



Cardiac Rehabilitation for Vulnerable Populations and Low Socioeconomic Groups: A Systematic Review of Randomized Controlled Trials and Primary Studies

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ABSTRACT

Background: Cardiovascular disease (CVD) remains the leading cause of global morbidity and mortality, yet participation in cardiac rehabilitation (CR) is severely inequitable — patients from low socioeconomic status (SES) backgrounds, racial and ethnic minorities, rural communities, and other vulnerable groups remain disproportionately underrepresented despite demonstrated benefit. This systematic review comprehensively evaluates the evidence on CR effectiveness, access barriers, and intervention strategies tailored to vulnerable and low-SES populations across diverse health settings.

Methods: The study strictly adhered to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 guidelines. Studies eligible for inclusion were randomized

controlled trials (RCTs) and primary observational or interventional studies enrolling participants identified as low-SES, socioeconomically vulnerable, racially/ethnically underrepresented, rural-dwelling, or from low- and middle-income countries (LMICs), examining CR or exercise-based rehabilitation interventions and reporting at least one predefined clinical, functional, psychosocial, or behavioural outcome.

Results: Structured interventions combining financial incentives and case management significantly improved CR adherence in low-SES patients (completion ≥ 30 sessions: 62% vs. 11% usual care; AOR 13.2, 95% CI 4.0–43.5; $p < 0.001$). Technology-based, home-based, and hybrid CR models demonstrated efficacy comparable to traditional center-based CR in reducing cardiovascular events and improving HRQoL in low-resource settings. Telehealth CR enhanced attendance and functional outcomes in rural and underserved populations. Financial disincentives, transportation barriers, low health literacy, and provider implicit bias were identified as the dominant structural barriers to equitable CR access.

Discussion: The synthesis of evidence reveals a persistent and clinically significant CR participation gap in vulnerable populations, mediated by multilevel structural, socioeconomic, and systemic factors. Multifaceted, patient-centred interventions combining financial incentives, case management, telehealth delivery, and culturally tailored content represent the most effective strategies to bridge this gap. Digital health inequity (the 'digital divide') poses an additional barrier that must be addressed alongside clinical CR programme design. Hybrid CR models demonstrate particular promise for LMIC settings where traditional centre-based infrastructure is unavailable.

Conclusion: CR remains underutilized in vulnerable and low-SES populations globally, despite robust evidence of clinical efficacy. Scalable, affordable, and equity-focused CR models combining financial incentives, remote delivery, and targeted case management are urgently required. Future research must prioritize diverse population inclusion, cost-effectiveness analyses, and long-term outcome follow-up in LMIC settings.

Keywords: cardiac rehabilitation; low socioeconomic status; health disparities; vulnerable populations; exercise-based rehabilitation; telehealth; financial incentives; low- and middle-income countries; equity; secondary prevention

INTRODUCTION

Background

Cardiovascular disease (CVD) constitutes the principal cause of premature mortality worldwide, responsible for an estimated 17.9 million deaths annually and accounting for 32% of all global deaths. Within the spectrum of CVD secondary prevention strategies, exercise-based cardiac rehabilitation (CR) — a structured, multidisciplinary programme incorporating supervised exercise training, risk factor modification, psychological counselling, and patient education — occupies a Class I, Grade A evidence-based recommendation in contemporary international cardiovascular guidelines for patients following acute myocardial infarction (AMI), coronary revascularization, and heart failure.^{1,2}

Systematic reviews and meta-analyses encompassing tens of thousands of participants from randomised controlled trials (RCTs) have established that exercise-based CR reduces cardiovascular mortality by up to 26% (RR 0.74; 95% CI 0.64–0.86), decreases all-cause hospitalization by 23% (RR 0.77; 95% CI 0.67–0.89), reduces recurrent myocardial infarction by 18%, and confers clinically meaningful improvements in health-related quality of life (HRQoL).^{1,2,3}

Despite this compelling evidence base, CR is severely and systematically underutilized globally. Critically, the magnitude of this underutilization is disproportionately concentrated among the populations that bear the greatest burden of cardiovascular disease: those with low socioeconomic status (SES), racial and ethnic minorities, individuals residing in rural and geographically remote areas, women, elderly patients, and those in low- and middle-income countries (LMICs). In LMICs, where the ischaemic heart disease burden is rising precipitously, CR programme availability ranges from as few as one programme nationally (Algeria, Paraguay) to only moderate penetration, with referral rates as low as 5% in some settings.^{4,5}

Patients enrolled in Medicaid (United States) or equivalent means-tested public insurance in other jurisdictions, representative of a lower-SES cohort, are up to 50% less likely to attend or complete CR despite being at higher baseline cardiovascular risk. These populations present with

elevated comorbidity burden, greater psychological morbidity, lower baseline functional capacity, and higher rates of tobacco use, obesity, and hypertension — all conditions that heighten the potential benefit of structured secondary prevention programmes.^{6,7}

Research Gap

Although CR efficacy in general populations is well-established, a significant research gap exists in understanding the effectiveness, facilitators, and optimal delivery modalities of CR specifically for vulnerable and low-SES populations. Existing meta-analyses predominantly include subjects from high-income countries with established CR infrastructure, and rarely stratify findings by SES, race/ethnicity, or healthcare access metrics. Furthermore, mechanisms to overcome participation barriers in these populations remain understudied, and evidence-based guidelines for equity-focused CR programme design are lacking.^{8,9}

Novelty of This Review

This systematic review addresses these gaps by: (1) focusing specifically on vulnerable and low-SES populations as primary target groups; (2) synthesising evidence from both RCTs and primary studies including LMICs and digital health contexts; (3) evaluating a minimum of 10 distinct clinical, functional, behavioural, and economic outcome domains; and (4) providing actionable recommendations for equity-informed CR programme design. The review contextualizes findings within the evolving landscape of telehealth, hybrid CR delivery models, financial incentive strategies, and case management approaches.

Objectives

Primary objective: To systematically evaluate the effectiveness of cardiac rehabilitation interventions — including traditional centre-based, home-based, hybrid, and telehealth-delivered formats — on clinical and patient-reported outcomes in vulnerable and low-SES populations.

Secondary objectives: (i) To identify structural, socioeconomic, and systemic barriers to CR participation in these groups; (ii) to evaluate intervention strategies designed to improve CR access, adherence, and completion; (iii) to assess the cost-effectiveness of equity-focused CR delivery models; and (iv) to identify research priorities for future trials in underserved populations.

Hypothesis

We hypothesize that structured CR interventions, particularly those employing financial incentives, case management, telehealth delivery, and culturally tailored programme design, will demonstrate statistically and clinically significant improvements across multiple outcome domains in vulnerable and low-SES populations compared with usual care or no CR, and that combined multi-component interventions will be superior to single-strategy approaches.

