no provider and was instead delivered exclusively via automated SMS text messages and a website (Maddison et al., 2015). Seven interventions were delivered by more than one provider (Brouwers et al., 2021; Frederix et al., 2015; Hakala et al., 2021; Sankaran et al., 2019; Southard et al., 2003; Zutz et al., 2007; Lear et al., 2014).

Mode of delivery (how)

Websites were the most frequently used mode of delivery, involved in delivering 18 interventions (Claes et al., 2020; Duan et al., 2018; Su & Yu, 2021; Wong et al., 2020; Brouwers et al., 2021; Devi et al., 2014; Frederix et al., 2015; Hakala et al., 2021; Vernooij et al., 2012; Reid et al., 2012; Southard et al., 2003; Widmer et al., 2017; Zutz et al., 2007; Tomita, 2009; Lear et al., 2014; Maddison et al., 2015; Maddison et al., 2019; Pfaeffli Dale et al., 2015). They were typically used to enable participants to record their physical activity and health behaviours, receive health education and feedback on their performance and host discussion forums. Smartphone applications were used similarly in ten studies (Dorje et al., 2019; Lunde et al., 2020; Maddison et al., 2019; Park et al., 2021; Sankaran et al., 2019; Skobel et al., 2017; Su & Yu, 2021; Varnfield et al., 2014; Widmer et al., 2017; Yudi et al., 2021). Telemonitoring devices were featured in 16 studies. Types of devices included accelerometers (Brouwers et al., 2021; Claes et al., 2020; Devi et al., 2014; Frederix et al., 2015; Hakala et al., 2021; Park et al., 2021), heart rate monitors (Brouwers et al., 2021; Claes et al., 2020; Dorje et al., 2019; Lear et al., 2014; Maddison et al., 2019; Zutz et al., 2007), blood pressure monitors (Claes et al., 2020; Dorje et al., 2019; Lear et al., 2014; Varnfield et al., 2014; Zutz et al., 2007), pedometers (Dorje et al., 2019; Pfaeffli Dale et al., 2015; Reid et al., 2012; Su & Yu, 2021; Varnfield et al., 2014), chest wearable sensors (Maddison et al., 2019; Skobel et al., 2017) and an ECG (Claes et al., 2020; Maddison et al., 2019). Ten studies used email (Claes et al., 2020; Lunde et al., 2020; Devi et al., 2014; Frederix et al., 2015; Vernooij et al., 2012; Reid et al., 2012; Southard et al., 2003; Widmer et al., 2017; Zutz et al., 2007; Tomita, 2009), while SMS text messages were used eight studies (Claes et al., 2020; Dorje et al., 2019; Frederix et al., 2015; Maddison et al., 2015; Maddison et al., 2019; Park et al., 2021; Pfaeffli Dale et al., 2015; Varnfield et al., 2014). These modes of delivery were typically used to provide advice and support, give feedback on performance, support goal achievement, and answer questions from participants. Two studies used phone calls, one to facilitate communication

between the intervention provider and participants (Southard et al., 2003), and another to hold a weekly consultation with patients to review patient data and provide personalised feedback (Varnfield et al., 2014). Many studies (n = 16) also included a face-to-face component. These sessions typically occurred once at the beginning of the intervention to provide participants with equipment and training on its use or to tailor the intervention to the participants' needs (Devi et al., 2014; Frederix et al., 2015; Lear et al., 2014; Lunde et al., 2020; Reid et al., 2012; Su & Yu, 2021; Tomita, 2009; Varnfield et al., 2014; Vernooij et al., 2012; Widmer et al., 2017; Wong et al., 2020; Yudi et al., 2021). In some cases, studies extended the face-to-face familiarisation sessions over two (Su & Yu, 2021), four (Claes et al., 2020), or six (Hakala et al., 2021) sessions, while one study (Hakala et al., 2021) held three five-day inpatient sessions at the beginning, middle (month 6), and end of the intervention (month 12). Overall, studies were delivered using an average of 2.6 modes of delivery. Only four studies delivered an intervention using a single form of technology (Duan et al., 2018; Sankaran et al., 2019; Wong et al., 2020; Yudi et al., 2021).

Location (where)

All interventions were conducted in the participants' homes. However, several interventions (n = 15) held initial training sessions at CR centres (n = 4) (Claes et al., 2020; Frederix et al., 2015; Hakala et al., 2021; Widmer et al., 2017), hospitals (n = 3) (Reid et al., 2012; Su & Yu, 2021; Yudi et al., 2021), and outpatient clinics (n = 2) (Brouwers et al., 2021; Vernooij et al., 2012). One intervention conducted the initial session in the participants' homes (Devi et al., 2014), and six interventions did not specify where these sessions took place (Lear et al., 2014; Lunde et al., 2020; Tomita, 2009; Varnfield et al., 2014; Wong et al., 2020; Zutz et al., 2007).

Duration and number of sessions (when and how much)

The duration of the supervised intervention period ranged from 6 weeks (Devi et al., 2014) to 16 months (Lear et al., 2014). More than half of the interventions (n = 13) were considered short in duration (≤3 months) (Brouwers et al., 2021; Devi et al., 2014; Duan et al., 2018; Frederix et al., 2015; Maddison et al., 2019; Park et al., 2021; Pfaeffli Dale et al., 2015; Sankaran et al., 2019; Su & Yu, 2021; Varnfield et al., 2014; Widmer et al., 2017; Yudi et al., 2021; Zutz et al., 2007), seven were medium (> 3 months) (Claes et al., 2020; Skobel et al., 2017; Dorje et al., 2019; Wong et al., 2020; Reid et al., 2012; Southard et al., 2003; Maddison et al., 2015), and five were long (≥12 months) (Hakala et al., 2021; Lear et al., 2014; Lunde et al., 2020; Tomita, 2009; Vernooij et al., 2012).

Intervention tailoring

Almost all interventions (n = 20) included some form of tailoring. This usually involved individualised exercise prescription based on an initial assessment, tailored goals relating to health behaviours such as exercise, diet and smoking, and individualised feedback based on performance.

Adherence and attrition (how well)

Attrition (drop out) in the trials was low (<13%) in 11 studies (Lunde et al., 2020; Brouwers et al., 2021; Devi et al., 2014; Frederix et al., 2015; Hakala et al., 2021; Vernooij et al., 2012; Southard et al., 2003; Widmer et al., 2017; Lear et al., 2014; Maddison et al., 2015; Pfaeffli Dale et al., 2015), medium (13-26%) in ten (Claes et al., 2020; Dorje et al., 2019; Maddison et al., 2019; Park et al., 2021; Sankaran et al., 2019; Su & Yu, 2021; Tomita, 2009; Wong et al., 2020; Yudi et al., 2021; Zutz et al., 2007), and high (>26%) in four (Duan et al., 2018; Reid et al., 2012; Skobel et al., 2017; Varnfield et al., 2014). Intervention adherence was measured using application/website logins, completion of tasks, data uploads, number of chat sessions attended, and feedback surveys.

TIDieR coding

Completeness of reporting in the studies among the TIDieR items ranged from 42% (n = 5) (Duan et al., 2018) to 92% (n = 11) (Claes et al., 2020; Pfaeffli Dale et al., 2015), with an average of eight out of the 12 items on the checklist being adequately reported in the studies. The most well-reported item was the mode of delivery (item 6), described in all studies. Next was a brief description (item 1; n = 21; 84%), followed by rationale (item 2) and tailoring (item 9) which were each reported in 20 studies (80%). Only one study included in the review reported modifications to the intervention (item 10) (Southard et al., 2003). The intervention materials (item 3) were adequately described in 6 studies (24%), and unclear in 18 (72%). The unclear rating was given as the intervention materials were not provided or described in sufficient detail to enable replication. For example, many interventions that included an educational component rarely provided the exact content that was presented to participants. The assessment of intervention adherence or fidelity (item 11) was reported in 9 studies (36%). The remaining items were adequately reported in 60% or more of the studies. A summary of the completeness of reporting of the TIDieR items in the studies is presented in Table 3.

Risk of bias of included studies

The risk of bias assessment is summarised in Figure 2. The risk of bias was low in eight studies (32%), of some concern in 14 studies (52%), and high in three studies (16%).

The high risk of bias in two studies was due to high rates of attrition and failure to use intention to treat analysis (Duan et al., 2018; Skobel et al., 2017), while in the third study an objective measure of daily steps (e.g., pedometer) was used in the intervention group and a self-reported measure (steps diary) was used in the control group (Park et al., 2021). The risk of bias assessment for each domain of the included studies can be found in the supplementary file (Supplementary Figure 2).

Outcomes

Of the included studies, physical activity (Brouwers et al., 2021; Claes et al., 2020; Devi et al., 2014; Duan et al., 2018; Hakala et al., 2021; Park et al., 2021; Reid et al., 2012; Su & Yu, 2021; Wong et al., 2020) and functional capacity (Dorje et al., 2019; Frederix et al., 2015; Lear et al., 2014; Lunde et al., 2020; Maddison et al., 2015; Maddison et al., 2019; Sankaran et al., 2019; Skobel et al., 2017; Yudi et al., 2021) were the most frequently reported primary outcomes, each used in nine studies. Other primary outcomes included the Framingham heart risk score (Vernooij et al., 2012), adherence to healthy guidelines (Pfaeffli Dale et al., 2015), re-hospitalisations (Widmer et al., 2017), and CR uptake, adherence and completion rates (Varnfield et al., 2014). Three studies did not specify a primary outcome (Southard et al., 2003; Zutz et al., 2007; Tomita, 2009), but of the studies that did, 64% (14/22) reported a statistically significant difference in favour of the intervention group. A summary of the effectiveness of primary outcomes is presented in Table 2.

Behavioural outcomes

Physical activity

Physical activity was included as an outcome in 22 studies. Ten studies used objective measures such as accelerometers (Brouwers et al., 2021; Claes et al., 2020; Devi et al., 2014; Frederix et al., 2015; Hakala et al., 2021; Maddison et al., 2019; Park et al., 2021; Skobel et al., 2017) or pedometers (Reid et al., 2012; Su & Yu, 2021). The remaining studies used self-reported measures, including the International Physical Activity Questionnaire (IPAQ) (Dorje et al., 2019; Duan et al., 2018; Frederix et al., 2015; Hakala et al., 2021; Maddison et al., 2015; Sankaran et al., 2019; Su & Yu, 2021), the Minnesota Leisure Time Physical Activity Questionnaire (Lear et al., 2014; Zutz et al., 2007) and the Godin-

Table 3. TIDieR reporting in each study.

	Brouwers et al. (2021)	Claes (2020)	Devi et al. (2014)	Dorje et al. (2019)	Duan et al. (2018)	Frederix et al. (2015)	Hakala et al. (2021)	Lear et al. (2014)	Lunde et al. (2020)	Maddison et al. (2015)	Maddison et al. (2019)	Park et al. (2021)	Pfaeffli Dale et al. (2015)	Reid et al. (2012)	Sankaran et al. (2019)	Skobel et al. (2017)	Southard et al. (2003)	Su and Yu (2021)	Tomita (2009)	Varnfield et al. (2014)	Vernooij et al. (2012)	Widmer et al. (2017)	Wong et al. (2020)	Yudi et al. (2021)	Zutz et al. (2007)	Total N = 25 (100%)
1. Brief name	Y	Y	Y	Y	N	Y	N	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	21 (84%)
2. Why	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	Y	Y	?	Y	Y	Y	Y	Y	Y	Y	Y	Y	?	?	20 (80%)
3. What (materials)	Y	Y	?	?	N	?	?	?	Y	?	?	?	Y	?	?	?	?	?	?	?	Y	?	Y	?	?	6 (24%)
4. What (procedure)	Y	Y	Y	Y	?	Y	Y	Y	Y	Y	Y	Y	Y	Y	?	?	?	Y	Y	Y	Y	?	Y	Y	?	19 (76%)
5. Who provided	?	Y	?	Y	?	Y	Y	Y	Y	Y	Y	Y	Y	Y	?	N	Y	Y	?	?	Y	Y	Y	N	Y	17 (60%)
6. How	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	25 (100%)
7. Where	Y	Y	Y	Y	Y	Y	Y	?	?	Y	Y	Y	Y	Y	Y	Y	Y	Y	?	?	Y	Y	?	Y	?	19 (76%)
8. When and how much	Y	Y	?	Y	Y	Y	?	?	Y	Y	Y	Y	Y	Y	N	Y	?	Y	?	Y	Y	?	Y	Y	?	17 (60%)
9. Tailoring	Y	Y	Y	Y	N	Y	N	Y	Y	Y	Y	?	Y	Y	Y	Y	Y	Y	?	Y	Y	N	Y	Y	Y	20 (80%)
10. Modifications	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	1 (4%)
11. How well (planned)	Y	Y	Y	Y	N	N	Y	N	N	N	N	Y	Y	N	N	Y	N	Y	N	Y	N	N	N	N	N	9 (36%)
12. How well (actual)	?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	?	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	21 (84%)
Total N = 12 (100%)	9 (75%)	11 (92%)	8 (66%)	10 (83%)	5 (42%)	9 (75%)	6 (50%)	7 (58%)	9 (75%)	9 (75%)	9 (75%)	8 (66%)	11 (92%)	8 (66%)	5 (42%)	8 (66%)	8 (66%)	10 (83%)	6 (50%)	9 (75%)	9 (75%)	6 (50%)	9 (75%)	7 (58%)	6 (50%)	

