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Wide variability in studies reporting on digital education interventions for patients undergoing cardiac procedures: A patient-commissioned mixed methods systematic review

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ABSTRACT

Background: Although cardiac rehabilitation is widely acknowledged as the gold standard for improved outcomes in cardiac procedures, it remains underutilized. Digital education tools have the potential to improve access and adherence to cardiac rehabilitation.
Objectives: The primary objective of this review is to determine the impact of digital education interventions for patients undergoing cardiac procedures on patient-level and health system-level outcomes.
Methods: Conceptualized by a patient partner, a mixed methods systematic review was conducted using JBI methodology. MEDLINE, Embase, CINAHL, and Scopus were searched. Studies were included if they reported on a digital education intervention for adult patients preparing for or recovering from cardiac procedures, and if they reported primary outcomes related to healthcare utilization, learning/knowledge, and/or patient-level health. Interventions were mapped onto the WHO taxonomy of Digital Health Interventions for Persons.
Results: 41 studies were included, and most reported a positive effect across several outcome categories: knowledge; behavior, attitude, and self-efficacy; physiological; healthcare utilization; mental health; quality of life; physical function and activity; and other. Considerable variation in outcomes, measurement instruments, and intervention characteristics hindered meta-analysis and made it challenging to draw broad conclusions.
Conclusion: Overall, interventions included in this review resulted in a positive effect on a wide range of outcomes. However, most studies did not report the use of an educational theory or underlying framework, leading to wide variability in intervention design and implementation. Future developers should consider using an educational framework to design and evaluate digital interventions. Additionally, engaging patients and knowledge users as co-designers could increase relevance, acceptability, and uptake.

Introduction

Cardiovascular diseases are the leading cause of death worldwide and represent 32% of global mortality.[1] Cardiac procedures are used to treat the progression of heart disease though procedures such as coronary artery bypass surgery (CABG), valvular surgery, ventricular assist device implant, or heart transplant.[2] While surgical techniques have advanced such that acute operative risks are minimal,[3–5] post-operative recovery still poses risks of mortality, morbidity, and institutionalization for a segment of the population.[6,7] Cardiac

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rehabilitation is often prescribed and recommended to ease the transition between hospital and home using interventions such as early mobilization, pulmonary rehabilitation, delirium prevention, aerobic exercises, resistance training, activities of daily living training, and patient education to improve patient outcomes.[8] Despite guidelines that recommend patients be referred to cardiac rehabilitation for cardiovascular conditions and surgical recovery, cardiac rehabilitation is underutilized.[8–10] Social determinants such as gender, race, socio-economic status, geographic location, and session or class scheduling are known to contribute to low participation rates[8,11] and a decline in post-operative health status after cardiac surgery.[12] Research suggests that patient activation and empowerment are essential to healthcare reform, leading to higher functional health status and enhancements in self-care management for those who can engage in these practices with their health providers.[13,14]

Patients undergoing cardiac procedures and their caregivers have previously identified education and information-sharing as important priorities for enhancing pre- and post-operative care,[15] which aligns with principles of patient-centered care for surgery recipients.[16,17] Digital education interventions have risen in prominence in recent years, particularly since the COVID-19 pandemic,[18] and the World Health Organization (WHO) have developed a global strategy on digital health (2020-2025) that highlights the importance of digital health solutions including patient education.[19] Digital education tools therefore have the potential to improve access and adherence to cardiac rehabilitation, improve patient-level and health system-level outcomes, and empower patient activation in preparing for and recovering from their cardiac surgical procedure.

Objective

The primary objective of this systematic review is to examine the impact of digital education interventions for patients preparing for, and recovering from, cardiac procedures on patient-level and health system-level outcomes. The secondary objectives are to explore patients' user satisfaction with the interventions, to map the types of media used to deliver digital patient education, and determine how digital education interventions are implemented.

Methods

This patient-commissioned project was brokered by the Strategy for Patient-Oriented Research (SPOR) Evidence Alliance as part of their 2023 patient and public health research topic priority-setting exercise.[20] In partnership with the patient commissioner (RW), the authors completed a mixed methods systematic review following the methodological guidance of the JBI Manual for Evidence Synthesis.[21] Mixed methods systematic reviews allow for the combination or integration of quantitative and qualitative data to produce informative conclusions that generate evidence to guide decision making. The review used a convergent segregated approach, which maintains distinction between qualitative and quantitative evidence, requiring synthesis to be conducted prior to the final integration of quantitative and qualitative evidence. The review is reported according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) 2020 guidelines[22] and the protocol was registered in PROSPERO (CRD42024540176).

Eligibility criteria

Population

Studies were included if they reported on adult patients (aged 18 years or older) preparing for, or recovering from, cardiac procedures including coronary artery bypass, percutaneous coronary intervention, aortic valve replacement, and mitral valve replacement.

Intervention

Eligible studies reported on at least one digital educational intervention whose purpose was to improve patient-level and health system-level outcomes by supporting learning about topics regarding procedure preparation, what to expect after the intervention and lifestyle modification support. The intervention must have been delivered digitally or using a hybrid digital/in person strategy. Eligible digital formats included websites, mobile and internet-based applications, online modules, use of multimedia resources, gaming applications, and artificial intelligence tools. The interventions could be patient- or provider-led, utilized in a synchronous or asynchronous mode, and deployed in an individual or group setting.

Interventions delivered exclusively over the telephone, such as telephone call follow-up or reminders, were excluded. Similarly, automated reminders or alerts sent via text message or SMS were excluded, as well as any other interventions focusing solely on providing patients with reminders. Informal peer-to-peer support groups were excluded, but paired peer-to-peer programs, in which a patient was formally assigned to a peer navigator, sponsor, or non-professional coach, were eligible as long as they were delivered in a digital or hybrid format.

Comparators

If present, the team extracted comparison data related to traditional, in-person types of educational interventions or resources, whether active or passive, without a digital component.

Outcomes

To be included in this review, studies must have reported any of the following as the primary outcome(s): patient-level health outcomes (e.g., health outcomes, mental health outcomes, quality of life, learning or knowledge outcomes) or health system-level outcomes (e.g., healthcare utilization, unplanned return visits). Outcomes must have been measured in real-world settings; simulated data were not eligible for inclusion.

If present, the team also extracted secondary outcomes related to patient satisfaction with the intervention, intervention modes of delivery, and outcomes related to intervention implementation.

Setting

Included educational interventions must have been designed to support patients preparing for their procedure at home or recovering after discharge from hospital to home. Exclusively hospital-based interventions were not eligible for inclusion. Studies based in simulated settings, including those used for the purpose of assessing usability of the intervention, were excluded.

Study designs

Controlled trials, quasi-experimental studies, observational studies, mixed-methods studies, and qualitative studies with or without a comparator group were included. Conference abstracts, protocols, commentaries, opinion pieces, editorials, and other papers not presenting original data were excluded. Literature reviews were excluded, but the studies included in eligible reviews were screened for inclusion in this review.

Search strategy

The search strategy was developed by a health information specialist who is a member of the review team (LB). As part of the topic priority-setting exercise, SPOR Evidence Alliance executed preliminary searches to retrieve previous systematic reviews related to the topic. No existing high-quality, relevant systematic reviews were identified. Results from the SPOR Evidence Alliance search and additional scoping searches by the review team were used to identify a group of relevant articles for use in developing the electronic database search strategy. The search approach also drew from that of a related scoping review of non-

pharmacological interventions to support coronary artery bypass graft patient recovery following discharge.[23] The search strategy included keywords and subject headings related to cardiac procedures, patient recovery, and digital education. A date limit of 2000 – current was applied to capture studies relevant to the current technological context. No study design or language limits were applied to the search.

Information sources

The health information specialist developed the primary search in MEDLINE All (Ovid). Another health information specialist peer reviewed the search using the Peer Review of Electronic Search Strategies (PRESS) guideline.[24] The search was then translated to Embase (Embase.com), CINAHL with Full Text (EBSCOhost), and Scopus (Scopus.com). No study registries were searched. Search results were limited 2000-current, and no other limits or search filters were used. MEDLINE and Embase records retrieved by the Scopus search were removed in Scopus prior to export using the command *AND NOT ((INDEX(medline)) OR (INDEX(embase)))*. The exact search strategies used in each database are included in Appendix A. The searches were executed in each database on June 28, 2024.

The team searched the grey literature using Google. Google searches were iterative and contained similar keywords to the electronic database search. Additionally, the team conducted handsearching of organizational websites with resources to support cardiac patients, including the Canadian Cardiovascular Society, the Cardiovascular Network of Canada, the Ottawa Hospital Research Institute, the American Heart Association, the Heart and Stroke Foundation of Canada, and the British Heart Foundation.

Citation searching of relevant systematic reviews was used as a supplementary search method. During screening, team members tagged systematic reviews with potentially relevant included studies. One reviewer was then assigned to rescreen the full text of each of the tagged reviews, and then to locate its included studies, which were then subject to full inclusion assessment in Covidence (https://www.covidence.org/).

Inclusion assessment

Records from the electronic database search were imported to Covidence for deduplication and screening. Duplicates were removed automatically using Covidence's built-in deduplication feature, and additional duplicates were marked manually as they arose during screening. Records were screened independently by two reviewers at the title/abstract and full text levels. Screening guidance sheets were created to promote consistency between screeners, and pilot screening was conducted by all screeners on a small group of studies to ensure team alignment before screening the full set of citations. Screening conflicts were resolved by a third reviewer or by consensus. The screening process was documented using a PRISMA Flow Diagram.[22]

Non-English titles and abstracts were translated to English using DeepL Translate (https://www.deepl.com/en/translator) for screening. Non-English articles that made it through to the full text screening round were translated using the same tool. If a full text could not be accessed through our authors' institutions or through inter-library loan, it was tagged as inaccessible and excluded from the review.

