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Longer-term effects of home-based exercise interventions on exercise capacity and physical activity in coronary artery disease patients: A systematic review and meta-analysis

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Abstract

Background: Exercise-based cardiovascular rehabilitation (CR) improves exercise capacity (EC), lowers cardiovascular risk profile and increases physical functioning in the short term. However, uptake of and adherence to a physically active lifestyle in the long run remain problematic. Home-based (HB) exercise programmes have been introduced in an attempt to enhance long-term adherence to recommended levels of physical activity (PA). The current systematic review and meta-analysis aimed to compare the longer-term effects of HB exercise programmes with usual care (UC) or centre-based (CB) CR in patients referred for CR.

Design: Systematic review and meta-analysis.

Methods: Non-randomised controlled trials (RCTs) or randomised trials comparing the effects of HB exercise programmes with UC or CB rehabilitation on EC and/or PA, with a follow-up period of $\geq$12 months and performed in coronary artery disease patients, were searched in four databases (PubMed, EMBASE, the Cumulative Index to Nursing and Allied Health Literature (CINAHL) and the Cochrane Central Register of Controlled trials (CENTRAL)) from their inception until September 7, 2016. Standardised mean differences (SMDs) were calculated and pooled by means of random effects models. Risk of bias, publication bias and heterogeneity among trials were also assessed.

Results: Seven studies could be included in the meta-analysis on EC, but only two studies could be included in the meta-analysis on PA (total number of 1440 patients). The results showed no significant differences in EC between HB rehabilitation and UC (SMD 0.10, 95% confidence interval (CI) –0.13 to 0.33). There was a small but significant difference in EC in favour of HB compared to CB rehabilitation (SMD 0.25, 95% CI 0.02–0.48). No differences were found for PA (SMD 0.37, 95% CI –0.18 to 0.92).

Conclusions: HB exercise is slightly more effective than CB rehabilitation in terms of maintaining EC. The small number of studies warrants the need for more RCTs evaluating the long-term effects of different CR interventions on EC and PA behaviour, as this is the ultimate goal of CR.

Keywords

Exercise, home-based, coronary, artery, disease, long-term, physical, activity, capacity

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Introduction

Cardiovascular diseases (CVDs) remain a major public health problem in high-income countries, and their prevalence in low- to middle-income countries is increasing rapidly.[1] From all non-communicable

diseases, CVD caused 17.3 million deaths in 2008 and accounted for 10% of the global disease burden.[1] The incidence of CVD increased by 5% between 1990 and 2000, and an additional increase of 25% is expected by 2030.[2]

Exercise capacity (EC) is a strong and independent predictor of cardiovascular and all-cause mortality in CVD.[3,4] It has been previously shown that one metabolic equivalent (MET) increase in EC is associated with 12% improved survival.[5] Therefore, exercise, as a means of increasing EC, is one of the key components in the current management of CVD.[6] This is supported by different meta-analyses of randomised trials evidencing that ambulatory exercise-based cardiac rehabilitation (CR) programmes significantly enhance EC and prevent premature mortality.[7–9] Despite this, uptake rates of exercise-based CR are disappointingly low, with only 30% of all eligible patients participating in supervised phase II CR programmes.[10,11] Moreover, from this low number of participants, only 50% remains active for 6 months or longer after completion of the CR programme.[11] However, as we aim to preserve the achieved EC and to improve prognosis, a continuation of exercise habits is essential.[12]

Among the environmental and social barriers contributing to this low uptake of physical activity (PA) and longer-term adherence, patients primarily report limited CR availability, accessibility, financial costs, lack of time and low self-efficacy as the main causes.[13,14] Home-based (HB) rehabilitation programmes might overcome some of these barriers and target a broader range of patients who would benefit from CR. Furthermore, it is anticipated that HB rehabilitation enhances patients' self-efficacy and facilitates the lifelong implementation of PA in their lifestyle.[15,16]

Indeed, meta-analyses showed that HB rehabilitation can be at least as effective as supervised rehabilitation for maintaining EC, with some evidence of higher levels of programme completion and adherence up to 12 months.[17,18] In the current meta-analysis, we aimed to evaluate the longer-term effects ($\geq$12 months) of HB exercise CR programmes on the EC and PA behaviours of cardiac patients referred for CR.

Methods

This analysis is reported as following the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) statement.[19] The review was registered in the International Prospective Register of Systematic Review (PROSPERO) Registry: CRD4201 6041981.

