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State-of-the-Art Review

Improving outcomes in acute coronary syndrome: A meta-analysis of home-based compared to hospital-based cardiac rehabilitation and usual care
3–4 months (end of the program) and 9–10 months (6 months after the end of the program)

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A R T I C L E I N F O

Keywords:
Home-based cardiac rehabilitation
Acute coronary syndromes
Quality of life
Cardiovascular capacity
Risk factors
Rehospitalization
Meta-analysis

A B S T R A C T

Aim: To assess the effectiveness of home-based cardiac rehabilitation (HBCR) in improving health-related quality of life (HRQoL) and other outcomes in patients with acute coronary syndrome (ACS), compared to hospital-based cardiac rehabilitation (CR) and usual care.

Methods: This systematic review followed PRISMA guidelines and included a comprehensive search across MEDLINE, CINAHL, ProQuest, Cochrane Library, Clinical Key, PubMed, Embase, and ClinicalTrials.gov up to June 2023. A total of 19 studies with 2822 participants were included. Eligible RCTs assessed the impact of HBCR on ACS patients, comparing it with hospital-based CR or usual care. The primary outcome was QoL, with secondary outcomes including cardiovascular capacity, cardiovascular disease risk factors, and rehospitalization rates. Statistical analysis was conducted using a random-effects model in R Statistic.

Results: HBCR improves QoL compared to all comparators (hospital-based CR and usual care) (SMD 0.17, 95 % CI 0.00 to 0.33). HBCR was equally effective as hospital-based CR in enhancing QoL, peak VO_2, 6-min walk distance (6 MWD), lipid profiles, and blood pressure. Compared to usual care, HBCR significantly improved QoL (SMD 0.29, 95 % CI 0.11 to 0.46) and HDL-cholesterol level (SMD 0.18, 95 % CI 0.02 to 0.34), while reducing triglyceride level more effectively (SMD −0.34, 95 % CI −0.57 to −0.11). However, no significant differences were observed between HBCR and usual care in terms of peak VO_2, rehospitalization rates, LDL-cholesterol, total cholesterol, or blood pressure.

Conclusions: HBCR significantly improves QoL and is equally effective as hospital-based CR across all measured outcomes. Compared to usual care, HBCR leads to significant improvements in specific aspects of QoL as a

Abbreviations: 6 MWT, 6-min walk test; ACS, acute coronary syndrome; AHA/ACC, American Heart Association and the American College of Cardiology; BMI, body mass index; BP, blood pressure; CABG, coronary artery bypass grafting; CAD, coronary artery disease; CHD, coronary heart disease; CR, cardiac rehabilitation; CRF, cardiorespiratory fitness; HBCR, home-based cardiac rehabilitation; HDL, high-density lipoprotein; HR, heart rate; HRQoL, health-related quality of life; LDL, low-density lipoprotein; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; PCI, percutaneous coronary intervention; QoL, quality of life; RCT, randomized controlled trial; SMD, standardized mean difference; SFAs, saturated fatty acids; VO_2, oxygen consumption.

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primary outcome, as well as in HDL-cholesterol and triglyceride levels. However, its impact on other outcomes, such as peak VO_2, LDL-cholesterol, total cholesterol, and blood pressure, is not consistently significant.

1. Introduction

Cardiovascular diseases are still the leading cause of death globally. In 2019, deaths from cardiovascular disease reached 17.9 million in 2021, representing 30 % of deaths caused worldwide. Coronary heart disease caused 9 million deaths globally [1]. In low- to middle-income countries, >75 % of deaths are related to cardiovascular diseases [2]. The Global Burden Disease states that deaths from ischemic cardiovascular disease in low- and middle-income countries accounted for 13.4 % of all death cases [2]. The acute spectrum of ischemic cardiovascular disease is acute coronary syndrome (ACS), which still exerts a substantial burden on patients and their families.

Cardiac rehabilitation (CR) is a crucial program for individuals grappling with cardiovascular diseases and is recommended by the American Heart Association and the American College of Cardiology (AHA/ACC) [3]. CR helps patients achieve better functional capacity and quality of life (QoL) and lower risk for myocardial infarction, hospitalization, and health costs [4]. However, the limited implementation of CR and low participation rates in hospitals—often averaging only 20–30 % of eligible patients—can be improved by transitioning the second phase of the CR program to the patient's environment as home-based cardiac rehabilitation (HBCR) [5]. The HBCR incurs lower costs than hospital-based CR. Patients undergoing HBCR experience cost efficiency because they do not need transportation and hospital costs [5].

Studies show that participation rates in HBCR can exceed 60–80 %, significantly higher than those for hospital-based programs. HBCR has been demonstrated to increase patient participation, program completion, and long-term compliance [6–8]. Additionally, HBCR is associated with greater reductions in cardiovascular disease risk factors, improved QoL, and enhanced exercise capacity compared to usual care in patients who have undergone coronary artery bypass grafting [9]. It also improves peak maximal oxygen consumption (VO_2) in patients with myocardial infarction, those who have had percutaneous coronary intervention (PCI), and heart transplant recipients [10]. Furthermore, HBCR is linked to a lower risk of all-cause rehospitalizations, decreased mortality [11] and fewer adverse events [12].

However, there are still limited systematic reviews (SRs) comparing the effectiveness of HBCR with other treatments after hospitalization, specifically looking at both hospital-based CR and usual care together. The importance of SRs on HBCR compared to hospital-based CR and usual care cannot be overstated, particularly for patients with ACS. Despite several studies evaluating HBCR's effectiveness in this population, the evidence remains inconclusive. The diversity of HBCR interventions complicates the identification of the most effective implementation strategies. Most existing SRs have primarily focused on the safety of HBCR in the general heart disease population [12] or on patients undergoing PCI [13]. This focus has created a critical gap in understanding HBCR's impact on clinical outcomes and cardiovascular disease risk factors specifically in ACS patients. Previous reviews have compared HBCR with only one group—either hospital-based CR or usual care—making the comparisons between these two groups unclear.

This study aims to compare the outcomes of HBCR with hospital-based CR and usual care to evaluate the effectiveness of HBCR. The selected outcomes focus on the secondary prevention goals of CR program, including improving QoL, cardiovascular capacity, and reducing mortality and rehospitalization rates—key indicators of treatment success. Additionally, we include lipid profiles and blood pressure as intermediate outcomes, reflecting the success of target behaviors such as exercise, diet, and medication adherence.

Lipid levels, particularly LDL-cholesterol, are strongly associated with the recurrence of ACS [14]. Similarly, hypertension can also increase the risk of recurrence [15,16]. While lipid-lowering therapy plays a crucial role, lifestyle modifications—such as diet, exercise, and adherence education—are core components of CR and also contribute to lipid improvements [17–21]. By including lipid profiles and blood pressure as secondary outcomes, we aim to assess CR's broader impact on reducing cardiovascular disease risk factors, in addition to preventing the recurrence of ACS. This approach underscores the potential benefits of combining medical treatment with lifestyle changes for better long-term outcomes.

2. Methods

This systematic literature review and meta-analysis were conducted following the preferred reporting items for SRs and meta-analyses (PRISMA) checklist [22]. This study has been registered in PROSPERO with ID CRD42023402527.

2.1. Eligibility criteria

Studies were included if they were RCTs that analyzed patients aged 18 years or older, who were hospitalized for ACS and received HBCR during the outpatient period. Only studies that compared HBCR with hospital-based CR or usual care were included. To qualify, studies had to report on at least one primary outcome. Primary outcomes included patient-related measures during follow-up periods, such as HRQoL, cardiovascular capacity assessed by peak VO_2, the 6-min walk distance (6 MWD), and cardiovascular disease risk factors for recurrent ACS and rehospitalization rates. Studies focusing on children or patients hospitalized for cardiovascular diseases other than ACS were excluded from this review.

2.2. Search strategy and selection studies

The literature search was conducted in eight databases including Medline, CINAHL, ProQuest, Cochrane Library, Clinical Key, PubMed, Embase, and ClinicalTrial.gov to extract relevant studies published up to June 2023. The search used a Medical Subject Heading and an entree of keywords representing population (P), intervention (I), comparison (C), and outcome (O). The search combination was "Cardiovascular Rehabilitations" AND Home Care" AND "Syndromes, Acute Coronary." Rayyan software was employed for the management of study selection.

The screening was conducted independently by two authors. Two independent reviewers (EM and MHR) screened titles and abstracts for inclusion. Studies were selected based on preplanned criteria. First, titles and abstracts were screened and classified as "possibly relevant" or "irrelevant." Articles identified as "possibly relevant" by both reviewers progressed to full-text review and were further classified as "included" or "excluded." During these processes, any disagreements between reviewers were resolved through discussion with a third reviewer (RDR) until a consensus was reached. The PRISMA flowchart (Fig. 1) provides detailed information about the search and selection process.

2.3. Data extraction

The sample size, mean score, and standard deviation of all outcomes at post-treatment or follow-up measurements were retrieved for statistical analysis. Additionally, study ID, participant characteristics (age and sex), study characteristics (country), therapy characteristics (type, format, session, duration, and frequency of therapy), and outcome characteristics (outcome, instrument, and time measurement) were extracted for reporting. The extraction process was conducted by two authors (EM, NY) using an Excel-based form following Cochrane guidelines [23] and was checked by the primary authors (ABH, H) to evaluate its accuracy and relevance.

2.4. Risk of bias assessment

The overall methodological quality of RCTs was assessed based on Cochrane Collaboration's risk-of-bias (ROB 2) tool by two reviewers (RD and EM). The aspects evaluated included the randomization process, deviations from the intended intervention, missing outcome data, measurement of the outcome, and reporting results. The assessment results were classified as low ROB, some concern, or high ROB.

2.5. Data synthesis

Data were examined and interpreted to identify significant results regarding the effectiveness of HBCR on HRQoL and patient outcomes. Due to the varied outcomes reported by the included studies, we categorized the outcomes into four groups: 1) QoL; 2) cardiovascular capacity, measured by peak VO_2 and the 6 MWD; 3) cardiovascular disease risk factors, including lipid profiles (total, HDL and LDL cholesterol, and triglycerides) and blood pressure; and 4) rehospitalization rates. Other relevant outcomes were synthesized narratively.

The statistical analysis was conducted using R version 4.4.0. Data were analyzed using the metacont package based on a random-effects model. Forest plots were generated to visually represent the outcome effects, with the pooled effectiveness reported in standardized mean differences (SMDs) along with a 95 % confidence interval (CI) and a 95 % prediction interval. Heterogeneity was analyzed using I^2, Q-statistic, and p-values, with $I^2 > 50$ % indicating significant heterogeneity [24]. A larger I^2 value suggested greater effects of study variations [25]. A sensitivity analysis was conducted by excluding one study at a time to evaluate its impact on the overall results. Publication bias was assessed using funnel plots and the Egger regression test, with a p-value <0.1 indicating significant publication bias.