Grey literature searching and screening was managed using Microsoft Excel. Searches were executed and documented by a group of independent reviewers who input potentially relevant results into Excel. To achieve saturation, Google search results were screened until the reviewer advanced two pages (i.e., 20 results) past the last potentially relevant result clicked. A second reviewer verified whether each resource input into Excel warranted further assessment. All resources included at this point underwent another level of more in-depth screening by two independent reviewers, and conflicts were resolved by a third reviewer if necessary. Grey literature searching was conducted in English; non-English items retrieved by the searches were translated using Google's built-in translation functions. The grey literature search and screening occurred between November 25 and December 5, 2024.

Data extraction

Data were extracted from included studies using Covidence. A preliminary data extraction form was designed *a priori* with input from the expert advisory panel. Elements included details about the digital education interventions and relevant outcomes. The preliminary form was pilot tested by all extractors with a small group of included studies. Minor changes were made to improve clarity and comprehensiveness of the extraction form following the pilot process. Additionally, a data extraction guidance sheet was developed to ensure consistency between extractors. The final data extraction form is included in Appendix B. Data were extracted in duplicate by two independent reviewers. After extraction, each pair of reviewers met to discuss any disagreements and reach consensus on the extracted data.

Critical appraisal

Included studies were critically appraised using JBI tools appropriate to each study design.[25–28] Each question in the appraisal tool was assigned "Yes", "No", "Unclear", or "Not applicable". Studies were critically appraised in duplicate by two independent reviewers. After independently appraising studies, each pair of reviewers met to reach consensus on the overall quality of each study through discussion of the completed JBI tools. Tables were then constructed to compare the item-level assessments across studies.

Data synthesis and integration

When reported in the included studies, reviewers extracted and analyzed data specific to sex and gender, rural versus urban patients, health literacy levels, and digital literacy levels. Patient partners and knowledge users on the team met at regular intervals and contributed to all methodological decisions and interpretation of evidence. The plan for data analysis was to follow a convergent segregated approach to synthesis and integration according to JBI methodology.[29]

Interventions in the included studies were mapped onto the World Health Organization (WHO) taxonomy of Digital Health Interventions for Persons as defined in their Classification of Digital Interventions, Services and Applications in Health.[30] The taxonomy of Digital Health Interventions for Persons was chosen from the classification system due to this review's focus on patient outcomes. The taxonomy is organized into eight categories: targeted communication to persons (1.1), untargeted communication to persons (1.2), person to person communication (1.3), personal health tracking (1.4), person-based reporting (1.5), on demand communication with persons (1.6), person-centered financial transitions (1.7), and person-centered consent management (1.8). Each category has a variable number of subcategories. One characteristic that was not represented in this taxonomy was on-demand communication with an actual health-care provider via phone, chat, or video; the team added this as an additional characteristic.

Study outcomes, outcome measures, measurement instruments, direction of effect (positive, negative, or no effect), and significance of effect were extracted and analysed narratively and in tabular format. Outcomes were placed, where possible, into one of eight categories: knowledge outcomes; behaviour, attitude, and self-efficacy outcomes; physiological outcomes; healthcare utilization outcomes; mental health outcomes; quality of life outcomes; physical function and activity outcomes; and an "other" category for outliers.

Patient and public involvement

This systematic review was conceptualized and commissioned by a patient partner who served as co-lead of the project (RW). This

individual participated in all stages of the review including protocol development, screening, data extraction, analysis, and interpretation of results. There was an additional patient partner on the team (DR) who sat on the review's expert advisory panel, which also included cardiovascular healthcare professionals and knowledge users (MH, GMH, RG, TBC). The expert advisory panel convened several times throughout the review process to advise on study inclusion, data extraction, and interpretation of results.

Results

The electronic database search yielded 5659 records. 1483 duplicates were removed by Covidence upon import, and the team manually identified an additional 55 duplicates. 78 records were identified and screened from the grey literature search. 136 records were identified from the citation search of relevant existing reviews, from which 58 duplicates were removed. Altogether, 4277 records were screened at the title/abstract level. 4130 were excluded at this stage. 147 full-text studies were assessed for eligibility, of which 106 were excluded. 41 studies were included in the review. [31–71] Figure 1 illustrates the screening process using a PRISMA flow diagram.

Study characteristics

Table 1 outlines key characteristics of the 41 included studies. Included studies were published between 2000 and 2024, with most published from 2021 to 2024 (n=22).[34–36,39,40,42,43,45–49,51–54,60,62–66] The United States was the most common study setting (n=13),[31–33,41,50,53,57–59,64,67,70,71] followed by China (n=12)[37,40,42,43,45,46,48,60,65,66,68,69] and Canada (n=3).[34,35,56] Almost all included studies used quantitative study methods, and randomized controlled trials (RCTs) were the most common study design

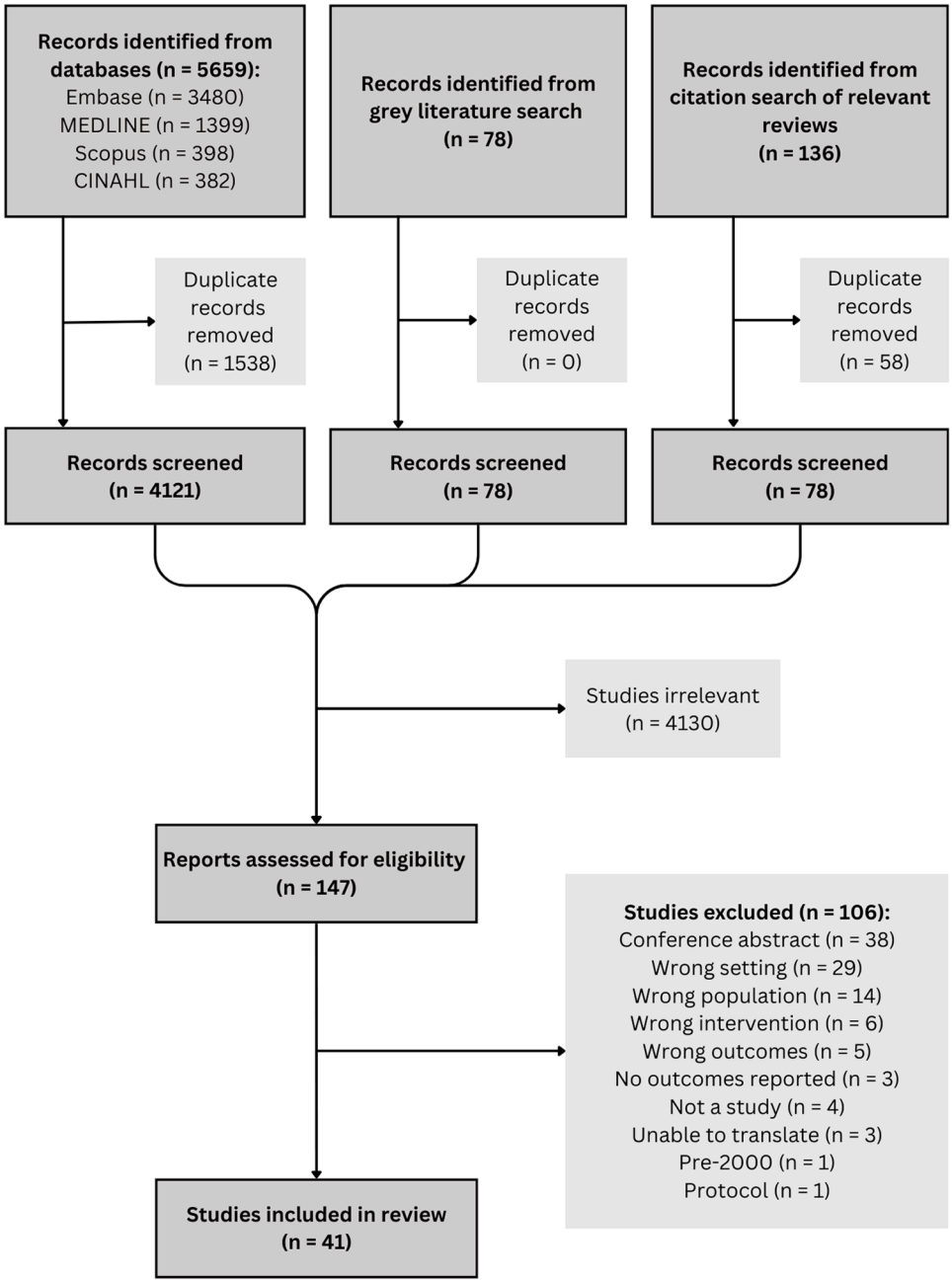

Figure 1. PRISMA flow diagram illustrating the screening process.

Table 1
Characteristics of included studies.

