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The Effect of Exercise-Based Cardiac Rehabilitation on Objectively Measured Physical Activity and Sedentary Behavior: A Systematic Review and Meta-analysis

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Abstract

Objective: Adequate physical activity following cardiac rehabilitation (CR) is required to reduce secondary cardiovascular disease risk. The aim of this review and meta-analysis was to determine the effect of exercise-based CR on objectively measured physical activity (PA) and sedentary behavior (SB) comparing pre- to postintervention, pre- to postchange compared to a control group, and in a longer term follow-up. **Methods:** Five databases were searched (PubMed, MEDLINE [OVID], Scopus, SPORTDiscus, and CINAHL) from inception to January 2019. Two reviewers screened and selected 15 studies involving 1434 participants. Data were synthesized descriptively and by meta-analyses. **Results:** CR resulted in an improvement in activity behaviors compared with preintervention levels (standardized mean difference [SMD] 0.50, 95% CI 0.25-0.55, $P < .0001$). CR resulted in a greater improvement in activity behaviors in the intervention compared with the control group (SMD 0.25, 95% CI 0.02-0.49, $P = .04$). Increased PA was maintained (SMD 0.32, 95% CI 0.22-0.41, $P < .0001$). Eight out of 15 studies showed an improvement in PA outcomes while 7 reported that objectively measured PA did not change immediately following the intervention compared to preintervention levels and/or compared with the control group. Of the 7 studies that reported changes in SB, 4 observed a reduction following CR while 3 reported no change. **Conclusion:** Participation in exercise-based CR programs is effective in improving PA and SB. However, our descriptive synthesis indicates that only half the studies were successful in improving activity behaviors following exercise-based CR. Standard guidelines for the assessment of activity behaviors following CR would be valuable in understanding of the effects of CR on long-term activity participation.

Keywords

cardiac rehabilitation, exercise, physical activity, sedentary behavior, accelerometer

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Introduction

Cardiac rehabilitation (CR) following a cardiac event is safe, delivers quality health outcomes and is cost effective.[1,2] One of the core components of comprehensive CR is the promotion of lifelong engagement in physical activity (PA) through behavior counseling and exercise training. Despite strong evidence showing a positive correlation between achieving PA recommendations and a lower CVD risk,[3-5] referrals to, uptake of, and long-term engagement in cardiac rehabilitation remains low globally.[1,6-10]

Major health care organizations recommend that CR patients consistently accumulate 30 to 60 minutes of moderate intensity PA per day on more than 5 days of the week and minimize the amount of time that is spent in sedentary behavior (SB).[3] However, even the majority of healthy older adults do not attain these levels of activity.[11] Nevertheless, the health benefits of cardiac rehabilitation appear to exist regardless of the type of cardiovascular disease, whether a patient is prescribed exercise only or comprehensive cardiac rehabilitation, the dose of exercise, when follow-up occurs, whether one exercises at home or at a center or the geographic location the intervention takes place in.[12]

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This raises a question as to whether or not PA levels change following CR.

There have been 3 systematic reviews investigating the effect of CR on PA and SB.[13-15] Dibben et al[13] assessed whether any form of CR changed PA, measured using both subjective and objective methods of assessment. The authors showed with a meta-analysis that CR increased the percentage of participants categorized as physically active in the short and long term. The same was true for SB at a long-term follow-up.[13] Another review and meta-analysis[14] investigated the effect commercial wearable devices with exercise advice had on PA and SB 4 weeks after having taken part in a form of phase II CR, that is, during phase III CR, including exercise and/or counseling and education. These authors found that wearable devices were better for increasing PA in phase III CR compared with wearing no device, but there was no influence on time spent in SB. A third systematic review[15] included studies investigating the impact of center- and home-based, exercise-based, psychosocial and education-based CR on PA measured both objectively and subjectively. They found that home-based CR had better long-term effects compared with center-based CR for improving and maintaining PA levels, and showed that modifying the type of CR had no additional benefit.

The aforementioned reviews all focused on a variety of different components of CR and activity behaviors. Most studies included in the reviews reported activity behaviors using subjective measures, which can introduce bias due to overestimation of patient self-reported activity.[16] Furthermore, although guidelines for the management of SB in people attending CR have not yet been established, there is a body of evidence that suggests sedentary behavior is an independent risk factor for cardiometabolic disease.[17-19] Although the interdependence of the relationship between SB and health is not quite clear,[20] time spent in the behavior should be reduced as much as possible.[21] It is not clear whether SB decreases following CR as few studies have measured this behavior objectively. Sedentary behavior level measurement following CR is important as it may be an alternative behavior to incorporate into the behavior counseling in patients during CR.

The current review sought to specifically identify only studies that included objective measures of PA and SB following participation in some form of exercise-based CR in order to synthesize the evidence and evaluate the effectiveness of exercise-based CR on PA and SB in adults with cardiac conditions. This review aimed to include an assessment of PA and SB immediately following phase II CR as well as to assess whether effects were maintained during a long-term follow-up of PA and SB, that is, in phase III CR. Meta-analyses were also performed to quantitatively determine the overall effect size of exercise-based CR on combined habitual activity levels immediately after attendance at CR and, where possible, in the long term.

New Contribution

Patients attending exercise-based CR increase participation in positive activity behaviors in the short and long term compared with receiving standard care without exercise training. Consensus on the optimal type and combination of activity outcomes, and how they are measured, is needed to support the conduct of high-quality trials into the effects of CR on activity behaviors.

Methods

The systematic review identified studies that measured PA and/or SB change using objective methods only in adults before and after exercise-based CR in any country. The review protocol was registered with the International Prospective Register for Systematic Reviews with registration number: PROSPERO 2019 CRD42019124971 (https://www.crd.york.ac.uk/prospero/). The review adhered to the reporting guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Supplementary Table S1).

Databases and Search Strategy

A comprehensive systematic search of the literature was performed by 2 reviewers (RMM and KT) in March 2019. Five databases were searched: PubMed (using best match instead of most recent), Medical Literature Analysis and Retrieval System Online (MEDLINE) (Ovid), Scopus, SPORTDiscus, and Cumulative Index to Nursing and Allied Health Literature (CINAHL) under the referencing system EBSCOHost. The literature search was conducted with medical subject headings (MeSH) and keywords in the title, abstract, and text for the population, intervention, comparator, and outcomes (PICO). The MeSH and keywords utilized in the searches were assembled into 15 sets of 3 MeSH and keyword combinations that all consisted of "Cardiac Rehab*" with the following keywords "Physical Activity," "Accelerometer," "Exercis*," "Sedentary Behavio*," "Pedometer," "Objectively Measured." This systematic review was conducted on published studies in the English language from inception to 2019. A final search was conducted from references found in literature reviews that related to topic of interest. Last, the reference list of systematic reviews found during title screening were examined for additional studies to be included in this systematic review. Duplicates of articles retrieved in the search were removed.