3. Result

3.1. Study selection and exclusion

A total of 237 articles were identified from seven databases and one trial registration platform. In total, 154 articles were screened based on their titles and abstracts after removing duplicates. Thereafter, 70

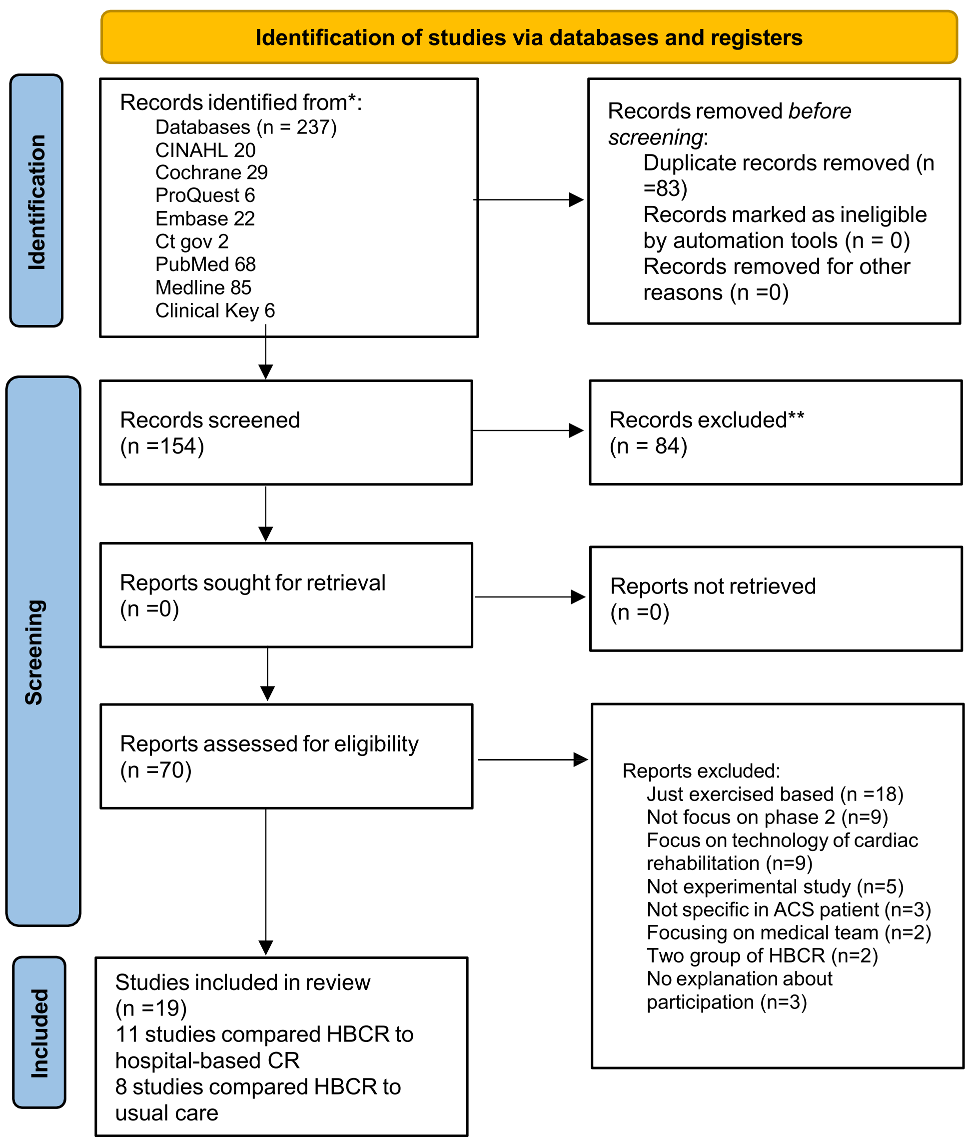

Fig. 1. PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only.

potential articles were screened based on their full texts. After a manual search through Google Scholar, no additional eligible articles were included; thus, 19 studies were eligible for inclusion in this meta-analysis. Of these, 11 studies compared HBCR with hospital-based CR, while 8 studies compared HBCR with usual care (Fig. 1).

3.2. Characteristics of included study

The characteristics of studies included in the analysis are shown in Table 1. Table 2 indicates the lists of types of HBCR interventions and outcomes: comparing HBCR and hospital-based CR. Table 3 indicates the list of types of HBCR interventions and outcomes: comparing HBCR and usual care.

3.3. Risk of bias

The quality of the included studies was evaluated by two authors independently (EM and RD). Among the RCTs, approximately 57.2 %, 9.5 %, and 33.3 % had a low, medium, and high ROB, respectively (Fig. 2).

3.4. Stratification of cardiovascular risk in included studies

To assess the stratification of the study populations in our analysis, we reviewed 19 studies included in the meta-analysis. Among these, 3 studies explicitly categorized participants into low and moderate/medium-risk groups as part of their inclusion criteria [5,42,43]. Two studies did not provide detailed information on their inclusion criteria [44,45]. The remaining 14 studies outlined both inclusion and exclusion criteria, from which we inferred that the exclusion criteria corresponded to high-risk categories, based on the guidelines of the American Association of Cardiovascular and Pulmonary Rehabilitation [46].

From this analysis, we conclude that the studies included in our meta-analysis predominantly involve populations classified as low to moderate risk. Specifically, two studies set participants in the low-risk category, while 14 studies included subjects in both low and moderate-risk categories. This finding aligns with previous research by Thomas et al. [21], which indicated that most HBCR studies primarily target subjects in low-to-moderate risk categories. Therefore, we can confidently state that the population in our analysis is relatively homogeneous with regard to cardiovascular risk. This stratification is crucial because it ensures that the results of our analysis reflect the outcomes typically observed in low-to-moderate risk populations—groups that are the primary focus of most HBCR interventions.

Subgroup analysis was not conducted for outcomes involving studies with low-risk participants (6 MWD, lipid profile, and blood pressure), as only one study provided data for each of these outcomes. Given the limited number of studies, subgroup analysis would not have provided additional meaningful information or insights. Therefore, these outcomes were considered as part of the overall analysis without further stratification. Future research, particularly that which includes high-risk individuals, is crucial for gaining a deeper understanding of how HBCR can be effectively tailored to meet the needs of all patient subgroups.

3.5. Effect of intervention

The primary outcome of this study was QoL, which is a key goal of CR program. Secondary outcomes included cardiovascular capacity, measured as peak VO_2 and 6 MWD, as well as cardiovascular risk factors such as lipid profiles (total, LDL, and HDL cholesterol, and triglycerides) and blood pressure. These two risk factors were considered intermediate outcomes, closely related to the risk of recurrent ACS, reflecting the broader effects of CR in reducing risk factors through core components such as diet, exercise, and medication adherence. Rehospitalization and mortality were also secondary outcomes. Although rehospitalization and mortality are key goals of CR, they were classified as secondary outcomes in this study due to the limited number of studies reporting data, which restricted the ability to analyze them as primary outcomes.

Each outcome was analyzed by comparing HBCR with hospital-based CR, as well as HBCR with usual care. Additionally, subgroup analyses will be performed based on follow-up duration, with groups divided into those with 3 months or less of follow-up and those with follow-up longer than 3 months. The 3-month cut-off was chosen because it is the minimum follow-up duration typically used in the CR studies. Further subgroup analyses based on specific time points (e.g., 3, 6, 9, and 12 months) were not feasible due to the limited number of studies available for each outcome. Other relevant outcomes will be summarized narratively, as they involve different measurement metrics across studies.

3.5.1. Primary outcome: quality of life

In the studies reviewed, significant variation was found in the presentation of QoL data across the analyzed studies. This variation is primarily due to differences in the measurement instruments used. Out of the 12 studies that measured QoL as an outcome, only seven studies reported overall QoL results, while the others reported results across various dimensions in different ways. Therefore, in our analysis, we present only the overall QoL data, as it was not feasible to analyze all studies due to the variation in the types of dimensions measured.

Table 1
Characteristics of the included studies.

No	Year	Country	Authors	Study design	Comparison group
1	2000	United States of America	Ades, et al.	Multicenter RCT	HBCR vs. Hospital based CR
2	2006	United Kingdom	Lee, et al.	RCT	HBCR vs. Hospital based CR
3	2007	United Kingdom	Jolly, et al.	RCT	HBCR vs. Hospital based CR
4	2007	United Kingdom	Dalal, et al.	RCT	HBCR vs. Hospital based CR
5	2011	Denmark	Oerkild, et al.	RCT	HBCR vs. Hospital based CR
6	2014	Australia	Varnfield, et al.	RCT	HBCR vs. Hospital based CR
7	2015	Canada	Grace, et al.	RCT	HBCR vs. Hospital based CR
8	2016	China	Xu, et al.	RCT	HBCR vs. Hospital based CR
9	2017	Netherland	Krall, et al.	RCT	HBCR vs. Hospital based CR
10	2021	Czech Republic	Batalik, et al.	RCT	HBCR vs. Hospital based CR
11	2022	China	Li, et al.	RCT	HBCR vs. Hospital based CR
12	2004	Turkey	Senuzune, et al.	RCT	HBCR vs. usual care
13	2011	United Kingdom	Bartnik, et al.	RCT	HBCR vs. usual care
14	2011	Canada	Houle et al.	RCT	HBCR vs. usual care
15	2012	China	Wang, et al.	RCT	HBCR vs. usual care
16	2016	Taiwan	Chen, et al.	RCT	HBCR vs. usual care
17	2019	Italy	Campo, et al.	RCT	HBCR vs. usual care
18	2020	China	He, et al.	RCT	HBCR vs. usual care
19	2020	Netherland	Snoek, et al.	RCT	HBCR vs. usual care

RCT, randomized controlled trial; HBCR, home-based cardiac rehabilitation; CR, cardiac rehabilitation.

Table 2
Types of home-based cardiac rehabilitation interventions and outcomes: comparing HBCR and hospital-based CR.

Study ID	Country setting	Participants (N, Gender)	Intervention of HBCR			Outcome	Measurement time	Risk-of-bias result
			Type	Session detail	Content			
[26]	United States of America	N = 133 Male, n (%) = 108 (84.5 %)	Telephonic HBCR	36 sessions/ 12 weeks Duration: 35–40 min	1. Exercise with telephone monitoring by a nurse 2. The exercise intensity for cardiac transplant recipients was guided by the Borg perceived exertion scale 3. A Tunturi executive ergometer (Redmond, WA) was used during exercises. The patient was accompanied by an adult for safety precaution	Peak capacity aerobic and QoL (health status questionnaire)	12 weeks	High
[27]	United Kingdom	N = 141 Male, n (%) = 114 (80.05 %)	Comprehensive HBCR	Session: not explained Duration: not explained	1. Guided by the Heart Manual 2. Relaxation exercises using audio tapes	Haemostatic function	3 months	High
[28]	United Kingdom	N = 525 Male, n (%) = 402 (76.6 %)	Comprehensive HBCR	Length of therapy: 12 weeks Session: every day Duration and intensity: not explained	1. Guided by the second edition of the Heart Manual 2. Encouragement to maintain a lifestyle 3. Exercises include daily walking and other enjoyable physical activities	Primary outcomes: smoking cessation, blood pressure, total and HDL cholesterol, and exercise capacity. Secondary outcomes: self-reported diet, physical activity, cardiac symptoms, and QoL	3, 6, and 12 months	Some concerns
[29]	United Kingdom	N = 104 Male, n (%) = 84 (80.7 %)	Comprehensive HBCR	Length of therapy: 3–4 months Session: not explained Duration: not explained	1. Guidance by a heart manual Home visits and telephone monitoring	Mental status (by HADS), QoL (MacNew questionnaire). Secondary outcome: smoking, BMI, blood pressure, and rates of revascularization procedures	3–4 months (end of the program) and 9–10 months (6 months after the end of the program)	Low
[30]	Denmark	N = 75 Male, n (%) = 45 (60 %)	Exercise-based HBCR	Session: every day Duration: 30 min	1. Intensity of exercise based on the 6 MWT and a maximal symptom-limited exercise capacity test on bicycle ergometer 2. The physical training was self-paced brisk walking and stationary bicycling 3. Physiotherapist did a home visit for supervised exercise twice every 6 weeks	Exercise capacity determined by peak VO_2 and 6 MWT, sit-to-stand test, self-reported level of activity, systolic and diastolic BP, total, HDL, and LDL cholesterol, BMI, waist-hip ratio, proportion of smokers and HRQoL estimated by SF-12 and HADS	3,6,12 month	High
[8]	Australia	N = 94 Male, n (%) = 82 (87.2 %)	Care assessment platform of CR with Smartphone preinstalled with health diary and activity monitoring	Session, duration, and intensity: not explained.	1. Guided by My Heart, My Life' manual installed on smartphones Web portal consultation every week	Primary outcome: adherence and completion of the CR program. Secondary outcome: modifiable lifestyle factors (physical activity, nutrition, and psychosocial functioning), biomedical risk factors (BP, heart rate, weight, BMI, waist circumference, and lipid profile), and HRQoL by EQ5D	6 weeks	Low
[7]	Canada	N = 169 Male, n (%) = 0 %	Comprehensive HBCR	Length of therapy: 12 weeks Session: not explained Duration: not explained	1. Patients receive education materials before the home program 2. Hospital visits at least three times continuing with exercises at home.	Program adherence and functional capacity	46 months	Low