Author, Year, Country	Study Design	Target Population	Sample Size	Primary Outcome(s) (Measure[s])
Barnason et al. 2003 United States of America (USA)	Randomized controlled trial (RCT)	Elderly coronary artery bypass graft (CABG) patients with ischemic heart failure	N=35 (Intervention group [I]: 18, Control group [C]: 17)	Perceived self-efficacy (Barnason Efficacy Expectation Scale) • Coronary artery disease (CAD) risk factor modification adherence (Cardiovascular Risk Factor Modification Adherence Instrument) Physiologic and psychosocial functioning (Medical Outcomes Study 36-itme short form [MOS SF-36])
Barnason et al. 2009 (a) USA	RCT	Older adults >65 years post coronary artery bypass surgery (CABS)	N=232 (I: 109, C: 123)	• Physical activity (activity interview, RT3 accelerometer, diary) Physiologic and psychosocial functioning (MOS SF-36) Health care use (self-reported and cross-validated with hospital or provider)
Barnason et al. 2009 (b) USA	Quasi-experimental	Older adults >65 years who had undergone CABS	N=55 (I: 23, C:17)	• Physical activity (activity interview [for baseline], RT3 accelerometer, diary) Physiologic and psychosocial functioning (MOS SF-36) Health care use (self-reported and cross-validated with hospital or provider)
Bellemare et al. 2022 Canada	Case Control	Patients receiving transcatheter aortic valve replacement (TAVR)	N=227 (I: 99, C: 128)	Emergency department (ED) visits at 30 daysReadmissionsCall volume • Functional recovery (self-reported digital Kansas City Cardiomyopathy Questionnaire)
Ben-Ali et al. 2021 Canada	Quasi-experimental	Patients having elective CABS or isolated valve procedures	N=1108 (I:703, C: 1100)	Health services utilization (recovery questionnaire) Infection (recovery questionnaire)
DaCosta et al. 2023 Portugal	Quasi-experimental	Participants with chronic heart disease who had been admitted for percutaneous coronary intervention (PCI)	N=23 (I: 12, C: 11)	Low density lipoprotein (LDL), triglyceride (TG), weight (kg), body mass index (BMI), abdominal perimeter (cm) • Adherence to pharmacological treatment (points [comparison of initial vs. 6 months]) Lifestyle questionnaire (Questionário estilo vida fantástico)Understanding of educational modules (true/false questionnaire)
Dorje et al. 2019 China	RCT	Patients over 18 years of age with coronary heart disease who had received PCI	N=312 (I: 156, C: 156)	Functional capacity (6-minute walk test [6MWT]) Knowledge and awareness of coronary heart disease (questionnaire) Blood pressure (mmHg) Lipid profile (total cholesterol, LDL, high density lipoprotein, TG) Adherence to medication (questionnaire) Obesity (BMI, waist-to-hip ratio) Psychosocial wellbeing (General Anxiety Disorder-7 [GAD-7], Patient Health Questionnaire-9 [PHQ-9]) Quality of life (12-item Short-Form Health Survey [SF-12]) Heart rate (beats per minute)
Fahimi et al. 2020 Iran	RCT	Patients undergoing CABG	N=110 (I: 55, C: 55)	Rates of delirium (Confusion Assessment Method for the Intensive Care Unit)
Gorbunova et al. 2021 Russia	RCT	Patients who have received heart valve replacements (biological or mechanical)	N=208 (I: 86, C: 122)	Physical and psychological quality of life (MOS SF-36) Adherence to treatment (S.V. Davydov's Questionnaire) Efficacy of anticoagulant therapy (therapeutic range time)
Gu et al. 2023 China	RCT	Patients with acute coronary syndrome (ACS) post-PCI	N=180 (I: 90, C: 90)	Physical Performance/Level of Functional Exercise (Short Physical Performance Battery, 6MWT Quality of life (EQ-5D, EQ VAS)
Harzand et al. 2018 USA	Quasi-experimental	Veterans qualifying for cardiac rehab post-PCI or CABG	N=18 (I: 18, C: 0)	Exercise capacity (metabolic equivalents [METS] achieved on exercise treadmill test) Systolic and dystolic blood pressure (resting, mmHg) Heart rate (beats per minute) Therapeutic capacity (questionnaire)
Jiang et al. 2021 China	RCT	Patients recovering from mechanical valve replacement who are on warfarin	N=100 (I: 50, C: 50)	Patient awareness (score) Correct warfarin taken days (diary entries in app or telephone survey monthly for non app users)
Lao et al. 2024 China	RCT	Adult Chinese patients given a diagnosis of coronary heart disease who underwent PCI	N=124 (I: 62, C: 63)	Anxiety and depression (Hospital Anxiety and Depression Scale [HADS] [Chinese-Cantonese]) Medication adherence (pill count) Exercise capacity (6MWT) Physical activity level (International Physical Activity Questionnaire – Chinese [IPAQ-C]) Self-efficacy (Cardiac Exercise Self-Efficacy Instrument [Chinese], Cardiac Diet Self-Efficacy Instrument [Chinese]) Quality of life (Cardiovascular Limitations and Symptoms Profile) Use of healthcare resources (cardiac-related readmission)
Lee et al. 2017 South Korea	Quasi-experimental	Patients who underwent PCI at Pusan National University, May–December 2016	N=48 (I: 24, C: 21)	Disease related knowledge (questionnaire) Heart health related behaviours (Heart-related Health

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Table 1 (*continued*)

Author, Year, Country	Study Design	Target Population	Sample Size	Primary Outcome(s) (Measure[s])
				Behavior Instrument) Medication adherence (8-item Morisky Medication Adherence Scale [MMAS-8]) Regular exercise (MET-min/week) Stress (Global Assessment of Recent Stress [Korean]) Diet (Korean Dietetic Association CAN Pro 5.0) Physical and mental quality of life (SF-12)
Li et al. 2024 China	RCT	Patients who underwent CABG at Shengjing Hospital, January 2018–December 2019	N=174 (I: 87, C: 87)	Anxiety (HADS [Chinese]) Depression (HADS [Chinese]) Medication adherence (MMAS-8 [Chinese]) Quality of life (SF-12 [Chinese]) Major adverse cardiovascular/cerebrovascular events (MACE) (phone call follow-up or readmission)
Liu et al. 2022 China	Quasi-experimental	PCI patients	N=66 (I: 35, C: 31)	Disease-related knowledge (Coronary Artery Disease Education Questionnaire - Short Version) Risk factor control (extracting blood pressure, lipids and anthropometrics from charts or patient self-report) Health behaviors (International Council of Cardiovascular Prevention and Rehabilitation's International Cardiac Rehabilitation Registry, CAD Self-Management Scale [Simplified Chinese]) Quality of life (SF-12)
Lyapina et al. 2023 Russia	Quasi-experimental	Patients recovering from CABG or aortic valve replacement/mitral valve replacement	N=46 (I: 24, C: 22)	Smoking cessation (self-reported) BMI Walking (self-reported) Adherence to recommended therapy (self-reported) Exercise (physical training)
Ma et al. 2021 China	Cohort	Patients > 18 years of age who were referred to the cardiac rehabilitation clinic at First Medical Center of Chinese PLA General Hospital after successful PCI	N=335 (I: 170, C: 165)	MACE (incidence of myocardial infarction unscheduled revascularization, stroke, cardiac death) Psychological stress (GAD-7, PHQ-9) Exercise capacity (METS, oxygen consumption (VO2); anaerobic threshold; carbon dioxide production; minute ventilation/carbon dioxide production relationship; VO2/work rate relationship Risk factors (blood pressure, LDL) Cardiac symptoms (Seattle Angina Questionnaire [SAQ]) Unscheduled hospitalizations
Mahfouz Khalil et al. 2024 Egypt	RCT	People 60 years or older undergoing a CABG	N=118 (I: 57, C: 61)	Symptoms (Coronary Revascularisation Outcome Questionnaire [CROQ]-CABG) Physical, psychosocial, and cognitive functioning (CROQ-CABG) Adverse effects (CROQ-CABG) Satisfaction (CROQ-CABG) Medication compliance (Sidani Doran Therapeutic Self-Care Measure [SDTSCM]) Recognizing and managing symptoms (SDTSCM) Carrying out activities of daily life (SDTSCM) Managing health conditions (SDTSCM)
Miller et al. 2007 USA	RCT	Post-CABG diabetic patients	N=49 (I: 25, C: 24)	Physical functioning (MOS SF-36, RT3 accelerometer, activity diary) Psychosocial functioning (MOS SF-36, HADS)
Noor Hanita et al. 2022 Malaysia	Quasi-experimental	Patients undergoing CABG Surgery	N=45 (I: 23, C: 22)	Anxiety and depression (HADS)
Pakrad et al. 2021 Iran	RCT	Patients having CABG at the center October 2019–April 2020	N=88 (I: 44, C: 44)	Quality of life (MOS SF-36) Functional capacity (treadmill before cardiac rehabilitation [CR] and at 1 and 3 months) Psychosocial well-being (Depression, Anxiety and Stress Scale) All-cause rehospitalization (chart check and patient report at 1 and 3 months)
Paruchuri et al. 2021 USA	Quasi-experimental	Hospitalized patients receiving PCI	N=461 (I: 118, C: 343)	30-day and 90-day all cause hospital readmission (chart review) Enrollment in CR within 90 days (chart review) Follow up with cardiologist within 1 month of hospitalization (chart review)
Saarikoski et al. 2024 Finland	RCT	Patients admitted to Oulu University Hospital due to ACS December 2017–January 2019 who underwent coronary angiography and were treated by PCI	N=47 (I: 24, C: 23)	Exercise capacity (aerobic capacity [METS, watts], maximal heart rate, time for 10 squats, lnHF power of the R-R) Quality of life, depression (Depression Scale, 15-D Quality of Life questionnaire)
Scalvini et al. 2013 Italy	Quasi-experimental	Patients at low to medium risk for early mortality (EuroSCORE 0–5) following CABG, valve replacement, or plastic surgery on valve	N=200 (I: 100, C: 100)	Left ventricular ejection fraction Clinical outcomes (electrocardiographic testing, cardiac echo color Doppler, chest radiography, routine blood tests)

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Table 1 (*continued*)