Study Eligibility Criteria

Longitudinal, pre-post, experimental studies (with or without control groups) that measured PA and/or SB using objective methods only, in adults before and any time after exercise-based CR were included in the review. Objective measures of PA and SB included accelerometers or pedometers. Studies were included if PA and/or SB was objectively measured prior to the onset of CR, after completion of CR and/or if they included a follow-up after cessation of the CR program. Studies were included if exercise training was conducted in a hospital-based (supervised) and/or free-living or community-based setting (unsupervised). Studies were excluded if they measured PA and/or SB subjectively using self-report and/or questionnaires or if they did not use a structured exercise program as the primary intervention, that is, studies using tele-rehabilitation or behavior change interventions only. Studies that did not explicitly state that they measured PA and/or SB before the onset and after the cessation of a CR program, that is, studies that only measured PA during the CR program were also excluded.

Study Selection

Two reviewers (KT and RMM) independently selected articles based on title, abstract, and full text articles. Disagreements of article selection based on title were resolved by discussion. Article selections were based on abstract and a third reviewer (LB) adjudicated full texts at each stage to resolve the disparity in article selection between the 2 primary reviewers.

Data Extraction

Two authors (RMM and KT) agreed a priori on which data to extract from the included articles. Data extraction from the included articles was performed using a predetermined data extraction sheet by one author (KT) and cross-checked for accuracy, detail, and consensus by the remaining authors (RMM and LB). For each included article, the following data were extracted, summarized, and presented in tables: study design, sample size, demographics, and pathology of included study participants; characteristics of the CR program with assessment time-points, type of accelerometer, the placement of the device, and the protocol used; outcome measures of objectively assessed PA and SB; and study findings. Data on compliance to the intervention and whether additional educational sessions or behavior counseling were included as part of the CR program were also extracted.

Critical Appraisal of Methodological Quality

The methodological quality of included studies was assessed using the Scottish Intercollegiate Guidelines Network (SIGN) checklist 2 for controlled trials or checklist 3 for cohort studies. Two authors (KT and RMM) assessed the risk of bias of the included studies. Agreement on the final ratings was reached by discussion between these 2 authors and adjudicated by the third author (LB).

Data Synthesis and Analysis

A descriptive synthesis of the evidence was undertaken by tabulating the main findings of each study; means, standard deviations, medians, interquartile ranges, confidence intervals, and *P* values were extracted. Meta-analysis (Comprehensive Meta-Analysis Version 3, Biostat) was conducted separately for pre- to immediate post CR follow-up points, pre- to immediate post CR in studies comparing with a control group, and pre- to long-term follow-up points where these data were collected. A random-effects model was used to account for external influences on the intervention outcomes between studies.[22] Individual study results were combined where more than one PA/SB outcome measure was used, and reported as standardized mean differences (SMDs) with 95% confidence intervals (CIs). Using SMDs allowed the studies to be combined on a uniform scale to account for variability observed in each study (ie, difference in mean outcome/standard deviation of the outcome). Within studies that had more than one intervention,[26,36] or follow-up period,[25,26,30,36] each intervention was entered into the meta-analysis separately. Effect sizes associated with these SMDs were allocated as follows: >0.8 large, 0.5 to 0.79 moderate, and 0.2 to 0.49 a weak effect.[23] Heterogeneity between studies was assessed using the I^2 statistic, where <25% indicates low risk, 25% to 75% indicates moderate risk, and >75% indicates high risk of heterogeneity.[24] Data are presented using Forest plots. In the plots, the squares represent point estimates of treatment effect (larger squares indicate larger samples), the horizontal lines (whiskers) are 95% CIs and the diamond represents the pooled treatment (summary) effect, while the vertical lines represents the size of the SMD and 95% CIs.

Results

Study Selection

A total of 876 articles were obtained from the initial electronic databases search excluding duplicates. An additional 17 were included through reference list searches. Titles of these 893 articles were screened and after adjudication, 146 articles were selected for further abstract screening. Abstract screening (RMM and KT) resulted in 26 articles selected for full text assessment. Full text screening resulted in 15 eligible studies for the final data analysis (Figure 1). Titles of the excluded full text screened studies with reasons are presented (Supplementary Table S2).

Methodological Quality Assessment

Of the 4 cohort studies, 3 were of acceptable quality while 1 was deemed low quality. Most randomized controlled trials were of acceptable quality. The most common risks of

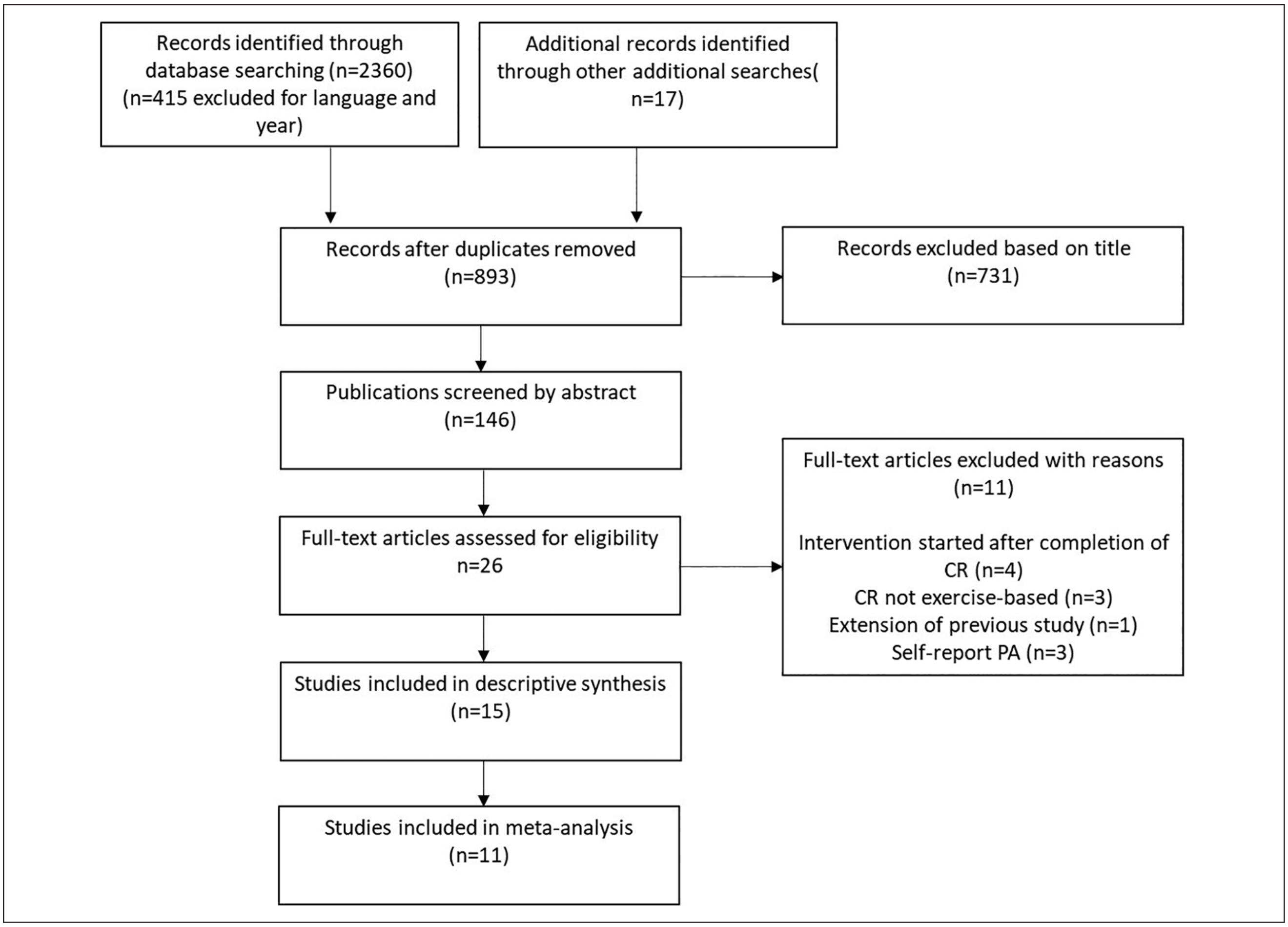

Figure 1. Flowchart showing the method of selection of studies included in the final analysis.