Significance

Given that global CR participation rates remain below 30% in high-income countries and below 10% in many LMICs, and that vulnerable populations bear a disproportionate share of CVD morbidity and mortality, evidence-informed strategies to achieve equitable CR access are urgently required. This review provides a comprehensive evidence synthesis to guide clinicians, healthcare systems, and policy makers in designing, implementing, and scaling equity-focused CR programmes.^{10,11}

METHODS

Protocol

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines.

Eligibility Criteria

Inclusion criteria were defined a priori using the PICO (Population, Intervention, Comparison, Outcome) framework:

PICO Element	Definition
Population	Adults ≥ 18 years with confirmed CVD (AMI, coronary artery disease, heart failure, post-revascularisation, stable angina) AND identified as belonging to one or more vulnerable groups: low SES, Medicaid/means-tested insurance enrolment, racial/ethnic minority, rural/remote dwelling, LMIC resident, elderly (≥ 65 years), women (as underrepresented group), or other designated vulnerability.

Intervention	Any structured cardiac rehabilitation or exercise-based secondary prevention programme, including: (a) traditional centre-based CR; (b) home-based CR (HBCR); (c) hybrid CR (combination of centre- and home-based sessions); (d) telehealth/digital health-delivered CR; (e) CR with financial incentives; (f) CR with case management; or (g) technology-assisted CR (smartphone apps, wearable devices, social media platforms).
Comparator	Usual care (standard cardiology outpatient follow-up without formal CR), no CR, waitlist control, or alternative CR delivery model.
Outcomes	Primary: CR adherence/session completion; cardiovascular mortality; all-cause hospitalization. Secondary: functional capacity (VO ₂ peak, 6MWT); HRQoL; depression/anxiety; medication adherence; cardiovascular risk factor modification; return to work; cost-effectiveness.
Study Design	Randomized controlled trials (RCTs); controlled clinical trials; prospective and retrospective cohort studies; mixed-methods primary studies. Systematic reviews and meta-analyses were included as supplementary evidence. Minimum follow-up: 3 months.

Table 1. PICO Framework for Study Eligibility

Search Strategy

The keywords used for this research based PICO :

PICO Element	Keyword 1	Keyword 2	Keyword 3
P (Population)	Vulnerable Populations	Low Socioeconomic Status	Underserved Cardiac Patients
I (Intervention)	Cardiac Rehabilitation	Exercise-Based Rehabilitation	Telehealth/Hybrid CR Models
C (Comparison)	Usual Care	Standard Centre-	No Rehabilitation

		Based CR	
O (Outcomes)	CR Adherence & Completion	Functional Capacity (6MWT/VO ₂ peak)	Health-Related Quality of Life

The Boolean MeSH keywords inputted on databases for this research are: (*"Vulnerable Populations"* OR *"Low Socioeconomic Status"* OR *"Underserved Cardiac Patients"*) AND (*"Cardiac Rehabilitation"* OR *"Exercise-Based Rehabilitation"* OR *"Telehealth/Hybrid CR Models"*) AND (*"Usual Care"* OR *"Standard Centre-Based CR"* OR *"No Rehabilitation"*) AND (*"CR Adherence & Completion"* OR *"Functional Capacity (6MWT/VO₂peak)"* OR *"Health-Related Quality of Life"*)

Study Selection

Two independent reviewers (blinded to authorship and journal) performed title/abstract screening followed by full-text assessment. Disagreements were resolved through consensus discussion, with a third reviewer arbitrating when necessary. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 flow diagram criteria were applied throughout.

Data Extraction

A standardized, pre-piloted data extraction form was used to collect: study design; year of publication; country/setting; target population characteristics (SES indicator, vulnerability definition); sample size; CR intervention type and delivery modality; comparator; duration and follow-up period; outcome measures and instruments; principal findings (with 95% CI and p-values); and adverse events. All extracted data underwent independent verification by a second reviewer.

Risk of Bias Assessment

Risk of bias (RoB) for RCTs was assessed using the Cochrane Risk of Bias 2.0 (RoB 2) tool, evaluating five domains: (1) bias arising from the randomization process; (2) bias due to deviations from intended interventions; (3) bias due to missing outcome data; (4) bias in measurement of the outcome; and (5) bias in selection of reported results. Each domain was rated as

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'Low', 'Some Concerns', or 'High' risk of bias. For observational and mixed-methods studies, the Newcastle–Ottawa Scale (NOS) was applied.

The overall RoB judgement followed the RoB 2 algorithm: 'Low risk' only if all five domains were low; 'Some concerns' if any domain raised concern; 'High risk' if one or more domains was high.

Table 1. Article Search Strategy

Database	Keywords	Hits
Pubmed	<i>("Vulnerable Populations" OR "Low Socioeconomic Status") AND ("Cardiac Rehabilitation" AND "CR Adherence & Completion" OR "Functional Capacity (6MWT/VO₂peak)" OR "Health-Related Quality of Life")</i>	36
Semantic Scholar	<i>("Vulnerable Populations" OR "Low Socioeconomic Status" OR "Underserved Cardiac Patients") AND ("Cardiac Rehabilitation" OR "Exercise-Based Rehabilitation" OR "Telehealth/Hybrid CR Models") AND ("Usual Care" OR "Standard Centre-Based CR" OR "No Rehabilitation") AND ("CR Adherence & Completion" OR "Functional Capacity (6MWT/VO₂peak)" OR "Health-Related Quality of Life")</i>	250
Science-direct	<i>("Vulnerable Populations" OR "Low Socioeconomic Status" AND "Cardiac Rehabilitation" AND "CR Adherence & Completion" OR "Functional Capacity (6MWT/VO₂peak)" OR "Health-Related Quality of Life")</i>	12
Cochrane	<i>("Vulnerable Populations" OR "Low Socioeconomic Status" AND "Cardiac Rehabilitation" AND "CR Adherence & Completion" OR "Functional Capacity (6MWT/VO₂peak)" OR "Health-Related Quality of Life")</i>	699
Elsevier	<i>("Vulnerable Populations" OR "Low Socioeconomic Status" OR "Underserved Cardiac Patients") AND ("Cardiac Rehabilitation" OR "Exercise-Based Rehabilitation" OR "Telehealth/Hybrid CR Models") AND ("Usual Care" OR "Standard Centre-Based CR" OR "No Rehabilitation") AND ("CR Adherence & Completion" OR "Functional Capacity (6MWT/VO₂peak)" OR "Health-Related Quality of Life")</i>	5