Author, Year, Country	Study Design	Target Population	Sample Size	Primary Outcome(s) (Measure[s])
				Exercise capacity (6MWT) CAD under antiplatelet or anticoagulant therapy (% of participants) Clinical events Length of rehabilitation
Scherrer-Bannerman et al. 2000 Canada	Mixed methods quasi-experimental	Patients on a cardiac surgery waitlist in British Columbia (type of procedure not specified)	N=72	Health status (Health Status Questionnaire-12) Qualitative outcomes (interviews, focus groups)
Seamless MD, no date (a) USA	Not reported	Patients undergoing cardiac surgery (type of procedure not specified)	N=233 (I: 115, C: 118)	Length of stay (days) 30-day readmission rate Discharge to skilled nursing facility (SNF)
Seamless MD, no date (b) USA	Cohort	Cardiac surgery patients (type of procedure not specified)	N=385 (I: 178, C: 207)	Readmissions Observation stays ED visits Length of stay (days) Discharge to SNF
Seamless MD, no date (c) USA	Cohort	Patients that underwent open heart surgery	N=258 (I: 95, C: 163)	Average length of stay (days) Readmissions ED visits Phone calls Discharge to SNF
Shi et al. 2022 China	RCT	Patients who receive PCI	N=5 (I: 25, C: 26)	Exercise tolerance (6MWT) Exercise compliance (% of minimum recommended weekly exercise) Disease-related cognition (questionnaire) Self-efficacy (Social-Emotional and Character Development Scale) Perception of social support (Perceived Social Support Scale)
Sorlie et al. 2007 Norway	RCT	Patients recovering from CABS	N=109 (I: 55, C: 54)	Anxiety (self-reported Beck Anxiety Inventory) Depression (Zung Self-Rating Depression Scale [SDS]) Subjective health (MOS SF-36) Length of post-operative stay (days)
Sumrattana et al. 2023 Thailand	RCT	Female and male patients with diabetes, aged 18 years and older, who had undergone CABG	N=60 (I: 30, C:30)	Sternal wound healing (Thai wound assessment inventory [WAI]) SVG donor site wound healing (WAI)
van Steenbergen et al. 2022 Netherlands	RCT	Patients after CABG	N=263 (I: 128, C: 135)	Healthcare utilization (Institute for Medical Technology Assessment Medical Consumption Questionnaire) Physical and mental health (HADS, Recovery Index-10)
Venkatraman et al. 2023 USA	Cohort	Patients undergoing surgery, including TAVR	N=388 (I: 238, C: 150)	90-day unplanned readmissions 90-day ED visit rates Complications (Clavien-Dindo scale)
Wang et al. 2022 China	RCT	Patients at a medical centre in a large metropolitan area in North China who underwent isolated CABG, were over age 18, and used WeChat	N=164 (I: 81, C: 83)	Medication adherence to secondary prevention (interviewer-led questionnaire, composite medication adherence score) Lifestyle variables (smoking cessation; physical activity; alcohol use cessation; increased fruit and vegetable intake; reduced fried food and meat intake; increased fibre and whole grain intake) Physiological parameters (systolic blood pressure; diastolic blood pressure; heart rate; BMI; TG; LDL)
Wang et al. 2023 China	Quasi-experimental	Patients with coronary heart disease (CHD) and who have had a PCI	N=76 (I: 38, C: 38)	Physical activity (IPAQ-Short Form) Rehabilitation exercise knowledge, attitude, and behaviour (Rehabilitation Exercise Knowledge-Belief-Practice Scale for Patients with CHD) Physical activity level (MET/min * time/day) Exercise adherence (diary)
Widmer et al. 2017 USA	RCT	Patients recovering from PCI for ACS	N=71 (I: 37, C: 34)	Exercise stress testing (blood pressure, height, weight, health behaviour questionnaire) Re-hospitalization and ED visits (chart review)
Yu et al. 2020 China	RCT	Patients undergoing isolated CABG	N=1000 (I: 501, C: 499)	CABG secondary prevention medication adherence (MMAS-8) Mortality Major adverse cardiovascular and cerebrovascular events Re-hospitalization Secondary prevention medication use after 6 month follow up (self-reported)
Zhou et al. 2020 China	Case Control	Patients who underwent PCI	N=63 (I: 31, C: 32)	Anxiety (SAQ) Depression (SDS) Angina (SAQ)
Zimmerman et al. 2004 USA	RCT	Elderly post-CABG patients	N=45 (I: 24, C: 21)	Symptom evaluation and response (Cardiac Symptom Survey [CSS]) Symptom interference with physical activity (CSS) Symptom interference with enjoyment of life (CSS)

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Table 1 (*continued*)

Author, Year, Country	Study Design	Target Population	Sample Size	Primary Outcome(s) (Measure[s])
Zimmerman et al. 2007 USA	RCT	Adults > 65 years post-CABG	N=40 (I: 23, C: 17)	Post operative problems (CSS) Healthcare utilization (chart review) Symptom evaluation at 6 weeks (CSS) Physical functioning (MOS SF-36) Physical activity (RT3 accelerometer, activity diary)

Abbreviations: 6MWT = 6-minute walk test; ACS = acute coronary syndrome; BMI = body mass index; C = control group; CABG = coronary artery bypass graft; CABS = coronary artery bypass surgery; CAD = coronary artery disease; CHD = coronary heart disease; CR = cardiac rehabilitation; CROQ = Coronary Revascularisation Outcome Questionnaire; CSS = Cardiac Symptom Survey; ED = emergency department; GAD-7 = General Anxiety Disorder-7; HADS = Hospital Anxiety and Depression Scale; I = intervention group; IPAQ = International Physical Activity Questionnaire; LDL = low density lipoprotein; MACE = major adverse cardiovascular/cerebrovascular events; MET(S) = metabolic equivalent(s); MMAS-8 = 8-item Morisky Medication Adherence Scale; MOS SF-36 = Medical Outcomes Study 36-item short form; PCI = percutaneous coronary intervention; PHQ-9 = Patient Health Questionnaire-9; RCT = randomized controlled trial; SAQ = Seattle Angina Questionnaire; SDS = Zung Self-Rating Depression Scale; SDTSCM = Sidani Doran Therapeutic Self-Care Measure; SF-12 = 12-item Short-Form Health Survey; SNF = skilled nursing facility; TAVR = transcatheter aortic valve replacement; TG = triglyceride; USA = United States of America; WAI = wound assessment inventory.

(n=21),[31,32,37–40,42,43,45,49,50,52,54,60,60,62,63,65,67,68,70] followed by quasi-experimental (n=12)[33,35,36,41,44,46,47,51,53,55,56,66] and cohort (n=4).[48,58,59,64] One study[56] used mixed methods. No studies using only qualitative methods were included. Studies excluded during full text screening are listed with reasons for exclusion in Appendix C.

Critical appraisal

RCT critical appraisal scores are shown in Table 2. Most RCTs used true randomization (Q1), included intervention and control groups that were similar at baseline (Q3) and treated them identically other than the intervention of interest (Q6). Outcomes were always measured in the same way for treatment groups (Q8). Due to the nature of digital education, it would have been impossible for participants to be blind to treatment assignment (Q4). It was often unclear whether allocation to treatment groups was concealed (Q2) or whether outcome assessors were blind to treatment assignment (Q7).

Quasi-experimental study critical appraisal scores are shown in Table 3. All quasi-experimental studies were clear about cause and effect (Q1). It was not always clear whether participants were receiving similar treatment or care (Q3) or if follow-up was complete (Q6). Outcomes were almost always measured in a reliable way (Q8) and analyzed

Table 2
Critical appraisal results for RCTs.

Study ID	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13
Barnason et al. 2003	Yes	Unclear	Yes	N/A	N/A	Unclear	Unclear	Yes	Yes	Yes	Yes	Yes	Yes
Barnason et al. 2009 (a)	Yes	Unclear	Yes	N/A	Unclear	Unclear	Unclear	Yes	Yes	Yes	Yes	Yes	Yes
Dorje et al. 2019	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fahimi et al. 2020	Yes	Unclear	Yes	N/A	No	Yes	Yes	Yes	Yes	N/A	Yes	Yes	Yes
Gorbunova et al. 2021	Unclear	Unclear	Yes	N/A	N/A	Yes	Unclear	Yes	Yes	Yes	Yes	Yes	Yes
Gu et al. 2023	Yes	Yes	Yes	N/A	No	Yes	Unclear	Yes	Yes	Unclear	Yes	Yes	Yes
Jiang et al. 2021	No	Unclear	Yes	N/A	N/A	Yes	Unclear	Yes	Yes	Yes	Unclear	Yes	No
Lao et al. 2024	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Lao et al. 2024	Yes	Yes	Yes	N/A	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Li et al. 2024	Unclear	Unclear	Yes	N/A	N/A	Yes	Unclear	Yes	Yes	Yes	Yes	Yes	Yes
Mahfouz Khalil et al. 2024	Yes	Yes	Yes	N/A	N/A	Yes	Unclear	Yes	Yes	Unclear	Yes	Yes	Yes
Miller et al. 2007	Yes	Yes	Yes	N/A	N/A	Yes	Unclear	Yes	Yes	Unclear	Unclear	Yes	Yes
Pakrad et al. 2021	Yes	Yes	Yes	N/A	No	Yes	Yes	Yes	Unclear	N/A	Yes	Yes	Yes
Saarikoski et al. 2024	Unclear	Unclear	No	N/A	N/A	Yes	Unclear	Yes	Yes	No	Yes	Yes	Yes
Shi et al. 2022	Yes	Unclear	Yes	N/A	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Sorlie et al. 2007	Yes	Yes	Yes	N/A	Yes	Yes	Yes	Yes	Unclear	Yes	Unclear	Yes	Yes
Sumrattana et al. 2023	Yes	Yes	Yes	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
van Steenbergen et al. 2022	Yes	Yes	Yes	N/A	N/A	Yes	Unclear	Yes	Yes	Yes	Yes	Yes	Yes
Wang et al. 2022	Yes	Yes	Yes	N/A	No	Yes	Unclear	Yes	Yes	Yes	Yes	Yes	Yes
Widmer et al. 2017	Yes	Unclear	Yes	N/A	No	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	Yes
Yu et al. 2020	Yes	Unclear	Yes	N/A	No	Yes	Yes	Yes	Unclear	N/A	Yes	Yes	No
Zimmerman et al. 2004	Yes	Yes	No	N/A	N/A	Yes	Unclear	Yes	Yes	Yes	Yes	Yes	Yes
Zimmerman et al. 2007	Yes	Yes	Yes	N/A	N/A	Yes	Unclear	Yes	Yes	Unclear	Yes	Yes	Yes

Legend
Q1 = Was true randomization used for assignment of participants to treatment groups?
Q2 = Was allocation to treatment groups concealed?
Q3 = Were treatment groups similar at the baseline?
Q4 = Were participants blind to treatment assignment?
Q5 = Were those delivering the treatment blind to treatment assignment?
Q6 = Were treatment groups treated identically other than the intervention of interest?
Q7 = Were outcome assessors blind to treatment assignment?
Q8 = Were outcomes measured in the same way for treatment groups?
Q9 = Were outcomes measured in a reliable way?
Q10 = Was follow up complete and if not, were differences between groups in terms of their follow up adequately described and analysed?
Q11 = Were participants analysed in the groups to which they were randomized?
Q12 = Was appropriate statistical analysis used?
Q13 = Was the trial design appropriate and any deviations from the standard RCT design (individual randomization, parallel groups) accounted for in the conduct and analysis of the trial?