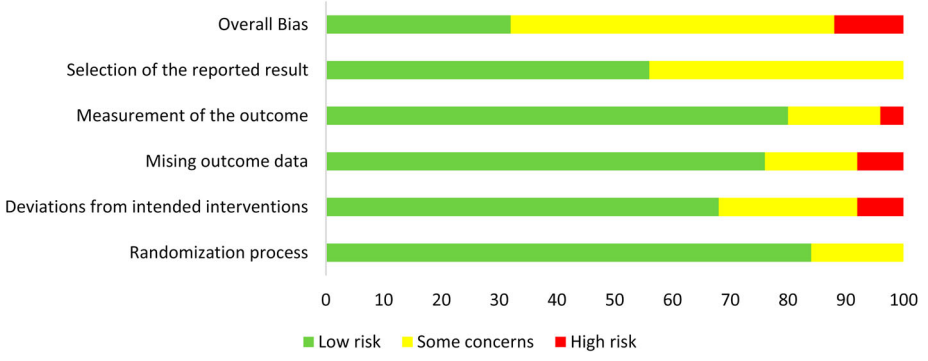


Figure 2. Risk of bias assessment in the included studies.

Shephard Leisure-Time Physical Activity Questionnaire (Reid et al., 2012; Wong et al., 2020). Due to variation in how studies reported and defined acceptable levels of physical activity, separate meta-analyses were performed for daily steps, light physical activity (LPA) and moderate to vigorous physical activity (MVPA).

Comparing digital CR to usual care, data pooling found that participants receiving digital CR reported significantly higher daily steps (n = 6; SMD 0.31, 95% CI = 0.10–0.51, I^2 = 37%; *P* = .003; Figure 3a) and LPA undertaken at 3–12 months post-intervention (n = 6; SMD 0.29, 95% CI = 0.08–0.50, I^2 = 15%; *P* = .006; Figure 3b). There was no evidence of a difference in MVPA between digital CR and usual care (n = 3; SMD 0.13, 95% CI = –0.06–0.33, I^2 = 0%; *P* = .19; Figure 3c). Between digital CR and centre-based CR, no statistically significant differences in LPA (n = 5; SMD 0.19, 95% CI = –0.10–0.48, I^2 = 76%; *P* = .20; Figure 3b), or MVPA were observed (n = 3; SMD – 0.04, 95% CI = –0.34–0.26, I^2 = 44%; *P* = .77; Figure 3c).

Data from five studies were not included in the meta-analysis due to the unavailability of mean and standard deviation units, and so instead were narratively synthesised. Of the studies comparing digital CR to usual care, two studies observed that digital CR produced significant improvements in self-reported MVPA (*P* = .003) at eight weeks (Duan et al., 2018) and self-reported total physical activity (vigorous, moderate and walking) (*P* = .015) at 12 weeks (Su & Yu, 2021). A third study (Tomita, 2009) found that participants in the digital CR group self-reported engaging in a significantly greater amount of exercise than those receiving usual care (*P* <.001). When comparing digital CR and centre-based CR, Maddison et al. (Maddison et al., 2015) found significantly higher self-reported leisure-time physical activity (MD 110.2 min/week, 95% CI = 0.8–221.3; *P* = .05) and walking (MD 151.4 min/week, 95% CI = 27.6–275.2; *P* = .02) in the digital CR group at 24 weeks, while Frederix et al. (Frederix et al., 2015) reported no significant difference in daily steps between the intervention and control groups.

Diet management

Seven studies included diet as an outcome, each of which used a different measure. Due to this variation in measurement, outcomes could not be pooled quantitatively and so were instead synthesised narratively. Five studies compared the effects of digital CR to usual care. Two studies (Duan et al., 2018; Lear et al., 2014) reported that participants receiving digital CR made significant improvements in their diet, while the remaining three studies found no significant between-group differences (Claes et al., 2020; Devi et al., 2014; Southard et al., 2003). Of the two studies that compared digital CR to centre-based CR, one reported a significant improvement in favour of digital CR (Widmer et al., 2017), while the other study found no statistically significant difference (Varnfield et al., 2014).

Smoking

Smoking was included as an outcome in nine studies and was measured in all via self-report. Data pooling from six studies revealed no significant difference between intervention and usual care in the overall smoking event rate at 2–12 months of follow up (RR 0.92, 95% CI = 0.65–1.30, $I^2 = 16\%$; $P = .62$; Figure 3d). Of the studies not included in the pooled analysis, Su et al. (Su & Yu, 2021) reported significantly higher rates of smoking cessation in the digital CR group versus usual care ($P = .04$) at 12 weeks. Two studies did not report results on this outcome (Claes et al., 2020; Widmer et al., 2017).

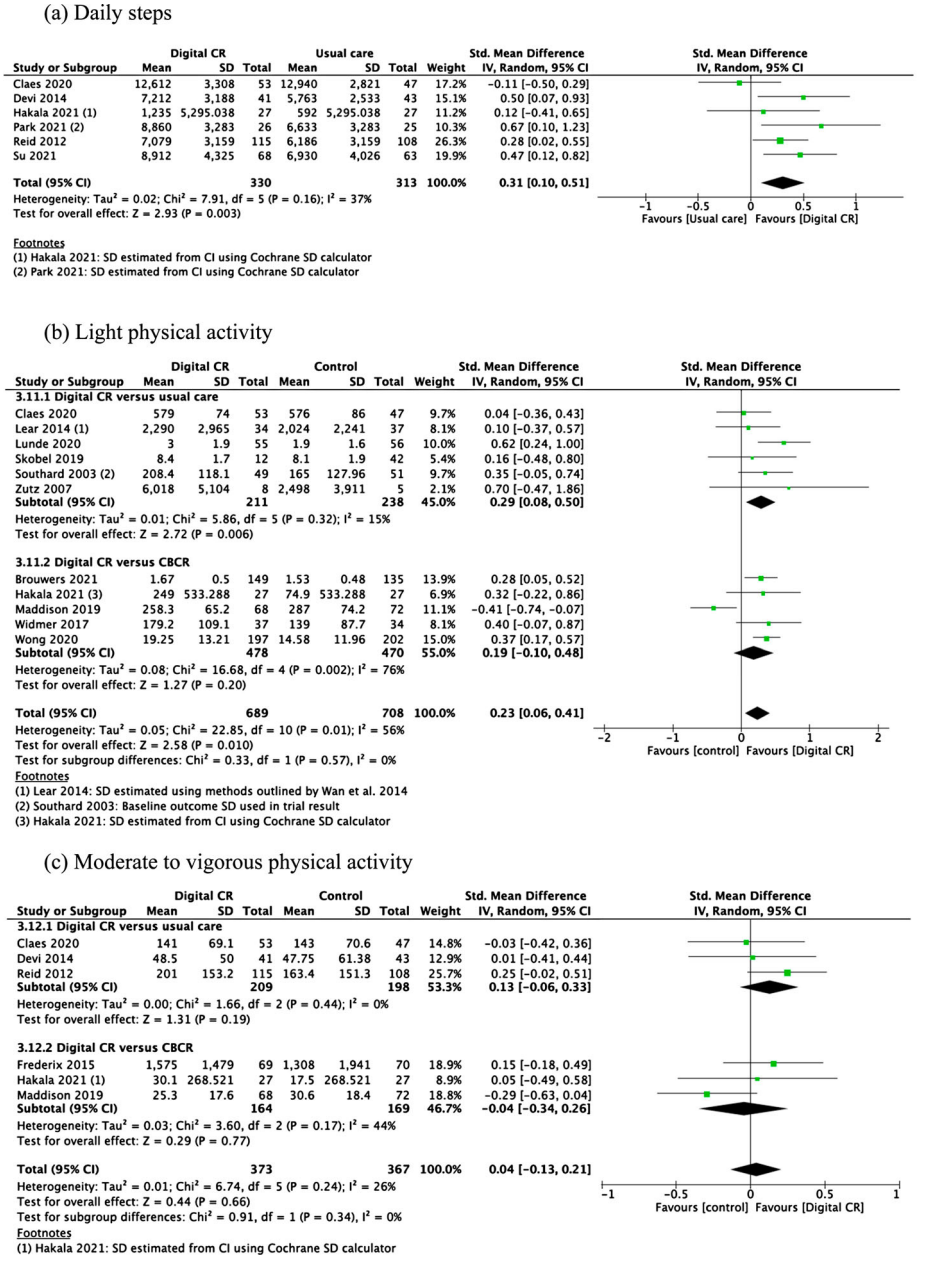


Figure 3. Forest plots of the effect of digital cardiac rehabilitation on behavioural outcomes.

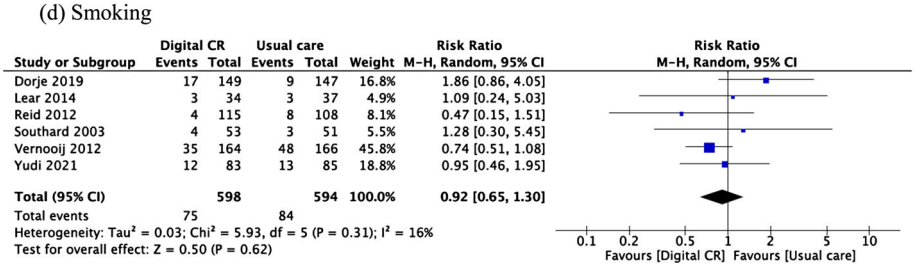


Figure 3. *Continued*.

Medication adherence

Three studies investigated the effects of digital CR on medication adherence. Outcomes were not pooled for meta-analysis due to significant heterogeneity ($I^2 = 80\%$; $p < .001$). Two studies measured medication adherence using the Morisky 8-item Medication Adherence Questionnaire. One found that the intervention group reported significantly greater adherence at 6 months compared with those receiving centre-based CR (MD 0.58, 95% CI = 0.19–0.97; $P = .004$) (Pfaeffli Dale et al., 2015), while a second reported no statistically significant difference between the intervention group and usual care at 6 months (Claes et al., 2020). Another study by Dorje et al. (Dorje et al., 2019) measured adherence to four core cardioprotective medications (aspirin, angiotensin-converting-enzyme inhibitor or angiotensin-receptor blocker, β-blocker, and statin) and found that patients in the intervention group were more likely to be adherent than those receiving usual care at 6 months (OR = 1.79, 95% CI = 1.76–1.87; $P = .019$), and 12 months (OR = 1.82, 95% CI = 1.78–1.93; $P = .011$).

Clinical outcomes

Functional capacity

Functional or exercise capacity was included as an outcome in 13 studies. A variety of metrics were reported for this outcome including peak aerobic capacity (VO_2 peak) (Claes et al., 2020; Frederix et al., 2015; Lunde et al., 2020; Maddison et al., 2019; Skobel et al., 2017), maximal time on a treadmill exercise test (Lear et al., 2014; Zutz et al., 2007), and walking distance (Dorje et al., 2019; Park et al., 2021; Varnfield et al., 2014; Yudi et al., 2021), measured by cardiopulmonary exercise testing (CPET), the Bruce protocol, and 6-minute walk test (6MWT) distance respectively.

Data pooling from eight studies revealed that digital CR significantly improved functional capacity when compared usual care (SMD 0.23, 95% CI = 0.10–0.37, $I^2 = 0\%$; $P < .001$; Figure 4a). However, when compared with centre-based CR no statistically significant difference was observed (SMD 0.10, 95% CI = –0.11–0.31, $I^2 = 0\%$; $P = .34$; Figure 4a). Two studies were not included in the meta-analysis due to the unavailability of mean and standard deviation units. They found no statistically significant differences in functional capacity between digital CR and usual care (Sankaran et al., 2019) or centre-based CR (Maddison et al., 2019).