Eligibility criteria

Randomised controlled trials (RCTs), randomised clinical trials and non-RCTs were considered for inclusion if they: 1) evaluated the longer-term effects ($\geq$12 months after starting an intervention) of a HB exercise CR intervention in comparison with a control group receiving usual care (UC) or a centre-based (CB) rehabilitation group; 2) were in coronary artery disease (CAD) patients referred for rehabilitation; and 3) reported on EC and/or PA. Patients allocated to a HB exercise intervention should have received clear instruction on how to exercise, and regular follow-ups on PA behaviour were a requirement (logbook, phone calls, home visits and repeated follow-up measurements). The UC group could receive standard medical care, but without any form of structured exercise. CAD patients were defined as patients eligible for CR and who had experienced a myocardial infarction and/or underwent a percutaneous coronary intervention (PCI) or coronary artery bypass grafting (CABG). Studies including CAD patients with other underlying pathologies, such as valve surgery or cardiomyopathy, were not excluded. If heart failure (HF) was due to ischaemic heart disease, inclusion was also considered. HF based on other underlying pathologies was defined as an exclusion criterion. The primary outcome EC could be reported in METs, Watts or peak oxygen consumption. PA could be assessed by means of objective (step counts or energy expenditure) or subjective instruments (questionnaires or scales). Adverse events included re-hospitalisation for cardiac events or death.

Data sources and searches

An electronic literature search was performed in four databases – PubMed medical database, including MEDLINE, EMBASE (OVID), the Cumulative Index to Nursing and Allied Health Literature (CINAHL) and the Cochrane Central Register of Controlled trials (CENTRAL) – from their inception date until September 7, 2016, with no language restrictions. Searches were limited to RCTs, non-RCTs or randomised clinical trials performed in humans. The latter two types of trial are defined as prospective trials with a comparison group. Two investigators (JC and NC) screened all titles and abstracts to identify all potentially eligible articles fulfilling above mentioned inclusion criteria. Screening of full-text reports was performed by three reviewers (JC, RB and VAC) independently in order to determine their eligibility for data extraction. Reference lists from these studies were hand searched in order to identify additional articles. A detailed search strategy for each of the databases can be found in Supplemental File 1.

Data extraction and analysis

Three unblinded reviewers (JC, RB and VAC) independently conducted the data extraction. A specifically developed data extraction sheet was used to extract data on sample size, study design, intervention, patient characteristics and outcome measures at follow-up. Discrepancies were resolved by discussion. In case of missing or incomplete data, authors were contacted by email (Lear et al.,[20] Oerkild et al.,[21] Marchionni et al.[22]).

Study quality

Trial quality was assessed using the Tool for the Assessment of Study Quality and Reporting in Exercise (TESTEX)[23] by two authors (NS and RB).

Statistical analysis

Meta-analytic statistical analysis was performed using Review Manager software version 5.3, developed by the Cochrane Collaboration. Descriptive data are reported as mean ± SD or median (range). Since the data were continuous, it was assumed that randomisation would adjust for baseline differences, and only follow-up data were used to calculate the effect sizes.[24] Given the variance in reporting of EC and PA measures, these differences were expressed as standardised mean differences (SMDs) and 95% confidence intervals (CIs). In order to allow interpretation of the SMDs, the guidelines of Cohen were applied, stating a SMD of 0.2 as low, a SMD of 0.5 as medium and a SMD of 0.8 as large.[25] Statistical heterogeneity among the studies was assessed using Cochran Q tests, with $p < 0.05$ considered statistically significant; an inconsistency I^2 statistic with a value > 50% was considered indicative of high heterogeneity. Given the large variety in interventions and the observed statistical heterogeneity (p-value for the χ^2 test of heterogeneity < 0.05), random effects models were used in order to pool the effect sizes and a leave-one-out sensitivity analysis was performed in order to check whether our findings were driven by a single study. We assessed publication bias by using the funnel plot symmetry and Egger regression intercept.

Results

Study selection

An overview of the screening and selection process is presented in Figure 1. From 19 full-text papers screened, only nine articles fulfilled all of the eligibility criteria,[20–22,26–31] and seven articles could be included in the quantitative meta-analysis.[20,26–31] Five studies compared HB rehabilitation with a UC group after completion of a phase II CR programme,[20,26,27,29,30] and one study used HB rehabilitation as a phase II CR programme.[22] Five trials compared a HB exercise programme with a CB group,[21,22,28,30,31] but only one of them implemented the HB and CB interventions after the phase II CR period.[30] One trial[27] included two different study groups of CAD patients, and three other trials compared the HB group with two other study groups (UC and CB[22,30] and CB treadmill and CB group exercise[31]). This yielded a total of 10 study groups evaluating the effects of HB interventions on EC and two study groups evaluating the effects on PA. The main reasons for exclusion of trials were short duration of follow-up, inadequate intervention, outcome measure or patient population or published in a language unknown by the reviewers (Japanese[32] and Russian[33]). A detailed overview of the excluded studies and the main reason for exclusion can be found in Supplemental File 2. Two trials were excluded from the quantitative analysis due to the lack of precise estimates of the post-intervention data (i.e. only figures or differences were available).[21,22]