Table 3
Critical appraisal results for quasi-experimental studies.

Study ID	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
Barnason et al. 2009 (b)	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Ben-Ali et al. 2021	Yes	Yes	Yes	Yes	Yes/No (outcome-dependent)	Yes	Yes	Yes	Yes
daCosta et al. 2023	Yes	No	Yes	Yes	No	Unclear	Yes	Yes	Unclear
Harzand et al. 2018	Yes	Unclear	Unclear	No	Yes	Yes	Yes	Yes	Yes
Lee et al. 2017	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Liu et al. 2022	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
Lyapina et al. 2023	Yes	Yes	Unclear	No	No	Yes	Yes	No	Yes
Noor Hanita et al. 2022	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Paruchuri et al. 2021	Yes	Yes	Unclear	Yes	No	Unclear	Yes/No (outcome-dependent)	Yes	Yes
Scalvini et al. 2013	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Scherrer-Bannerman et al. 2000	Yes	Yes	Yes	Unclear	No	No	Unclear	Yes	Unclear
Wang et al. 2023	Yes	Yes	Unclear	Yes	No	Unclear	Yes	Yes	Yes

Legend
Q1 = Is it clear in the study what is the "cause" and what is the "effect" (i.e. there is no confusion about which variable comes first)?
Q2 = Was there a control group?
Q3 = Were participants included in any comparisons similar?
Q4 = Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?
Q5 = Were there multiple measurements of the outcome, both pre and post the intervention/exposure?
Q6 = Were the outcomes of participants included in any comparisons measured in the same way?
Q7 = Were outcomes measured in a reliable way?
Q8 = Was follow-up complete and if not, were differences between groups in terms of their follow-up adequately described and analyzed?
Q9 = Was appropriate statistical analysis used?

appropriately (Q9). Notably, most did not measure outcomes at multiple time points pre- and post-intervention (Q5).

Synthesis

The studies included in this review incorporated a range of methods, interventions and outcomes, therefore it was not possible to pool results using meta-analysis or meta-aggregation. Additionally, none of the included studies used a qualitative research design, and only one used mixed methods. Therefore, the *a priori* plan to follow a convergent segregated approach to synthesis and integration according to JBI methodology[29] was abandoned following study selection.

Participants

A total of 8645 patients preparing for or recovering from cardiac procedures were included in this review. Most interventions targeted patients preparing for or recovering from coronary artery bypass surgery (CABS) (n=20).[31–33,35,38,41,45,47,49–52,55,61–63,65,68,70,71] Percutaneous coronary intervention (PCI) (n=14)[36,37,40,41,43,44,46,48,53,54,60,66,67,69] and valve replacement surgeries including transcatheter aortic valve replacement (TAVR) (n=7)[34,35,39,42,47,55,64] were the next most represented categories of procedure. Participants' ages ranged from 35 to 97 years, with a mean age of 62.8 ± 6.5 years. Thirty-three studies[31,32,36,37,39–56,60,62–71] reported on the sex and/or gender of participants; of these studies, 2073 participants were male, and 673 participants were female. Eight studies[36,40,42,45,49,52,60,69] reported whether participants were located in rural (n=353) or urban (n=444) areas. Few studies reported on other sociodemographic characteristics. The most commonly reported sociodemographic characteristic was education level (n=16),[32,36,37,40,42–46,49–51,60,65–67] followed by employment status (n=13),[33,36,37,40,42,44–46,48–50,60,67] marital status (n=13),[32,40,42–46,49,51,60,61,67,70] income (monthly or annual; n=6),[37,43–45,51,60] race/-ethnicity (n=4),[32,41,42,70] and living arrangements (n=1).[36]

Intervention characteristics

Table 4 outlines the key characteristics of the interventions described in the included studies. Most interventions were fully digital (n=33), and eight[36,43,44,47,49,51,52,61] were offered in a hybrid format combining digital and in-person elements. Nineteen[31–35,38,40,46–48,50,54,56–59,64,70,71] were delivered completely asynchronously, and 21 were delivered using a combination of asynchronous and synchronous formats. Only one intervention[39] was delivered completely synchronously. Most interventions (n=37) required active participation from the patient; only four[38,46,62,64] required passive or mostly passive participation. Mobile applications were the most common mode of delivery (n=21).[34,35,37,40–44,48,51,53,57–60,62,64,65,67–69] Video content (including videoconferencing) was featured in five[36,39,55,61,63] interventions. Some interventions were the subject of multiple included studies: the Health Buddy was the subject of six included studies[31–33,50,70,71] and Seamless MD was the subject of four included studies.[35,57–59]

Only one study[51] referred to a specific educational framework (the ADDIE Model) when describing the development of the intervention. Accessibility features were described in five studies[34,49,51,56,64] and included examples such as bilingual content, enlargeable text size, and keeping content at an accessible reading level. Six interventions[36,40,46,51,62,64] allowed caregivers to use the educational tools on behalf of patients uncomfortable using the technology on their own, and two interventions were designed specifically to accommodate those with low digital literacy[41] and low health literacy.[63] Notably, one study[65] purposely excluded potential participants who were uncomfortable using a mobile device. About half of the interventions (n=22) were offered in combination with other support, and were typically offered in addition to routine or traditional care.

A map of intervention characteristics according to the WHO Digital Health Interventions for Persons classification system is shown in Table 5. Of the 34 interventions analyzed, most interventions utilized some form of targeted communication to person(s) (1.1) in their intervention (n=30). Many (n=28) employed characteristics 1.1.2 (transmitting targeted health information to person(s) based on health status or demographics), and 1.1.3, (transmitting targeted alerts and reminders to person[s]) (n=18). Only one intervention employed characteristic 1.1.4 (transmit diagnostics result, or availability of result, to person[s]). Two interventions utilized person-to-person communication through peer groups (1.3.1).

Twenty-three interventions employed in 26 studies featured characteristics of personal health tracking (n=26). The most frequent characteristic utilized by interventions was 1.4.3 (active data capture/documentation by an individual) (n=17). 14 interventions (17 studies)

Table 4
Characteristics of interventions described in included studies.

Author, Year	Intervention Objective	Intervention Type (Intervention Name, if provided)	Intervention Content
Barnason et al. 2003 Barnason et al. 2009 (a) Barnason et al. 2009 (b) Miller et al. 2007 Zimmerman et al. 2004 Zimmerman et al. 2007	To increase self-efficacy related to symptom management, functioning, and coronary artery disease (CAD) risk-factor modification adherence	Telehealth device attached to phone line (Health Buddy)	• Daily sessions through a telephone line providing participants with assessment of symptoms and strategies to manage reported symptoms • Education on coronary artery bypass graft (CABG) recovery, CAD risk-factor modification education and strategies, and positive reinforcement • Assessments of the daily sessions
Bellemare et al. 2022	To improve patient education and clinical trajectory monitoring	Mobile app	• Education and to-do lists, symptom tracking, and recommendations
Ben-Ali et al. 2021 Seamless MD, no date (a) Seamless MD, no date (b) Seamless MD, no date (c)	To track health status, protocol compliance, and patient-reported outcomes in the postoperative period; additionally, to provide patient preoperative education, preoperative and postoperative tasks based on reminders, to-do lists, and evidence-based content	Mobile and web app	• Cardiac Enhanced Recovery After Surgery reminders, tasks, and education • Interaction pre- and post-op surveys to track symptoms and protocol compliance • Intelligent algorithms to flag patient issues and automatically provide feedback on how to self-manage care • Recovery questionnaires • Ability to send in photos of wound healing
daCosta et al. 2023	To improve secondary prevention of cardiovascular disease in patients undergoing percutaneous coronary intervention (PCI)	Video chat and online modules	• Education on medication adherence • Behavioral counselling and support for lifestyle related risk factors
Dorje et al. 2019	To support the delivery of a comprehensive home cardiac rehabilitation (CR) and secondary prevention programme	Mobile app	• Educational modules • Risk factor monitoring and support • Motivational cartoons • Medical counselling
Fahimi et al. 2020	To provide preoperative education in three short educational videos	Multimedia compact disc	• Educational videos
Gorbunova et al. 2021	To provide education on anticoagulation therapy to patients unable to travel in for classroom education	Video chat	• Medication discussions to prevent negative side-effects
Gu et al. 2023	To improve physical performance and quality of life in patients with acute coronary syndrome who underwent percutaneous coronary intervention	WeChat-based intervention (WeChat-based Education and Rehabilitation Program)	• Education • Rehabilitation training • Patient communication
Harzand et al. 2018	To provide CR to veterans recovering from PCI or CABG	Mobile app	• Daily reminders to exercise, and a virtual diary to document exercise sessions and vital signs • Videos on heart conditions and risk factor modification • 2-way messaging with a coach
Jiang et al. 2021	To improve the medication adherence and patient awareness, and reduce anticoagulant related complications	Mobile app (Yixing)	• Medical education and daily reminders to take medication • Input medical history and test results • Online counselling
Lao et al. 2024	To support self-care and improve CR effects in phase II CR	Mobile app (Mobile Health Cardiac Rehab [mCR] App)	• Educational page • Record health behavior modification, including blood pressure, pulse, and fasting blood glucose every day; weight, smoking status, alcohol consumption, medication status, and exercise status once a week • Push notifications of medication use • Health data entry
Lee et al. 2017	To improve patient knowledge, health behaviours, and quality of life	Mobile app, smart band, chat feedback, telephone counselling (Smart Program – Percutaneous Coronary Intervention)	• Once weekly, self-learning educational modules • Walking exercise goals using a smart band • Encouraging messages sent twice a week via KakaoTalk • Telephone counselling once a week
Li et al. 2024	To facilitate information collection, knowledge education, attitudes generation, and practice formation over 12 months post-CABG	Web-based intervention including WeChat group (Web-Based Information-Knowledge-Attitude-Practice [WIKAP] Intervention)	• Information collection (health record establishment, development of individualised nursing program based on each patients needs and demographics) • Knowledge education (CABG Recovery Experience Share and Exchange family - online communication, regular educational seminars, CAD-related knowledge) • Attitudes generation (weekly video follow up,