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Table 2 (*continued*)

Study ID	Country setting	Participants (N, Gender)	Intervention of HBCR			Outcome	Measurement time	Risk-of-bias result
			Type	Session detail	Content			
[31]	China	$N = 52$ Male, n (%) = 44 (84.6 %)	comprehensive HBCR	Length of therapy: 4 weeks Session: 3 times/week Duration: 30 min Intensity: not explained	Telephoned monitoring every week or every 2 weeks based on program protocols and patient need 1. Supervised training according to the American Heart Association's recommendation 2. The health education brochure contained information about cardiac disease, management of risk factors, the importance of continuing exercise training, nutritional management, psychological support, and compliance 3. Aerobic exercises include walking or jogging and gymnastics Telephoned monitoring and motivation every week	Coronary angiography for assessing global and segmental myocardial functions	4 weeks	Low
[32]	Netherlands	$N = 90$ Male, n	Exercise-based HBCR used heart rate monitor with a chest strap, Garmin FR70	Length of therapy: 12 weeks Session: 2x/week Duration: 45–60 min on continuous training Intensity: 70–85 % of HRmax	Type: (%) = 80 (88.9 %) Content: 1. Exercise training 2. Motivational education Self-management skills	Psychological status, physical fitness, physical activity levels, health-related QoL, psychosocial status, patient satisfaction, training adherence, and cost-effectiveness	12 weeks	Low
[33]	Czech Republic	$N = 44$ Male, n (%) = 36 (81.8 %)	Telerehabilitation with Wrist monitor of HR Polar M430 and Polar Flow application for sharing exercise data	Length of therapy: 1 year Session: 3x/week Duration: 20 min Intensity: 70–80 % of HR max	1. Guided by an educational booklet 2. Participants received telephone consultation every week based on the global position system telemonitoring	Cardiorespiratory fitness parameters including peak VO_2, anthropometric, HRQoL, SF36, and hospitalization and death rates	12 weeks and 1 year	Low
[6]	China	$N = 80$ Male, n (%) = 52 (65 %)	Exercise-based remote HBCR	Length of therapy: 12 weeks Session: Duration: not mentioned Intensity: not explained	1. Setup WeChat groups for intervention and the doctor in charge 2. Patients were taught the Borg grading and heart rate using a checkup app or exercise bracelet 3. HR and Borg's scale recorded every day Telephoned monitoring every week	Compliance, cardiac function, satisfaction, LDL level, unplanned readmission rate, and occurrence of antagonistic cardiac proceedings	3 and 6 months	High

BMI, body mass index; BP, blood pressure; CR, cardiac rehabilitation; HBCR, home-based cardiac rehabilitation; HDL, high-density lipoprotein; HR, heart rate; HRQoL, health-related quality of life; LDL, low-density lipoprotein; QoL, quality of life; CAD, coronary artery disease; CHD, coronary heart disease; 6 MWT, 6 min walk test.

3.5.1.1. QoL comparison between HBCR and comparator groups. Seven studies [8,20,21,24,32,33,35] compared QoL between HBCR and various comparator groups, including hospital-based CR and usual care. These studies involved a total of 2438 participants. The study by Kraal et al. [32] was excluded from the analysis due to its exceptionally high SMD value, which indicated that its results were significantly different from those of the other studies and made it an outlier. In our sensitivity analysis, we found that this had a disproportionate influence on the meta-analysis results and contributed substantially to the observed heterogeneity across the studies. Excluding this study caused a significant change in the overall effect estimate. Before removal, the overall effect estimate was 0.51, with a confidence interval (CI) of [0.02 to 0.99]. After excluding this study, the effect estimate decreased to 0.17, with a narrower CI of [0.0 to 0.33]. The other effect is further demonstrated by a reduction in heterogeneity, which dropped from 91.7 % to 73.1 %.

Table 3
Types of Home-Based Cardiac Rehabilitation Interventions and Outcomes: Comparing HBCR and Usual Care.

Study ID	Country setting	Participants (N, Gender)	HBCR intervention			Outcome	Measurement time	Risk-of-bias result
			Type	Session detail	Content			
[34]	Turkey	$N = 60$ Male, n (%) = 55 (91.6 %)	Exercise-based HBCR	Length of therapy: 12 weeks Session: 3x/ week Duration: 45–60 min	1. Written and audiovisual education about the home-based cardiac exercise program 2. Intervention to enhance self-efficacy, monitoring, motivating, and exercise reviewing	Exercise tolerance, serum lipid levels, and self-efficacy (using the cardiac exercise self-efficacy index)	12 weeks	Low
[35]	United Kingdom	$N = 115$ Male, n (%) = 97 (84.3 %)	Exercise-based HBCR	Length of therapy: 3–4 months Session: 5x/ week Duration: 15–30 min (gymnastics) and 30–60 min (speed walking) Intensity: 70 % of the maximal HR	1. Guided by physical training guidebooks. 2. A diary for recording exercise data. 3. Doctor phone consultation. 4. Physical training includes gymnastics and speed walking. The intervention group was divided according to the level of compliance based on exercise guidelines	Peak workload and self-reported leisure time physical activity	3 and 12 months	High
[36]	Canada	$N = 65$ Male, n (%) = 56 (80 %)	Comprehensive HBCR	Length of therapy: 12 months Session: every day Duration: 3000 steps per Intensity: moderate day	1. Education about the benefits of physical activity, nutrition management, medication, smoking cessation, and stress management 2. Moderate-intensity walking 3. Participants receive a phone call 2 weeks after discharge and five direct consultations 4. Social cognitive theory intervention by the clinical nurse specialist includes four sources of efficacy expectation	Physical activity behavior, cardiovascular risk factors (waist circumference, blood pressure, resting heart rate, lipid profile, and fasting blood glucose), and self-efficacy expectation	3, 6, 9, and 12 months after discharge for physical activity behavior and 6 and 12 months after discharge for other variables	Low
[37]	China	$N = 133$ Male, n (%) = 111 (83.4 %)	HBCR using self-help heart manual	Length of therapy: 6 weeks Session, duration, and intensity: not explained	Guided by the self-help heart manual, which was developed by the researchers and adapted to Chinese culture.	QoL using the Chinese Short Form 36-Item Health Survey and on 3 of the 7 dimensions of the Chinese myocardial infarction dimensional assessment scale and psychological status using the Chinese version of the hospital anxiety and depression scale (HADS).	6 weeks, 3 months, and 6 months	Low
[38]	Taiwan	$N = 64$ Male, n (%) = 58 (90.6 %)	Comprehensive HBCR	Length of therapy: 12 months Session: 3x/ week Duration: 30 min (10-min warmup and 10-min cooldown) Intensity: 11–13 on the Borg scale	1. Education about the exercise program 2. Individual counseling on smoking cessation 3. Informed about risk factors, diet management, and reason to continue the program at home. 4. Training for using large muscles and walking or jogging depending on patient preferences	Modifiable risk factor control and exercise capacity	3, 6, and 12 months	High

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Table 3 (*continued*)

Study ID	Country setting	Participants (N, Gender)	HBCR intervention			Outcome	Measurement time	Risk-of-bias result
			Type	Session detail	Content			
					5. Telephoned monitoring for 3 months every week and cardiologist consultation at months 1, 3, 6, and 12 regarding risk factor management and medical adjustment			
[39]	Italy	$N = 235$ Male, *n* (%) = 184 (77 %)	Exercise-based	Length of therapy: 1 year Session: 3x/ week Duration: 20 min Intensity: not explained	1. A long-term home-based exercise program designed by a sports physician. Combination of an individualized home-based exercise program and four supervised training 1, 2, 3, and 4 months after hospital discharge.	Physical performance, QoL (EuroQoL), functional capacity, social function (ADL), anxiety and depression (EuroQoL5 domain), cardiac death, and hospitalization for cardiac problems.	1, 6, and 12 months	Low
[40]	China	$N = 524$ Male, *n* (%) = 244 (46.5 %	Exercise-based	Length of therapy: 52 sessions Session: 3x/ week Duration: 47 min, including 5 min of warmup, 37 min of exercise, and 5 min of cooldown Intensity: 65 %–75 % of HR (heart rate) max	1. 6 weeks of supervised exercise before starting the program. 2. Individual supervision and individual motivational education through WeChat Bicycling or running in moderate intensity	QoL, all-cause mortality, and major adverse cardiovascular events	1 year for SF-36 and 3 years for cardiorespiratory capacity	Some concern
[41]	Netherlands	$N = 179$ Male, *n* (%) = 145 (81 %)	Home-based mobile-guided cardiac rehabilitation with smartphone and heart rate belt	Length of therapy: 6 months Session: 5x/ week Duration: 30 min Intensity: moderate	1. Mobile health rehabilitation website for recording and presenting data, which could be accessed by the participants, researchers, and medical providers. Motivational interview.	Peak oxygen uptake (peak VO_2 measured in 6 MWT	6 and 12 months	Low

BMI: body mass index, BP: blood pressure, CR: cardiac rehabilitation, HBCR: home-based cardiac rehabilitation, HDL: high-density lipoprotein, HR: heart rate, HRQoL: health-related quality of life, LDL: low-density lipoprotein, QoL: quality of life, CRF: cardiorespiratory fitness, CAD: coronary artery disease, CHD: coronary heart disease, 6M WT: 6 min walk test.

Using the random-effects model based on data from six studies, a statistically significant difference in QoL was found between HBCR and all comparator groups (SMD = 0.17, 95 % CI = [0.00 to 0.33), with significant heterogeneity among the studies ($I^2 = 73.1$ %) (Fig. 3).

3.5.1.2. HBCR and hospital-based CR. Three studies comparing HBCR with hospital-based CR [5,28,44,47], involving a total of 1213 participants. According to the random-effects model, no significant difference in QoL was found between HBCR and hospital-based CR (SMD 0.05, 95 % CI −0.16 to 0.25), with no significant heterogeneity across the studies ($I^2 = 56.3$ %). The group receiving HBCR had similar QoL scores to the group receiving hospital-based CR (Fig. 3).

3.5.1.3. HBCR and usual care. Three studies involving a total of 1343 participants, compared QoL between HBCR and usual care. According to the random-effects model, a statistically significant difference in QoL was found between HBCR and usual care (SMD 0.29, 95 % CI 0.11 to 0.46), with no significant heterogeneity among the studies ($I^2 = 54$ %). The group receiving HBCR had significantly higher QoL scores compared to the group receiving usual care (Fig. 3).

3.5.2. Secondary outcomes: HBCR and hospital-based CR

3.5.2.1. Mortality. A meta-analysis could not be conducted due to the availability of only one study reporting mortality events between HBCR and hospital-based CR, which had some concerns regarding the risk of bias [48]. This study found no significant difference in mortality events between the HBCR and hospital-based CR groups at the 12-month follow-up (p-value = 0.3).