Quality of life

QoL was reported using validated measures in 16 studies. The measures included five generic instruments: the Euro-QoL-5D (EQ-5D) (Lunde et al., 2020; Maddison et al., 2015; Maddison et al., 2019; Sankaran et al., 2019; Skobel et al., 2017; Yudi et al., 2021), the Medical Outcomes Study Short Form (SF) 36 (Claes et al., 2020; Maddison et al., 2015; Yudi et al., 2021) and 12 (Dorje et al., 2019), the World Health Organisation's QoL questionnaire (WHOQoL) (Duan et al., 2018), the Dartmouth Cooperative Functional Assessment Charts QoL (Dartmouth COOP) (Southard et al., 2003), the Dartmouth QoL survey (Widmer et al., 2017) and two disease-specific instruments: the MacNew heart

disease QoL (MacNew) (Brouwers et al., 2021; Devi et al., 2014; Reid et al., 2012; Su & Yu, 2021), and the HeartQoL (Frederix et al., 2015; Lunde et al., 2020).

Data could not be pooled in a meta-analysis due to significant heterogeneity ($I^2 = 87\%$; $P = <.001$), thus a narrative synthesis was performed. Ten studies compared digital CR to usual care. Four studies reported a statistically significant improvement in QoL in favour of digital CR (Claes et al., 2020; Dorje et al., 2019; Sankaran et al., 2019; Skobel et al., 2017; Yudi et al., 2021). One study found no between-group differences but reported a significant improvement in QoL from baseline in the intervention group (Lunde et al., 2020). The remaining five studies found no statistically significant differences between those receiving digital CR and usual care (Claes et al., 2020; Dorje et al., 2019; Sankaran et al., 2019; Skobel et al., 2017; Yudi et al., 2021). Six studies compared digital CR to centre-based CR. Four studies reported statistically significant between-group differences in QoL in favour of digital CR (Frederix et al., 2015; Maddison et al., 2015; Varnfield et al., 2014; Widmer et al., 2017), one study reported significant improvements from baseline within the intervention group (Brouwers et al., 2021), and one study found no statistically significant difference between the groups (Maddison et al., 2019).

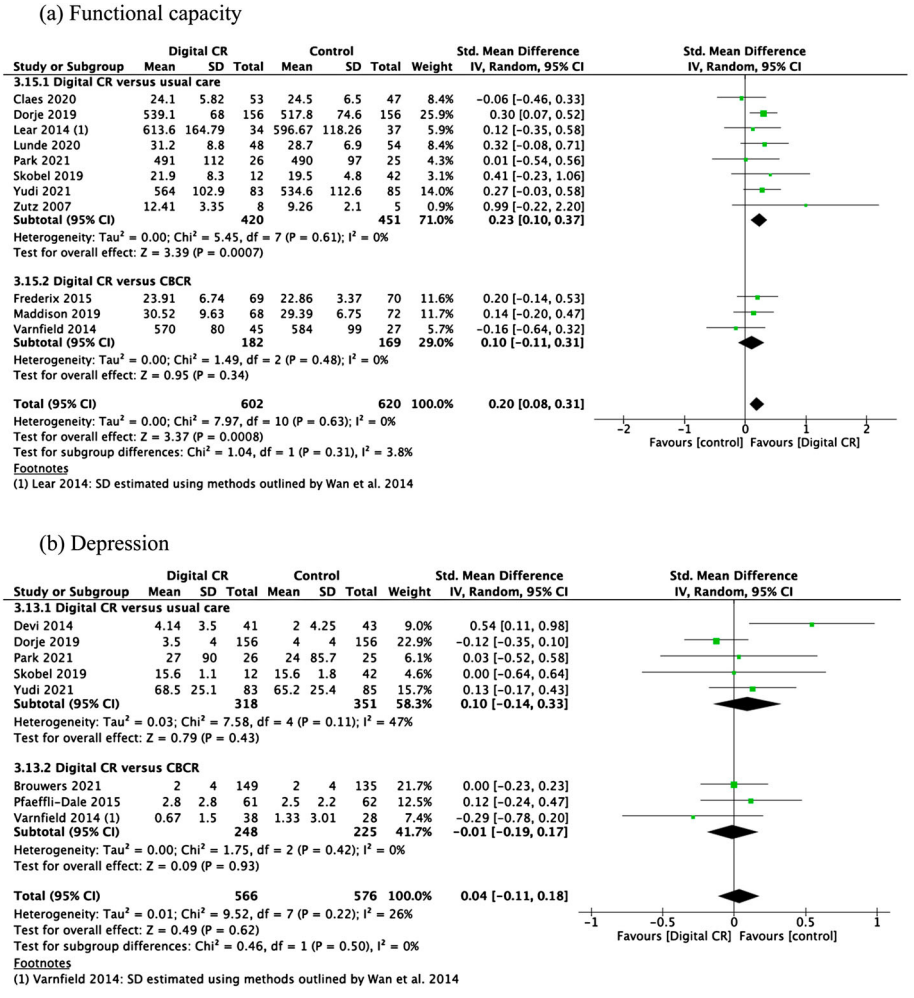
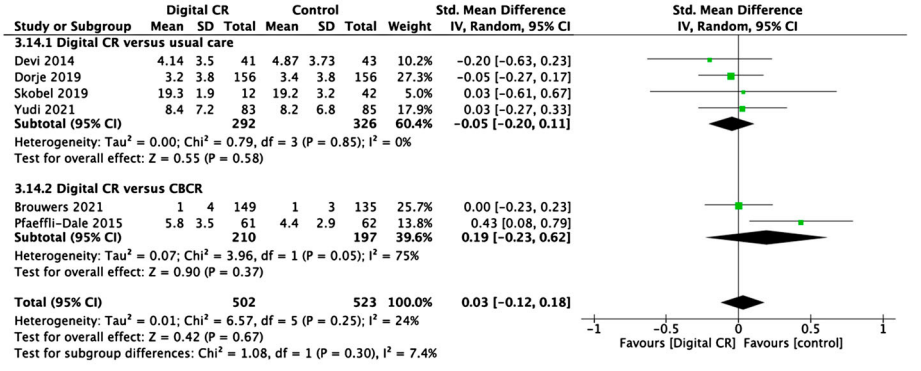
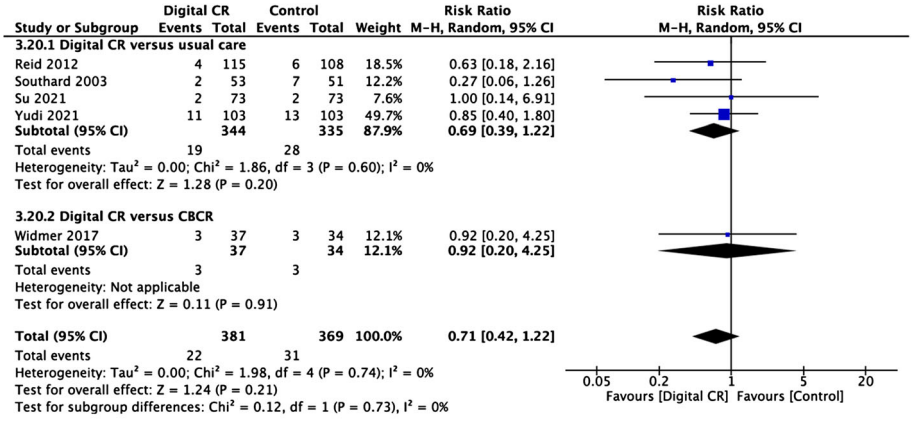


Figure 4. Forest plots of the effect of digital cardiac rehabilitation on clinical outcomes.

(c) Anxiety



(d) Cardiac-related re-hospitalisation



(e) Mortality

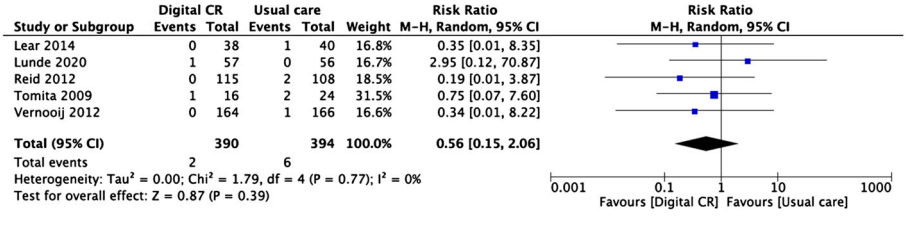


Figure 4. *Continued.*

Depression and anxiety

Depression was evaluated in ten studies using the Patient Health Questionnaire (PHQ-9) (Brouwers et al., 2021; Claes et al., 2020; Dorje et al., 2019; Park et al., 2021), the Hospital Anxiety and Depression Scale (HADS) (Devi et al., 2014; Pfaeffli Dale et al., 2015; Skobel et al., 2017), Beck's Depression Inventory (Southard et al., 2003), the Cardiac Depression Scale (Yudi et al., 2021), the Centre for Epidemiological Studies-Depression (CES-D) (Duan et al., 2018), the Depression, Anxiety and Stress Scale (DASS) (Varnfield et al., 2014), and the Depression Scale-Short Form (Yudi et al., 2021). Data pooling revealed no significant difference between digital CR and usual care (n = 5; SMD 0.10, 95% CI = –0.14–0.33, $I^2 = 47\%$; $P = .43$; Figure 4b) or centre-based CR

(n = 3; SMD −0.01, 95% CI = −0.19–0.17, I^2 = 0%; *P* = .93; Figure 4b). Two studies not included in the meta-analysis due to unavailability of mean and standard deviation found no statistically significant difference between digital CR and usual care (Duan et al., 2018; Southard et al., 2003).

Anxiety was included as an outcome in seven studies. It was measured using the HADS (Devi et al., 2014; Pfaeffli Dale et al., 2015; Skobel et al., 2017; Yudi et al., 2021), the General Anxiety Disorder scale (GAD-7) (Brouwers et al., 2021; Dorje et al., 2019), and the DASS (Varnfield et al., 2014). Meta-analysis of six studies found no statistically significant difference between digital CR and usual care (n = 4; SMD −0.05, 95% CI = −0.20–0.11, I^2 = 0%; *P* = .58; Figure 4c) or centre-based CR (n = 2; SMD 0.19, 95% CI = −0.23–0.62, I^2 = 75%; *P* = .37; Figure 4c). One study not included in the pooled analysis reported no significant between-group difference between digital CR and centre-based CR (Varnfield et al., 2014).

Cardiac-related re-hospitalisation and mortality

Cardiac-related re-hospitalisations were reported in five studies, with the comparison being usual care in four studies (Su & Yu, 2021; Reid et al., 2012; Southard et al., 2003; Yudi et al., 2021) and centre-based CR in one study (Widmer et al., 2017). Data pooling of four studies revealed no significant difference between digital CR and usual care in cardiac-related re-hospitalisation 3–12 months following the intervention (RR 0.69, 95% CI = 0.39–1.22, I^2 = 0%; *P* = .20; Figure 4d). Similarly, Widmer et al. (Widmer et al., 2017) compared the effects of digital CR to centre-based CR and found no statistically significant difference in this outcome six months post-intervention.

Mortality was included as an outcome in five studies, with the comparison in all being usual care. Data pooling revealed no significant difference between digital CR and usual care 12–16 months post-intervention (RR 0.56, 95% CI = 0.15–2.06, I^2 = 0%; *P* = .39; Figure 4e).

Physiological outcomes

Pooling of quantitative data 2–12 months post intervention revealed low-density lipoprotein-cholesterol (LDL-C) was significantly improved in the digital CR group when compared to usual care (n = 9; SMD −0.18, 95% CI = −0.30 to −0.05, I^2 = 13%; *P* = .006), but not when compared to centre-based CR (n = 4; SMD 0.13, 95% CI = −0.22–0.47, I^2 = 61%; *P* = .47). No significant differences between digital CR and usual care or centre-based CR were observed on systolic blood pressure, diastolic blood pressure, total cholesterol, high-density lipoprotein-cholesterol, triglycerides, body mass index (BMI), and weight. Forest plots for the physiological outcomes can be found in Figure 5 (a-h).