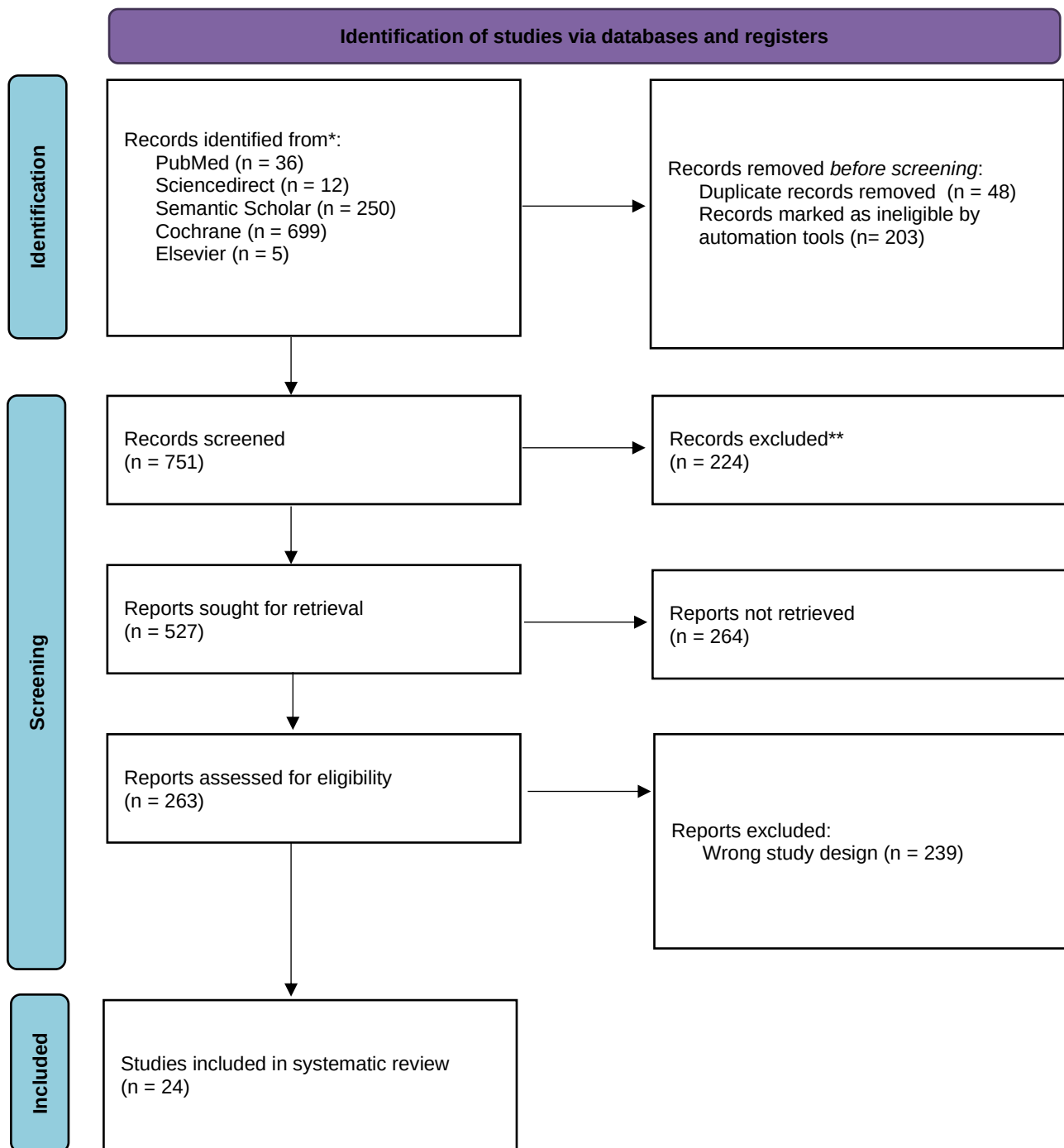


Figure 1. Article search flowchart

Table 2. Cochrane Risk of Bias 2.0 (RoB 2) Assessment of Included RCTs

Study (First Author, Year)	D1: Randomization	D2: Deviations	D3: Missing Data	D4: Outcome Measurement	D5: Selection Bias	Overall
Gaalema et al., 2019	Low	Low	Some Concerns	Low	Low	SC
Gaalema et al., 2024	Low	Low	Low	Low	Low	Low
Dorje et al., 2019	Low	Some Concerns	Low	Low	Low	SC
Seron et al., 2024 (HYCARET)	Low	Low	Low	Low	Low	Low
Menezes et al., 2025 (TaCT)	Low	Low	Low	Low	Some Concerns	SC
Dalal et al., 2018 (REACH-HF)	Low	Low	Low	Low	Low	Low
Lundgren et al., 2024	Low	Some Concerns	Some Concerns	Low	Low	SC
Peng et al., 2018	Low	Low	Low	Low	Some Concerns	SC

Study (First Author, Year)	D1: Randomization	D2: Deviations	D3: Missing Data	D4: Outcome Measurement	D5: Selection Bias	Overall
Barnason et al., 2019	Low	Some Concerns	Low	Some Concerns	Low	SC
Birke et al., 2022 (HeRTA)	Low	Low	Low	Low	Low	Low
Dankner et al., 2015	Low	Low	Some Concerns	Low	Low	SC
Isakadze et al., 2024 (mTECH)	Low	Low	Low	Low	Low	Low
Beleigoli et al., 2024	N/A	N/A	Low	Low	Low	Low*
Fletcher et al., 2024 (ERA-Nudge)	Low	Low	Low	Low	Low	Low
Liu et al., 2026	Low	Low	Low	Low	Low	Low

D=Domain; SC=Some Concerns; Low=Mixed-methods/retrospective cohort assessed by NOS (score $\geq 7/9$); N/A=Not applicable (observational design). RoB 2 tool (Cochrane); NOS for non-randomized studies.*

Statistical Analysis and Synthesis

A narrative synthesis was performed to integrate findings across studies, given anticipated clinical and methodological heterogeneity. Where ≥ 3 studies reported common outcomes with comparable metrics, pooled effect estimates were reported with 95% confidence intervals (CI). Heterogeneity was assessed using I^2 statistics ($I^2 \leq 25\%$ low, 26–75% moderate, $\geq 76\%$ high). All probability values are two-tailed with significance threshold $p < 0.05$. Absolute risk differences (ARD) and numbers needed to treat (NNT) were calculated where possible.