3.5.2.2. Rehospitalization. Only one study [49] with a high risk of bias (Fig. 2) compared the rehospitalization rates between the HBCR and hospital-based CR groups, involving a total of 80 participants with a follow-up period of 6 months. The results indicated a significant difference in rehospitalization rates between the HBCR group compared to the hospital-based CR group (p value<0.01)

3.5.2.3. Cardiovascular capacity. Three studies assessed 6 MWD [6,8,20], comparing results of 6 MWT between HBCR and hospital-based CR, with a total of 1,075 participants. The random-effects model showed no significant difference in 6 MWD between the HBCR and hospital-based

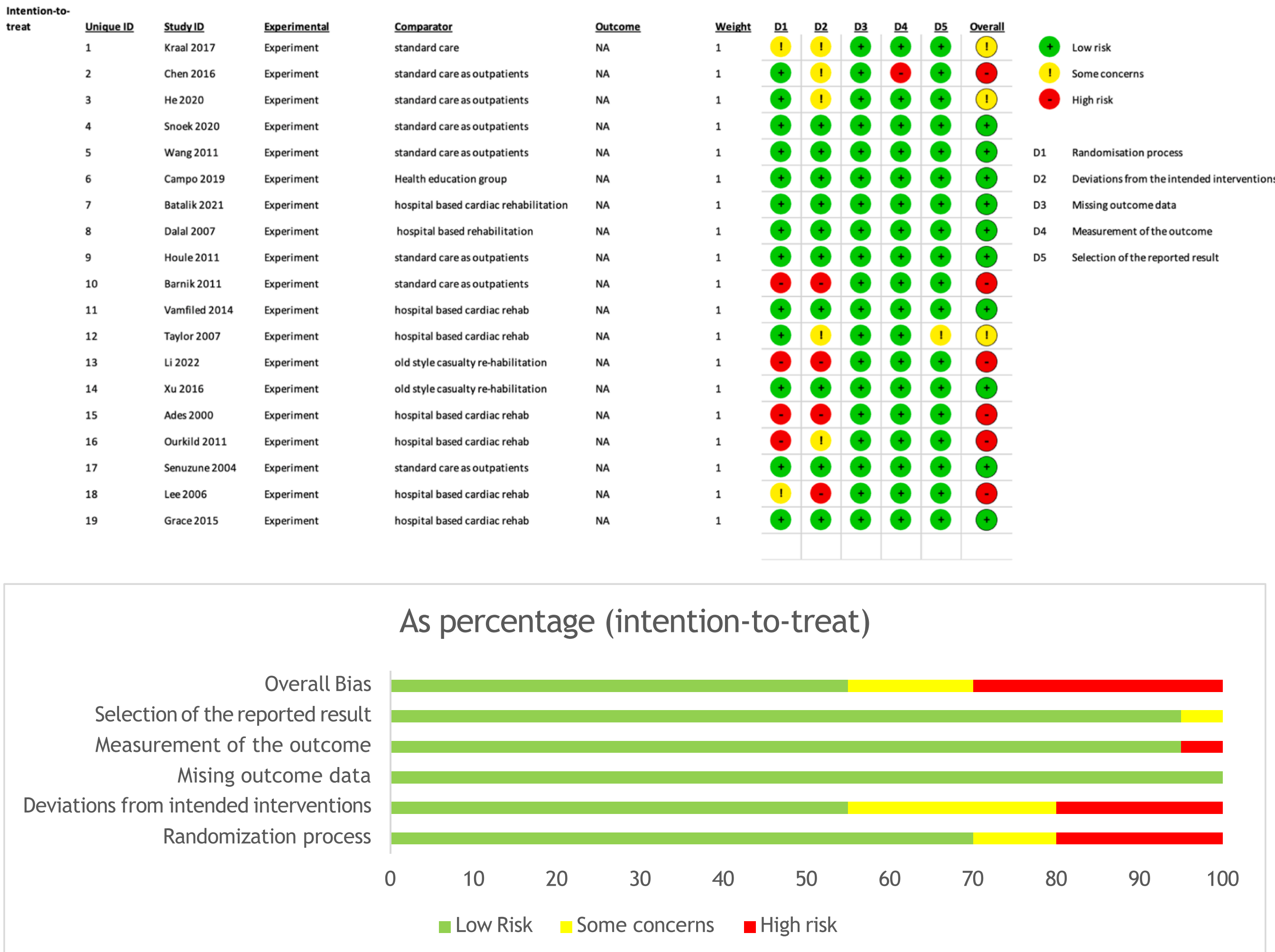


Fig. 2. Risk of bias in included studies.

CR groups (SMD 0.34, 95 % CI −0.21 to 0.88), but there was significant heterogeneity across the studies ($I^2 = 90$ %, $p < 0.01$) (Fig. 4).

Furthermore, three studies reported peak VO_2 values between HBCR and hospital-based CR [18,24,25], involving a total of 255 participants. The random-effects model found no significant difference in peak VO_2 between the two groups (SMD 0.02, 95 % CI [−0.55 to 0.60]), with notable heterogeneity observed ($I^2 = 77.7$ %, $p = 0.0113$) (Fig. 4). Two studies that reported long-term effects (12 and 15 months) [5,40] indicated better improvements in peak VO_2 for the HBCR group. However, these improvements were not statistically significant.

3.5.2.4. Cardiovascular risk factors. No significant differences were observed in total, LDL, or HDL cholesterols levels between the HBCR and hospital-based CR groups. Only triglyceride level showed a statistically significant difference, favoring the HBCR group. One study with a low risk of bias compared triglyceride level between the groups, involving 76 participants with a 6-week follow-up. The HBCR group had significantly lower triglyceride level than the hospital-based CR group (SMD −0.26, 95 % CI −0.51 to −0.0, $p = 0.04$) (Fig. 5). Similarly, no significant differences were found between the HBCR and hospital-based CR groups for either systolic or diastolic blood pressure (Fig. 6).

3.5.3. Secondary outcomes: HBCR and usual care

3.5.3.1. Mortality. Two studies involving 414 participants with a 1-year follow-up reported mortality data for the HBCR and usual care groups [39,50]. The meta-analysis showed no significant difference in mortality between the HBCR and usual care groups (OR 0.74, 95 % CI [0.09 to 6.18]), with no significant heterogeneity among the studies ($I^2 = 19.9$ %) (Fig. 7). The risk of bias across the studies was low.

One study could not be included in the meta-analysis because it did not report the number of mortality events. However, this study demonstrated a significant reduction in all-cause mortality (log-rank $p = 0.049$) over 3 years in the CR+ group compared to the CR− group. This finding contrasts with the results of the meta-analysis, where no significant difference in mortality was observed.

3.5.3.2. Rehospitalization. Two studies [39,50] reported rehospitalization events in patients undergoing HBCR versus usual care, involving a total of 414 patients with a 12-month follow-up period. The meta-analysis indicated no significant difference in rehospitalization rates between the HBCR and usual care groups (OR 1.09, 95 % CI [0.50 to 2.35]), with no significant heterogeneity across the studies ($I^2 = 55{,}7$ %) (Fig. 7). The risk of bias across the studies was low (Fig. 2).

3.5.3.3. Cardiovascular capacity. Three studies [31,33,34], involving a total of 946 participants, compared peak VO_2 between HBCR and usual care. Due to high heterogeneity among the studies ($I^2 = 99.15$ %), a meta-analysis was not conducted. In the previous study, a significant improvement in peak VO_2 was observed in patients with MINOCA (myocardial infarction with non-obstructive coronary arteries) who underwent HBCR [40]. These improvements were noted both at the

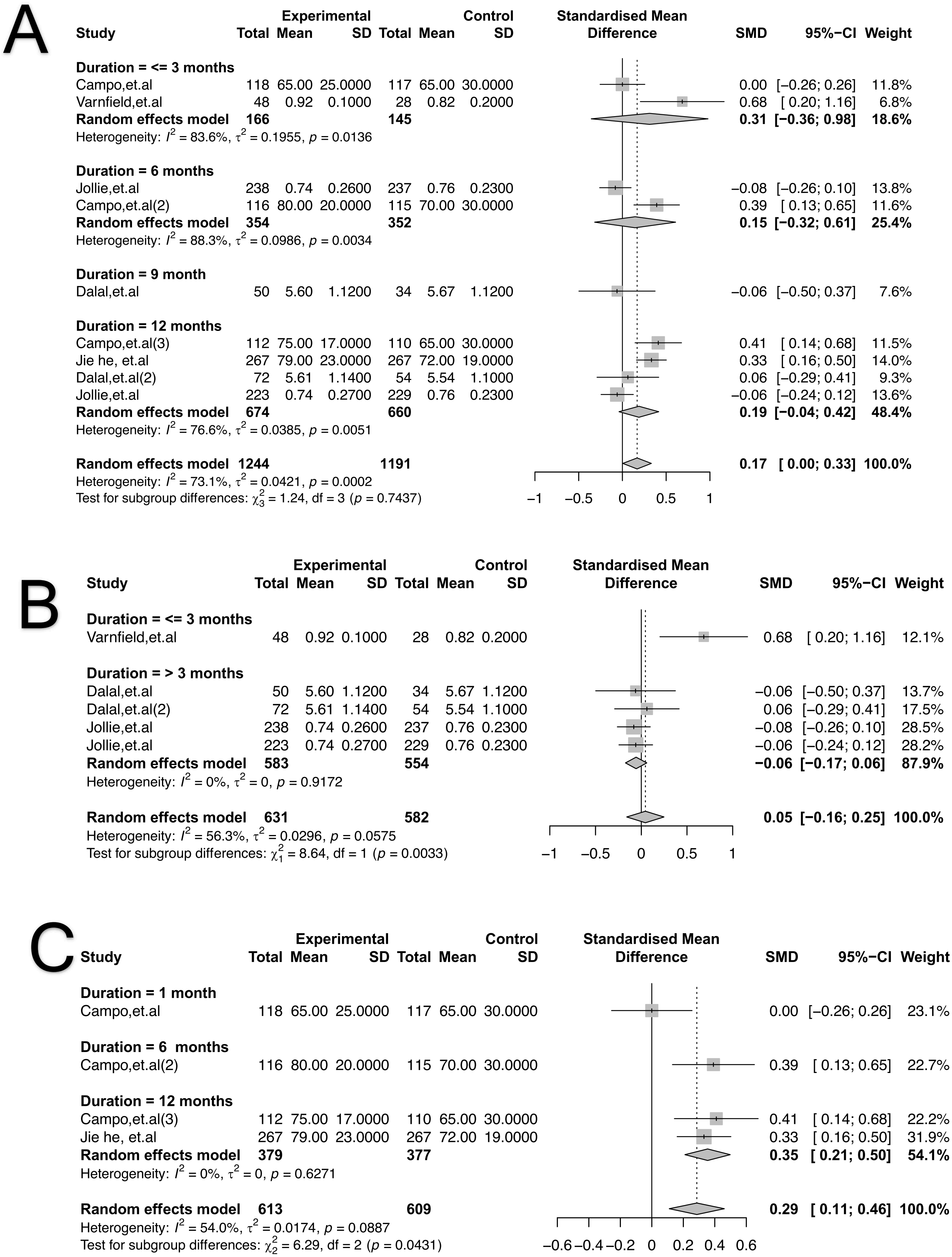


Fig. 3. Effect of HBCR on QoL. A. Effect of HBCR on QoL compared to all comparator; B. Effect of HBCR on QoL compared to Hospital-based CR; C. Effect of HBCR on QoL compared to usual care. HBCR: Home-based Cardiac Rehabilitation, CR: Cardiac Rehabilitation, QoL: Quality of life, SD: Standard Deviation, CI: Confidence Interval, SMD: Standardised Mean Difference.