(*continued on next page*)

Table 4 (*continued*)

Author, Year	Intervention Objective	Intervention Type (Intervention Name, if provided)	Intervention Content
			caregiver reminders, previous patients who have successfully recovered share their self-care experiences, targeted psychological guidance once weekly) • Practice formation (medication reminders, recovery monitoring, recording daily diet, activity, and symptoms, weekly self-care plan, compliance improvement)
Liu et al. 2022	To provide digital education in modular format on cardiac disease topics	WeChat-based intervention	• Education on treating heart disease, being active, healthy eating, psychosocial well-being and self-management • Patients could ask questions at any time, and a provider would answer within 12 hours
Lyapina et al. 2023	To act as a CR program offering education and exercises	Mobile app	• Exercise recommendations and education • Communication between patients and healthcare providers • Daily logging of blood pressure, heart rate, and Borg fatigue/obesity level
Ma et al. 2021	To provide a CR intervention plan, based on standardized home-based CR and secondary prevention guidelines	WeChat-based intervention	• Online modules • Reminders of upcoming appointments • Educational materials, both text articles and videos, included education about hypertension, diabetes, cardiovascular health, healthy nutritional advice, medications, psychological well-being, and smoking cessation
Mahfouz Khalil et al. 2024	To improve therapeutic self-care and health related quality of life for those that cannot access in-person services	Instructional video, 48- hour post-discharge telephone call, weekly home visits (Home-based transitional cardiac telerehabilitation [Hb-T-CTR] program)	• Comprehensive education from admission, preparing CABG patients for the operation and managing expectations
Noor Hanita et al. 2022	To assist patients scheduled for CABG, providing insight on the procedure itself, ways to overcome possible emotional and physical repercussions, as well as preoperative and postoperative self-care management	Web app (MyEducation: CABG)	• Education on CAD, CABG surgery, and recovery planning support • Online diary to track mood and pain level
Pakrad et al. 2021	To educate on cardiac diseases, control of medical risk factors with cardiac medications, control of lifestyle risk factors, and cardiac resuscitation	Mobile app	• In-person sessions based on the continuous care model • Group discussion sessions • Virtual discussions through the app
Paruchuri et al. 2021	To provide patients with education, tracking, reminders and live health coaches for up to 90 days post-discharge	Mobile app	• Personalized adaptive daily health checklist including reminders to engage in health behaviors and a series of personalized, interactive surveys, articles and encouragement
Saarikoski et al. 2024	To guide exercise training time, volume, and intensity	Take-home tablet computers with app	• Tablet computers to motivate and monitor an exercise training program • Animated virtual physiotherapist to motivate the patients
Scalvini et al. 2013	To reproduce at home the in-hospital CR protocol procedures in patients at low to medium risk after cardiac surgery	Video conferencing, DVD (Home-based cardiac rehabilitation program)	• Face-to-face appointment with a nurse • Training on using the service, mobile telephone, and its applications • Physical activity and exercise training including education by a physical therapist (DVD) • Home intervention by a physical therapist • Behavioural modification strategies and risk-factor management • Wellness diary to record weight, food intake, sleep, alcohol, smoking, exercise, and blood pressure • Educational sessions by a nurse • Nutritional counselling: Dietitian interview at discharge • Psychological and psychosocial management: video conference applications, weekly teleconferences
Scherrer-Bannerman et al. 2000	To reduce stress and anxiety in patients awaiting surgery	Website	• Education on the basics of heart disease, types of heart surgery, what to expect during the hospital stay, what to do at home after discharge
Shi et al. 2022	To provide multidisciplinary exercise management besides routine care	Mobile app	• Individual mobile app guidance • Individual remote exercise monitoring,

(*continued on next page*)

Table 4 (*continued*)

Author, Year	Intervention Objective	Intervention Type (Intervention Name, if provided)	Intervention Content
			reminders, health education, and individual counseling • Remote echocardiogram monitoring device • Daily exercise reminders • Automatically recorded exercise details and corresponding reports • Communication group including various members from the multidisciplinary exercise management group and patients.
Sorlie et al. 2007	To provide support on "intra- and inter-personal components involving both cognitive and behavioral activities as well as interpersonal interactions seeking such as experiential confirmation, emotional support and information"	Video information sessions	• Two specifically designed patient-centered information sessions (educational videos) viewed at home prior to hospital admission and on admission to the hospital
Sumrattana et al. 2023	To provide education and wound monitoring using multimedia and a surgical wound care booklet and monitor the wound through the application on a smartphone after hospital discharge	Multimedia education and wound care (Telehealth Program for Wound Healing Promotion) and mobile app (LINE)	• Multimedia videos (controlling blood glucose: before surgery, consuming healthy diet, surgical wound care, signs of surgical site infection) • Wound monitoring through the LINE app
van Steenbergen et al. 2022	To provide virtual education following CABG	Web-based videos and video consultations	• Web-based educational videos • Postoperative video consultations with a physician
Venkatraman et al. 2023	To engage patients throughout their interventional journey with structured education and tasks	Mobile and web app (ManageMySurgery)	• Educational content through frequently asked questions and informational links specific to the surgery • Communication with care team • Tasks to complete through the application, including checking into appointments, confirming the completion of preoperative instructions, and completing preoperative and postoperative surveys
Wang et al. 2022	To improve adherence to secondary prevention medicines, lifestyles and clinical risk markers	WeChat-based intervention	• Cardiac health education, medication reminders and cardiologist-based follow-up service • Online medication reviews • Individual treatment decision, including medication adjustments and changes in lifestyle, if required
Wang et al. 2023	To increase exercise knowledge and activity	Web app	• Health education including the recuperation environment, diet, living habits, prevention of infection and other guidance • Optional video calls
Widmer et al. 2017	To report dietary and exercise habits throughout CR and provide educational information towards patient's healthy lifestyles	Mobile and web app	• Reporting of dietary and exercise habits throughout CR • Educational information toward patients' healthy lifestyles
Yu et al. 2020	To provide cardiac surgery patients medication reminders, cardiac health education, health questionnaires and feedback, and a personal data center	Mobile app	• Automatic medication reminders • Educational readings on secondary preventive cardiac care • Eight-item questionnaire about medication adherence and secondary prevention goals
Zhou et al. 2020	To carry out continuous nursing via the WeChat platform for patients who underwent PCI	WeChat-based intervention	• Information on postoperative diet, exercise, medication, daily behavior observations, postoperative psychological guidance, and other aspects related of rehabilitation • Patient reporting of eating habits, sleeping habits, exercise, psychological status, degree of recovery, and medication reminders • Patient reminders their medications on time and encouraged them to share their nursing experiences with family • Guidance, comfort, explanation, encouragement, and other supportive methods were used to actively guide patients with anxiety and depression

Abbreviations: CABG = coronary artery bypass graft; CAD = coronary artery disease; CR = cardiac rehabilitation; PCI = percutaneous coronary intervention

utilized characteristic 1.4.2 (self-monitoring of health or diagnostic data by the individual). Only 3 interventions employed characteristic 1.4.1 (access by the individual to own medical or summary health records). One intervention utilized characteristic 1.5.1 (reporting of health system feedback by persons). One intervention utilized characteristic 1.6.1 (look-up of information on health and health services by individuals). 13 studies used on-demand communication with healthcare providers (our add-on intervention). Characteristics in categories 1.2, 1.7, and 1.8 were not identified in any of the interventions included in this review and are therefore not represented in Table 3.

Intervention outcomes

The included studies targeted a wide variety of outcomes using many different measures. Outcomes of digital interventions were grouped into eight categories: knowledge; behaviour, attitude, and self-efficacy; physiological; healthcare utilization; mental health; quality of life; physical function and activity; and other. Appendix D contains tables showing outcomes, outcome measures, measurement instruments, direction of effect, and significance of study findings as they relate to intervention characteristics and quality.

Knowledge (n=7)

Knowledge outcomes included disease-related knowledge, understanding of educational modules, rehabilitation exercise knowledge, and patient awareness. All seven studies[36,37,42,44,46,56,66] reporting on these outcomes showed a positive effect on knowledge, five of which were significant. Knowledge outcome measurement instruments included varied questionnaires on coronary artery disease and/or heart disease; knowledge, beliefs, and behaviour of rehabilitation exercise; knowledge of warfarin treatment; and interview or focus group questions. There were no standardized methods of measuring knowledge-related outcomes across studies (Appendix D, Table 1).