bias were inadequate concealment methods or concealment methods not mentioned, and participants and investigators not blinded to treatment allocation. Additionally, another common weakness was that intervention and control groups were not similar at baseline (6/11 = 55%). The results of the SIGN assessment appear in Supplementary Tables S3 and S4.

Characteristics of Included Studies

A total sample size of 1434 participants were recruited into the 15 studies and entered into an exercise or control group. Approximately 80% of participants were male (1150) and 20% were female (294). The mean ages of the participants ranged between 54.8 and 79.5 years.

A detailed description of the design and participant characteristics in each study appears in Table 1. Of the included studies, 4 were prospective cohort studies[25-28] and 11 were randomized controlled trials[29-39] published between 2004 and 2019. The study by Ribeiro et al[35] was a subanalysis of 2 randomized controlled trials.

Three studies were conducted in the Netherlands,[28,36,37] 2 in Portugal,[33,35] 2 in Belgium,[31,32] 2 in the United States,[27,39] 2 in Canada,[26,34] 1 in Australia,[25] 2 in the United Kingdom,[30,38] and 1 in Sweden.[29] The patient profile within the studies included patients with heart failure (mostly systolic dysfunction, NYHA [New York Heart Association] class II and III) with reduced or preserved ejection fraction,[29,30,37,38] those who had been diagnosed with coronary artery disease, ischemic heart disease, and/or acute coronary syndrome and who were treated for such including via coronary artery bypass grafting or revascularization surgery.[25-28,31-36,39]

Characteristics of the Exercise-Based Cardiac Rehabilitation Programs

The descriptions of the CR programs, compliance to the intervention, and whether additional educational sessions or behavior counseling was included as part of the CR program are presented in Supplementary Table S5. The duration of CR exercise programs ranged from 4 to 8 weeks with

Table 1. Study Characteristics.

Authors (year)	Study design	Intervention duration	No. of participants	Gender, male/female (n/n) or % male	Age,[a] years	BMI, kg/m^2	Diagnosis
van den Berg-Emons et al (2004)	RCT	3 months	IG 18; CG 16	IG 12/6; CG 13/3	IG 58.6 (12.1); CG 58.6 (10.6)	IG 25.2 (3.0); CG 30.1 (4.6)	Stable heart failure (primarily systolic dysfunction, NYHA class II/III); left ventricular ejection fraction < 40%: ischemic heart disease, idiopathic dilated cardiomyopathy, hypertension, nonobstructive valve disease
Stevenson et al (2009)	Prospective study	4-6 weeks	22	14/6	65.6 (13.2)	29.1 (4.6)	Patients who had undergone percutaneous coronary intervention or coronary artery bypass graft
Cowie et al (2011)	RCT	8 weeks	60 randomized to hospital-based (n = 20), home-based (n = 20) or control group (n = 20)	Hospital 16/4; home 18/2; control 17/3	Hospital 71.2 [59-85]; home 65.5 [35-82]; control 61.4 [39-79]	[b]Hospital 27.3; home 26.6; control 27.1.	Left ventricular systolic dysfunction on echo, clinically stable for 1 month, on optimized medication dose
Witham et al (2012)	RCT	8-week hospital-based then 16 week home-based	IG 53; CG 54	IG 35/18; CG 37/17	IG 80.4 (5.8); CG 79.5 (4.9)	NR	Confirmed diagnosis of heart failure due to left ventricular systolic dysfunction (NYHA classes II and III) and a history of signs and symptoms of congestive heart failure
Borland et al (2014)	RCT	3 months	IG 25; CG 23	IG 20/5; CG 18/5	IG 70 (6); CG 71 (9)	NR	Stable chronic heart failure NYHA class II-III
Oliveira et al (2014)	RCT	8 weeks	IG 47; CG 45	IG 40/7; CG 37/8	IG 54.8 (10.6); CG 58.6 (10.7)	IG 27.0 (3.6); CG 27.5 (3.3)	4 weeks postacute myocardial infarction
Frederix et al (2015a)	Multicenter, prospective RCT	18 weeks	IG 69; CG 70	IG 59/10; CG 55/15	IG 61 (9); CG 61 (8)	IG 28 (5); CG 28 (4)	Coronary artery disease and treated with percutaneous coronary intervention or coronary artery bypass grafting, chronic heart failure (NYHA class I, II, and III) with reduced ejection fraction or preserved ejection fraction
Frederix et al (2015b)	Prospective RCT	Centre-based = 12 weeks. Internet telerehabilitation = 24 weeks	IG 32; CG 34 (all randomized participants = 80, 40 in each group)	[c]Male (%): IG 81; CG 85	IG 58 (9); CG 63 (10)	IG 29.1 (4.9); CG 26.8 (3.6)	Acute coronary syndrome or coronary artery bypass graft

(continued)

Table 1. (continued)

Authors (year)	Study design	Intervention duration	No. of participants	Gender, male/female (n/n) or % male	Age,[a] years	BMI, kg/m^2	Diagnosis
Yates et al (2015)	Repeated-measures design of pilot study with an embedded RCT	3 months	35 couples randomized into 2 groups, usual care and PaTH groups. Final analysis included: IG 18 couples; CG 17 couples[d]	IG 15/2; CG 13/4	IG 64 [33-77] years; CG 66 [40-77] years	NR	Coronary artery bypass graft and partners required to be married or living with the patient >1 year, both classified as low to moderate risk for the occurrence of cardiac events during exercise
Ramadi et al (2016)	Prospective 2-arm repeated-measures study	Patients entering 2 CR programs: Traditional (T) 12 weeks; Fast-track (FT) 8 weeks	T 24; FT 20	T 17/7; FT 17/3	T 61 (10); FT 64 (7)	T 28.6 (5.1); FT 27.9 (4.1)	Patients referred to CR with a diagnosis of coronary artery disease
Ribeiro et al (2017)	Subanalysis of 2 prospective RCTs	8 weeks	IG 25; CG 25	IG 23/2; CG 20/5	IG 54 (9); CG 58 (9)	IG 28.9 (4.0); CG 27.8 (4.0)	Acute myocardial infarction
ter Hoeve et al (2017)	Prospective cohort study	10-13 weeks	135	106 (29)	58.8 (8.5)	28.0 (3.8)	Acute coronary syndrome
Prince et al (2018)	Single center, 2-arm pilot RCT	8 weeks	IG 17; CG 21	IG 10/7; CG 13/8	IG 62.4 (10.7); CG 61.5 (9.7)	IG 28.7 (25.7, 31.6); CG 30.5 (28.0, 32.9)	Coronary artery disease and referred to CR
ter Hoeve et al (2018)	RCT	3 months	CR and face-to face counseling (CR + F): 161, CR and telephonic counselling (CR + T): 165. CR only: 163	CR + F 129/32; CR + T 141/24; CR only 131/32	CR + F 58.8 (9); CR + T 58.2 (9); CR only 59.1 (8)	NR	Acute coronary syndrome
Freene et al (2019)	Prospective cohort design, phase II CR trial	6 weeks	72	79%	64.2 (9.6)	30.1 (5.0)	Stable coronary heart disease and receiving treatment with or without revascularization