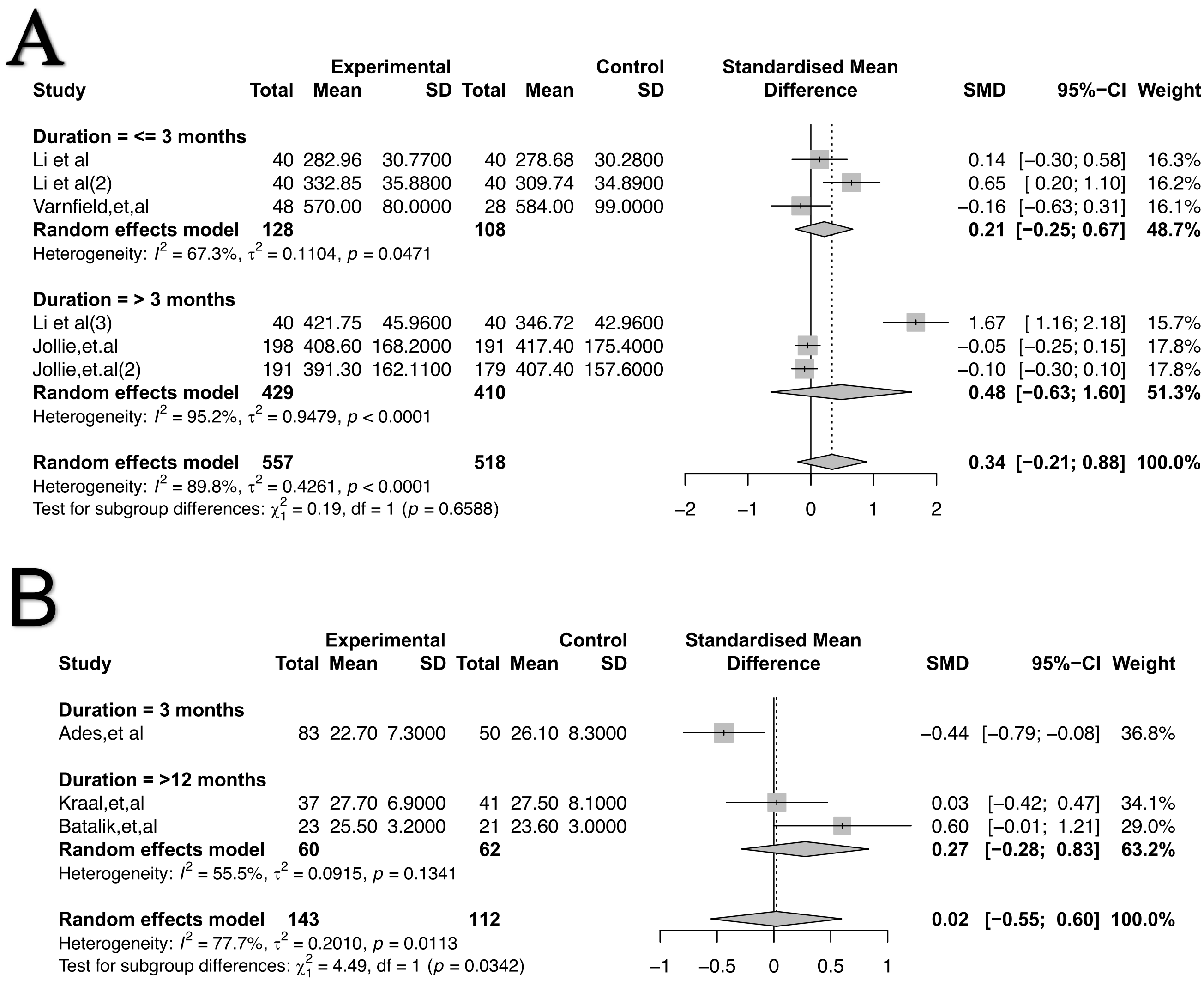


Fig. 4. Effect of HBCR on cardiovascular capacity compared to Hospital-based CR. A. Effect of HBCR on 6 MWD compared to Hospital-based CR; B. Effect of HBCR on peak VO_2 compared to Hospital-based CR. HBCR: Home-based Cardiac Rehabilitation, CR: Cardiac Rehabilitation, 6 MWD: 6-min walk distance, SD: Standard Deviation, CI: Confidence Interval, SMD: Standardised Mean Difference.

beginning of the intervention and after 36 months of follow-up ($p < 0.01$). In contrast, no significant changes were found in the usual care group. Although the study by Chen et al. did not show a significant difference in peak VO_2 between the HBCR and usual care groups, it did report a notable improvement within the HBCR group, with peak VO_2 increasing from baseline to 3 months of follow-up [38]. In the study by Snoek et al., peak VO_2 increased by 8.5 % after 6 months and 6.5 % after 12 months in the HBCR group, while no significant improvement was observed in the usual care group [50]. In summary, while the statistical significance of these improvements could not be firmly established, these three studies collectively suggest that HBCR has a positive impact on cardiovascular capacity, as reflected by improvements in peak VO_2.

3.5.3.4. Cardiovascular risk factors. No significant differences were observed in total cholesterol and LDL cholesterol levels between the HBCR and usual care groups (Fig. 8). Similarly, no significant differences were found between the HBCR and usual care groups for either systolic or diastolic blood pressures (Fig. 9).

However, a significant difference in HDL cholesterol level was observed across five studies [26,27,29,31,34], involving a total of 703 participants. Using the random-effects model, the results showed a significant difference in HDL cholesterol level between the HBCR and usual care groups (SMD 0.18, 95 % CI 0.02–0.34), with no significant heterogeneity among the studies ($I^2 = 4.6$ %) (Fig. 8). Similarly, a significant difference in triglyceride level was found between the HBCR and usual care groups in three studies [26,27,29], involving 345 participants (SMD −0.34, 95 % CI −0.57 to −0.11), with no significant heterogeneity among the studies ($I^2 = 0.00$ %) (Fig. 8).

3.5.4. Patient satisfaction and adherence

A study conducted by Varnfield et al. [51] showed that the ACS patient group undergoing HBCR using smartphones and a specific platform (CAP CR: Care Assessment Platform of CR) had higher adherence and completion rates compared to those receiving hospital-based CR. Similarly, Grace et al. [7] found that women participating in HBCR demonstrated higher adherence rates than their counterparts in the hospital, with a focus exclusively on woman participants.

Additionally, patients undergoing HBCR exhibited greater adherence to walking exercises and medication compared to those receiving hospital-based CR [6]. Beyond adherence rates, HBCR also resulted in higher patient satisfaction levels compared to hospital-based CR. This was highlighted in a study by Kraal et al. [32] which found that while there were no significant differences in exercise adherence between patients in home and hospital settings, satisfaction levels were significantly higher among those rehabilitating at home. Furthermore, another study [6] indicated that patient satisfaction was greater after 12 months

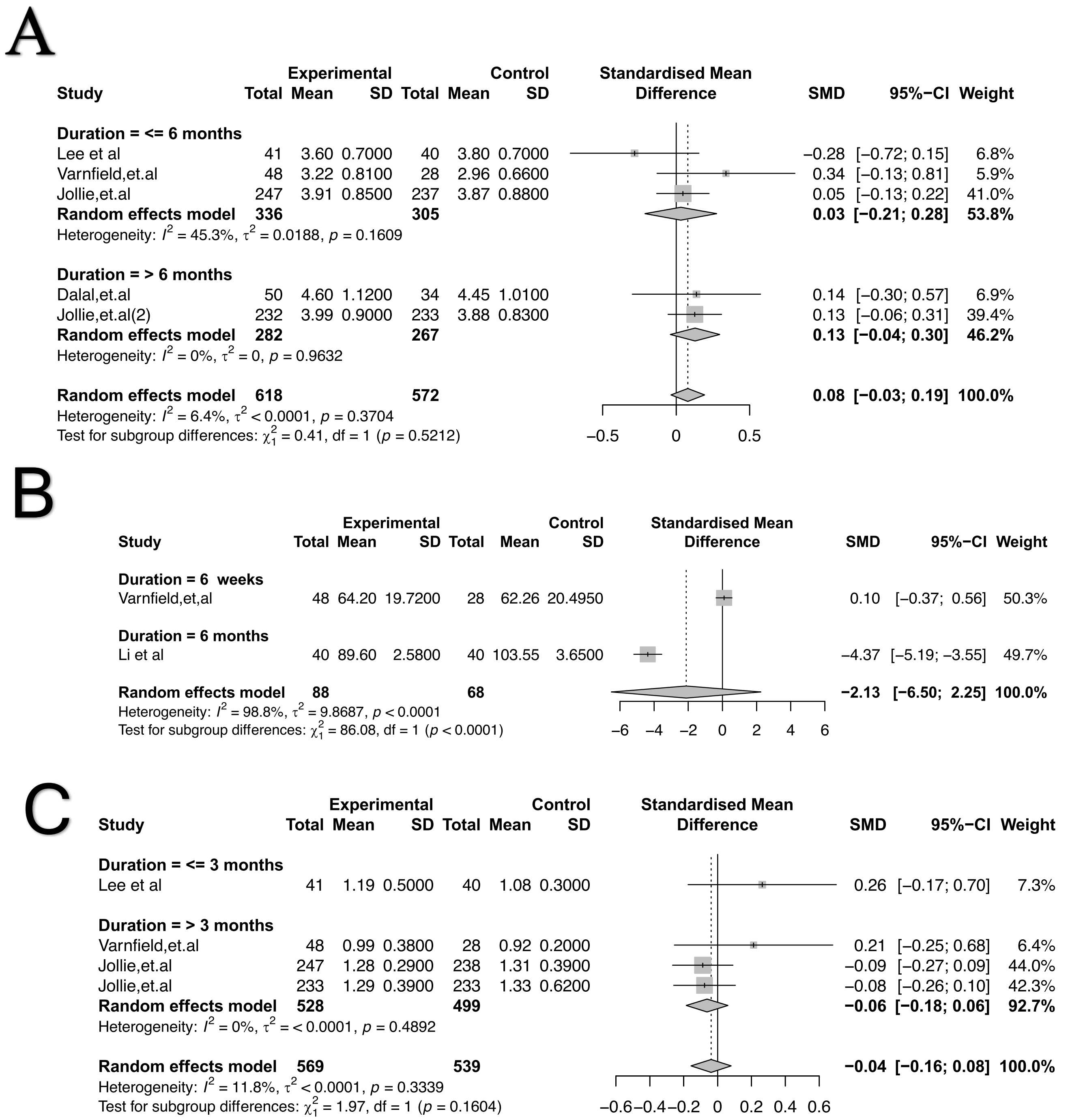


Fig. 5. Effect of HBCR on lipid profile compared Hospital-based CR. A. Effect HBCR on total cholesterol compared to Hospital-based CR; B. Effect of HBCR on LDL -cholesterol compared to Hospital-based CR; C. Effect HBCR on HDL cholesterol compared to Hospital-based CR. HBCR: Home-based Cardiac Rehabilitation, CR: Cardiac Rehabilitation, HDL: High Density Lipoprotein, LDL: Low Density Lipoprotein, SD: Standard Deviation, CI: Confidence Interval; SMD: Standardised Mean Difference.

of participating in the HBCR program compared to those undergoing hospital-based CR.

4. Discussion

4.1. The HBCR enhances QoL

In the overall analysis, HBCR demonstrated a statistically significant improvement in QoL compared to the comparator groups (SMD 0.51, 95 % CI 0.02 to 0.99), indicating that, on average, HBCR has a positive impact on QoL. However, the observed heterogeneity ($I^2 = 73$ %, $p < 0.01$) suggests considerable variability across the included studies. To address the impact of extreme values on heterogeneity, we conducted sensitivity analyses by removing outliers in the SMD, which reduced the I^2 to a more moderate level(91,7 % to 73 %). While some heterogeneity remains, it is considered within acceptable limits for meta-analysis, particularly in rehabilitation research [52]. Heterogeneity in CR studies is inevitable and can arise from various factors, including differences in patient characteristics such as age range and clinical diagnoses like ACS, as well as the diversity in intervention types (e.g., exercise modalities, duration, intensity, and settings). Previous systematic reviews in the field of CR have reported similar levels of