Sensitivity analysis

The removal of three studies (Claes et al., 2020; Lunde et al., 2020; Skobel et al., 2017) that recruited patients who had previously completed a CR programme revealed that digital CR no longer significantly improved LPA when compared to usual care (n = 3; SMD 0.27, 95% CI = −0.02–0.57, I^2 = 0%; *P* = .07). However, when these studies were added to the centre-based CR comparison group the effect of digital CR on LPA became statistically significant (n = 8; SMD 0.22, 95% CI = 0.00–0.44, I^2 = 68%; *P* = .05). Forest plots of the behavioural, clinical, and physiological outcomes for the sensitivity analysis can be found in Supplementary Figure 3.

Behaviour change techniques

A total of 37 unique BCTs of a possible 93 in the taxonomy (Michie et al., 2013) were identified in the 25 interventions. BCTs were explicitly named using BCT taxonomy labels in four studies (Claes et al., 2020; Devi et al., 2014; Maddison et al., 2019; Pfaeffli Dale et al., 2015), and were

coded in the remaining 21 studies. Interventions used an average of 8.2 BCTs (*SD* = 5.37; range 3–23). The coded BCTs belonged to 14 of 16 possible groups. The most common BCT group was 'feedback and monitoring', which compromised 29% of all coded BCTs. This was followed by 'goals and planning' (23%), 'natural consequences' (9%), and 'social support' (8%). The two groups that were not coded were 'scheduled consequences', and 'covert learning'. The most frequently coded BCTs were 2.3 self-monitoring of behaviour (n = 21; 84%), 2.2 feedback on behaviour (n = 17; 68%), 5.1 information about health consequences (n = 16; 64%), 7.1 prompts/cues (n = 14; 56%) and 1.1 goal-setting (behaviour) (n = 13; 52%). Table 4 presents the frequency of BCTs coded in each study.

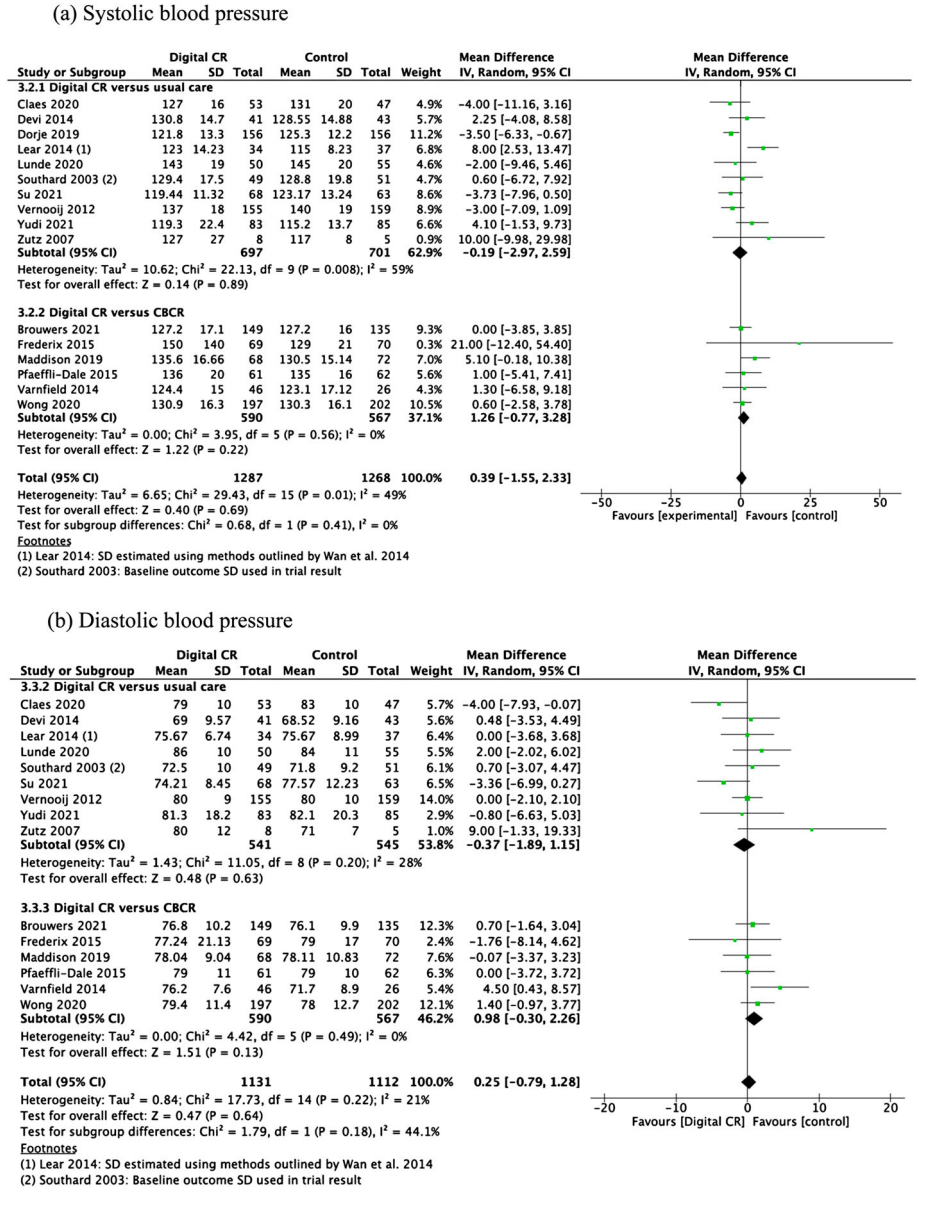
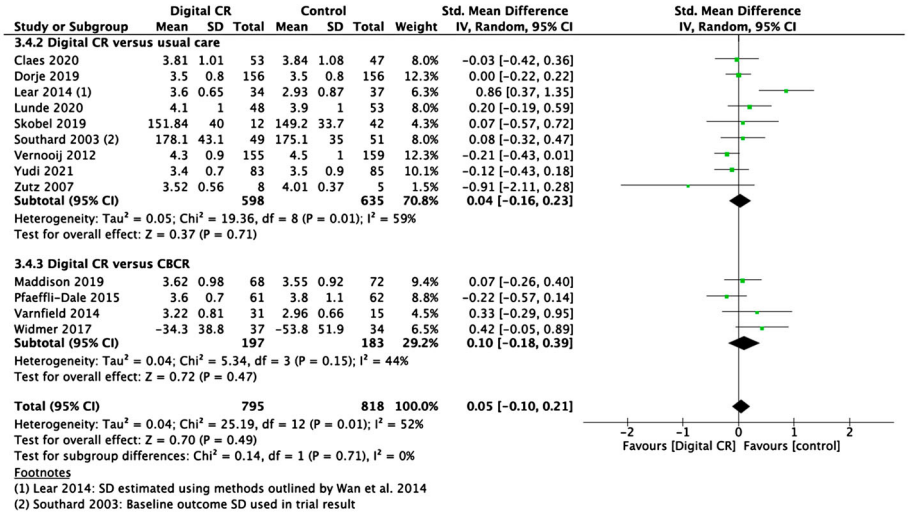


Figure 5. Forest plots of the effect of digital cardiac rehabilitation on physiological outcomes.

(c) Total cholesterol



(d) High-density lipoprotein cholesterol

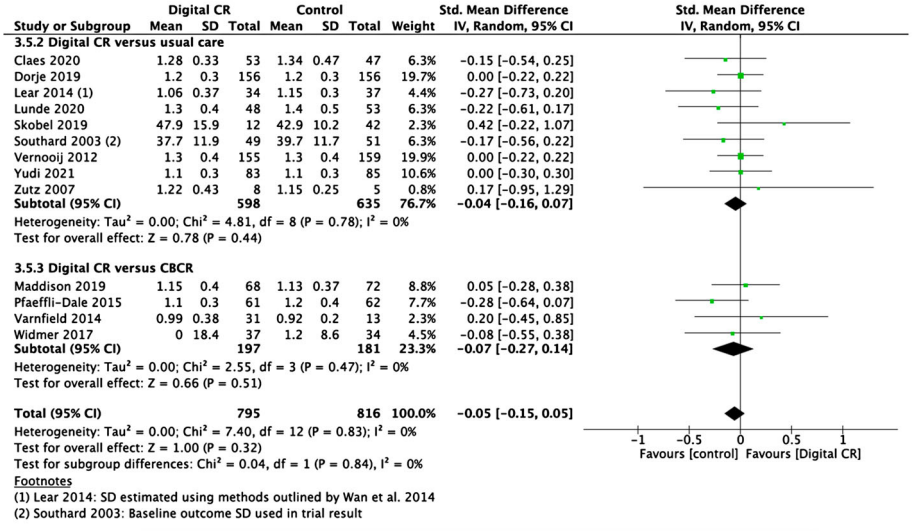
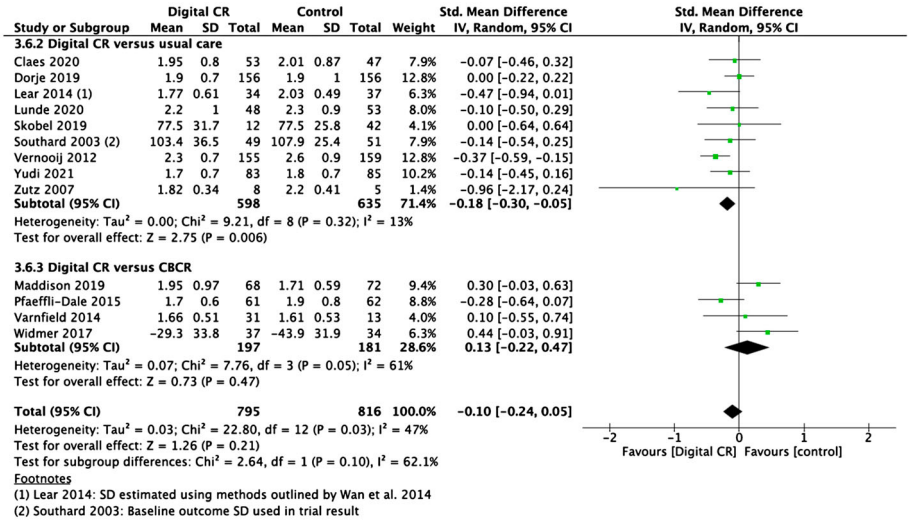


Figure 5. *Continued.*

Behaviour change techniques in effective interventions by outcome

A complete list of BCTs used in effective and non-effective interventions stratified by outcome is presented in Table 5. Of the studies that included physical activity as an outcome, 11 (55%) reported a statistically significant improvement in favour of digital CR (Balady et al., 2007; Chong et al., 2021; De Vos et al., 2013; Goodwin et al., 2016; Kotseva & Wood, 2018; Ramachandran et al., 2021; Smith et al., 2011; Thomas et al., 2019; Turk-Adawi & Grace, 2014; WHO, 2021; Zheng et al., 2019). The most commonly used BCTs in effective interventions were 2.3 self-monitoring of behaviour (n = 8, 73%), 5.1 information about health consequences (n = 7, 64%), 2.2 feedback on behaviour (n = 7, 64%), 1.1 goal-setting (behaviour) (n = 6, 55%), and 3.1 social support (unspecified) (n = 5, 45%). Five BCTs

(e) Low-density lipoprotein cholesterol



(f) Triglycerides

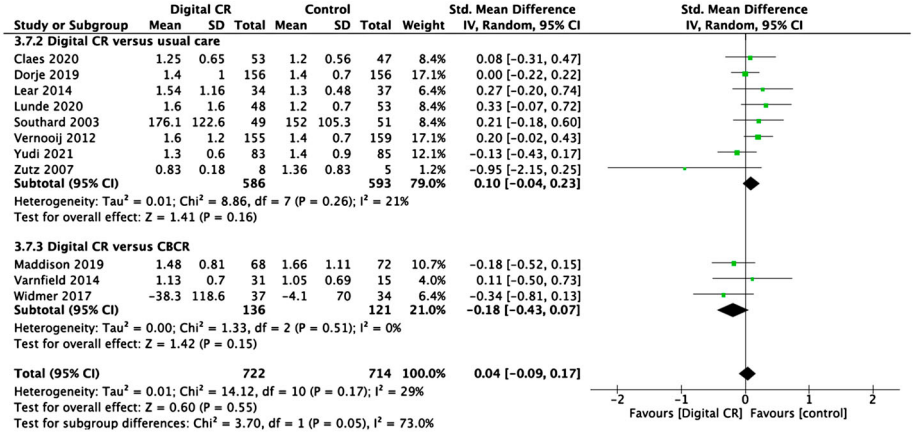
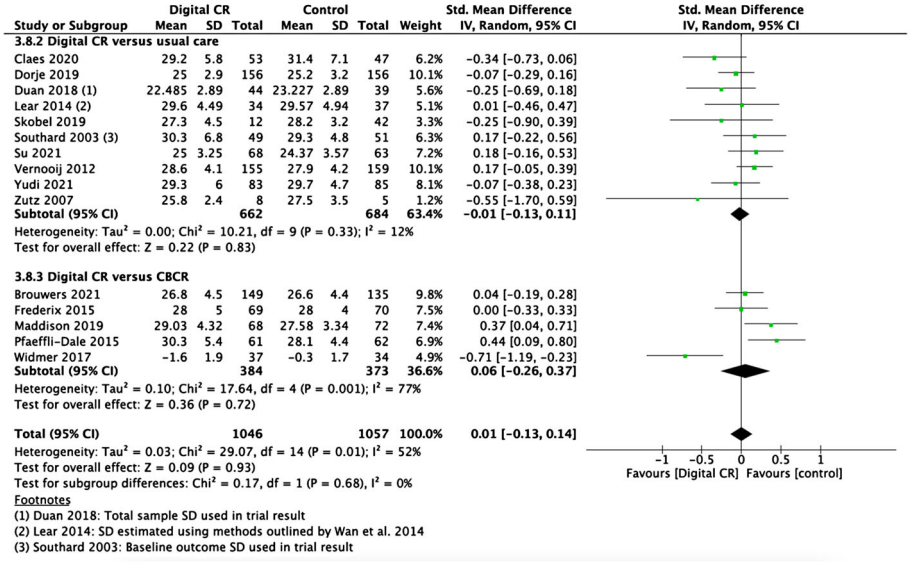