Abbreviations: CR, cardiac rehabilitation; RCT, randomized controlled trial; IG, intervention group; CG, control group; NYHA, New York Heart Association; NR, not reported.
[a]Age reported as mean (SD) or mean [range].
[b]Standard deviation not reported.
[c]Not reported if % is for baseline number of participants or those who completed the intervention.
[d]Data for patients only and not spouses.

a frequency of visits between 2 and 3 times per week. Nine out of the 15 studies included a follow-up after the intervention,[25,28,30-32,36,38,39] which ranged between 18 weeks and 18 months. Exercise sessions lasted between 15 and 60 minutes. All studies involved aerobic exercises with 6 including balance and/or resistance training.[28,29,34,36,38,39] Five studies did not specify either the mode of exercise or the intensity of training.[25,27,28,31,34] Ten studies incorporated education and counseling sessions on improving lifestyles, PA and its consequences, strategies on improving PA and improving lifestyle and diet (Figure 2).[25,26,28,30-32,34-36,38,39] All but 2 studies[29,36] reported intervention compliance results.

Summary of Physical Activity and Sedentary Behavior Outcomes and Changes

A range of accelerometer devices were used to measure PA and/or SB, the most common being the ActiGraph accelerometer. The accelerometers were worn for periods ranging from 2 to 7 days prior to the start of, and after CR, to a full 12 weeks of continuous consecutive wear during the study.[32] Five out of the 15 studies included some measure of SB as an outcome. A description of the accelerometer protocol for each study, the data reduction methods applied, and the main activity outcomes findings is presented in Table 2.

Eight out of the 15 included studies showed a significant improvement in PA outcomes while 7 studies reported that objectively measured PA did not change immediately following the intervention compared with preintervention levels and/or compared with the control group (if relevant) (Figure 2). One study did not report on whether the actual change in PA was significant following the intervention, rather they showed that there was a correlation between aerobic daily step count and VO_{2peak} which increased significantly in the intervention group.[31] Of the 7 studies that reported changes in SB, 4 observed a significant change immediately following CR[25,26,28,33] while 3 did not[34-36] (Figure 2). Of the 4 studies that observed a significant reduction in SB immediately after CR, three studies assessed SB outcomes at a long-term follow up.[25,26,28] All 3 studies were prospective follow-up studies with no control group. One study found that the SB decrease was maintained at a 1-year follow-up,[28] while the other found that the six month SB level was comparable to baseline.[26] The third RCT followed up their patients 6 and 12 months after CR and found that at both time points patterns of SB were significantly decreased compared to baseline levels.[25]

Meta-analysis

Of the total number of studies meeting inclusion criteria, there were 11 that provided data for meta-analysis. The pooled data from nine studies reporting a pre- to postchange in PA and SB indicated that cardiac rehabilitation produced a moderate effect on activity behavior (SMD 0.50, 95% CI 0.25-0.55, $P < .0001$). Heterogeneity was high ($I^2 = 78.4\%$, $P = .001$). The forest plot is shown in Figure 3.

The pooled data from 5 studies comparing an intervention and control group indicated with a weak effect that cardiac rehabilitation resulted in a greater improvement in activity behaviors in the intervention compared with the control group (SMD 0.25, 95% CI 0.02-0.49, $P = .04$). Heterogeneity was low ($I^2 = 0\%$, $P = .95$). The forest plot is shown in Figure 4.

The pooled data from 5 studies that included a longer term follow-up indicated improved activity behaviors were maintained but this was associated with a weak effect (SMD 0.32, 95% CI 0.22-0.41, $P < .0001$). Heterogeneity was moderate ($I^2 = 70.3\%$, $P < .0001$). The forest plot is shown in Figure 5.

Discussion

PA and SB have well-documented associations with cardiovascular health outcomes,[17,18] and as technology to measure these behaviors improves, research has emerged into whether cardiac rehabilitation modifies PA and SB. This current systematic review included 15 studies that investigated whether taking part in an exercise program as part of CR improved objectively measured PA and SB in patients diagnosed with and/or recovering from cardiovascular disease. Overall, it appears that taking part in exercise-based CR favors improvements in objectively measured PA and/or SB immediately following rehabilitation and when compared with a control group. Half of the studies that assessed changes in SB, showed an improvement in SB while the other half showed no change. An additional aim of this systematic review was to determine long-term changes in PA and/or SB following participation in exercise-based CR. Overall in the long term, participants who attended exercise-based CR appeared to sustain their increased engagement in positive activity behaviors, as shown by the meta-analysis. Two studies measuring long-term improvements in SB after CR showed reductions in SB were maintained for at least a year.

Our results are slightly different to those of a previous systematic review[13] that analyzed PA outcomes from studies using both objective and subjective measurements. Although the outcome variables used in this current meta-analysis were pooled, as there were too few studies measuring the same construct in the same way to allow individual analysis, the previous systematic review stratified their results by type of activity outcome measure.[13] While we found that overall there is a moderate but significant increase in PA in general, Dibben et al[13] found no effect of CR on the time spent sedentary, in light, moderate or vigorous activity. However, the authors of the latter study reported that CR participation was associated with an

	Study author (year)	Significant change in PA immediately after CR	Significant change in PA after follow up	Significant change in SB immediately after CR	Significant change in SB after follow up	Education during intervention	Follow up period
Cohort studies	Stevenson et al (2009)						N/A
	Ramadi et al (2016)						6 months
	ter Hoeve et al (2017)						12 months
	Freene et al (2019)						6 & 12 months
Randomised controlled trials	van den Berg-Emons (2004)						N/A
	Cowie et al (2011)						6 months
	Witham et al (2012)						24 weeks
	Borland et al (2014)						N/A
	Oliveira et al (2014)						N/A
	Frederix et al (2015a)						24 weeks
	Frederix et al (2015b)						18 weeks
	Yates et al (2015)						6 months
	Ribeiro et al (2017)						N/A
	Prince et al (2018)						N/A
	ter Hoeve et al (2018)						18 months

Figure 2. Heat map of changes in physical activity (PA) and sedentary behavior (SB) immediately after and at the long-term follow-up after cardiac rehabilitation by type of study. Whether each study included a behavior intervention or counseling in addition to exercise as part of their cardiac rehabilitation is also included. Red, no; Green, yes; no color, not applicable/not reported.

Table 2. Study Accelerometer Protocols and Main Activity Outcome Findings.