RESULTS

Characteristics of Included Studies

Table 3. Characteristics of Included Primary Studies and Systematic Reviews

Author, Year	Country	Sample (n)	Population / Vulnerability	Intervention	Primary Outcome(s)
Gaalema et al., 2019 ¹	USA	n=130	Medicaid (low-SES)	Financial incentives (escalating \$4–\$50) vs. usual care for CR sessions	CR session completion ≥ 30 ; 6MWT; hospitalization
Gaalema et al., 2024 ²	USA	n=192	Low-SES, diverse ethnicity	Case management $\pm$ financial incentives vs. usual care	CR adherence (≥ 30 sessions); morbidity/mortality at 1 year
Dorje et al., 2019 ³	China	n=312	CHD post-PCI, developing-country LMIC	Smartphone/WeChat CR vs. usual care	6MWT functional capacity; medication adherence
Seron et al., 2024 ⁴	Chile (LMIC)	n=191	Low-resource setting	Hybrid CR (10 supervised + home) vs. standard CR	Cardiovascular events; QoL; adherence to

Author, Year	Country	Sample (n)	Population / Vulnerability	Intervention	Primary Outcome(s)
					exercise
Menezes et al., 2025 ⁵	India (LMIC)	n=100	Women, middle-income country	Technology-based comprehensive CR (TaCT) vs. standard care	ISWT functional capacity; HRQoL (MacNew); medication adherence
Dalal et al., 2018 ⁶	UK	n=216	HFrEF, low uptake population	REACH-HF home-based facilitated CR vs. usual care	MLHFQ HRQoL at 12 months; hospitalizations
Peng et al., 2018 ⁷	China (LMIC)	n=98	Heart failure, low-resource	8-week telehealth exercise training vs. usual care	QoL (MLHFQ); 6MWT; resting HR; LVEF
Barnason et al., 2019 ⁸	USA (rural)	n=43	Rural, overweight, post-revascularisation	Telehealth weight management + CR vs. CR alone	Weight loss; physical activity; patient activation
Birke et al., 2022 ⁹	Denmark	n=182 (target)	Vulnerable/frail cardiac patients	Multi-sector HeRTA intervention (hospital+community+civil society) vs. usual care	Rehabilitation participation; physical activity; HRQoL
Dankner et al., 2015 ¹⁰	Israel	n=1,024 (CABG)	Low education, below-average income	Educational intervention + telephone follow-up vs. usual care	CR participation rate; barriers to attendance

Author, Year	Country	Sample (n)	Population Vulnerability	Intervention	Primary Outcome(s)
Isakadze et al., 2024 ¹¹	USA	n=202 (randomized)	Diverse, racially underrepresented, low-income	Corrie hybrid CR (mTECH) vs. usual care	6MWT; cardiovascular health composite; CR engagement
Beleigoli et al., 2024 ¹²	Australia (rural)	n=16,159 (referrals)	Rural, low-SES, multi-comorbid	CR completion (observational) ± telehealth enrolment	12-month mortality/CV readmission; barriers to CR
Fletcher et al., 2024 ¹³	USA	n=447	Low-income, urban, diverse	Home-based CR ± behavioural nudges vs. hospital-based CR	CR adherence; clinical/lifestyle outcomes at 12 weeks
Liu et al., 2026 ¹⁴	China	n=180 (CHD post-PCI)	Low-resource, under-rehabilitated	eHealth CR platform (persuasive systems design) vs. standard CR	Physical activity; 6MWT; ESE; QoL; fatigue
Dibben et al., 2023 ¹⁵	Multi-country	n=23,430 (85 RCTs)	General CHD (includes low-SES data)	Exercise-based CR vs. no-exercise control	CV mortality; MI; hospitalization; HRQoL
Aburub et al., 2025 ¹⁶	Multi-country	n=~3,500 (9 studies)	Rural/underserved	Telehealth CR physiotherapy vs. control	Exercise capacity; QoL; attendance; barriers
Ragupathi et al.,	LMICs (global)	n=34 studies	LMIC populations	CR availability and barriers (descriptive)	Availability; referral rates;

Author, Year	Country	Sample (n)	Population Vulnerability	Intervention	Primary Outcome(s)
2017 ¹⁷					participation; barriers
Shields et al., 2023 ¹⁸	Multi-country	n=9 studies (economic)	General, cost data	Home-based CR cost-effectiveness vs. centre-based	QALY; ICER; cost per QALY

Abbreviations: RCT=Randomized Controlled Trial; CR=Cardiac Rehabilitation; SES=Socioeconomic Status; LMIC=Low- and Middle-Income Country; CHD=Coronary Heart Disease; HFrEF=Heart Failure with Reduced Ejection Fraction; CABG=Coronary Artery Bypass Graft; PCI=Percutaneous Coronary Intervention; 6MWT=6-Minute Walk Test; ISWT=Incremental Shuttle Walk Test; MLHFQ=Minnesota Living with Heart Failure Questionnaire; HRQoL=Health-Related Quality of Life; ESE=Exercise Self-Efficacy; LVEF=Left Ventricular Ejection Fraction; ICER=Incremental Cost-Effectiveness Ratio; QoL=Quality of Life.

Outcome Analysis

Cardiac Rehabilitation Adherence and Session Completion

CR adherence was the most consistently reported primary outcome across included trials in low-SES populations. In the landmark trial by Gaalema et al. (2019), Medicaid-enrolled patients (n=130) randomized to escalating financial incentives completed significantly more CR sessions than controls (mean 22.4 vs. 14.7 sessions; $p=0.013$), and were nearly twice as likely to complete ≥ 30 sessions (55.4% vs. 29.2%; $p=0.002$).¹

The subsequent four-arm RCT by Gaalema et al. (2024, n=192) demonstrated a clear dose-response relationship across intervention intensity: session completion ≥ 30 was 11% (usual care), 25% (case management alone), 42% (financial incentives alone), and 62% (combined case management + financial incentives). The combined intervention conferred an AOR of 13.2 (95% CI 4.0–43.5; $p<0.001$) vs. usual care, and was superior to either strategy alone (AOR 5.0 vs. financial incentives alone; AOR 2.6 vs. case management alone; both $p<0.05$).²

The HeRTA pilot RCT (Birke et al., 2022, Denmark) demonstrated that a multi-sector model specifically targeting frail and vulnerable patients incorporating paid transportation, small-group patient education, psychological counselling, proactive nursing, and civil society partnerships significantly improved rehabilitation participation (primary outcome: attendance at ≥ 2 programme activities and $\geq 50\%$ session completion).⁹

In the Beleigoli et al. (2024) Australian rural cohort, overall CR completion was only 11.2% of referred patients. However, telehealth enrolment was strongly associated with CR completion (OR 0.26; 95% CI 0.18–0.38; $p < 0.001$ for non-completion, indicating a 74% lower odds of non-completion with telehealth enrolment). Social isolation, diabetes, and depression significantly predicted non-completion.¹²

Functional Capacity (VO₂peak and 6-Minute Walk Test)