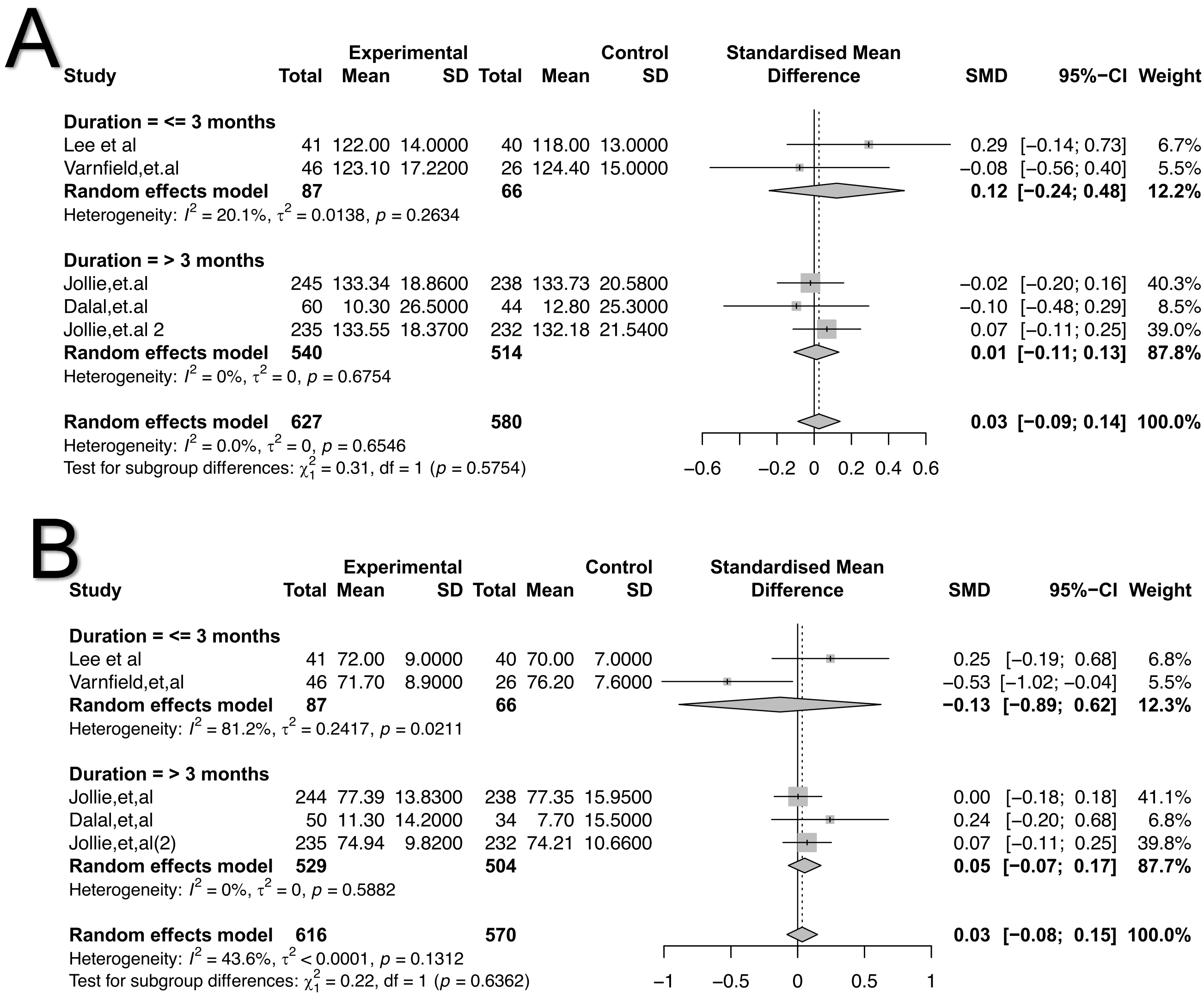


Fig. 6. Effect of HBCR on blood pressure compared to Hospital-based CR. A. Effect of HBCR on systolic blood pressure compared to Hospital-based CR. B. Effect HBCR on diastolic blood pressure compared to Hospital-based CR. HBCR: Home-based Cardiac Cehabilitation, CR: Cardiac rehabilitation, SD: Standard Deviation, CI: Confidence Interval, SMD: Standardised Mean Difference.

heterogeneity, which is typically associated with variations in interventions, patient populations, and outcome measures [52,53]. This aligns with findings from other meta-analyses in CR, where moderate-to-high heterogeneity is commonly observed and does not undermine the validity of the findings, as it reflects the real-world complexity of CR programs.

Despite this variability, the significant effect size supports the conclusion that HBCR is beneficial in improving QoL. A review by Zhong et al. [13] further supports this conclusion, noting enhancements in physical functioning among patients undergoing PCI in the HBCR group using telemonitoring, compared to the control group. One key factor contributing to these positive outcomes is the higher adherence rates observed in HBCR programs. Consistent with previous research, HBCR is not only comparably effective but also more cost-effective. Notably, among the 11 studies reviewed, only one reported low adherence, suggesting that HBCR effectively promotes exercise continuity and patient commitment, leading to improved QoL outcomes [42]. The CR, particularly HBCR, plays a crucial role in enhancing QoL by encouraging increased physical activity, improving vocational status, and fostering psychological well-being [54].

When comparing HBCR to hospital-based CR the overall impact on QoL was similar. This suggests that, while hospital-based CR may provide more immediate or higher-impact results, HBCR serves as a viable and comparable alternative—particularly for individuals who may not have easy access to hospital-based CR. When comparing HBCR to hospital-based CR, the overall impact on QoL was similar. Eight studies evaluated health-related QoL between HBCR and hospital-based CR, with six finding no significant differences [6,8,28–30,32,33,55]. Both groups showed significant improvements; however, in two studies, the HBCR group demonstrated better QoL, particularly in the emotional dimension, after six weeks [28,29,32]. This suggests that, while hospital-based CR may provide more immediate or higher-impact results, HBCR serves as a viable and comparable alternative—particularly for individuals who may not have easy access to hospital-based CR. The study by Varnfield et al. even showed better QoL outcomes for patients undergoing HBCR compared to those receiving hospital-based CR [8]. The study utilized smartphones, allowing patients to track their daily exercise progress and receive weekly education, which helped improve adherence and effectiveness in their daily exercise routine [8].

Compared to usual care, HBCR demonstrated significant improvements in QoL, although with substantial heterogeneity. Notably, the long-term follow-up groups (≥12 months) highlighted sustained benefits of HBCR, with these benefits becoming more pronounced over time compared to usual care. In the study by Campo et al., elderly patients in

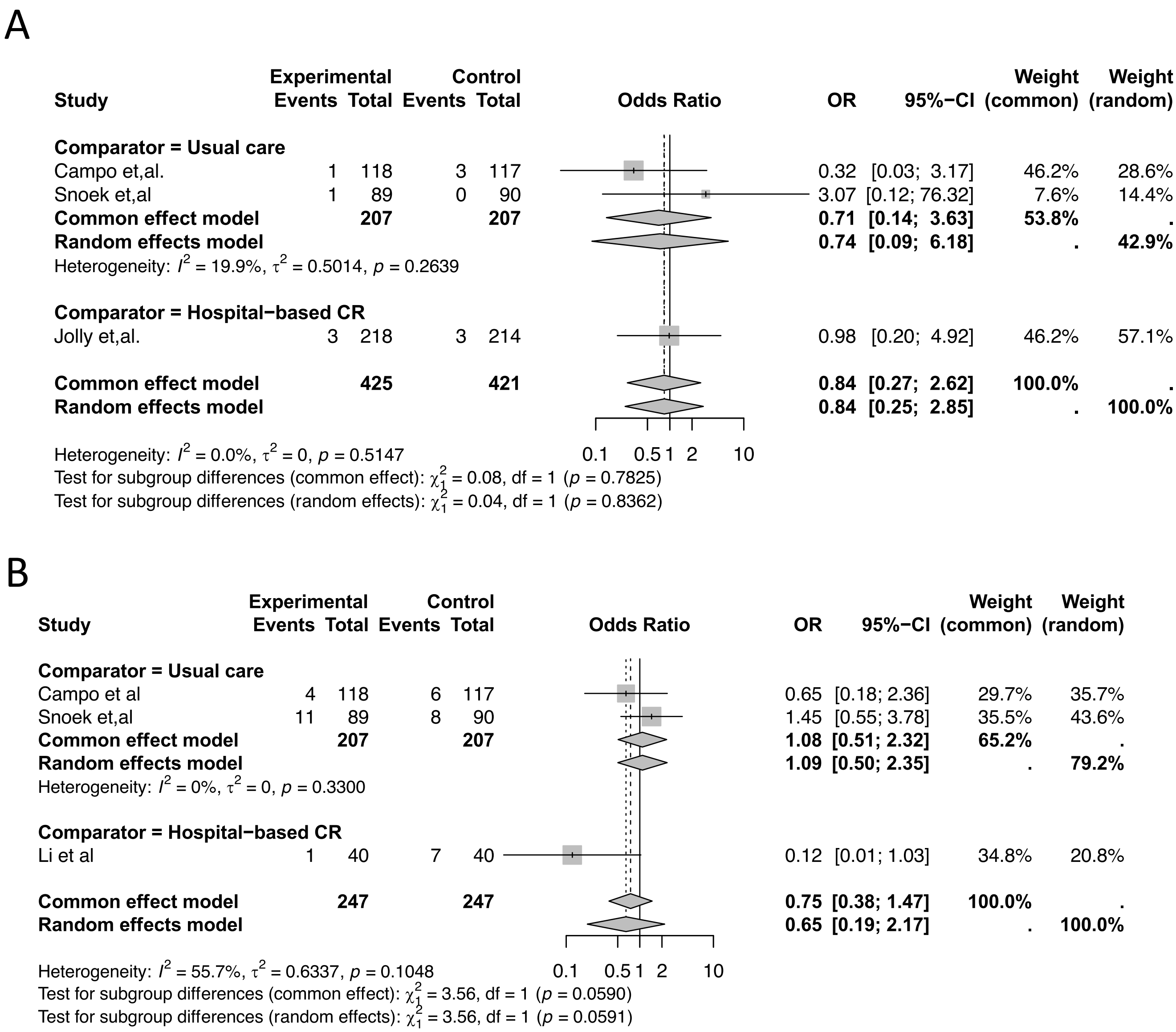


Fig. 7. Effect of HBCR on mortality and rehospitalization compared to usual care. A. Effect of HBCR on mortality compared to usual care. B. Effect of HBCR on rehospitalization compared to usual care. HBCR: Home-based Cardiac Rehabilitation, OR: Odds ratio; CI: Confidence interval.

the intervention group showed better QoL scores at both the 6-month and 1-year visits [39]. This was further supported by a reduction in physical complaints and mobility difficulties compared to the control group [39]. A similar finding was observed in the study by He et al., where MINOCA patients showed better physical QoL scores after 1 year, although no significant differences were found in the emotional dimension [40].

The long-term benefits of HBCR on QoL are likely attributed to a combination of sustained lifestyle changes, psychological adaptation, and cumulative physiological improvements resulting from ongoing participation in rehabilitation activities. While HBCR produces immediate health benefits in the short term, its effects on QoL are more consistently sustained and become more evident over time. Patients are better prepared for the transition following illness through a comprehensive CR program. Psychological benefits, such as improvements in mood, self-esteem, and stress reduction, are also more pronounced in the long term. Previous studies demonstrated that the HBCR group showed significant improvements in anxiety [29,37]. Moreover, these long-term improvements are shaped by patients' ability to adapt to their health conditions and develop effective coping strategies. As patients become more familiar with their condition and the rehabilitation process, they are better equipped to rely on these strategies, leading to more stable and lasting improvements in their overall QoL.

However, patients cannot be left to navigate the HBCR process alone. Consistently changing habits is difficult because patients are often stuck in old routines and feel incapable of making changes without guidance from healthcare professionals [56]. Adequate information and ongoing monitoring by healthcare providers are essential to ensure that patients remain consistent in making lifestyle changes and achieving the desired outcomes.

The study by Zhong et al. highlighted the positive impact of HBCR, especially when telerehabilitation was used [57]. It demonstrated significant improvements in cardiovascular capacity and (QoL. Patients were better prepared for recovery through a comprehensive CR program, which included regular communication with healthcare providers via social media platforms, weekly educational videos, and access to physical exercise data shared between healthcare providers and patients [57].