Authors (year)	Accelerometer name	Duration and placement of accelerometer wear	PA and/or SB outcome of interest	Main activity findings
van den Berg-Emons et al (2004)	Activity Monitor (AM, Temec Instruments, Kerkrade, The Netherlands).	2 days	Everyday PA (duration, rate, and moment of occurrence of static activities, dynamic activities, and transitions between posture. Pretreatment (t_0) and posttreatment: after 3-month intervention (t_3).	No difference in the between-group change in everyday PA outcomes.
Stevenson et al (2009)	Actigraph GT1M	During entry week and exit week for 7 days. Valid day = 480 minutes of recorded PA data. Nonwear 60 or more minutes of consecutive zeroes. Minimum 4 days for valid data, including minimum 1 CR day 1 non-CR day and 1 weekend day.	Total activity (counts per observation minute), light intensity PA (min/d), MVPA (min/d) and inactivity time (<260 cpm; % of total observation minutes per day) were recorded for CR and non-CR days from entry to exit (4-6 weeks).	Overall activity counts greater on CR days (224.0 (15.6)) vs non-CR days (188.2 (14.5)); $P < .05$. Increase in total activity counts from entry to exit not but not significant ($P = .054$). No differences in light activity. Moderate intensity PA was significantly increased from entry (mean (SE): 13.9 (2.3)) to exit (18.7 (2.5)), $P < .05$. On non-CR days, patients were more inactive at entry (82.5 (1.1%)) than at exit (79.7 (1.6%)); $P < .05$). Patients performed an overall greater amount of total activity (~36 counts per observation minute) and moderate intensity PA (~7 min/d) on days with CR than non-CR days. No vigorous PA was recorded.
Cowie et al (2011)	activPAL (PAL Technologies Ltd, Glasgow, Scotland)	Anterior thigh. One week prior to start of CR, immediately on completion of CR and 6 months follow-up after cessation of CR (subgroup analysis), 24-hour protocol.	Time spent in upright position, mean number of steps per day. Walking pattern: mean steps per day taken and mean cadence during extra-long (>500 steps), long (100-499 steps), moderate (20-99 steps), and short (<20 steps) walks.	No within- or between-group difference in upright duration or steps per day for all groups. No within- or between-group differences in cadence of walking patterns. At 8 weeks, hospital-based group showed significant increase in steps/day for extra-long (399 steps/day) and long (530 steps/day) walks. Within-group change in steps/day was significantly greater for hospital compared with control for extra-long ($P = .02$) and long ($P = .0.3$) walks. Home group increased upright duration from 8 weeks to 6 months (45 minutes more).
Witham et al (2012)	RT3 triaxial accelerometer (Stay Healthy Inc)	Placement NR. Worn during waking hours for 7 days at baseline, 8 weeks, and 24 weeks.	Six-minute walk test time. Secondary outcomes of PA were total activity counts	No difference in change in activity counts between IG and CG for baseline to 8 weeks or baseline to 24 weeks.
Borland et al (2014)	KeepWalking LS2000 pedometer (KeepWalking Scandanavia, Klamar, Sweden).	Waist. 7 days at baseline and at 3 months. Overweight participants placed pedometer on ankle. Worn for entire day and self-record daily number of steps in a diary and reset device to zero each morning.	Pedometer measured step count. Secondary outcomes of self-reported PA (IPAQ), physical fitness (symptom-limited cycle ergometer test), 6-minute walk test, muscle endurance, unilateral isoinertial shoulder flexion, bilateral isometric shoulder abduction, unilateral isoinertial heel-lift, health-related quality of life.	No difference in steps per day between intervention and control group after 3 months.

(continued)

Table 2. (continued)

Authors (year)	Accelerometer name	Duration and placement of accelerometer wear	PA and/or SB outcome of interest	Main activity findings
Oliveira et al (2014)	ActiGraph GT1M	Right hip. Worn for 7 days except during sleeping, bathing, and water activities. Used Troiano cut-points to reduce data to time spent in PA intensities.	Total PA (cpm), sedentary, light, and MVPA time (min/d).	A significant treatment × time interaction was observed for sedentary behavior, but no difference in the change in SB between IG and CG at final assessment. No difference in change in time spent in light and MVPA.
Frederix et al (2015a)	Yorbody accelerometer (Belgium)—no additional detail provided.	Accelerometer placement not mentioned, worn continuously from beginning of CR to end (12 weeks). Accelerometer provided daily recordings of aerobic (defined as sustained activity at ≥60 steps/min for more than 10 minutes	Daily number of aerobic steps defined as ≥60 steps/min during at least 10 minutes without stopping; regular daily steps defined as steps at <60 steps/min; number of total daily steps = sum of aerobic and regular steps. Exercise tolerance, biochemical markers of cardiometabolic health. Measured at start of Telerehab study (6 weeks after initiation of phase II CR), 6 weeks into Telerehab study and at end of Telerehab study (week 18).	Correlations between aerobic daily step count and increase in VO_{2peak} during follow-up ($P = .03$, $r = 0.47$); HDL concentration and total daily step count ($P = .021$, $r = 0.49$) as well as regular daily step count ($P = .03$, $r = 0.163$). No correlation between HDL and aerobic step count.
Frederix et al (2015b)	Yorbody (no manufacturer details provided).	From beginning of Telerehab II study, 6 weeks of intervention and at 18 weeks after intervention start. Worn for 7 consecutive days during waking hours and removed for water activities. No data reduction methods provided.	Primary measures were peak aerobic capacity (VO_{2peak}) at baseline, after 6 weeks and 24 weeks. Secondary measures were duration of physical activity levels gathered from steps/min.	Total daily steps in IG at baseline (median=7448), 6 weeks (median = 7799) and 24 weeks (median = 8233) however $P = .24$. In CG, baseline (median = 5678), 6 weeks (median = 6630) and 24 weeks (5265) with $P = .85$. Total daily steps were positively correlated with VO_{2peak} at baseline ($P = .01$), 6 weeks ($P = .03$), 24 weeks ($P < .01$).
Yates et al (2015)	Actiheart (CamNTech Company, UK).	Chest. 7 days at each data collection point (baseline, 3 and 6 months), measures energy expenditure, no other data reduction given.	PA behavior = average weekly level of PA spent in METs of 3 or more (time in moderate physical activity (min/wk ≥3.0 METs), dietary intake behaviors and biomarkers at baseline, post-CR (3 months) and follow-up (at 6 months).	Patients: physical activity (min/wk >3 METs) from baseline, post CR and between 3 months and 6 months (PaTH = 31.5, 89.3, 64.8, respectively and UC = 28.0, 133, 121.6, respectively). Patients did not meet 150 min/wk of moderate physical activity.