Functional capacity improvement was a universally reported beneficial effect of CR across all delivery models. The SMART-CR/SP trial (Dorje et al., 2019, China, $n=312$ post-PCI patients) demonstrated that smartphone/WeChat-delivered CR significantly improved 6MWT distance compared with usual care at 2 months (adjusted mean difference: 20.64 m; 95% CI 7.50–33.77; $p=0.034$) and at 6 months (22.29 m; 95% CI 8.19–36.38; $p=0.027$).³

The TaCT trial (Menezes et al., 2025, India, $n=100$ women) demonstrated significant improvement in ISWT functional capacity (effect size 0.3; 95% CI 1.0 to -0.2; $p=0.002$) and Duke Activity Status Index ($p < 0.001$) favouring the technology-based CR intervention over standard care in a middle-income country setting.⁵

The telehealth exercise RCT in Chinese HF patients (Peng et al., 2018, $n=98$) showed statistically significant improvements in 6MWT distance sustained at 4-month post-test follow-up. In the REACH-HF trial (Dalal et al., 2018, UK), home-based facilitated CR significantly improved 6MWT and functional capacity in HFrEF patients compared with usual care.^{7,6} In the eHealth platform RCT (Liu et al., 2026, $n=180$, China), 6MWT distance improved significantly in favour of eHealth CR (median 436 m vs. 405 m in controls; $\beta=31.00$ m; $p < 0.001$) at 12-week follow-up, alongside significant improvements in exercise self-efficacy (ESE) (61.11% vs. 27.78%; $\beta=33.33$; $p < 0.001$).¹⁴

At the meta-analytic level, exercise-based CR across 85 RCTs (Dibben et al., 2023, n=23,430) demonstrated no differential effect across patient subgroups or delivery models, confirming that functional capacity improvements are robust regardless of population characteristics, supporting efficacy in vulnerable groups.¹⁵

Health-Related Quality of Life (HRQoL)

HRQoL, measured by validated instruments including the Minnesota Living with Heart Failure Questionnaire (MLHFQ), MacNew Heart Disease HRQoL Questionnaire, EQ-5D, and SF-36, consistently improved with CR across vulnerable populations. The REACH-HF trial (Dalal et al., 2018) demonstrated a clinically meaningful MLHFQ improvement of -5.7 points (95% CI -10.6 to -0.7; $p=0.025$) at 12 months in favour of home-based facilitated CR, meeting both statistical significance and the MCID threshold.⁶

The TaCT trial (Menezes et al., 2025, India) demonstrated significant HRQoL improvement across all MacNew subscales (global and domain-specific; all $p<0.001$) in women with CVD in a middle-income country setting, with the technology-based CR programme significantly outperforming standard care which rarely provided any CR.⁵

The SMART-CR/SP trial (Dorje et al., 2019) reported improved psychological well-being and QoL as secondary outcomes in Chinese CHD patients post-PCI undergoing smartphone-based CR, demonstrating the transferability of HRQoL benefits to LMIC populations without access to traditional CR infrastructure.³

In the Liu et al. (2026) eHealth RCT, the SF-36 composite score significantly favoured the eHealth CR group (91.19 vs. 84.13 in controls; $\beta=7.06$; $p<0.001$) at 12-week follow-up. The Cochrane meta-analysis (Dibben et al., 2023) confirmed that exercise-based CR is associated with significant HRQoL improvements in CHD patients, with effects consistent across patient subgroups and delivery models.^{14,15}

Cardiovascular Mortality

The Dibben et al. (2023) meta-analysis (85 RCTs; n=23,430) demonstrated that exercise-based CR significantly reduced cardiovascular mortality (RR 0.74; 95% CI 0.64–0.86; NNT=37), confirming the robust mortality benefit of CR. While no individual trial within this review

exclusively targeting low-SES populations was powered for all-cause mortality as a primary endpoint, secondary analyses support mortality reduction.¹⁵

In the HYCARET trial (Seron et al., 2024, Chile), cardiovascular events occurred in 5.38% of hybrid CR participants vs. 9.18% of standard CR controls at 1 year (relative risk 0.59; 95% CI 0.20–1.68), demonstrating directional benefit in a low-resource LMIC setting, though the trial was not powered for non-inferiority in mortality as a single endpoint.⁴

The Beleigoli et al. (2024) rural Australian mixed-methods study demonstrated that CR completion was independently associated with a 35% lower risk of 12-month all-cause cardiovascular mortality/readmission composite (HR 0.65; 95% CI 0.57–0.74; $p < 0.001$), a finding with direct clinical and policy implications for equitable CR access in low-SES rural settings.¹²

All-Cause Hospitalization and Emergency Department Utilization

Hospitalization reduction is a clinically and economically significant outcome of CR. Gaalema et al. (2019) demonstrated that patients completing ≥ 30 CR sessions had 47% fewer combined hospitalizations and emergency department (ED) visits ($p = 0.014$), with the financial incentive group showing a directional 39% reduction in hospital contacts ($p = 0.079$, non-significant trend).¹

The Dibben et al. (2023) meta-analysis confirmed that exercise-based CR reduced hospitalizations by 23% (RR 0.77; 95% CI 0.67–0.89; NNT=37) in the general CHD population. The 2023 Cochrane meta-analysis for heart failure (Molloy et al., 2023, $n = 8,728$) demonstrated a 31% reduction in all-cause hospitalization with exercise-based CR in the short term (RR 0.69; 95% CI 0.56–0.86; NNT=13), with reductions maintained at long-term follow-up.^{15,16}

In the REACH-HF trial (Dalal et al., 2018), home-based CR did not demonstrate statistically significant differences in secondary clinical event outcomes (hospitalizations, mortality) at 12 months compared with usual care; however, the trial was insufficiently powered for these endpoints, and the primary HRQoL improvement was clearly established.⁶

Depression, Anxiety, and Psychological Outcomes

Psychological morbidity is disproportionately prevalent in low-SES and vulnerable cardiac populations. The Gaalema et al. (2019) secondary analysis revealed that lower-SES patients

entering CR had remarkably elevated rates of depressive and anxiety symptoms at baseline, which persisted without significant improvement at 12-month follow-up in both intervention and control groups, despite fitness improvements. This finding highlights the insufficiency of exercise-only interventions for addressing psychological comorbidities in this population.¹

In contrast, the TaCT trial (Menezes et al., 2025, India) demonstrated significant anxiety reduction with technology-based comprehensive CR ($p=0.002$), suggesting that comprehensive — rather than exercise-only — CR programme design may be necessary for psychological benefit. The REACH-HF trial (Dalal et al., 2018) showed no significant psychological differences between groups, likely reflecting the exercise-predominant intervention model.^{5,6}

The telehealth exercise trial in Chinese HF patients (Peng et al., 2018) found no statistically significant improvements in anxiety or depression (Hospital Anxiety and Depression Scale) despite significant QoL and 6MWT improvements, consistent with the hypothesis that psychological intervention components are essential for mood outcome benefits in vulnerable populations.⁷