Study characteristics

A general description of each trial is provided in Table 1. All studies were prospective randomised or non-randomised controlled studies or randomised clinical trials with a parallel design, conducted between 2000 and 2016. Two studies were performed in Canada,[20,28] two in Norway[29,31] and the remaining were conducted in Switzerland,[26] the USA,[30] Finland,[27] Denmark[21] and Italy.[22] Sample sizes at baseline ranged from 48 to 302, resulting in a total of 1628 participants (mean age HB = 64.2 years, UC = 62.43 years, CB = 65.90 years, 834 participants were men, 258 were women and 536 were of unknown gender). A total of 188 participants dropped out (range: 11–44, median: 16, 91 in HB, 49 CB and 48 UC), leaving 1440 patients (645 HB, 261 CB and 534 UC) to be included in the final analysis. Dropout rates were similar across intervention groups except for Marchionni et al.,[22] who found a greater dropout rate in the HB group in comparison with the CB and UC groups. A PCI was performed in 458 patients and CABG in 517, and 758 patients had a history of myocardial infarction. All studies reported an equal distribution of cardiac treatment between study groups, except for Lear et al.,[20] who reported a greater proportion of CABG patients in their UC group. Concerning medication use, one study did not report medication,[22] five studies only reported medication at baseline[20,21,27,28,31] and two studies stated that patients were optimally medically treated.[21,29] Three studies explicitly reported differences in medication use between baseline and

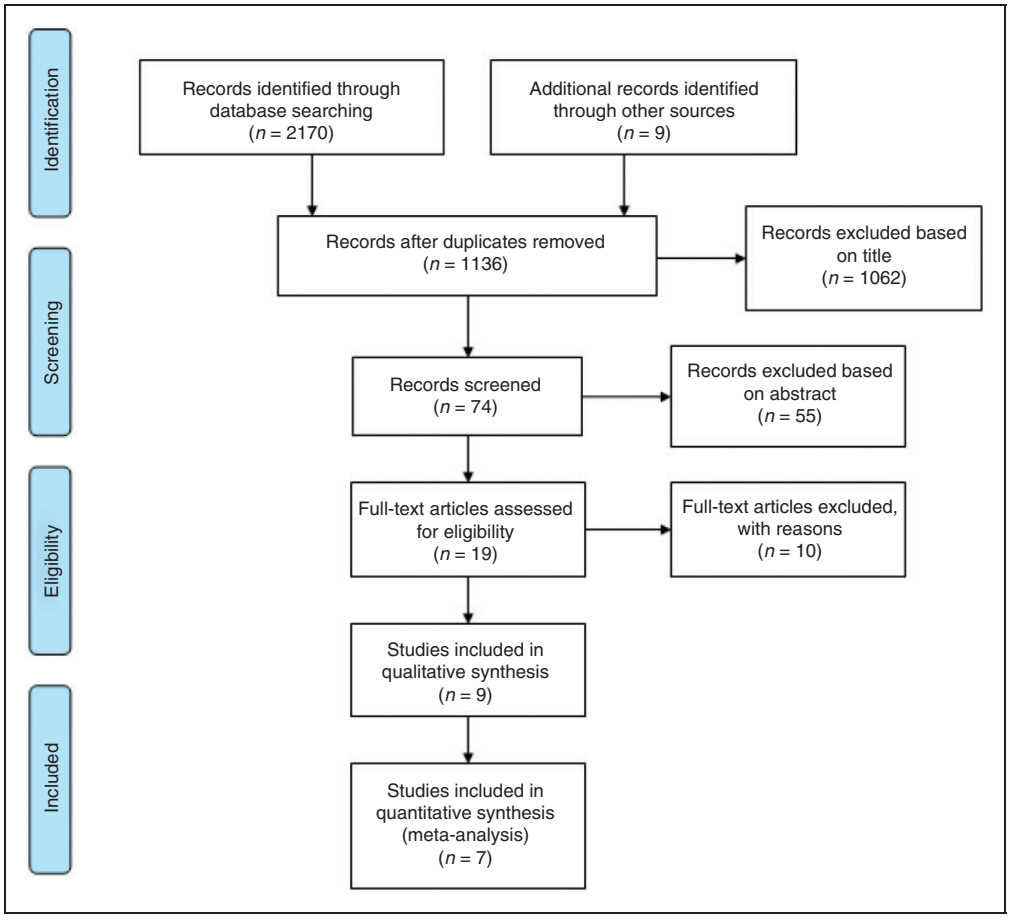

Figure 1. PRISMA flow diagram for selection of studies.

follow-up,[26,30,31] but only Brubaker et al.[30] excluded patients from the analysis of EC if changes in β-blocker medication were present.