(continued)

Table 2. (continued)

Authors (year)	Accelerometer name	Duration and placement of accelerometer wear	PA and/or SB outcome of interest	Main activity findings
Ramadi et al (2016)	Sense Wear Mini Armband (BodyMedia, Pittsburgh, PA)	Upper arm, continuously for 5 days, removal for water activities. Data that was more than 80% of daily wear time included in analysis, sleep removed. Obtained 1-minute epochs.	Exercise capacity (6-minute walk test), no. of steps per day, energy expenditure, sedentary time (h/d and % of waking hours), light PA (h/d and % of waking hours), MVPA (min/d) and $MVPA_{10}+$ in continuous 10-minute bouts (10+ min/d at baseline, 12 weeks after program, and at 6 months after program).	Exercise capacity in both groups showed significant improved compared to baseline and were maintained at 6 months ($P < .05$) and change was not different across the 2 groups ($P = .107$). No change in step count in both groups over all time points ($P = .194$). Significant decrease in sedentary time from baseline to 12 weeks in both groups ($P < .05$) with no difference in both groups ($P = .757$). However, at 6 months sedentary time not different to baseline ($P = 1.000$). Significant effect of time was detected for light PA ($P < .05$, group difference $P = .405$), no significant change in light physical activity or in percentage of waking time spent in light PA at any of the assessment intervals ($P > .05$). No significant change was seen in overall MVPA ($P = .069$) and $MVPA_{10}+$ ($P = .130$).
Ribeiro et al (2017)	Actigraph GT1M (ActiGraph LLC).	Hip. 7 days during waking hours. Remove for sleep and water activities. Used own developed software (POPERO version 1.0.18 for Mac OSX. to determine time spent in different intensity activities. 10 minutes of consecutive zeros = nonwear. Minimum 8 hours per day for a valid day.	Change in MVPA (min/d) after intervention.	EG increased MVPA after program: mean (SD) 43.2 (36.3) to 53.5 (31.9) min/d ($P < .03$). CG no change in MVPA: 40.8 (26.2) to 36.8 (26.5) min/d. No significant changes in total PA (counts/min), sedentary (minutes/day), light (min/d), and other secondary measures.
ter Hoeve et al (2017)	ActiGraph GT3X+ (ActiGraph LLC).	Hip. 8 days at t_0, t_1, and t_2 during waking hours. Taken off for water activities and recorded in logbook. Used vector magnitude.	Week before CR (t_0) to after CR (t_1) and at 12 months after the start of CR (t_2). Change in total PA (activity counts/min, steps/min) and proportion of time spent awake in each activity (MVPA, light, and SB). Distribution of PA = lengths of MVPA and SB bouts, number of MVPA bouts >10 minutes, SB bouts >30 minutes (% of wear time).	Total activity counts/min mean (SD) difference: $t_0 - t_1$: +50.56 (128.2), $P < .001$, $t_0 - t_2$: +55.04 (148.2), $P < .001$. Daily step count compliance to 6500 steps/day (%): t_0 = 39.3%, t_1 = 51.4% ($P < .001$ vs t_0) and t_2 = 46.5% ($P < .001$ vs t_0). Proportion of wear time mean (SD) difference: $t_0 - t_1$: MVPA= +0.65 (2.21)%, $P = .002$, light = +1.84 (5.65)%, $P = .001$, SB = −2.49 (6.57)%, $P < .001$; $t_0 - t_2$: MVPA = 0.5 (2.51)%, $P = .37$, light = 2.98 (6.49)%, $P > .001$, SB = −3.48 (7.75)%, $P < .001$. No change in MVPA distribution. Mean (SD) difference in length in SB bouts: $t_0 - t_1$: −0.05 (0.14) minutes, $P < .001$; $t_0 - t_2$: −0.07 (0.16) minutes, $P < .001$. SB bouts >30 minutes: $t_0 - t_1$: −3.10 (10.0) minutes, $P = .001$; $t_0 - t_2$: −5.11 (10.7), $P < .001$.

(continued)

Table 2. (continued)

Authors (year)	Accelerometer name	Duration and placement of accelerometer wear	PA and/or SB outcome of interest	Main activity findings
Prince et al (2018)	activPAL3 (PAL Technologies, Glasgow, UK).	Placed on right thigh and worn during waking time for seven days before first CR class. Valid data = minimum 4 valid days and 10 hours wear time per valid day.	Primary outcomes: intervention adherence. Secondary: change in sedentary time (ST) (min/d and % of wear time), steps (per day), MVPA (min/d). Measured before CR and in the last/8th week of CR.	No overall significant changes were observed in SB and PA. Average reduction in ST in IG (1.5%) and CG (1%) showed a mean difference in ST of 30.3 min/d (95% CI: −51.7, 112.2) favoring the IG ($P = .458$). Standing, step count, MVPA had a positive trend in both groups despite no significant difference from baseline.
ter Hoeve et al (2018)	Actigraph GT3X+ (ActiGraph LLC).	Hip. Directly after randomization (T0), after CR (T3m), after after-care for 8 days during waking hours, used vector magnitude, at least 4 days with minimum 660 minutes per day. Nonwear = 60 minutes of consecutive zeroes. MVPA ≥672.5 counts, light activity = 37.5-672.5 counts, SB ≤ 37.5 counts.	Baseline directly after randomization (T0), post CR (T3m, 3 months after randomization), completion of after-care (T12m, 12 months after randomization), and 6 months after completion of after-care (T18m, 18 months after randomization). Duration of time spent in MVPA and SB as % of wear time, step count, MVPA bouts >10 minutes, SB bouts <30 minutes, number of patients attaining at least 6500 steps, and attaining 21.4 minutes prolonged MVPA/day.	CR + F vs CR-only: No overall intervention-effect for MVPA time and SB time. Overall intervention effect for step-count and prolonged MVPA (bout >10 minutes). At T3m, CR + F patients improved step count more than CR-only patients. During after-care program (3-12 month after CR) difference in step count not maintained. CR + T vs CR-only: no overall intervention effect.
Freene et al (2019)	ActiGraph ActiSleep, (Fort Walton Beach, FL, USA)	Right hip, worn for 24 h/d for 7 days. Nonwear defined as >60 consecutive minutes of zero activity, allowing for 2 minutes of counts between 0 and 100). Valid day was more than 10 h/d wear time and data included if 4 or more days of valid data. Freedson combination energy expenditure algorithm was used to determine PA and SB (<100 cpm) intensity cut-points. Used general time filter (07:00-22:30 hours. Average sleep and wake time reported by participants).	PA and SB time/day, MVPA bouts (minimum bout length = 10 minutes, tolerance of 2 minutes), SB bout time (minimum bout length 10 minutes but no drop time), number of breaks in sedentary time, adherence to AP recommendations. Measured at baseline, 6 weeks after CR and at a 6-month and 12-month follow-up.	Significant increase in MVPA from baseline to 12 months: 39 (23) to 45 (25) min/d. Significant increase in MVPA from 6 weeks to 6 months: 40 (24) to 44 (24) min/d. Significant increase in low physical activity from baseline to 6 weeks: 73 (22) to 82 (30) min/d, and to 12 months: 84 (26). Significant decrease in total SB time from baseline to 6 months: 723 (58) to 651 (81) min/d; and baseline to 12 months: 648 (79) min/d. Significant decrease in SB bouts and SB breaks from baseline to all time points.

Abbreviations: CR, cardiac rehabilitation; NR, not reported; MVPA, moderate to vigorous physical activity; IG, intervention group; CG, control group; PA, physical activity; SB, sedentary behavior; ST, sitting time; VO_2, oxygen consumption; cpm, activity counts per observation minute.