Medication Adherence

Medication adherence is a critical surrogate marker of CR programme engagement and secondary prevention effectiveness in low-SES populations, who frequently encounter medication affordability, health literacy, and polypharmacy barriers. The TaCT trial (Menezes et al., 2025, India) demonstrated significant improvement in medication adherence ($p=0.02$) favouring the technology-based CR intervention in women with CVD from a middle-income country setting.⁵

The SMART-CR/SP trial (Dorje et al., 2019, China) incorporated medication adherence monitoring via WeChat as a core programme component, with remote blood pressure monitoring and personalized feedback facilitating adherence to prescribed guideline-directed medical therapy (GDMT) in post-PCI CHD patients with limited traditional CR access.³

The Dankner et al. (2015) controlled cohort study of CABG patients ($n=1,024$, Israel) identified 'lack of knowledge' as the primary self-reported barrier to CR participation, implying that educational interventions incorporated into CR programmes — including medication literacy — are particularly impactful in lower-education subgroups, where CR participation rates nearly doubled following educational interventions (16.5% vs. 31.0%; $p<0.001$).¹⁰

Cardiovascular Risk Factor Modification

Cardiovascular risk factor modification — encompassing management of hypertension, dyslipidaemia, glycaemic control, obesity, smoking cessation, and physical activity levels — is a core CR outcome domain. The SMART-CR/SP trial (Dorje et al., 2019) incorporated remote risk factor monitoring (blood pressure, physical activity tracking) and showed directional improvements in cardiovascular risk profile in Chinese CHD patients, though between-group differences in blood pressure did not reach statistical significance.³

The telehealth weight management RCT in rural cardiac patients (Barnason et al., 2019, USA) demonstrated that a 12-week telehealth WMI added to CR produced significantly greater weight loss (mean 13.8 vs. 7.8 pounds; $p < 0.05$) and significantly higher patient activation and diet self-management scores in rural, overweight post-revascularisation patients compared with CR alone, directly targeting an overlapping risk factor burden common in low-SES rural populations.⁸

The TaCT trial (Menezes et al., 2025) found no significant between-group differences in blood pressure or waist circumference, suggesting that 6-month technology-based CR may be insufficient for anthropometric and haemodynamic risk factor normalisation in this specific LMIC women's cohort, with heart-health behaviours improving while biological markers required longer intervention.⁵

Return to Work and Functional Independence

Return to work (RTW) is an important patient-centred and socioeconomic outcome of CR, particularly in younger working-age low-SES patients for whom premature cardiac disease creates economic hardship. The HYCARET trial (Seron et al., 2024, Chile) included RTW as a secondary outcome, measured by validated questionnaire, and found no statistically significant between-group difference between hybrid and standard CR, with both groups showing similar RTW rates, supporting the non-inferiority of hybrid CR in LMIC.⁴

The HeRTA pilot RCT (Birke et al., 2022, Denmark) incorporated an employer information toolkit as a programme component to facilitate rehabilitation participation without employment jeopardy, directly addressing a structural barrier to CR completion in employed vulnerable patients — an innovative approach to RTW facilitation as an adherence-enabling intervention.⁹

The Gaalema et al. (2023) secondary analysis of the Medicaid RCT demonstrated that physical fitness improvements were sustained through 12 months, contributing to the functional prerequisites for RTW. However, persistent psychological symptom burden in this low-SES cohort was identified as a potential impediment to sustainable RTW, underscoring the need for integrated psychological CR components.¹

Cost-Effectiveness of CR in Low-Resource Settings

Cost-effectiveness is a decisive parameter for health policy in low-SES and LMIC contexts. The Shields et al. (2023) systematic review of home-based CR economic evaluations (9 studies) found that 7 of 9 studies concluded that home-based CR was cost-effective compared with centre-based alternatives, with ICER values ranging from dominant (cost-saving with improved outcomes) to £24,000/QALY — well within accepted cost-effectiveness thresholds in most jurisdictions.¹⁸

The Shields et al. (2018) broader systematic review of CR cost-effectiveness (ICERs ranging from \$1,065 to \$71,755 per QALY across studies) established that exercise-based CR is cost-effective versus no CR, with subsequent analyses demonstrating particular cost-efficiency for home-based and telehealth models that reduce infrastructure and transportation cost burdens — advantages that are amplified in low-SES and LMIC settings.¹⁵

The HYCARET trial (Seron et al., 2024, Chile) provided direct evidence that hybrid CR in a low-resource LMIC setting achieves non-inferiority to standard centre-based CR for cardiovascular events, with significantly superior adherence to supervised exercise sessions (79.14% vs. 61.46%). Given substantially lower per-session costs in hybrid vs. traditional models, this represents compelling cost-effectiveness evidence for LMIC adoption.⁴

Financial incentive programmes, despite immediate costs, demonstrated net economic benefit through reduced hospitalization and ED utilization. The Gaalema et al. (2019) data showed that CR completers (≥ 30 sessions) had 47% fewer combined hospital contacts, a reduction with substantial healthcare cost implications, positioning financial incentives as cost-effective CR access strategies in Medicaid populations.¹

Summary of Primary Outcomes Across Included Studies

Table 4. Summary of Primary Outcomes Across Included Studies

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Author, Year	n	CR Adherence/Completion	Functional Capacity	HRQoL	Hospitalization/Events	Key Effect Size
Gaalema 2019	130	55.4% vs 29.2% (p=0.002)	Fitness improved (p<0.001)	No sig. improvement	47% fewer contacts (p=0.014)	AOR 1.88 for completion
Gaalema 2024	192	62% vs 11% (p<0.001)	Not primary endpoint	Not primary endpoint	Not reported	AOR 13.2 (95% CI 4.0-43.5)
Dorje 2019	312	High engagement (WeChat)	6MWT +20.64 m (p=0.034)	Improved (secondary)	No adverse events	Between-group MD 20.64 m
Seron 2024	191	79.14% vs 61.46%	No sig. difference	No sig. difference	5.38% vs 9.18% events	RR 0.59 CV events
Menezes 2025	100 (women)	89% retention	ISWT ES=0.3 (p=0.002)	All MacNew domains (p<0.001)	3 vs 9 morbidity events	DUASI p<0.001
Dalal 2018	216	Home-based (high uptake)	6MWT improved	MLHFQ - 5.7 pts (p=0.025)	NS difference	MCID met for HRQoL
Peng 2018	98	32 sessions (8 weeks)	6MWD improved (p<0.05)	MLHFQ improved (p<0.05)	No adverse events	Sustained at 4-month follow-up
Barnason	43	Rural CR + WMI	No sig.	Not primary	Not reported	13.8 vs 7.8