Behaviours, attitudes, and self-efficacy (n=16)

Behaviour, attitude, and self-efficacy related outcomes included health and heart health-related behaviours, adherence to medication and treatment, risk factor control (smoking cessation, alcohol cessation, dietary habits) and activities of daily living (ADL). Of the 16 studies[32,36,37,39,42–47,49,53,60,65,66,68] reporting on this outcome category, 13 showed a positive effect in at least one outcome. Of the 34 individual outcomes across all studies, 23 showed a positive effect (16 of which were significant), and 11 showed no effect. Outcome measurement instruments varied, and included the Morisky Medication Adherence Scale, the Sidani Doran Therapeutic Self-Care Measure, an adapted Heart Related Health Behaviour Instrument, Validated Coronary Artery Disease Self-Management Scale, chart reviews, self-reported adherence to health behaviours, diary entries, and pill counts (Appendix D, Table 2).

Physiological (n=20)

Physiological outcomes included clinical events, major adverse cardiac events, complications (sternal wound healing, anticoagulation, disease-related cognition, delirium, infection, angina), symptom evaluation and response, and physiological parameters (blood pressure, body mass index, low-density lipoprotein, triglycerides, abdominal perimeter). Of the 20 studies[31,35–38,41,42,45,47–49,55,60,62,64,65,68–71] reporting on this outcome group, 15 showed a positive effect in at least one outcome. Of the 47 total outcomes reported across studies, 31 showed a positive effect (18 of which were significant), 2 showed a negative effect, and 14 showed no effect. Physiological outcome measurement instruments included the Seattle Angina Questionnaire, Seamless MD Recovery Questionnaire, Coronary Revascularization Outcome Questionnaire, the Thai Wound Assessment Inventory, self-reports, the Clavien-Dindo Scale, the Cardiac Symptom Survey, vital signs, laboratory blood tests, body mass index, and document and medical record review (Appendix D, Table 3).

Healthcare utilization (n=14)

Healthcare utilization outcomes included post-operative length of stay, unplanned readmissions, use of healthcare resources, length of rehabilitation, telephone consultations, and emergency department visits. Of the 14 studies[32,43,48,52,53,55,57–59,61,63,67,68,70] reporting on this outcome group, ten showed a positive effect in at least one outcome. In the 35 total outcomes reported across studies, 27 showed a positive effect (11 of which were significant), and eight showed no effect. Healthcare utilization outcome measurement instruments included length of stay in days, percentage of patients requiring observation stay, readmissions, and discharges to skilled nursing facilities, outpatient clinic visits, unscheduled hospitalizations, and self-reports (Appendix D, Table 4).

Mental health (n=13)

Outcomes for mental health included anxiety, depression, psychosocial well-being, psychosocial functioning, and stress. Of the 13 articles[31,32,37,43–45,50–52,56,61,63,69] reporting on these outcomes, ten reported a positive effect in at least one mental health outcome. Of the 28 total outcomes reported across studies, 20 showed a positive effect (15 of which were significant), and eight showed no effect. The most common mental health outcome measurement instrument was the Hospital Anxiety and Depression Scale, used in five of the 13 studies. Other measures included the Depression, Anxiety, and Stress Scale, the Medical Outcomes Study Short Form-36 (MOS SF-36), the Global Assessment of Recent Stress Scale, the Self-Report Beck Anxiety Inventory, the Zung Self-Rating Depression Scale, as well as interview/focus group questions and self-rating and report (Appendix D, Table 5).

Quality of life (n=10)

Quality of life outcomes were measured using various tools across studies. Of the 10 studies[37,39,40,43–46,52,54,70] reporting on quality of life, six showed a positive effect. Of the 13 total outcomes reported across studies, nine showed a positive effect (four of which were significant), and four showed no effect. The most common quality of life outcome measurement instrument was the MOS SF-36, used in five of the ten studies. Other measures included the Medical Outcomes Study Short Form-12, the EuroQol-5 Dimensions Scale, the Cardiac Symptom Survey, the Cardiovascular Limitations and Symptoms Profile, and the Quality of Life Questionnaire (Appendix D, Table 6).

Physical function and activity (n=20)

Physical function and activity outcomes included exercise capacity, functional capacity, physical activity level, exercise tolerance, regular exercise, symptom interference with physical activity, and stress testing. Of the 20 studies[32–34,37,40,41,43,44,47–50,52,54,55,60,66,67,70,71] reporting on these outcomes, 15 showed positive effect in at least one exercise-related outcome. Of the 36 total outcomes reported across studies, 23 showed a positive effect (18 of which were significant), and 13 showed no effect. Methods of measuring physical function and activity were highly variable across studies. The most common measurement instruments were the 6-Minute Walk Test (five studies), metabolic equivalents (four studies), and accelerometry using the RT3 accelerometer (three studies). Other measures included the Short Physical Performance Battery, varied vital sign measurements, activity diaries, oxygen consumption, questionnaires (e.g., Digital Kansas City Cardiomyopathy Questionnaire, Cardiac Symptom Survey), and self-reports (e.g., activity diaries) (Appendix D, Table 7).

Other (n=9)

The outcomes that could not be assigned to an existing group[36,39,41,53,55,56,60,61,71] included cardiology follow-up, social support, therapeutic capacity, lifestyle, efficacy of anticoagulation therapy, presence of anticoagulation therapy, relationship between symptoms and physical functioning, and subjective health. Of the nine outcomes, eight had a positive effect (three of which were significant), and one had no effect. There were varied methods to measuring these outcomes, including chart reviews, interviews, and validated scales/questionnaires (Appendix D, Table 8).

Correlation between interventions and outcomes

Figures 2 and 3 use heat maps to illustrate intervention classifications and outcome categories within the RCTs and quasi-experimental studies included in the review that reported a positive effect. Among

Table 5
Interventions mapped onto the WHO taxonomy of Digital Health Interventions for Persons.

Study	Targeted communications to Persons			Person to Person Communication	Personal Health Tracking			Person based reporting	On demand communication with Persons	Actual communication (phone, video, messaging) with healthcare provider	Direction of effect per outcome measured ◯ = no effect ⊕ = positive effect ⊖ = negative effect
	1.1.2	**1.1.3**	**1.1.4**	**1.3.1**	**1.4.1**	**1.4.2**	**1.4.3**	**1.5.1**	**1.6.2**	*Added for this review*	
Health Buddy studies						X					
Barnason et al. 2003											⊕⊕⊕⊕
Barnason et al. 2009 (a)											◯◯⊖◯◯◯
Barnason et al. 2009 (b)											⊕◯
Miller et al. 2007											◯◯◯◯
Zimmerman et al. 2004											◯◯◯◯◯
Zimmerman et al. 2007											◯⊕⊕⊕
Bellemare et al. 2022	X	X				X	X				⊕
Seamless MD studies	X	X				X	X	X			
Ben-Ali et al. 2021											⊕◯
Seamless MD, nd (a)											N/A
Seamless MD, nd (b)											N/A
Seamless MD, nd (c)											◯⊕⊕⊕
daCosta et al. 2023	X					X				X	N/A
Dorje et al. 2019	X	X								X	◯◯⊕⊕◯◯
Fahimi et al. 2020	X										⊕
Gorbunova et al. 2021	X									X	N/A
Gu et al. 2023	X	X		X			X				◯⊕◯⊕◯⊕⊕⊕◯⊕⊕⊕
Harzand et al. 2018	X	X				X	X			X	⊕⊕⊕◯
Jiang et al. 2021	X	X	X			X				X	⊕◯◯
Lao et al. 2024	X	X			X	X	X				⊕⊕⊕⊕⊕⊕⊕⊕⊕◯
Lee et al. 2017	X	X								X	⊕◯⊕⊕⊕⊕◯◯⊕
Li et al. 2024	X	X				X	X			X	◯⊕⊕⊕◯
Liu et al. 2022	X	X					X			X	⊕⊕⊕⊕⊕⊕

(*continued on next page*)

Table 5 (*continued*)

Study	Targeted communications to Persons		Person to Person Communication	Personal Health Tracking			Person based reporting	On demand communication with Persons	Actual communication (phone, video, messaging) with healthcare provider	Direction of effect per outcome measured ◯ = no effect ⊕ = positive effect ⊖ = negative effect
Lyapina et al. 2023	X	X				X				⊕◯
Ma et al. 2021	X	X				X				◯◯⊕⊕⊕⊕⊕⊕⊕⊕⊕
Mahfouz Khalil et al. 2024	X								X	⊕⊕⊕⊕⊕⊕⊕⊕
Noor Hanita et al. 2022	X				X					⊕⊖⊖◯◯⊕
Pakrad et al. 2021	X								X	◯◯◯⊕⊕⊕⊕
Paruchuri et al. 2021	X	X				X				⊕◯◯
Saarikoski et al. 2024	X			X	X	X		X		◯⊕⊕
Scalvini et al. 2013	X				X	X			X	◯◯⊕◯⊕
Scherrer-Bannerman et al. 2000	X									N/A
Shi et al. 2022		X	X			X			X	⊕⊕⊕⊕
Sorlie et al. 2007	X									◯◯
Sumeattana et al. 2023	X									◯⊕
van Steenbergen et al. 2022	X								X	⊕◯⊕⊕⊕⊕
Venkatraman et al. 2023		X								N/A
Wang et al. 2022	X	X				X				◯⊕◯⊕⊕⊕◯◯◯
Wang et al. 2023	X	X				X			X	⊕◯⊕⊕⊕◯
Widmer et al. 2017	X				X	X				◯◯◯⊕◯◯◯◯
Yu et al. 2020	X	X		X	X	X				◯◯◯◯
Zhou et al. 2020	X	X				X				⊕⊕⊕⊕◯⊕

1.1.2: Transmit targeted health information to person(s) based on health status or demographics; 1.1.3: Transmit targeted alerts and reminders to person(s); 1.1.4: Transmit diagnostics results, or availability of result to person(s); 1.3.1: Peer group for individuals; 1.4.1: Access by the individual to own medical or summary health records; 1.4.2: Self monitoring of health or diagnostic data by the individual; 1.4.3: Active data capture/documentation by an individual; 1.5.1: Reporting of health system feedback by persons; 1.6.2 Simulated human-like conversations with individual(s)

the RCTs, interventions that transmitted targeted health information to person(s) based on health status or demographics (1.1.2) was the most represented classification, correlating most often with positive effects on physiological and physical exercise outcomes. 1.1.2 was represented in every quasi-experimental study in the map, most frequently correlating with positive effects on behaviour, attitude, and self-efficacy outcomes and knowledge outcomes. Transmitted targeted alerts and reminders to person(s) (1.1.3) and actual communication with healthcare providers (the review team's add-on classification) were correlated most often with positive effects on behaviour, attitude, and self-efficacy outcomes in both RCTs and quasi-experimental studies, and with physical exercise outcomes in RCTs.