In addition to adequate information and monitoring by healthcare professionals, behavior change is influenced by many factors, such as psychological stress, daily life pressures, and barriers from social environments [58]. Family can play a crucial role as a supportive factor by

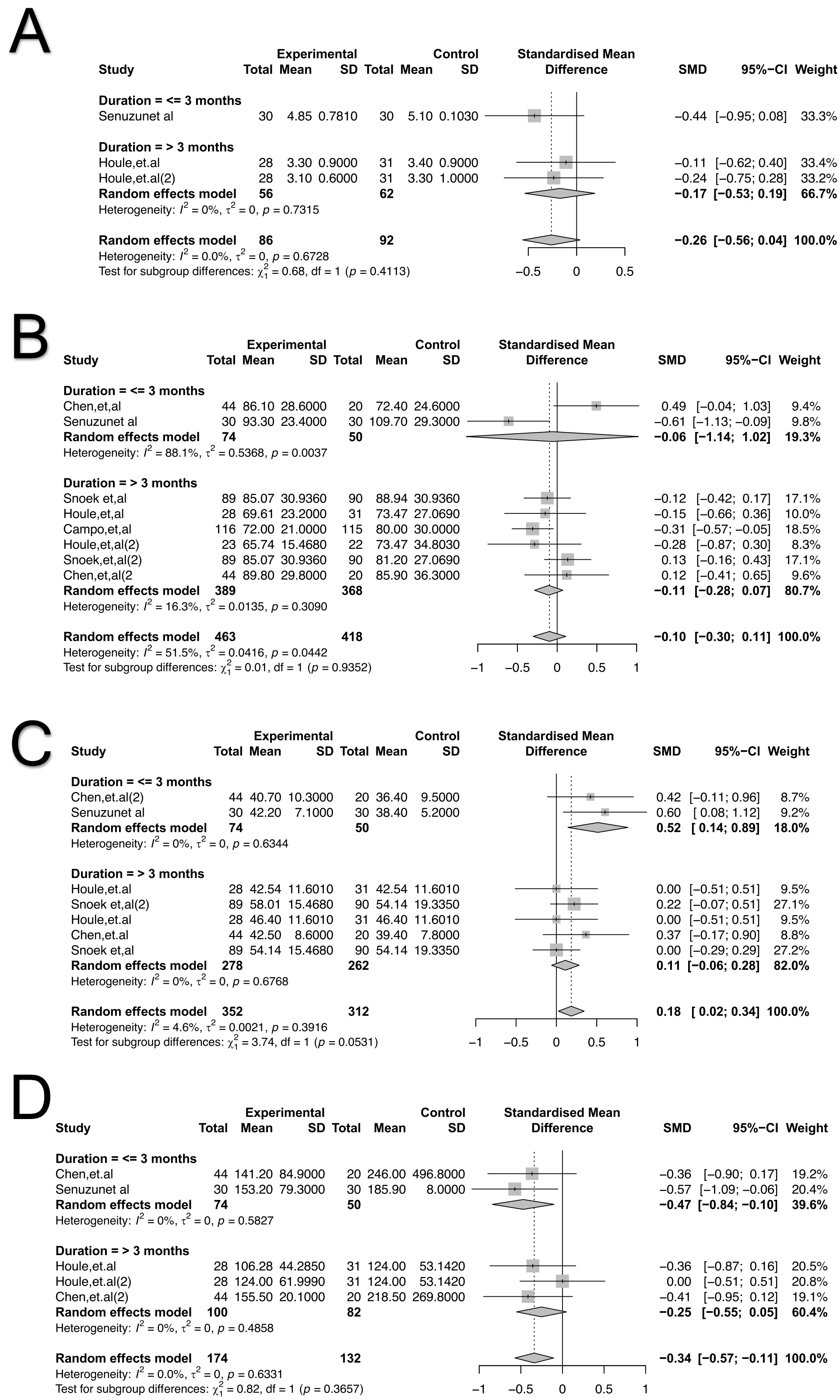


Fig. 8. Effect of HBCR on lipid profile compared to usual care. A. Effect of HBCR on total cholesterol compared to usual care; B. Effect of HBCR on LDL cholesterol compared to usual care; C. Effect of HBCR on HDL cholesterol compared to usual care; D. Effect of HBCR on triglycerides compared to usual care. HBCR: Home-based Cardiac Rehabilitation, HDL: High Density Lipoprotein, LDL: Low Density Lipoprotein, SD: Standard Deviation, CI: Confidence Interval, SMD: Standardised Mean Difference.

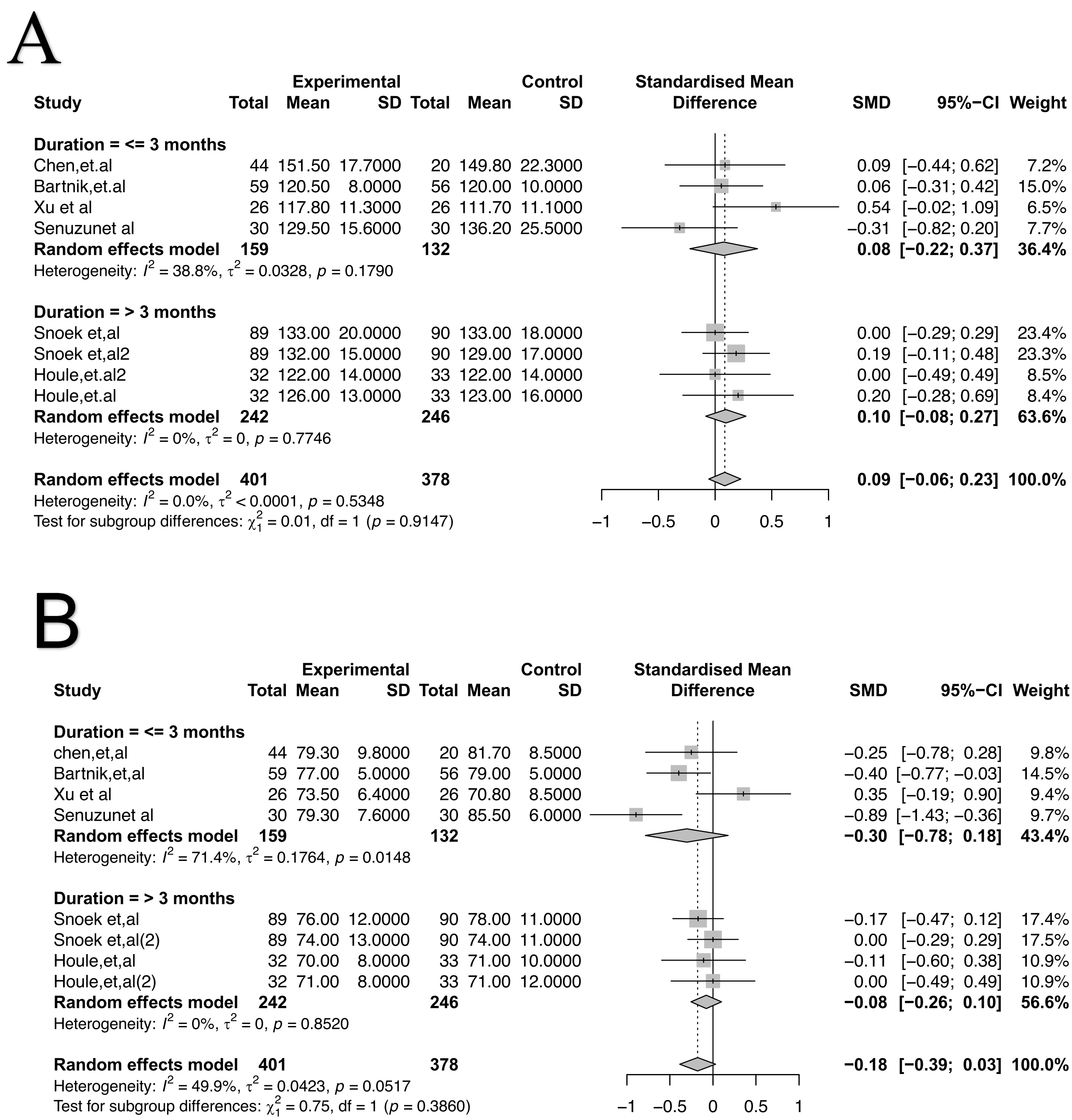


Fig. 9. Effect of HBCR on blood pressure compared to usual care. A. Effect of HBCR on systolic blood pressure compared to usual care; B. Effect of HBCR on diastolic blood pressure compared to usual care. HBCR: Home- based Cardiac Rehabilitation, SD: Standard Deviation, CI: Confidence Interval; SMD: Standardised Mean Difference.

providing positive encouragement, which can enhance the long-term effectiveness of HBCR in improving QoL [59]. Family-centered care has been shown to increase adherence to therapeutic regimens and diet in patients with heart disease Thus, a family-centered approach may serve as an effective strategy to improve patient health status and overall QoL [60].

4.2. HBCR is as effective as hospital-based CR in enhancing cardiovascular function and reducing risk factors

A subgroup meta-analysis comparing HBCR to hospital-based CR found no differences across peak VO_2, 6 MWD, lipid profiles, and blood pressure, indicating that HBCR is as effective as hospital-based CR [28,29,32]. Furthermore, HBCR was associated with higher satisfaction levels and lower costs compared to hospital-based CR [32] Similarly, Li et al. found that satisfaction levels in the HBCR group were higher 12 months post-program [49].

Although improvements were observed in both groups during the follow-up period, no differences in peak VO_2 values were found between patients undergoing HBCR with telemonitoring and those in hospital-based CR [32,42]. A notable difference was seen in the study by Batalik et al., where peak VO_2 was higher in patients undergoing HBCR as compared to those receiving hospital-based CR after 1 year of follow-up [33]. This may be related to the structure of the HBCR program, which included supervision by cardiologists and physiotherapists, teleconsultations, and daily progress monitoring through a web platform [33]. These factors may have contributed to the higher quality of physical activity performed by patients at home.

This finding is significant, indicating that HBCR is as effective as hospital-based CR in improving cardiovascular metrics and reducing cardiovascular disease risk factors including blood pressure and lipid profile. This is crucial, as it demonstrates that HBCR programs can serve as an effective alternative, particularly for patients who may have difficulty accessing hospital facilities. Additionally, it could reduce costs and enhance patient adherence to CR programs.

However, the study by Lee et al. found that improvements in lipid profile and blood pressure occurred only in the hospital-based CR group and not in the HBCR group [27]. This may be due to more adequate exposure to information and education, with a stronger emphasis on diet management in the hospital setting. This finding underscores an important consideration for the development of HBCR programs, highlighting the need to ensure that HBCR offers sufficient information and monitoring to support effective diet management and overall health improvement.

This is further supported by the Varnfield et al. study [8], which showed better results in diastolic blood pressure and triglyceride levels of HBCR as compared to hospital-based CR. These improvements were attributed to the use of smartphones for exercise and vital sign monitoring, as well as the delivery of motivational and educational materials to participants via text messages and videos.

In conclusion, while systematic reviews indicate that HBCR is as effective as hospital-based CR in improving outcomes, it is crucial to note the importance of ongoing monitoring by healthcare professionals in the implementation of these programs.

4.3. HBCR demonstrates superior effectiveness compared to usual care in QOL, HDL, and triglyceride

In a comprehensive subgroup meta-analysis comparing HBCR with usual care, significant improvements were observed in QoL, triglyceride level, and HDL cholesterol, highlighting HBCR as a superior rehabilitation approach. Patients participating in HBCR demonstrated lower mean scores on modifiable risk factors compared to those receiving traditional outpatient care [9,54].

The QoL assessments conducted between 3 and 12 months revealed that individuals undergoing HBCR outperformed their counterparts in routine outpatient programs [37,39,40]. Furthermore, HBCR participants exhibited enhanced physical activity levels, greater average daily steps, and improved exercise capacity relative to those receiving standard outpatient treatment [9,34–36]. These findings are significant as they serve as indicators of successful risk reduction, given that HDL cholesterol is a key component in the atherosclerosis process, with higher HDL cholesterol levels being associated with a reduced risk of atherosclerosis [61]. Additionally, these results suggest that lipid-lowering medications may be more effective when combined with consistent physical exercise [34].