Figure 5. *Continued.*

were identified more often in effective interventions than in non-effective interventions. These were 1.2 problem solving (identified in 36% of effective interventions versus 11% of non-effective interventions), 3.1 social support (unspecified) (45% versus 22%), 3.2 social support (practical) (27% versus 11%), 5.1 information about health consequences (64% versus 44%), and 6.1 demonstration of the behaviour (27% versus 0%). Furthermore, interventions effective at improving physical activity were more frequently theory-based (64% versus 44%), used email (64% versus 22%), websites (82% versus 67%), telemonitoring devices (73% versus 56%) and face-to-face sessions (73% versus 56%) as modes of delivery, and provided participants with motivational messages (45% versus 11%) and personalised feedback (73% versus 56%).

Regarding diet, three (43%) of the seven studies that included diet as an outcome reported a significant improvement in the intervention group (Anderson et al., 2017; Piepoli et al., 2016; Zheng et al., 2019). The most commonly used BCTs to target diet in these interventions included 1.3 goal-setting (outcome) (n = 2, 66%), 2.2 feedback on behaviour (n = 2, 66%), and 5.1 information about health consequences (n = 2, 66%). Effective interventions also more frequently allowed

(g) BMI



(h) Weight

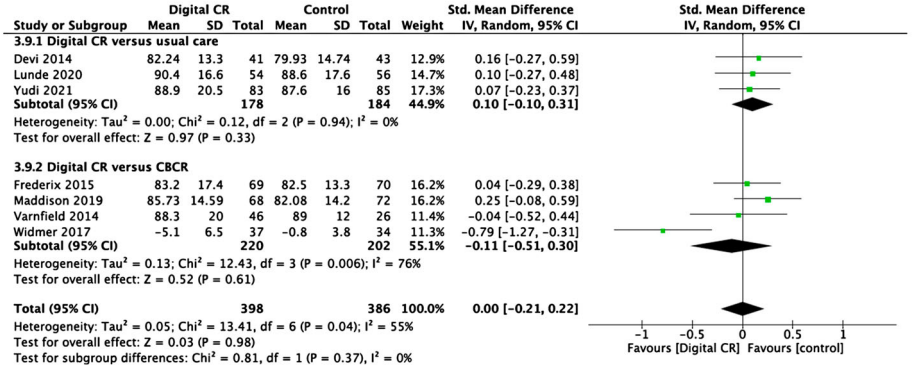


Figure 5. *Continued.*

participants to ask questions (67% versus 50%). Two studies (33%) reported significant improvements in smoking (Ramachandran et al., 2021; Su et al., 2020). The interventions in both studies targeted smoking using the BCTs 2.3 self-monitoring of behaviour, 5.1 information about health consequences, and 7.1 prompts/cues. Finally, two studies (67%) reported significant improvements in medication adherence in favour of the intervention group (Dibben et al., 2021; Ghisi et al., 2021). The interventions in these two studies included the BCTs 5.1 information about health consequences, and 7.1 prompts/cues.

Discussion

This systematic review and meta-analysis seeks to develop a greater understanding of not only the effectiveness of digital CR interventions but also the components and characteristics of these interventions by exploring the relationships between these features and programme effectiveness. Adopting the use of tools such as the TIDieR checklist and the behaviour BCT taxonomy (v1)

Table 4. Frequency of BCTs in the interventions.

BCT no.	BCT Label	Brouwers et al. (2021)	Claes et al. (2020)	Devi et al. (2014)	Dorje et al. (2019)	Duan et al. (2018)	Frederix et al. (2015)	Hakala et al. (2021)	Lear et al. (2014)	Lunde et al. (2020)	Maddison et al. (2015)	Maddison et al. (2019)	Park et al. (2021)	Pfaeffli Dale et al. (2015)	Reid et al. (2012)	Sankaran et al. (2019)	Skobel et al. (2017)	Southard et al. (2003)	Su and Yu (2021)	Tomita (2009)	Varnfield et al. (2014)	Vernooij et al. (2012)	Widmer et al. (2017)	Wong et al. (2020)	Yudi et al. (2021)	Zutz et al. (2007)	Total $N = 25$ (100%)
2.3	Self-monitoring of behaviour	✓	✓	✓	✓		✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		21 (84%)
2.2	Feedback on behaviour	✓	✓	✓	✓	✓	✓	✓		✓		✓		✓	✓		✓	✓		✓	✓		✓		✓		17 (68%)
5.1	Information about health consequences		✓	✓	✓	✓	✓				✓	✓		✓			✓		✓	✓	✓	✓	✓	✓	✓		16 (64%)
7.1	Prompts/cues	✓	✓		✓			✓		✓			✓	✓		✓	✓		✓			✓	✓	✓	✓		14 (56%)
1.1	Goal setting (behavior)	✓	✓	✓	✓	✓	✓	✓			✓	✓		✓		✓			✓		✓						13 (52%)
2.4	Self-monitoring of outcome(s) of behaviour		✓		✓							✓	✓					✓		✓	✓	✓	✓	✓			10 (40%)
1.3	Goal setting (outcome)		✓		✓				✓	✓		✓			✓								✓	✓	✓		9 (36%)
8.7	Graded tasks		✓	✓	✓		✓			✓		✓		✓									✓		✓		9 (36%)
3.1	Social support (unspecified)		✓			✓						✓	✓	✓	✓			✓		✓							8 (32%)
1.4	Action planning		✓			✓					✓	✓		✓			✓		✓								7 (28%)
1.5	Review behavior goal(s)	✓	✓	✓		✓						✓		✓					✓								7 (28%)
4.1	Instruction on how to perform the behavior		✓			✓		✓				✓		✓					✓	✓							7 (28%)
1.2	Problem solving		✓			✓					✓	✓		✓	✓												6 (24%)
2.7	Feedback on outcome(s) of behavior		✓		✓				✓												✓				✓	✓	6 (24%)
2.6	Biofeedback		✓						✓			✓					✓									✓	5 (20%)
3.2	Social support (practical)		✓		✓				✓		✓															✓	5 (20%)
9.1	Credible source		✓								✓	✓		✓						✓							5 (20%)
3.3	Social support (emotional)	✓										✓							✓	✓							4 (16%)
6.1	Demonstration of the behavior		✓											✓					✓	✓							4 (16%)
10.4.	Social reward			✓	✓							✓												✓			4 (16%)
1.6	Discrepancy between current		✓									✓							✓								3 (12%)

(*Continued*)

Table 4. Continued.

BCT no.	BCT Label	Brouwers et al. (2021)	Claes et al. (2020)	Devi et al. (2014)	Dorje et al. (2019)	Duan et al. (2018)	Frederix et al. (2015)	Hakala et al. (2021)	Lear et al. (2014)	Lunde et al. (2020)	Maddison et al. (2015)	Maddison et al. (2019)	Park et al. (2021)	Pfaeffli Dale et al. (2015)	Reid et al. (2012)	Sankaran et al. (2019)	Skobel et al. (2017)	Southard et al. (2003)	Su and Yu (2021)	Tomita (2009)	Varnfield et al. (2014)	Vernooij et al. (2012)	Widmer et al. (2017)	Wong et al. (2020)	Yudi et al. (2021)	Zutz et al. (2007)	Total $N = 25$ (100%)
	behaviour and goal																										
10.10	Reward (outcome)															✓	✓		✓								3 (12%)
11.2	Reduce negative emotions			✓										✓							✓						3 (12%)
6.2	Social comparison													✓					✓								2 (8%)
8.6	Generalisation of target behaviour				✓							✓															2 (8%)
15.1	Verbal persuasion about capability					✓						✓															2(8%)
15.3	Focus on past success		✓									✓															2 (8%)
1.7	Review outcome goal(s)		✓																								1 (4%)
2.1	Monitoring of behavior by others without feedback											✓															1 (4%)
5.6	Information about emotional consequences		✓																								1 (4%)
8.1	Behavioural practice/ rehearsal											✓															1 (4%)
10.2	Material reward																	✓									1 (4%)
10.3	Non-specific reward																						✓				1 (4%)
10.9	Self-reward											✓															1 (4%)
11.1	Pharmacological support						✓																				1 (4%)
12.2	Restructuring the social environment		✓																								1 (4%)
13.2	Framing/ reframing											✓															1 (4%)
	Total number of BCTs	6	23	8	13	9	6	5	4	4	7	24	4	15	5	4	7	5	12	9	7	4	8	6	7	3	

Table 5. Frequency of BCTs in effective and non-effective interventions stratified by outcome.

		Physical activity (*N* = 20)				Diet (*N* = 7)				Smoking (*N* = 6)				Medication adherence (*N* = 3)			
		Effective (*N* = 11)		Non-effective (*N* = 9)		Effective (*N* = 3)		Non-effective (*N* = 4)		Effective (*N* = 2)		Non-effective (*N* = 4)		Effective (*N* = 2)		Non-effective (*N* = 1)	
BCT No.	BCT label	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
Goals and planning																	
1.1	Goal setting (behavior)	6	55%	4	44%	1	33%	2	50%	1	50%	0	0%	0	0%	1	100%
1.2	Problem solving	4	36%	1	11%	1	33%	0	0%	-	-	-	-	-	-	-	-
1.3	Goal setting (outcome)	3	37%	4	44%	2	67%	1	25%	0	0%	1	25%	0	0%	1	100%
1.4	Action planning	4	36%	2	22%	1	33%	0	0%	1	50%	0	0%	-	-	-	-
1.5	Review behavior goal(s)	4	36%	2	22%	1	33%	1	25%	1	50%	0	0%	-	-	-	-
1.6	Discrepancy between current behaviour and goal	2	18%	1	11%	-	-	-	-	1	50%	0	0%	-	-	-	-
1.7	Review outcome goal(s)	1	9%	0	0%	-	-	-	-	-	-	-	-	-	-	-	-
Feedback and monitoring																	
2.1	Monitoring of behavior by others without feedback	0	0%	1	11%	-	-	-	-	-	-	-	-	-	-	-	-
2.2	Feedback on behaviour	7	64%	5	56%	2	67%	3	75%	0	0%	1	25%	1	50%	0	0%
2.3	Self-monitoring of behaviour	8	73%	8	89%	1	33%	1	25%	2	100%	0	0%	-	-	-	-
2.4	Self-monitoring of outcome(s) of behaviour	3	27%	4	44%	1	33%	1	25%	1	50%	0	0%	-	-	-	-
2.6	Biofeedback	2	18%	3	33%	-	-	-	-	-	-	-	-	-	-	-	-
2.7	Feedback on outcome(s) of behavior	2	18%	1	11%	0	0%	1	25%	0	0%	1	25%	-	-	-	-
Social support																	
3.1	Social support (unspecified)	5	45%	2	22%	1	33%	0	0%	-	-	-	-	-	-	-	-
3.2	Social support (practical)	3	27%	1	11%	1	33%	0	0%	0	0%	1	25%	1	50%	0	0%
3.3	Social support (emotional)	2	18%	2	22%	-	-	-	-	1	50%	0	0%	-	-	-	-
Shaping knowledge																	
4.1	Instruction on how to perform the behavior	4	36%	2	22%	1	33%	0	0%	-	-	-	-	-	-	-	-
Natural consequences																	
5.1	Information about health consequences	7	64%	4	44%	2	67%	2	50%	2	100%	1	25%	2	100%	0	0%
5.6	Information about emotional consequences	1	9%	0	0%	-	-	-	-	-	-	-	-	-	-	-	-
Comparison of behaviour																	
6.1	Demonstration of the behavior	3	27%	0	0%	-	-	-	-	-	-	-	-	-	-	-	-
6.2	Social comparison	1	9%	0	0%	-	-	-	-	1	50%	0	0%	-	-	-	-
Associations																	
7.1	Prompts/cues	4	36%	5	56%	1	33%	0	0%	2	100%	1	25%	2	100%	0	0%
Repetition and substitution																	
8.1	Behavioural practice/ rehearsal	0	0%	1	11%	-	-	-	-	-	-	-	-	-	-	-	-
8.6	Generalisation of target behaviour	0	0%	2	22%	-	-	-	-	-	-	-	-	-	-	-	-
8.7	Graded tasks	4	36%	2	22%	1	33%	1	25%	-	-	-	-	-	-	-	-

(*Continued*)

Table 5. Continued.