Secondary outcomes

Patient satisfaction

Four studies[41,46,51,55] measured patient satisfaction with the intervention. Outcome measures and results were mixed, ranging from more than 50% satisfaction[51] to 84% satisfaction.[41] Acceptability, perceived usefulness, and/or usability were measured in three studies[36,37,46] and results were similarly varied.

Barriers and facilitators to implementation

Few studies reported barriers and/or facilitators to implementation of interventions. Examples of facilitators included having dedicated teams in place to support implementation,[35,45] offering training to intervention users,[71] and taking advantage of a social media platform already commonly used by participants.[37] Barriers included staff resistance to behaviour change[35] and technology barriers such as lack of access or familiarity.[37,56] None of the studies reported using a co-design approach to create the interventions.

Discussion

Overall, there was a considerable lack of consistency in outcomes, outcome measures and interventions across studies, which ultimately affected the ability to carry out a meta-analysis and draw definitive conclusions. For example, the MOS SF-36 was used in seven publications to measure nine outcomes.[31,32,39,50,52,61,71] Three publications used a new version of the MOS SF-36, and two used select questions of the questionnaire, overall limiting the ability to compare across studies. When the MOS SF-36 was used in the same manner, follow-up was measured at varying times which included: one month[52]; six weeks[31,32]; three months[31,32]; six months[32]; and nine months.[39] Comparison across studies was further hindered by variation in intervention delivery methods.

Apart from one study,[51] included studies did not explicitly report the use of an educational framework or describe clear, theory-driven learning outcomes underpinning their digital education intervention design. Interventions commonly focused on knowledge transfer, behaviour change, or self-management, but studies offered limited detail about psychological theories, pedagogical rationale or alignment with established models of adult education or health literacy. Despite utilizing a wide array of modalities (mobile apps, web platforms, telehealth devices, videos), the majority of trials focused on practical outcomes, such as medication adherence, exercise facilitation, or knowledge of postoperative complications, and failed to link outcomes with causal mechanisms grounded in adult learning theory (andragogy), health behavior change models (Social Cognitive Theory, Health Belief Model), or frameworks like Bloom's Taxonomy. Further, educational content was often described in terms of topics and formats (e.g., educational modules, reminders, alerts, to-do lists) instead of learning objectives, teaching strategies, or theoretical underpinnings. The absence of frameworks leads to a lack of clarification regarding expected causal mechanisms, wide variability in intervention design, and poor alignment with important outcomes. Knowledge, attitudes, behavior, self-efficacy, and self-care were targeted with a focus on content, but with little description of how content complexity, sequencing, or reinforcement were structured. While interactive and personalized elements were sometimes present (e.g., adaptive checklists, feedback loops, goal

	Knowledge Outcomes	Behaviour, Attitude, and Self-Efficacy Outcomes	Physiological Outcomes	Healthcare Utilization Outcomes	Mental Health Outcomes	Quality of Life Outcomes	Physical Function and Activity Outcomes	Total number of times each category is represented in RCTs with positive effect
1.1.2 Transmit targeted health information to person(s) based on health status or demographics	2	4	5	4	4	3	5	**27**
1.1.3 Transmit targeted alerts and reminders to person(s)	2	4	3	1	2	3	4	**19**
1.1.4 Transmit diagnostics result, or availability of result, to person(s)	1							**1**
1.3.1 Peer group for individuals		1	1			1	2	**5**
1.4.1 Access by the individual to own medical or summary health records				1	1	1	1	**4**
1.4.2 Self-monitoring of health or diagnostic data by the individual	1	2	3	2	3	2	2	**15**
1.4.3 Active data capture/documentation by an individual		3	2	2	1	3	3	**14**
1.5.1 Reporting of health system feedback by persons								**0**
1.6.2 Simulated human-like conversations with individuals								**0**
Add-on: Actual communication (phone, video, messaging) with healthcare provider	2	4	2	2	2	1	4	**17**

Figure 2. Heat map of intervention classifications and outcome categories in RCTs reporting a positive effect.

	Knowledge Outcomes	Behaviour, Attitude, and Self-Efficacy Outcomes	Physiological Outcomes	Healthcare Utilization Outcomes	Mental Health Outcomes	Quality of Life Outcomes	Physical Function and Activity Outcomes	Total number of times each category is represented in quasi-experimental studies with positive effect
1.1.2 Transmit targeted health information to person(s) based on health status or demographics	5	7	4	2	3	3	4	28
1.1.3 Transmit targeted alerts and reminders to person(s)	3	5	2	1	1	2	3	17
1.1.4 Transmit diagnostics result, or availability of result, to person(s)								0
1.3.1 Peer group for individuals								0
1.4.1 Access by the individual to own medical or summary health records								0
1.4.2 Self-monitoring of health or diagnostic data by the individual	1	1	4	1	1		2	10
1.4.3 Active data capture/documentation by an individual	2	4	3	2		1	3	15
1.5.1 Reporting of health system feedback by persons								0
1.6.2 Simulated human-like conversations with individuals								0
Add-on: Actual communication (phone, video, messaging) with healthcare provider	5	5	1	1	1	3	3	19

Figure 3. Heat map of intervention classifications and outcome categories in quasi-experimental studies reporting a positive effect.

setting), these were not contained within any explicit instructional model or adult education principle. Learning outcomes were often equated with factual or procedural knowledge, adherence, or self-reported confidence, rather than validated instruments grounded in educational theory.

The findings of this review may have varied implications for different audiences. Existing literature suggests that there are opposing needs and perspectives of patients and providers regarding digital education tools, which may influence how the review findings are interpreted.[72] For example, healthcare professionals often view digital education interventions as a complement to traditional methods of health education rather than a replacement.[73] Healthcare professionals view hybrid models of patient education, utilizing both digital and in-person methods, as an ideal way to facilitate health education.[73] Many included studies reported delivering digital education interventions in addition to "usual care", but it is unclear the impact of these interventions independently. Additionally, many studies did not report which members of the healthcare team delivered and facilitated the digital education interventions for patients; however, nurses were the most common healthcare providers identified. Despite most often being administered by nursing staff, implications for nursing practice were seldom discussed.

From a patient perspective, health and digital literacy are pertinent barriers to uptake of digital education interventions.[72,74,75] For patients with barriered access to health care due to sociodemographic factors, digital education provides a more accessible means of health support and education. However, patients lacking the necessary digital and health literacy to effectively engage in these interventions are also at a disadvantage. This is reflected in our findings, as patients who were not capable of independently utilizing digital education interventions were sometimes deemed ineligible for participation. Exploring the impact of digital education interventions on individuals with diverse sociodemographic circumstances (education level, geographic location, age, income, etc.) is necessary to draw conclusions about the universal benefit of digital education interventions.

There were few signals from the data that indicated patients or end-users were actively engaged in the design or the evaluation of interventions through processes such as co-production or co-design. Co-design is an iterative process, where people (i.e., researchers, clinicians, patient-partners and/or end-users) come together to discuss health-related issues and design solutions.[76] Co-designed interventions improve their relevance, usability, and acceptability,[77] therefore optimizing healthcare outcomes such as patient satisfaction and knowledge.[78,79] In the future, more work must be done to involve patients and end-users as active partners in the design and evaluation of interventions, instead of passive recipients.[80] This will ensure that patients receive the care they want and need.

Strengths and limitations

This patient-commissioned mixed methods systematic review followed JBI methodology and was additionally strengthened by the involvement of patient partners and knowledge users. Involving knowledge users in research has become integral in knowledge translation projects.[81] Recently, recommendations on involving knowledge users in systematic reviews have become normalized.[82] Involving knowledge users within systematic review processes can improve the relevance, usefulness, and impact of a systematic review.[83–86]

As discussed, initial plans to conduct a meta-analysis as a component of this review were hindered by variability across included studies, which makes it difficult to draw broad conclusions from the literature. However, this illustrates where there is room for improvement in the design and evaluation of digital education interventions.

Conclusion

Overall, the digital education interventions for patients undergoing cardiac procedures assessed in this systematic review tended to have a

positive effect on a wide range of patient-level and health system-level outcomes. However, drawing conclusions across studies was difficult due to wide variability, which may have been exacerbated by a lack of standardized principles of educational design and evaluation of interventions. Future tool developers should consider using an educational framework to design and evaluate digital interventions, including pedagogy, learning outcomes, and rationale for content and strategy selection. Additionally, engaging cardiac patients and knowledge users as co-designers has the potential to increase relevance, acceptability, and uptake of these tools.

List of Abbreviations

ADL = activities of daily living
CABG = coronary artery bypass graft
CABS = coronary artery bypass surgery
MOS SF-36 = Medical Outcomes Study Short Form-36
PCI = percutaneous coronary intervention
PRESS = Peer Review of Electronic Search Strategies
PRISMA = Preferred Reporting Items for Systematic reviews and Meta-Analyses
RCT = randomized controlled trial
SPOR = Strategy for Patient-Oriented Research
TAVR = transcatheter aortic valve replacement
WHO = World Health Organization

Data statement

All relevant data for this systematic review are included in the manuscript and supplementary files.

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Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Janet A. Curran reports financial support was provided by SPOR Evidence Alliance. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Supplementary materials

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