Importantly, the HBCR group recorded significantly lower mean triglyceride levels compared to the usual care group [34,36,38] and a notable difference in HDL cholesterol level was also in favor of the HBCR group [34]. Four studies indicated that HBCR led to greater decreases in triglyceride level compared to usual care [34,36,38,62]. These findings reinforce previous research, emphasizing that the core components of HBCR—physical exercise, dietary management, and medication adherence—can have a more significant impact on patients receiving lipid-lowering treatment. Numerous studies have shown the positive effects of consistent physical activity in improving lipid profile [63–67]. Adherence to diets rich in monounsaturated fatty acids (MUFAs), polyunsaturated fatty acids (PUFAs), and low in saturated fatty acids (SFAs) has been shown to improve lipid profile in patients with cardiovascular disease [66,68,69]. Improved adherence to these components in HBCR programs can lead to sustained lifestyle changes, ultimately resulting in better long-term health outcomes for patients. However, the LDL and total cholesterol levels in the HBCR group were not significantly different from those in the usual care group, suggesting the need for further investigation into barriers, particularly in dietary management and oversight during HBCR. A qualitative study found that a higher percentage of patients with poor dietary adherence participated in CR compared to those with good dietary adherence [70]. This highlights the potential impact of dietary habits on the effectiveness of the CR program.

No significant differences were found between HBCR and usual care regarding peak VO_2, and blood pressure. Nonetheless, when examining the studies individually, patients undergoing HBCR showed improvements in peak VO_2, physical activity, mean daily steps, and exercise capacity compared to those receiving standard care [34–36,41,71]. This warrants further investigation into why the CR program does not positively impact heart function as measured by peak VO_2 and blood pressure. One possible explanation for these findings is the typically lower exercise intensity in HBCR. Since HBCR often lacks direct supervision, the intensity of physical activity may not be sufficient to achieve the same physiological improvements seen in HBCR [38,72]. The effectiveness of physical exercise in enhancing heart function should be reconsidered within the context of HBCR. Key questions to explore include whether patients are performing exercises in line with the prescribed program, whether they are executing the exercises correctly, and what barriers may still hinder physical activity. Identifying these factors is essential for understanding the limitations of HBCR and improving patient outcomes in future CR efforts.

Another contributing factor may be the lack of professional support in HBCR. The limited involvement of healthcare providers in supporting HBCR participation presents a significant challenge to patient compliance [73]. Without continuous medical supervision, patients may lack the motivation and guidance necessary to perform exercises correctly, which could diminish the program's overall effectiveness. Additionally, variability in HBCR protocols across different studies can lead to inconsistent outcomes. This is consistent with the findings of previous systematic reviews [74]. Differences in factors such as program duration, exercise intensity, and the use of technology can influence the results, making it difficult to draw definitive conclusions. The comparison of mortality and rehospitalization rates between HBCR and usual care shows no significant difference. However, there is insufficient evidence to conclude that HBCR significantly impacts mortality compared to usual care. This lack of conclusive evidence is due to contradictory results from the two studies that reported mortality and rehospitalization outcomes [39,41]. Additionally, the broad confidence interval (CI) and the absence of statistical significance highlight uncertainty in the findings. Therefore, further studies with larger sample sizes and longer follow-up periods are needed to provide more definitive conclusions. Indicate uncertainty in the results, underscoring the need for additional research to draw more definitive conclusions.

4.4. Challenges in HBCR

Although the benefits of HBCR on QoL are more evident in the long term, the effects of HBCR on other outcomes appear to be more prominent in the short term. Our analysis reveals that HBCR has varying effects on lipid profiles depending on the follow-up duration. LDL cholesterol levels showed no significant change, regardless of follow-up length. In contrast, HBCR had a more pronounced effect on HDL cholesterol and triglycerides in the short term ($\leq$3 months), with these benefits diminishing over time (follow-up $>$3 months).

The decline in long-term follow-up scores is also reflected in the outcomes of the 6 MWT result. The 6MWD by the HBCR group decreased from 408.6 m at 6 months to 391.3 m at 12 months [28]. A similar finding was reported in Li et al. study, where at 3 and 6 months, the 6 MWT outcomes for patients in HBCR were lower compared to those in the hospital-based CR group [6].

Short-term improvements in HDL cholesterol, triglycerides, and physical capacity are likely the result of acute physiological responses to exercise, temporary dietary changes, and improved psychological well-being. A combination of lipid interventions, including diet, medication, and appropriate exercise training, may be beneficial and help optimize individualized medical management for lipid disorders [75]. However, these benefits may not be sustained in the long term due to factors such as reduced exercise intensity, a return to previous eating habits, and metabolic adaptation. The effects of repeated low-intensity physical activities may lead to only minor, transient changes in lipid profiles that may not be noticeable in clinical trials. However, frequent aerobic training over a longer period may result in lasting improvements in lipid profiles [75]. Therefore, further research is needed to explore the long-term effects of HBCR and the factors influencing these outcomes. These time-dependent effects underscore the importance of understanding the mechanisms behind these changes and whether extended interventions or maintenance strategies can help sustain the benefits of HBCR over time.

Additionally, a more targeted approach to HBCR is essential to maintain its long-term benefits, particularly through family empowerment strategies [76–78]. These strategies can provide ongoing support and guidance, helping patients maintain lifestyle changes and coping strategies beyond the rehabilitation program. Another challenge identified in this study is that HBCR was less effective in improving physical capacity and blood pressure. No significant differences were observed in peak VO_2 or blood pressure between the HBCR and usual care groups. This may be related to the suboptimal nature of physical exercise performed at home without supervision. This highlights the need for an enhanced approach to HBCR, in addition to what is currently being implemented. Patients require ongoing support to maintain a healthy lifestyle over the long term. Furthermore, during physical exercise, patients should be guided to ensure that the frequency, intensity, duration, type, and progression of the exercises are appropriate. Given the limited time healthcare professionals have for monitoring patients at home, family members are likely to play a key role in providing support.

4.5. Strength and limitations of this study

This analysis includes a diverse range of studies involving ACS patients who underwent various interventions, such as PCI, CABG, or no intervention at all. The patient population spans a wide age range, from those under 50 to those over 70, offering a comprehensive view across different age groups. Additionally, the HBCR interventions varied significantly, including telerehabilitation with remote monitoring, smartphone applications, and traditional HBCR with modules and diaries for self-reporting. The studies were conducted across multiple geographical regions, including Europe, Asia, and Australia.

The diversity in patient populations, the variety of HBCR interventions, and the geographical spread of the studies all contribute to the strengths of this analysis. These factors enhance the external validity of the findings, making the results more generalizable across different settings, contexts, and patient populations.

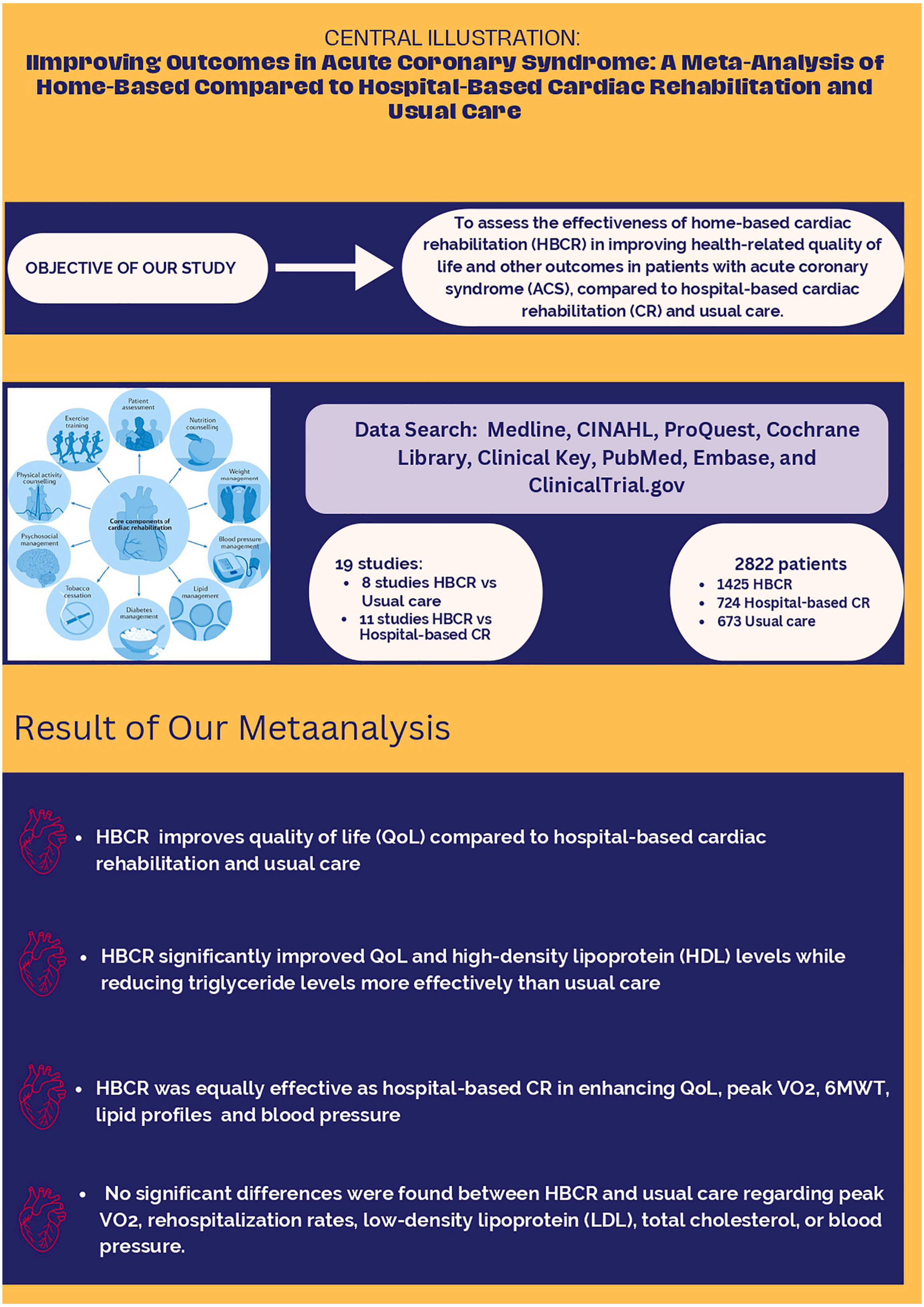
Despite these strengths, significant heterogeneity was observed across the studies, which limits the consistency and interpretability of the results [23]. This variability is likely due to differences in patient characteristics (such as age and type of ACS), the types of HBCR interventions used, and the geographical settings of the studies. Consequently, the findings should be interpreted with caution, as this heterogeneity may affect both the generalizability and reliability of the results.

Furthermore, the study was limited to published articles in English, which may have excluded relevant research published in other languages or gray literature. The number of studies for certain outcomes was also limited, meaning the analysis for some outcomes was based on only a small number of studies. Additionally, several studies had small sample sizes ($<$100 participants), which further limits the strength of the conclusions drawn. Finally, some studies did not provide detailed descriptions of how the HBCR program was implemented, making it difficult to assess the consistency and quality of the interventions or to replicate them in other settings.

5. Conclusions

HBCR has consistently shown improvements in QoL compared to hospital-based CR and usual care. Subgroup meta-analyses indicate significant benefits in QoL, triglyceride level, and HDL cholesterol, positioning HBCR as a superior rehabilitation approach. Additionally, HBCR is as effective as hospital-based CR in all outcomes measured.

However, key gaps remain in the literature. No studies have compared the six-minute walk test (6 MWT) between HBCR and usual care patients. Furthermore, studies measuring mortality and rehospitalization as key long-term outcomes of HBCR are very limited. Variability in HBCR implementation may also contribute to these inconsistencies, highlighting the need for more standardized protocols. Furthermore, trends suggest a decline in outcomes over time, with suboptimal results in LDL, peak VO_2, and blood pressure, underscoring the importance of addressing challenges in the implementation of HBCR. Further research is needed to explore specific approaches, such as family involvement, in sustaining the rehabilitation process and improving long term outcomes.



Central illustration.

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CRediT authorship contribution statement

Eva Marti: Writing – original draft, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Anggoro Budi Hartopo:** Writing – review & editing, Validation, Supervision, Resources, Conceptualization. **Haryani:** Writing – review & editing, Validation, Supervision. **Margareta Hesti Rahayu:** Investigation, Data curation. **Riris Diana:** Methodology. **Ninik Yunitri:** Writing – review & editing, Methodology, Formal analysis.

Declaration of competing interest

The authors 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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