Study name		Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
van den Berg-Emons 2004	Combined	0.120	0.183	0.034	-0.239	0.479	0.656	0.512
Oliveria 2008	Combined	1.719	0.318	0.101	1.095	2.343	5.400	0.000
Stevenson 2009	Combined	0.226	0.168	0.028	-0.104	0.555	1.342	0.180
Ramadi 2016 (Con)	Combined	0.522	0.169	0.029	0.191	0.854	3.092	0.002
Ramadi 2016 (FT)	Combined	0.141	0.174	0.030	-0.200	0.483	0.812	0.417
Riberio 2017	Combined	0.219	0.157	0.025	-0.089	0.527	1.394	0.163
ter Hoeve 2017	Combined	0.306	0.075	0.006	0.158	0.453	4.065	0.000
Prince 2018	Combined	0.170	0.186	0.035	-0.195	0.536	0.914	0.361
ter Hoeve 2018 (CR+F)	Combined	0.487	0.073	0.005	0.345	0.629	6.705	0.000
ter Hoeve 2018 (CR+T)	Combined	0.233	0.068	0.005	0.100	0.365	3.446	0.001
ter Hoeve 2018 (CR)	Combined	0.298	0.071	0.005	0.160	0.436	4.221	0.000
Freene 2019	Combined	1.191	0.194	0.038	0.811	1.571	6.139	0.000
		0.400	0.075	0.006	0.252	0.548	5.300	0.000

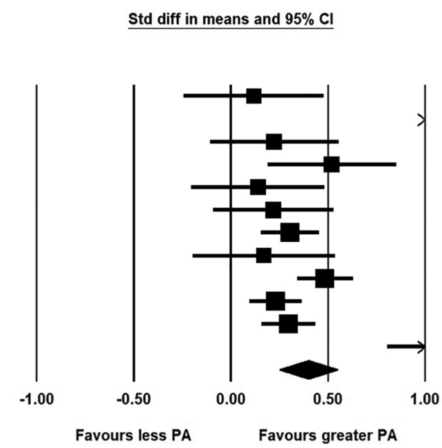

Figure 3. Forest plot of effect sizes for studies of pre-post exercise-based cardiac rehabilitation. The overall point estimate revealed a small effect favoring greater objective physical activity (PA) and sedentary behavior (SB) immediately following exercise-based cardiac rehabilitation. Arrow denotes the effect was greater than 1.

Study name		Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
van den Berg-Emons 2004	Combined	0.124	0.344	0.118	-0.550	0.798	0.361	0.718
Cowie 2011	Combined	0.100	0.317	0.100	-0.520	0.721	0.316	0.752
Cowie 2011 b	Combined	0.186	0.317	0.101	-0.436	0.808	0.586	0.558
Borland 2014	Steps/day	0.174	0.289	0.084	-0.393	0.742	0.602	0.547
Oliveria 2014	Combined	0.389	0.241	0.058	-0.082	0.861	1.617	0.106
Riberio 2017	Combined	0.405	0.286	0.082	-0.156	0.965	1.414	0.157
		0.253	0.120	0.014	0.018	0.487	2.112	0.035

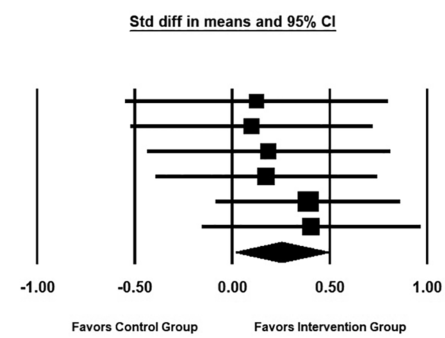

Figure 4. Forest plot of intervention versus control group for the change in activity behaviors following cardiac rehabilitation. The overall point estimate revealed a small effect favoring structured exercise-based cardiac rehabilitation versus nonexercise or alternative control interventions on objective physical activity (PA) and sedentary behavior (SB).

increase in objectively measured daily step count. The most obvious explanation for the difference in findings is the fact that we excluded self-reported measures of PA because of the known bias in self-reporting PA levels,[16] a limitation that was confirmed by the authors of the previous review. Nevertheless, when considered together the results of both reviews are promising especially for long-term changes in PA behaviors following CR.

The moderate to high heterogeneity observed in the meta-analysis for the pre-post studies and those that included a long-term follow-up, may result from the large number of different activity outcomes measured in the studies, the differences in the exercise-based program protocols as well as the number of participants at each time point within and between each study. Although combining PA and SB outcome measures may also have contributed to the heterogeneity in the meta-analysis due to them being slightly different constructs, considering that the 2 behaviors are naturally correlated it made the most sense to combine them as an outcome of total activity behavior change in the positive or negative direction. Treating them as independent variables when they are related constructs would affect the size of the point estimate and significance. In the pre-post analysis, the high heterogeneity across studies is most likely due to variation in exercise-based CR protocols that were delivered (eg, frequency, duration, and intensity of exercise, home vs clinic-based, aerobic plus strength vs aerobic only), even though there was a moderate effect size for the intervention. In the meta-analysis for the intervention versus control, there was low heterogeneity across studies, likely because both groups were exposed to similar environments within each individual study and the same outcomes were measured for both groups. Thus, the magnitude of changes between control and intervention groups was consistent between studies. However, there was

Study name	Outcome	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Cowie 2011- Home	Combined	0.122	0.247	0.061	-0.362	0.606	0.495	0.621
Cowie 2011- Hosp	Combined	0.234	0.248	0.062	-0.253	0.721	0.942	0.346
Ramadi 2016- T	Combined	0.190	0.160	0.025	-0.122	0.503	1.193	0.233
Ramadi 2016- FT	Combined	-0.009	0.173	0.030	-0.349	0.331	-0.051	0.959
ter Hoeve 2017	Combined	0.281	0.074	0.006	0.135	0.426	3.786	0.000
ter Hoeve 2018- F12	Combined	0.307	0.072	0.005	0.166	0.448	4.272	0.000
ter Hoeve 2018- F18	Combined	0.226	0.072	0.005	0.085	0.367	3.140	0.002
ter Hoeve 2018- T12	Combined	0.196	0.068	0.005	0.063	0.329	2.880	0.004
ter Hoeve 2018- T18	Combined	0.360	0.075	0.006	0.212	0.507	4.785	0.000
ter Hoeve 2018- CR12	Combined	0.205	0.072	0.005	0.064	0.345	2.860	0.004
ter Hoeve 2018- CR18	Combined	0.309	0.072	0.005	0.168	0.449	4.305	0.000
Freene 2019- 6	Combined	0.684	0.105	0.011	0.478	0.889	6.522	0.000
Freene 2019- 12	Combined	0.740	0.107	0.011	0.530	0.950	6.904	0.000
		0.315	0.049	0.002	0.219	0.411	6.433	0.000