		Physical activity (*N* = 20)				Diet (*N* = 7)				Smoking (*N* = 6)				Medication adherence (*N* = 3)			
		Effective (*N* = 11)		Non-effective (*N* = 9)		Effective (*N* = 3)		Non-effective (*N* = 4)		Effective (*N* = 2)		Non-effective (*N* = 4)		Effective (*N* = 2)		Non-effective (*N* = 1)	
BCT No.	BCT label	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
Comparison of outcomes																	
9.1	Credible source	3	27%	1	11%	-	-	-	-	-	-	-	-	-	-	-	-
Reward and threat																	
10.2	Material reward	0	0%	1	11%	-	-	-	-	-	-	-	-	-	-	-	-
10.3	Non-specific reward	0	0%	1	11%	1	33%	0	0%	-	-	-	-	-	-	-	-
10.4.	Social reward	1	9%	2	22%	0	0%	1	25%	-	-	-	-	-	-	-	-
10.9	Self-reward	0	0%	1	11%	-	-	-	-	-	-	-	-	-	-	-	-
10.10	Reward (outcome)	1	9%	2	22%	-	-	-	-	1	50%	0	0%	-	-	-	-
Antecedents																	
12.2	Restructuring the social environment	1	9%	0	0%	-	-	-	-	-	-	-	-	-	-	-	-
Identity																	
13.2	Framing/ reframing	0	0%	1	11%	-	-	-	-	-	-	-	-	-	-	-	-
Self-belief																	
15.1	Verbal persuasion about capability	1	9%	1	11%	1	33%	0	0%	-	-	-	-	-	-	-	-
15.3	Focus on past success	1	9%	1	11%	-	-	-	-	-	-	-	-	-	-	-	-

allowed us to provide an in-depth evaluation of digital CR interventions and gain a better understanding of how they may achieve their effects.

Key findings

The results presented here indicate that digital CR led to significantly greater improvements in daily steps, LPA, medication adherence, functional capacity, and LDL-C when compared to usual care, and produced effects on these outcomes comparable to centre-based CR. The observed improvements in physical activity are broadly in line with previous systematic reviews (Ramachandran et al., 2021; Rawstorn et al., 2016; Su et al., 2020). The evidence for greater daily step counts appears to be particularly strong as this outcome was objectively measured in all studies. However, the evidence for increases in LPA is less strong as this was self-reported in most studies. The various definitions and measures of physical activity make determining the effect of digital CR on this outcome challenging. This could be improved in future studies by using objective measures and reporting the dimensions of physical activity (frequency, intensity, time, type, and volume) in a more standardised fashion (Kaminsky et al., 2016). Digital CR also demonstrated a positive effect on medication adherence. Interventions targeting this outcome used SMS text messages to provide reminders and prompts for participants to adhere to medication. This finding is supported by a previous review of m-Health in patients with coronary artery disease which found that interventions incorporating text message reminders and education were associated with improved medication adherence (Brørs et al., 2019). There was some evidence linking digital CR to improved diet. However, the improvements were only reported in the three studies that calculated diet scores, and not in any of the four studies that used validated measures. Greater use of validated measures and consistency in their selection is required to provide stronger evidence for the effect of digital CR on this outcome.

That digital CR was associated with a significant increase in functional capacity when compared to usual care is important as functional capacity is a powerful and independent predictor of cardiac and all-cause mortality in patients with CVD (Martin et al., 2013). The evidence for improved QoL in this review was mixed. The majority (n = 4; 66%) of the studies comparing digital CR to centre-based CR noted significant improvements in QoL in favour of the intervention group, while compared to usual care only 40% (n = 4) of the studies reported significant improvements. This difference may be partially explained by the patient population in two of these studies (Claes et al., 2020; Skobel et al., 2017) having previously attended a CR programme. Previous systematic reviews have also reported mixed results for QoL. A Cochrane review comparing home- and centre-based CR found no strong evidence of a difference in QoL (Anderson et al., 2017), while a review that found a large improvement in QoL in favour of digital CR rated the quality of evidence for this finding was rated as low, as there was significant heterogeneity among the included studies ($I^2 = 95\%$; $P < .001$) (Su et al., 2020). The wide variation in selected QoL measures makes synthesising the findings on this outcome difficult.

Of the physiological outcomes, digital CR was associated with a significant improvement in LDL-C when compared to usual care. No statistically significant between-group differences were observed in other clinical (depression, anxiety, cardiac-related re-hospitalisations, or mortality) or physiological outcomes when compared to centre-based CR or usual care. Previous systematic reviews have broadly reported similar findings on these outcomes (Ramachandran et al., 2021; Rawstorn et al., 2016; Su et al., 2020).

Behaviour change techniques and effective interventions

A total of 32 unique BCTs were coded across the 25 RCTs included in this review, with the most frequently coded being 2.3 self-monitoring of behaviour, 2.2 feedback on behaviour, 5.1 information about health consequences, 7.1 prompts/cues, and 1.1 goal-setting (behaviour). The BCTs coded

here contrast with those identified in alternative CR modalities. For example, a systematic review of BCTs in home-based CR programmes found that 3.1 social support, 1.1 goal setting (behaviour), 11.2 reduce negative emotions, and 4.1 instruction on how to perform the behaviour were the most commonly coded (Heron et al., 2016). While a study coding BCTs in a community-based CR programme found the most frequently used were 9.1 credible source, 5.1 information about health consequences, 4.1 instruction on how to perform a behaviour, and 1.2 problem-solving (McAuliffe et al., 2021). In contrast to these other types of CR, digital CR appears to place a stronger emphasis on personal accountability, promoting the self-management and self-regulation of daily lifestyle behaviours.

Compared to non-effective interventions, interventions that were effective at improving physical activity more frequently included the BCTs 1.2 problem solving, 3.1 social support (unspecified), 3.2 social support (practical), 5.1 information about health consequences, and 6.1 demonstration of the behaviour. Effective interventions also tended to be theory-based, feature in-person sessions, websites, telemonitoring devices and email as modes of delivery, and provide participants with motivational messages and personalised feedback.

Compared to non-effective interventions, interventions that improved diet included the BCTs 1.3 goal-setting (outcome), 2.2 feedback on behaviour, and 5.1 information about health consequences, and allowed participants to ask questions. Smoking improved in interventions that included the BCTs 2.3 self-monitoring of behaviour, 5.1 information about health consequences, and 7.1 prompts/cues. Interventions with improved medication adherence featured the BCTs 5.1 information about health consequences and 7.1 prompts/cues more than non-effective interventions.

Social cognitive theory was the most commonly used theoretical framework. Of the five studies in the review that used this framework, four reported a significant effect on a behavioural outcome (Claes et al., 2020; Park et al., 2021; Pfaeffli Dale et al., 2015; Su & Yu, 2021). Social cognitive theory specifies that health behaviour is determined by one's knowledge, perceived self-efficacy, outcome expectations, goals, and perceived socio-structural facilitators and impediments (Bandura, 2004). The BCTs identified in effective interventions appear to align with these key determinants. In particular, the BCTs 1.2 problem solving, 6.1 demonstration of the behaviour and 8.7 graded tasks are known to target perceived self-efficacy, arguably the most important component of social cognitive theory and one which has been previously linked to adherence to health behaviour change in CR (Woodgate & Brawley, 2008). The findings here suggest that behavioural outcomes may be improved by the inclusion of BCTs which target the determinants of social cognitive theory.

TIDieR assessment

The TIDieR assessment of intervention reporting demonstrated that inadequate reporting is an issue within trials of digital CR. The assessment found that none of the included studies adequately reported all 12 items and only three studies (Claes et al., 2020; Pfaeffli Dale et al., 2015; Vernooij et al., 2012) (12%) reported all the core items deemed necessary for study replication (items 3–8). This finding is in line with a previous study (Abell et al., 2015) which assessed the completeness of reporting in trials of exercise-based CR and found only 11/74 interventions (15%) sufficiently described these core items. The reporting of the intervention materials (item 3) in the studies included in this review was particularly poor, with the exact content used in an intervention rarely provided. This is problematic as inadequate detail on this aspect of the intervention makes any future attempts at replication almost impossible. Studies that sufficiently reported this item often did so by providing additional detail on intervention materials in online supplementary files.

Also poorly reported was intervention fidelity, defined as the degree to which an intervention was delivered as intended (Carroll et al., 2007). This is of concern as the effectiveness of any intervention must be interpreted with caution if the extent of fidelity is unknown. Information regarding fidelity is also important for clinicians, as it provides an insight into the feasibility of a given intervention as well as the degree of non-adherence to be expected. Abell et al. (Abell et al., 2015) found that

when contacted, trial authors were often capable of providing additional information on intervention fidelity (e.g., attendance records, exercise logs). Therefore, it is recommended that authors include this information when publishing trial results.

Strengths and limitations

This review extends existing knowledge by deconstructing interventions in an attempt to identify the active ingredients and characteristics. Additionally, this is the first review to code digital CR interventions using the TIDieR checklist and BCT taxonomy (v1).

However, this review also has limitations. Firstly, we considered an intervention 'effective' if a statistically significant between-group difference in a behavioural outcome was reported by the study authors. This definition of effectiveness is limited as it contains no information on the magnitude of the effect produced or its clinical significance. Second, our approach to characterising the BCTs included in effective interventions may also have identified BCTs that do not contribute to effectiveness but are frequently included in intervention packages. However, it has been noted that existing methods for identifying effective BCTs linked to target behaviour and content all have important inherent limitations (Michie et al., 2018). Third, the identification of BCTs was largely dependent on the detail in which the interventions were reported in published papers. Only four studies (Claes et al., 2020; Devi et al., 2014; Maddison et al., 2019; Pfaeffli Dale et al., 2015) included in the review explicitly mentioned the BCTs that were applied in the interventions. These four studies reported using a significantly greater number of BCTs (mean 17.5) than the remaining studies (mean 6.4). It is unclear whether this is a genuine difference or if it reflects the challenge of coding BCTs from intervention descriptions in published materials. Also challenging was determining the behaviour being targeted by a given BCT, as the studies which explicitly mentioned the BCTs used in the interventions often failed to specify how these were linked to the intervention components. A further limitation was that a second reviewer completed only 20% of screening and data extraction. Finally, only studies that included a behavioural outcome were included in the review. Therefore, the results presented on clinical and physiological outcomes must be interpreted with caution as some eligible RCTs of digital CR targeting these outcomes may have been excluded.

Recommendations for future research

The National Institute for Health and Care Excellence (NICE) guidance for individual-level behaviour change interventions for promoting change in modifiable risk factors recommends the use of BCTs shown to be effective at changing behaviour (National Institute for Health and Care Excellence 2014).

Specifically, it recommends the inclusion of BCTs related to goals and planning, feedback and monitoring, and social support as there is strong evidence for the effectiveness of these BCTs in behaviour change interventions. The findings of this review support this recommendation as several BCTs belonging to these groups were associated with effective interventions. Future studies aiming to improve behavioural outcomes for patients with CVD may benefit from including BCTs related to these groups.