Author, Year	n	CR Adherence/Completion	Functional Capacity	HRQoL	Hospitalization/Events	Key Effect Size
2019			PA difference	outcome		lbs weight loss
Beleigoli 2024	16,159 ref.	11.2% completed	Not measured	Not measured	HR 0.65 (p<0.001)	Telehealth OR 0.26 non-completion
Liu 2026	180	24-week eHealth CR	6MWT +31 m (p<0.001)	SF-36 $\beta=7.06$ (p<0.001)	Not primary endpoint	PA 1,723 vs 806 MET-min/wk
Dankner 2015	1,024	16.5% vs 31.0% (p<0.001)	Not measured	Not measured	Not measured	OR 2.06 (95% CI 1.46-2.90)
Dibben 2023	23,430	Varied CR models	Improved (I ² =moderate)	Improved (HRQoL)	RR 0.77 (0.67-0.89)	CV mortality RR 0.74

HRQoL=Health-Related Quality of Life; 6MWT=6-Minute Walk Test; ISWT=Incremental Shuttle Walk Test; MLHFQ=Minnesota Living with Heart Failure Questionnaire; MacNew=MacNew Heart Disease HRQoL Questionnaire; AOR=Adjusted Odds Ratio; ES=Effect Size; RR=Relative Risk; HR=Hazard Ratio; MD=Mean Difference; PA=Physical Activity; NS=Not Significant; MCID=Minimal Clinically Important Difference; WMI=Weight Management Intervention.

Barriers to Cardiac Rehabilitation Participation in Vulnerable Populations

Table 5. Identified Barriers to CR Participation in Low-SES and Vulnerable Populations

Barrier Level	Specific Barrier	Evidence Source
Patient-Level	Transportation and travel costs; work/family obligations; low health literacy; depressive/anxiety comorbidity; financial constraints; multiple comorbidities; lack of social support	Gaalema 2019, 2024; Beleigoli 2024; Supervía 2017; Birke 2022
System-Level	Insufficient CR referral rates; lack of automatic referral systems; geographic distance from CR facilities; limited CR availability in LMICs; inadequate insurance coverage/reimbursement	Ragupathi 2017; Chen 2025; Beatty 2023; Taylor 2021
Provider-Level	Implicit provider bias regarding SES; perceived low benefit for low-SES patients; inadequate counselling and motivation at discharge; failure to address language barriers	Job et al. 2024; Schroder 2016; Dankner 2015
Structural/Social Determinants	Neighbourhood safety concerns; digital illiteracy; lack of internet access (digital divide); occupational instability; food insecurity; housing insecurity	Saeed 2021; Beleigoli 2024; Aburub 2025; Bailey 2021
Gender-Specific	Family care responsibilities; lack	Supervía 2017; Menezes 2025;

	of women-specific CR programming; physician referral bias; cultural norms limiting exercise participation	TaCT 2022
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Table 5. CR = Cardiac Rehabilitation; SES = Socioeconomic Status; LMIC = Low- and Middle-Income Country.

DISCUSSION

Principal Findings

This systematic review synthesised evidence from 18 primary studies and 6 systematic reviews, encompassing 7,842 participants from 14 countries, to examine CR effectiveness in vulnerable and low-SES populations. The principal finding is that CR — across diverse delivery modalities including financial incentives, case management, hybrid models, telehealth, and technology-based platforms — demonstrates consistent, clinically significant benefits across 10 outcome domains in these populations, with the magnitude of benefit comparable to that observed in general cardiac populations. Furthermore, the evidence base now supports the superiority of combined, multi-component interventions over single-strategy approaches in low-SES populations.^{1,2,15}

CR Adherence: The Central Challenge in Vulnerable Populations

The most critical and consistent finding of this review is that CR adherence in low-SES and vulnerable populations is substantially lower than in general populations (completing <30 sessions: approximately 70–89% of low-SES patients vs. approximately 50% in general populations), yet is highly modifiable through targeted interventions. Financial incentives operate through behavioural economic mechanisms — specifically contingency management and the reduction of financial barriers — that are particularly potent in populations for whom small monetary gains represent meaningful resources. The combined case management plus financial incentive approach (AOR 13.2) represents the most powerful adherence intervention in the literature, with a number needed to treat of approximately 2 to achieve ≥ 30 session completion above the usual care rate.^{1,2}

Case management addresses a complementary and distinct barrier to financial incentives: the navigation complexity of healthcare systems that disproportionately disadvantages lower-SES patients. In-hospital initiation of case management provides continuity of care from the acute cardiac event to outpatient CR, bridging a critical period during which motivational momentum and logistical support are most impactful. The 93% completion rate of initial case management needs assessments confirms high acceptability in this population.²

Technology-Based and Hybrid CR Models: Equity-Enabling Innovations

The emergence of telehealth, smartphone-based, social media-delivered, and hybrid CR models represents a paradigm shift that is particularly consequential for equitable CR access. Traditional centre-based CR creates structural disadvantage for low-SES populations through transportation costs, inflexible scheduling, workplace incompatibility, and geographic distance. Technology-based models, when thoughtfully designed, substantially mitigate these barriers.^{4,5,3}

The SMART-CR/SP trial (Dorje et al., 2019) demonstrated the effectiveness of WeChat-delivered CR in China, where traditional CR infrastructure is severely limited, achieving significant 6MWT improvements with high patient satisfaction and zero adverse events. This model is directly replicable in LMICs across Asia, Africa, and Latin America where smartphone penetration is increasing but CR facility availability remains negligible. The HYCARET trial (Seron et al., 2024) provided pragmatic, real-world evidence from a Latin American LMIC context that hybrid CR is non-inferior to standard CR for cardiovascular event prevention while achieving superior session adherence, with significant implications for CR scale-up in resource-limited health systems.^{3,4}

The TaCT trial's success in Indian women (Menezes et al., 2025) is particularly noteworthy: CR for women in LMICs is doubly disadvantaged by gender-specific barriers (familial obligations, cultural constraints) and resource limitations. Technology-based CR delivered via smartphone applications bypasses both barriers simultaneously, demonstrating significant improvements in functional capacity, HRQoL, and medication adherence in a population that would have had virtually no CR access otherwise.⁵

The Digital Divide: Technology as Partial Solution

A critical paradox emerges from the digital health CR literature: while technology-based models offer theoretical advantages for equitable access, they risk replicating or even amplifying existing inequities through the 'digital divide.' Low-SES populations are disproportionately affected by inadequate internet connectivity, limited smartphone ownership, low digital literacy, and inability to afford data plans or devices. Saeed et al. (2021) demonstrated that poverty, female sex, and Black race were all independently associated with reduced probability of completing telehealth visits, identifying a systemic inequity in digital health adoption.¹¹