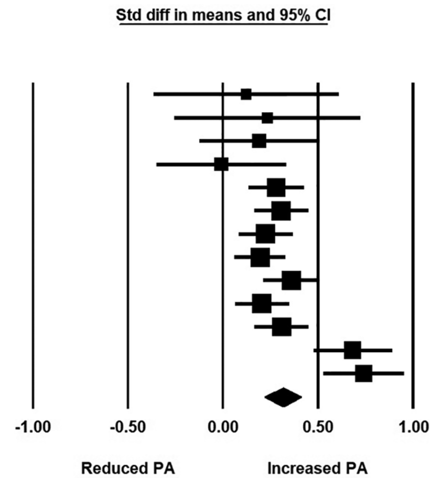

Figure 5. Forest plot of studies that included a long-term follow-up of activity outcomes versus baseline. The overall point estimate revealed a small effect favoring greater objective physical activity (PA) and sedentary behavior (SB) at longer term follow-up after completion of exercise-based rehabilitation.

only a weak effect on overall change in activity outcomes between groups. For the meta-analysis of studies that included a long-term follow-up, we also found moderate variability in sample estimates between studies, again possibly due to the different types of exercise-based CR intervention protocols and outcome measures utilized. While statistically significant, the pre-post difference for long-term follow-up were accompanied by a small effect size. The heterogeneity observed when combining studies investigating CR intervention studies emphasizes the vast differences in exercise-based CR approaches, making it difficult to determine whether one approach is better than another, and the overall impact of CR on objectively measured PA and SB.

The short- and long-term health benefits of CR seem to exist regardless of the type of cardiovascular disease, whether a patient is prescribed exercise only or comprehensive CR, the dose of exercise, length of follow-up, whether one exercises at home or at a center, or the geographic location of the intervention.[40] Given this, adherence to exercise prescription in the long term is difficult for some patients and uptake of phase III CR is often poor.[7,41,42] Frequency, duration, and intensity of exercise additionally differed between studies in this review, and whether these variables play a significant role in determining individual engagement in long-term positive activity behaviors for health remains to be elucidated. A study by Ayabe et al[43] objectively measured patient activity level during exercise-based CR and found that patients achieved their PA targets during the time (7 AM to 9 AM) that they were attending CR. However, for the remainder of the day activity levels were no different to that of non-CR days[43] leading to the question as to what motivates a person to remain active after CR is completed. The effect that exercise-based CR has on activity behaviors in the long-term is important for patient autonomy over their own health. Self-efficacy, self-regulation, and motivation are important factors to consider in enhancing long-term PA, and these factors are predictors of improvements in PA in adults following CR.[44] The positive improvements in activity behaviors immediately following CR found in the current meta-analysis may be an expected finding however. Most programs were supervised in a research or laboratory settings, which are social and supportive environments and, therefore, it may be expected that PA should increase and SB decrease following CR. It is unclear from this current review whether education or counseling played a role in the long-term maintenance of increased PA levels when activity behaviors were assessed in a long-term follow-up. The studies that included education and counseling as part of their intervention did not necessarily show significant changes in PA or SB immediately following exercise-based CR or at the long term follow up. Ultimately, the purpose of CR is to promote lifetime engagement in positive activity behaviors and, therefore, the role that CR has to play in long-term activity behavior change is a question of increasing interest to researchers. Telerehabilitation may provide an answer; however, this method of CR delivery was outside the scope of the current review.

Seven studies assessed SB as an outcome measure following participation in exercise-based CR. It is important to note that there were many different definitions and measures of SB outcomes and/or data reduction techniques across these studies. In both studies led by ter Hoeve,[28,36] an Actigraph GT3X was used, which does not distinguish between active standing and being sedentary. Stevenson et al[27] classified inactivity as being <260 cpm (activity counts per observation minute) measured with an ActiGraph GT1M, which may have included the <100 cpm, which typically defines time spent being sedentary when measured with the GT1M. Given that the definitions as well as the physiology between inactivity and sedentary behavior appear to be different,[18,45] these misclassifications may have ramifications for studies using different definitions of activity and their conclusions on health outcomes. Only 1 study[34] used the activPAL in the assessment of SB, which is currently the most accurate monitor to do so.[46] Data from the intervention group was excluded from this meta-analysis because the intervention group had their SB constantly interrupted with another device that gave alerts to participants when they were sedentary for too long. However, it is interesting to note that the alerting device had no additional effect on reducing SB compared with the control group who only participated in exercise-based CR for the duration of the 8-week intervention. This finding appears to indicate that SB may not be modified following CR. However, there are not enough studies on the effect of exercise-based CR on SB to provide a definitive answer at this time and more studies using the activPAL to quantify SB are needed.

Activity behaviors occur as a continuum throughout the day and previous research has analyzed compositions of activities in a day (ie, proportions of SB, light, and moderate to vigorous physical activity [MVPA]) and found associations between certain compositions and better health outcomes in adults.[47] There is currently a lack of research on the effect that holistically modifiable behaviors (ie, enhanced light and/or MVPA in combination with reduced SB) have on the health of patients with cardiac disease. It is therefore interesting to note that in the study by Ribeiro et al,[35] the exercise group significantly increased their participation in MVPA following CR. Although not statistically significant, the control group (who received usual care and education) reduced the amount of time spent in SB by almost 19 minutes per day (95% CI −43.0 to 5.7) and increased their time spent in light activity by an additional 28 minutes per day (95% CI −0.4 to 57.2). These findings indicate future research may wish to consider the effect of exercise-based CR on combinations of behaviors and their impact on health outcomes.[47,48] Overall, our findings justify the need for more consensus on what the most relevant and modifiable activity behavior combinations may be following exercise-based CR, the most optimum way to measure them, and to elucidate the effect of those combinations on health outcomes in this patient population. The most relevant and modifiable activity behavior combination, is currently a potential avenue of research for trials on exercise-based CR.

Clinically, this would mean advising individuals on multiple activity behavior changes rather than individual activity intensities, that is, increasing MVPA. A more pragmatic and holistic approach for individuals may increase the uptake and compliance to engagement in physical activity for health in those with cardiac conditions.

Strengths and Limitations

The main strength of this systematic review is that we excluded studies that did not explicitly state that activity behaviors were measured before the onset of and after the cessation of the CR program. Furthermore, we only included studies that reported objective measures of PA and SB, providing outcomes that are not biased by subjective recall. One limitation of this systematic review stems from the heterogeneity of included studies.[49] For example, different interventions were used and compared with "a traditional CR program" which itself varied by frequency, mode, and intensity of the CR exercises, education and counseling, follow-up sessions, model of accelerometer, and when the outcome measures were obtained. Another limitation is that only a few studies measured SB, and so PA and SB outcome measures were combined, which did not allow separate conclusions to be drawn between an increase in PA and a reduction in SB.

Furthermore, conclusions of a systematic review depend on the quality of the included studies. Limitations to the internal validity of the studies included in this review were that many studies could not blind those who were administering the intervention; however, most studies at least included a blinded outcome assessor. Furthermore, some studies did not exclude participants who had already attended another cardiac rehabilitation program prior to starting the intervention. Activity levels may have been different between participants at baseline across within studies, and this may have influenced the magnitude of change in PA and/or SB due to the CR program.

More trials monitoring home-based CR and activity are needed to delineate whether it is the intervention or the constant attention of having an intervention delivered in a laboratory setting that drives the improvement in PA engagement post CR program. Comparisons in activity behaviors between home- and center-based CR programs should be undertaken, particularly with multiple follow-ups as there little long-term data for how CR delivery mode influences habitual activity.

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Supplemental Material

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