A recommendation for future researchers is to improve the description and reporting of digital CR. There has been a sharp increase in the number of RCTs examining the effectiveness of digital CR, with 13 of the 25 studies included here being published in the last five years. To maximise this research potential, researchers are encouraged to provide detailed descriptions of interventions. The use of standard reporting guidelines such as TIDieR to describe intervention and comparator content would enable this process, enhancing transparency and allowing for greater comparison between studies. Also, researchers should aim to describe the intervention rationale and theoretical basis in greater detail, and where possible explicitly state the BCTs being applied and the proposed mechanisms of change.

This additional information could be published in trial protocols, intervention development papers, or web-based supplementary files.

Future systematic reviews should attempt to examine the factors that influence adherence and attrition in digital CR interventions. It would be particularly valuable to determine if the rates of adherence and attrition differ based on the mode of delivery, or the number/type of BCTs included in the interventions. Finally, while this review has described the associations between BCTs and intervention characteristics and effective interventions, causality can not be inferred. Future research to experimentally tease apart the effects of individual components is required. This could be done using novel approaches such as the Multiphase Optimisation Strategy (MOST) or Sequential Multiple Assignment Randomised Trial (SMART) (Collins et al., 2007).

Conclusion

Overall, the findings of this review indicate that digital CR can improve outcomes for patients with CVD. BCTs belonging to the groups feedback and monitoring, goals and planning, natural consequences, and social support were frequently employed in effective interventions. An assessment of the completeness of intervention reporting using the TIDieR checklist revealed many characteristics of digital CR interventions are not adequately described, preventing accurate interpretation of results and intervention replication. Future work should aim to improve the quality of reporting of interventions and their theoretical basis.

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Data sharing

The data that support the findings of this study are available from the corresponding author, EK, upon reasonable request.

Disclosure statement

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ORCID

Eanna Kenny http://orcid.org/0000-0002-0959-5405
Rory Coyne http://orcid.org/0000-0001-6252-4035
John W. McEvoy http://orcid.org/0000-0001-6530-5479
Jenny McSharry http://orcid.org/0000-0001-5459-1588
Rod S. Taylor http://orcid.org/0000-0002-3043-6011
Molly Byrne http://orcid.org/0000-0001-8900-4320

References

Abell, B., Glasziou, P., & Hoffmann, T. (2015). Reporting and replicating trials of exercise-based cardiac rehabilitation. *Circulation: Cardiovascular Quality and Outcomes*, *8*(2), 187–194. https://doi.org/10.1161/CIRCOUTCOMES.114.001381

Anderson, L., Sharp, G. A., Norton, R. J., Dalal, H., Dean, S. G., Jolly, K., Cowie, A., Zawada, A., & Taylor, R. S. (2017). Home-based versus centre-based cardiac rehabilitation. *Cochrane Database of Systematic Reviews*, *6*, https://doi.org/10.1002/14651858.CD007130.pub4

Balady, G. J., Williams, M. A., Ades, P. A., Bittner, V., Comoss, P., Foody, J. M., Franklin, B., Sanderson, B., & Southard, D. (2007). Core components of cardiac rehabilitation/secondary prevention programs: 2007 update. *Circulation*, *115*(20), 2675–2682. https://doi.org/10.1161/CIRCULATIONAHA.106.180945

Bandura, A. (2004). Health promotion by social cognitive means. *Health Education & Behavior*, *31*(2), 143–164. https://doi.org/10.1177/1090198104263660

Brørs, G., Pettersen, T. R., Hansen, T. B., Fridlund, B., Hølvold, L. B., Lund, H., & Norekvål, T. M. (2019). Modes of e-health delivery in secondary prevention programmes for patients with coronary artery disease: A systematic review. *BMC Health Services Research*, *19*(1), 364. https://doi.org/10.1186/s12913-019-4106-1

Brouwers, R. W. M., Kraal, J. J., Regis, M., Spee, R. F., & Kemps, H. M. C. (2021). Effectiveness of cardiac telerehabilitation With relapse prevention: SmartCare-CAD randomized controlled trial. *Journal of the American College of Cardiology*, *77*(21), 2754–2756. https://doi.org/10.1016/j.jacc.2021.03.328

Carroll, C., Patterson, M., Wood, S., Booth, A., Rick, J., & Balain, S. (2007). A conceptual framework for implementation fidelity. *Implementation Science*, *2*(1), 40. https://doi.org/10.1186/1748-5908-2-40

Chong, M. S., Sit, J. W. H., Karthikesu, K., & Chair, S. Y. (2021). Effectiveness of technology-assisted cardiac rehabilitation: A systematic review and meta-analysis. *International Journal of Nursing Studies*, *124*, 104087. https://doi.org/10.1016/j.ijnurstu.2021.104087

Claes, J., Cornelissen, V., McDermott, C., Moyna, N., Pattyn, N., Cornelis, N., Gallagher, A., McCormack, C., Newton, H., Gillain, A., Budts, W., Goetschalckx, K., Woods, C., Moran, K., & Buys, R. (2020 Feb 4). Feasibility, acceptability, and clinical effectiveness of a technology-enabled cardiac rehabilitation platform (physical activity toward health-I): Randomized controlled trial. *Journal of Medical Internet Research*, *22*(2), e14221. https://doi.org/10.2196/14221

Collins, L. M., Murphy, S. A., & Strecher, V. (2007). The multiphase optimization strategy (MOST) and the sequential multiple assignment randomized trial (SMART): New methods for more potent eHealth interventions. *American Journal of Preventive Medicine*, *32*(5, Supplement), S112–S1S8. https://doi.org/10.1016/j.amepre.2007.01.022

Devi, R., Powell, J., & Singh, S. (2014). A web-based program improves physical activity outcomes in a primary care angina population: Randomized controlled trial. *Journal of Medical Internet Research*, *16*(9), e186. https://doi.org/10.2196/jmir.3340

De Vos, C., Li, X., Van Vlaenderen, I., Saka, O., Dendale, P., Eyssen, M., & Paulus, D. (2013). Participating or not in a cardiac rehabilitation programme: Factors influencing a patient's decision. *European Journal of Preventive Cardiology*, *20*(2), 341–348. https://doi.org/10.1177/2047487312437057

Dibben, G., Faulkner, J., Oldridge, N., Rees, K., Thompson, D. R., Zwisler, A.-D., & Taylor, R. S. (2021). Exercise-based cardiac rehabilitation for coronary heart disease. *Cochrane Database of Systematic Reviews*, *11*), https://doi.org/10.1002/14651858.CD001800.pub4

Dorje, T., Zhao, G., Tso, K., Wang, J., Chen, Y., Tsokey, L., Tan, B.-K., Scheer, A., Jacques, A., Li, Z., Wang, R., Chow, C. K., Ge, J., & Maiorana, A. (2019). Smartphone and social media-based cardiac rehabilitation and secondary prevention in China (SMART-CR/SP): a parallel-group, single-blind, randomised controlled trial. *The Lancet Digital Health*, *1*(7), e363–ee74. https://doi.org/10.1016/s2589-7500(19)30151-7

Duan, Y. P., Liang, W., Guo, L., Wienert, J., Si, G. Y., & Lippke, S. (2018 Nov 19). Evaluation of a Web-based intervention for multiple health behavior changes in patients With coronary heart disease in home-based rehabilitation: Pilot randomized controlled trial. *Journal of Medical Internet Research*, *20*(11), e12052. https://doi.org/10.2196/12052

Frederix, I., Hansen, D., Coninx, K., Vandervoort, P., Vandijck, D., Hens, N., Van Craenenbroeck, E., Van Driessche, N., & Dendale, P. (2015). Medium-Term effectiveness of a comprehensive internet-based and patient-specific telerehabilitation program With text messaging support for cardiac patients: Randomized controlled trial. *Journal of Medical Internet Research*, *17*(7), e185. https://doi.org/10.2196/jmir.4799

Ghisi, G. L. d. M., Xu, Z., Liu, X., Mola, A., Gallagher, R., Babu, A. S., Yeung, C., Marzolini, S., Buckley, J., Oh, P., Contractor, A., & Grace, S. L. (2021). Impacts of the COVID-19 pandemic on cardiac rehabilitation delivery around the world. *Global Heart*, *16*(1), https://doi.org/10.5334/gh.939

Goodwin, L., Ostuzzi, G., Khan, N., Hotopf, M. H., & Moss-Morris, R. (2016). Can We identify the active ingredients of behaviour change interventions for coronary heart disease patients? A systematic review and meta-analysis. *PLOS ONE*, *11*(4), e0153271. https://doi.org/10.1371/journal.pone.0153271

Hakala, S., Kivistö, H., Paajanen, T., Kankainen, A., Anttila, M.-R., Heinonen, A., & Sjögren, T. (2021). Effectiveness of distance technology in promoting physical activity in cardiovascular disease rehabilitation: Cluster randomized controlled trial. *JMIR Rehabilitation and Assistive Technologies*, *8*(2), e20299. https://doi.org/10.2196/20299

Heron, N., Kee, F., Donnelly, M., Cardwell, C., Tully, M. A., & Cupples, M. E. (2016). Behaviour change techniques in home-based cardiac rehabilitation: A systematic review. *British Journal of General Practice*, *66*(651), e747. https://doi.org/10.3399/bjgp16X686617

Higgins, J. P. T., Thompson, S. G., Deeks, J. J., & Altman, D. G. (2003). Measuring inconsistency in meta-analyses. *BMJ*, *327*(7414), 557–560. https://doi.org/10.1136/bmj.327.7414.557

Hoffmann, T. C., Glasziou, P. P., Boutron, I., Milne, R., Perera, R., Moher, D., Altman, D. G., Barbour, V., Macdonald, H., Johnston, M., Lamb, S. E., Dixon-Woods, M., McCulloch, P., Wyatt, J. C., Chan, A.-W., & Michie, S. (2014). Better reporting of interventions: Template for intervention description and replication (TIDieR) checklist and guide. *BMJ: British Medical Journal*, *348*(mar07 3), g1687. https://doi.org/10.1136/bmj.g1687

Kaminsky, L. A., Brubaker, P. H., Guazzi, M., Lavie, C. J., Montoye, A. H. K., Sanderson, B. K., & Savage, P. D. (2016). Assessing physical activity as a core component in cardiac rehabilitation: A position statement of the American association of cardiovascular and pulmonary rehabilitation. *Journal of Cardiopulmonary Rehabilitation and Prevention*, *36*(4), 217–229. https://doi.org/10.1097/hcr.0000000000000191

Kenny, E., McEvoy, J., McSharry, J., Collins, L., Taylor, R., & Byrne, M. (2021). Are behaviour change techniques and intervention features associated with effectiveness of digital cardiac rehabilitation programmes? A systematic review protocol [version 1; peer review: 2 approved]. *HRB Open Research*, *4*(88), https://doi.org/10.12688/hrbopenres.13355.1

Kotseva, K., & Wood, D. (2018). De bacquer D, on behalf of Ei. Determinants of participation and risk factor control according to attendance in cardiac rehabilitation programmes in coronary patients in Europe: EUROASPIRE IV survey. *European Journal of Preventive Cardiology*, *25*(12), 1242–1251. https://doi.org/10.1177/2047487318781359

Lear, S. A., Singer, J., Banner-Lukaris, D., Horvat, D., Park, J. E., Bates, J., & Ignaszewski, A. (2014). Randomized trial of a virtual cardiac rehabilitation program delivered at a distance via the internet. *Circulation: Cardiovascular Quality and Outcomes*, *7*(6), 952–959. https://doi.org/10.1161/CIRCOUTCOMES.114.001230

Lunde, P., Bye, A., Bergland, A., Grimsmo, J., Jarstad, E., & Nilsson, B. B. (2020 Nov). Long-term follow-up with a smartphone application improves exercise capacity post cardiac rehabilitation: A randomized controlled trial. *European Journal of Preventive Cardiology*, *27*(16), 1782–1792. https://doi.org/10.1177/2047487320905717

Maddison, R., Pfaeffli, L., Whittaker, R., Stewart, R., Kerr, A., Jiang, Y., Kira, G., Leung, W., Dalleck, L., Carter, K., & Rawstorn, J. (2015). A mobile phone intervention increases physical activity in people with cardiovascular disease: Results from the HEART randomized controlled trial. *European Journal of Preventive Cardiology*, *22*(6), 701–709. https://doi.org/10.1177/2047487314535076

Maddison, R., Rawstorn, J. C., Stewart, R. A. H., Benatar, J., Whittaker, R., Rolleston, A., Jiang, Y., Gao, L., Moodie, M., Warren, I., Meads, A., & Gant, N. (2019). Effects and costs of real-time cardiac telerehabilitation: Randomised controlled non-inferiority trial. *Heart*, *105*(2), 122–129. https://doi.org/10.1136/heartjnl-2018-313189

Martin, B.-J., Arena, R., Haykowsky, M., Hauer, T., Austford, L. D., Knudtson, M., Aggarwal, S., & Stone, J. A. (2013). Cardiovascular fitness and mortality after contemporary cardiac rehabilitation. *Mayo Clinic Proceedings*, *88*(5), 455–463. https://doi.org/10.1016/j.mayocp.2013.02.013

McAuliffe, H., Mc Sharry, J., Dunne, D., Byrne, M., & Meade, O. (2021). Identifying the active ingredients of cardiac rehabilitation: A behaviour change technique and qualitative analysis. *British Journal of Health Psychology*, *26*(4), 1194–1218. https://doi.org/10.1111/bjhp.12531

Michie, S., Richardson, M., Johnston, M., Abraham, C., Francis, J., Hardeman, W., Eccles, M. P., Cane, J., & Wood, C. E. (2013). The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: Building an international consensus for the reporting of behavior change interventions. *Annals of Behavioral Medicine*, *46*(1), 81–95. https://doi.org/10.1007/s12160-013-9486-6

Michie, S., West, R., Sheals, K., & Godinho, C. A. (2018). Evaluating the effectiveness of behavior change techniques in health-related behavior: A scoping review of methods used. *Translational Behavioral Medicine*, *8*(2), 212–224. https://doi.org/10.1093/tbm/ibx019

National Institute for Health and Care Excellence. (2014). Behaviour change: individual approaches. NICE guidelines [PH49]. January 2014; Available from: https://www.nice.org.uk/guidance/ph49.