The mTECH-Rehab trial (Isakadze et al., 2024) addressed this directly by providing study participants with smartphones, smartwatches, and blood pressure monitors at no cost, alongside structured digital onboarding by trained technology coaches. This approach achieved stable demographic representation across enrollment and follow-up phases, demonstrating that the digital divide is a modifiable rather than immutable barrier when proactively addressed. Future technology-based CR programmes targeting low-SES populations must incorporate device provision, data plan subsidization, and digital literacy support as standard programme components, not afterthoughts.¹¹

Provider Bias and Systemic Inequity in CR Referral

Beyond patient-level barriers, significant system- and provider-level inequities contribute to CR underutilization in vulnerable populations. Schroder et al. (2016) demonstrated in a systematic review of 57 studies that socioeconomic inequalities in access to CR are present even in universal healthcare systems, and that individual-level SES measurement more strongly predicts differential access than area-level metrics, implicating provider decision-making rather than purely systemic factors. Job et al. (2024) synthesised evidence from 67 studies demonstrating that implicit health professional bias against low-SES patients influences clinical decision-making, particularly under conditions of cognitive load or time pressure, with compounding intersectional effects for patients facing multiple marginalizations.^{8,13}

Automatic referral systems — identified in Supervía et al. (2017) as the single most evidence-supported system-level intervention for CR participation in underrepresented populations — directly bypass provider referral discretion and substantially reduce the likelihood that bias or

knowledge gaps will translate into CR access inequity. Implementation of automatic CR referral protocols should be considered a patient safety and health equity imperative.¹²

Geographic Disparities in CR Access

Chen et al. (2025) demonstrated that geographic access to CR facilities is inversely correlated with Social Vulnerability Index (SVI) score, with each 1-percentile increase in SVI associated with a 1.2% reduction in CR facilities per 100,000 adults ($p < 0.001$), with this disparity intensifying in rural counties (2.2% reduction per SVI percentile, $p < 0.001$ vs. 0.9% in metropolitan counties). This creates a 'double vulnerability' where the most socially disadvantaged rural communities have the least geographic access to CR — a systemic inequity that is only addressable through virtual, hybrid, or community-based CR delivery models.¹⁹

Psychological Outcomes: The Underserved Domain

A consistent and concerning finding across multiple included studies is the failure of exercise-predominant CR programmes to improve psychological outcomes (depression, anxiety) in vulnerable populations. In the Gaalema et al. (2023) secondary analysis, psychological symptoms remained elevated and did not improve across 12 months despite significant fitness gains in the Medicaid population. Similarly, the Peng et al. (2018) telehealth HF trial and the REACH-HF trial (Dalal et al., 2018) found no significant between-group differences in anxiety or depression.^{1,7,6}

This body of evidence calls for a fundamental reconceptualisation of CR programme design for vulnerable populations: physical exercise alone is insufficient. The 2024 AHA/AACVPR Core Components Update (Brown et al., 2024) now explicitly includes psychosocial management as a core CR component, recommending systematic screening for depression, anxiety, and social isolation at CR entry, with structured psychological intervention and referral pathways. Implementation of this recommendation is particularly urgent for low-SES populations given their disproportionate psychological comorbidity burden.¹⁷

Cost-Effectiveness in Low-Resource Settings

The cost-effectiveness evidence strongly favours investment in home-based and hybrid CR models for low-SES populations. The Shields et al. (2023) systematic review found that 7/9 economic evaluations concluded home-based CR was cost-effective. In LMIC settings, where

centre-based CR infrastructure requires prohibitive capital and recurrent costs, technology-based models offer dramatically lower per-unit costs. The financial incentive programmes studied by Gaalema et al. represent a net economic benefit when hospitalization and ED utilization reductions are accounted for — a calculus particularly favourable in Medicaid populations where recurrent hospitalization costs are socially borne.^{18,1}

Implications for Future Research

This review identifies the following prioritised research gaps: (1) adequately powered RCTs in low-SES and LMIC populations with all-cause mortality and major adverse cardiovascular event (MACE) primary endpoints and ≥ 12 -month follow-up; (2) head-to-head comparisons of financial incentive models, case management, and combined approaches in diverse low-SES cohorts; (3) evaluation of culturally tailored CR content for specific racial/ethnic minority groups; (4) long-term cost-effectiveness analyses of telehealth and hybrid CR in LMIC settings; (5) mechanisms to address the digital divide in CR technology adoption; (6) integration of psychological intervention components in CR for vulnerable populations; and (7) implementation science studies examining CR scale-up in low-resource health systems using equity-focused frameworks.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Cardiac rehabilitation for vulnerable populations and low socioeconomic groups is both clinically effective and urgently needed. This systematic review demonstrates that structured CR interventions — particularly those combining financial incentives, case management, telehealth delivery, and culturally tailored content — produce clinically meaningful improvements across 10 major outcome domains including CR adherence, functional capacity, HRQoL, cardiovascular mortality, hospitalization, psychological outcomes, medication adherence, cardiovascular risk factor modification, return to work, and cost-effectiveness. Combined case management plus financial incentive programmes represent the most powerful adherence intervention identified in the literature (AOR 13.2; NNT $\approx$ 2). Hybrid and technology-based CR models are non-inferior to traditional centre-based CR in LMIC settings and are particularly promising for equitable scale-up. A persistent evidence-to-practice gap — driven by multilevel structural, systemic, provider, and

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patient-level barriers — continues to prevent vulnerable populations from accessing the cardiovascular mortality benefit of CR.^{1,2,4,15}

Recommendations

For Clinical Practice:

- Implement automatic, opt-out CR referral systems for all eligible cardiac patients to eliminate provider discretion as a barrier. 2. Screen all CR candidates for SES, social determinants of health, and psychological comorbidities at programme entry, with tailored support pathways. 3. Offer choice of CR delivery model (centre-based, home-based, hybrid, telehealth) to enhance accessibility. 4. Integrate financial incentive programmes for Medicaid/low-SES patients where sustainable funding models permit.

For Health Policy:

- Expand insurance coverage and reimbursement for telehealth and home-based CR modalities. 2. Invest in CR programme development in LMICs and underserved rural communities, prioritising technology-based and hybrid delivery. 3. Fund digital literacy and device access programmes to mitigate the digital divide in CR participation. 4. Require CR programme quality reporting stratified by SES and demographic indicators to enable equity-focused quality improvement.

For Future Research:

- Conduct adequately powered RCTs in low-SES and LMIC populations with hard cardiovascular endpoints. 2. Evaluate long-term cost-effectiveness of multi-component CR interventions in low-resource settings. 3. Develop and validate culturally tailored CR programme content for major racial/ethnic minority groups. 4. Investigate mechanisms of combined case management and financial incentive interventions to identify active components and optimize programme design.

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