Ouzzani, M., Hammady, H., Fedorowicz, Z., & Elmagarmid, A. (2016). Rayyan—a web and mobile app for systematic reviews. *Systematic Reviews*, *5*(1), 210. https://doi.org/10.1186/s13643-016-0384-4

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*, *372*, n71. https://doi.org/10.1136/bmj.n71

Park, L. G., Elnaggar, A., Lee, S. J., Merek, S., Hoffmann, T. J., Von Oppenfeld, J., Ignacio, N., & Whooley, M. A. (2021). Mobile health intervention promoting physical activity in adults post cardiac rehabilitation: Pilot randomized controlled trial. *JMIR Formative Research*, *5*(4), e20468. https://doi.org/10.2196/20468

Pfaeffli Dale, L., Dobson, R., Whittaker, R., & Maddison, R. (2016). The effectiveness of mobile-health behaviour change interventions for cardiovascular disease self-management: A systematic review. *European Journal of Preventive Cardiology*, *23*(8), 801–817. https://doi.org/10.1177/2047487315613462

Pfaeffli Dale, L., Whittaker, R., Jiang, Y., Stewart, R., Rolleston, A., & Maddison, R. (2015). Text message and internet support for coronary heart disease self-management: Results from the Text4Heart randomized controlled trial. *Journal of Medical Internet Research*, *17*(10), e237. https://doi.org/10.2196/jmir.4944

Piepoli, M. F., Hoes, A. W., Agewall, S., Albus, C., Brotons, C., Catapano, A. L., Cooney, M.-T., Corrà, U., Cosyns, B., Deaton, C., Graham, I., Hall, M. S., Hobbs, F. D. R., Løchen, M.-L., Löllgen, H., Marques-Vidal, P., Perk, J.,

Prescott, E., Redon, J., … Verschuren, W. M. M. (2016). European guidelines on cardiovascular disease prevention in clinical practice: The sixth joint task force of the European society of cardiology and other societies on cardiovascular disease prevention in clinical practice (constituted by representatives of 10 societies and by invited experts)Developed with the special contribution of the European association for cardiovascular prevention & rehabilitation (EACPR). *European Heart Journal*, *37*(29), 2315–2381. https://doi.org/10.1093/eurheartj/ehw106

Ramachandran, H. J., Jiang, Y., Tam, W. W. S., Yeo, T. J., & Wang, W. (2021). Effectiveness of home-based cardiac telerehabilitation as an alternative to phase 2 cardiac rehabilitation of coronary heart disease: A systematic review and meta-analysis. *European Journal of Preventive Cardiology*, https://doi.org/10.1093/eurjpc/zwab106

Rawstorn, J. C., Gant, N., Direito, A., Beckmann, C., & Maddison, R. (2016). Telehealth exercise-based cardiac rehabilitation: A systematic review and meta-analysis. *Heart*, *102*(15), 1183. https://doi.org/10.1136/heartjnl-2015-308966

Reid, R. D., Morrin, L. I., Beaton, L. J., Papadakis, S., Kocourek, J., McDonnell, L., D'Angelo, M. E. S., Tulloch, H., Suskin, N., Unsworth, K., Blanchard, C., & Pipe, A. L. (2012). Randomized trial of an internet-based computer-tailored expert system for physical activity in patients with heart disease. *European Journal of Preventive Cardiology*, *19*(6), 1357–1364. https://doi.org/10.1177/1741826711422988

Sankaran, S., Dendale, P., & Coninx, K. (2019). Evaluating the impact of the HeartHab App on motivation, physical activity, quality of life, and risk factors of coronary artery disease patients: Multidisciplinary crossover study. *JMIR MHealth and UHealth*, *7*(4), e10874. https://doi.org/10.2196/10874

Skobel, E., Knackstedt, C., Martinez-Romero, A., Salvi, D., Vera-Munoz, C., Napp, A., Luprano, J., Bover, R., Glöggler, S., Bjarnason-Wehrens, B., Marx, N., Rigby, A., & Cleland, J. (2017). Internet-based training of coronary artery patients: The heart cycle trial. *Heart and Vessels*, *32*(4), 408–418. https://doi.org/10.1007/s00380-016-0897-8

Smith, S. C., Benjamin, E. J., Bonow, R. O., Braun, L. T., Creager, M. A., Franklin, B. A., Gibbons, R. J., Grundy, S. M., Hiratzka, L. F., Jones, D. W., Lloyd-Jones, D. M., Minissian, M., Mosca, L., Peterson, E. D., Sacco, R. L., Spertus, J., Stein, J. H., & Taubert, K. A. (2011). AHA/ACCF secondary prevention and risk reduction therapy for patients With coronary and other atherosclerotic vascular disease: 2011 update: A guideline from the American heart association and American college of cardiology foundation endorsed by the world heart federation and the preventive cardiovascular nurses association. *Journal of the American College of Cardiology*, *58*(23), 2432–2446. https://doi.org/10.1016/j.jacc.2011.10.824

Southard, B. H., Southard, D. R., & Nuckolls, J. (2003). Clinical trial of an internet-based case management system for secondary prevention of heart disease. *Journal of Cardiopulmonary Rehabilitation*, *23*(5), 341–348. https://doi.org/10.1097/00008483-200309000-00003

Sterne, J. A. C., Savović, J., Page, M. J., Elbers, R. G., Blencowe, N. S., Boutron, I., Cates, C. J., Cheng, H.-Y., Corbett, M. S., Eldridge, S. M., Emberson, J. R., Hernán, M. A., Hopewell, S., Hróbjartsson, A., Junqueira, D. R., Jüni, P., Kirkham, J. J., Lasserson, T., Li, T., … Higgins, J. P. T. (2019). Rob 2: A revised tool for assessing risk of bias in randomised trials. *BMJ*, *366*, l4898. https://doi.org/10.1136/bmj.l4898

Su, J. J., & Yu, D. S. (2021). Effects of a nurse-led eHealth cardiac rehabilitation programme on health outcomes of patients with coronary heart disease: A randomised controlled trial. *International Journal of Nursing Studies*, *122*, 104040. https://doi.org/10.1016/j.ijnurstu.2021.104040

Su, J. J., Yu, D. S. F., & Paguio, J. T. (2020). Effect of eHealth cardiac rehabilitation on health outcomes of coronary heart disease patients: A systematic review and meta-analysis. *Journal of Advanced Nursing*, *76*(3), 754–772. https://doi.org/10.1111/jan.14272

Thomas, R. J., Beatty, A. L., Beckie, T. M., Brewer, L. C., Brown, T. M., Forman, D. E., Franklin, B. A., Keteyian, S. J., Kitzman, D. W., Regensteiner, J. G., Sanderson, B. K., & Whooley, M. A. (2019 Jul 2). Home-Based cardiac rehabilitation: A scientific statement from the American association of cardiovascular and pulmonary rehabilitation, the American heart association, and the American college of cardiology. *Circulation*, *140*(1), e69–e89. https://doi.org/10.1161/CIR.0000000000000663

Tomita, M. R. (2009). Effects of multidisciplinary internet-based program on management of heart failure. *Journal of Multidisciplinary Healthcare*, *2*, 13. https://doi.org/10.2147/jmdh.s4355

Turk-Adawi, K., & Grace, S. L. (2014). Smartphone-based cardiac rehabilitation. *Heart*, *100*(22), 1737–1738. https://doi.org/10.1136/heartjnl-2014-306335

Varnfield, M., Karunanithi, M., Lee, C.-K., Honeyman, E., Arnold, D., Ding, H., Smith, C., & Walters, D. L. (2014). Smartphone-based home care model improved use of cardiac rehabilitation in postmyocardial infarction patients: Results from a randomised controlled trial. *Heart*, *100*(22), 1770. https://doi.org/10.1136/heartjnl-2014-305783

Vernooij, J. W. P., Kaasjager, H. A. H., van der Graaf, Y., Wierdsma, J., Grandjean, H. M. H., Hovens, M. M. C., de Wit, G. A., & Visseren, F. L. J. (2012). Internet based vascular risk factor management for patients with clinically manifest vascular disease: Randomised controlled trial. *BMJ*, *344*(jun12 1), e3750. https://doi.org/10.1136/bmj.e3750

Wan, X., Wang, W., Liu, J., & Tong, T. (2014). Estimating the sample mean and standard deviation from the sample size, median, range and/or interquartile range. *BMC Medical Research Methodology*, *14*(1), 135. https://doi.org/10.1186/1471-2288-14-135

WHO. (2021). Fact sheet. Cardiovascular diseases (CVDs); Available from: https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds).

Widmer, R. J., Allison, T. G., Lennon, R., Lopez-Jimenez, F., Lerman, L. O., & Lerman, A. (2017). Digital health intervention during cardiac rehabilitation: A randomized controlled trial. *American Heart Journal*, *188*, 65–72. https://doi.org/10.1016/j.ahj.2017.02.016

Widmer, R. J., Collins, N. M., Collins, C. S., West, C. P., Lerman, L. O., & Lerman, A. (2015). Digital health interventions for the prevention of cardiovascular disease: A systematic review and meta-analysis. *Mayo Clinic Proceedings*, *90*(4), 469–480. https://doi.org/10.1016/j.mayocp.2014.12.026

Wong, E. M.-L., Leung, D. Y. P., Chair, S.-Y., & Sit, J. W. H. (2020). Effects of a Web-based educational support intervention on total exercise and cardiovascular risk markers in adults With coronary heart disease. *Worldviews on Evidence-Based Nursing*, *17*(4), 283–292. https://doi.org/10.1111/wvn.12456

Woodgate, J., & Brawley, L. R. (2008). Self-efficacy for exercise in cardiac rehabilitation: Review and recommendations. *Journal of Health Psychology*, *13*(3), 366–387. https://doi.org/10.1177/1359105307088141

Yudi, M. B., Clark, D. J., Tsang, D., Jelinek, M., Kalten, K., Joshi, S. B., Phan, K., Ramchand, J., Nasis, A., Amerena, J., Koshy, A. N., Murphy, A. C., Arunothayaraj, S., Si, S., Reid, C. M., & Farouque, O. (2021). SMARTphone-based, early cardiac REHABilitation in patients with acute coronary syndromes: A randomized controlled trial. *Coronary Artery Disease*, *32*(5), https://doi.org/10.1097/MCA.0000000000000938

Zheng, X., Zheng, Y., Ma, J., Zhang, M., Zhang, Y., Liu, X., Chen, L., Yang, Q., Sun, Y., Wu, J., & Yu, B. (2019). Effect of exercise-based cardiac rehabilitation on anxiety and depression in patients with myocardial infarction: A systematic review and meta-analysis. *Heart & Lung*, *48*(1), 1–7. https://doi.org/10.1016/j.hrtlng.2018.09.011

Zutz, A., Ignaszewski, A., Bates, J., & Lear, S. A. (2007). Utilization of the internet to deliver cardiac rehabilitation at a distance: A pilot study. *Telemedicine and e-Health*, *13*(3), 323–330. https://doi.org/10.1089/tmj.2006.0051