Intervention characteristics

A detailed description of the applied interventions in each of the trials can be found in Table 1. All studies varied widely in frequency, intensity, type and time (FITT) parameters of prescribed HB exercise interventions. Overall, the median follow-up length after enrolment in the study was 12 months (range: 12–24 months). Frequency of training ranged from two to six times per week (median: four times). Intensity was expressed as a percentage of Heart rate reserve (HRR),[27,28,30] and varied between 50% and 65% and 70% and 80% of HRR, or as a percentage of maximum heart rate (HRmax) (70–95%)[22,29,31] or using the Borg scale (intensity 11–13).[21] The four studies that provided information on the type of exercise all used some type of endurance training,[22,27,29,30] except for Karjalainen et al.,[27] who also added one additional strength training session per week. The eight studies that provided data on the duration of a training session advised to train for at least 30 minutes per session. Two studies limited the exercise duration to 40 minutes per session,[27,30] while one study recommended a training duration of 60–70 minutes per session.[28] Monitoring of training was mainly performed by means of a logbook/diary,[20,22,26–28,30] telephone calls,[20,21,28,30] group gatherings[20,26,28,29] and home visits.[21,22,30] In one study, there was no contact with the patients from the end of CR until the follow-up measurements.[31] Four studies provided some type of behavioural cognitive therapy (BCT) on top of the specific exercise prescription.[20–22,30] Patients entering in a CB group trained two to five times per week at a prescribed intensity and were supervised by hospital staff. In two studies, participants were encouraged to train at home during the CB intervention[21] period or received the same training instructions as the HB group after completion of the CB programme, but without the patient contact.[28] Patients randomised to the UC control group received the standard information about risk factor modification and were encouraged to remain active.

Table 1. Overview of study characteristics.

Study (year)	Origin	Design	Follow-up	Participants	Home-based exercise intervention	Control	PF and PA assessment	Adverse events
Arrigo et al.[25]	Switzerland	RCT – parallel design	12 months	$n = 228$ in final analysis – 105 HB (61 ± 10 years, 91 men, 45 cardiac surgery, 64 PCI) – 123 UC (61 ± 9 years, 104 men, 51 cardiac surgery, 68 PCI)	After a 12–week outpatient programme they were instructed on how to use diary sheets. One group session once every 3 months	Usual care	Symptom-limited CPET on a bicycle (Watts) – PA expressed in % of patients doing ≥ 30 minutes three or more times per week with increase in pulse rate and breathing frequency	HB: 17 nonfatal cardiac events (4 PCIs and 13 other) UC: 12 nonfatal cardiac events (1 PCI and 11 other)
Brubaker et al.[29]	USA	Non-randomised trial – parallel design	12 months	$n = 48$ in final analysis – 16 HB (61 ± 11 years, 6 MI, 5 CABG, 2 PCI, 1 AP, 1 CHF, 1 valve) – 15 UC (59 ± 14 years, 4 MI, 6 CABG, 4 PCI, 1 CHF) - 17 CB (65 ± 8 years, 7 MI, 4 CABG, 2 PCI, 2 AP, 1 CHF, 1 valve)	One home visit by a physiologist to inform the patient about the exercise logs and to select the mode of endurance activity 30-40 minutes, 3–5×/week, 50–75% of HRR of the test performed after 3 months CR. Telephone calls every other week	Usual care – CB: 3 times per week, walking or stationary cycling, 50–85% HRR	PF: symptom-limited CPET on a treadmill (METs) PA: average of exercise days/week	Not reported
Karjalainen et al.[26]	Finland	RCT – parallel design	24 months	$n = 267$ in final analysis – 63 HB CAD + T2D (62 ± 5 years, 51 men, 29 history AMI, 38 PCI, 13 CABG) – 48 UC (61 ± 7 years, 48 men, 28 history AMI, 38 PCI, 14 CABG) – 72 HB CAD + T2D (62 ± 5 years, 36 history AMI, 43 PCI, 18 CABG) – 68 UC (61 ± 6 years, 28 history AMI, 39 PCI, 12 CABG)	First 3 months: endurance 3 × 30 minutes/week at 50–60% HRR, 1 × 30 minutes/week strength. Last 6 months: 1 × 40 minutes strength, 5 × 40 minutes/week endurance at 50–60% (2×), 60–70% (2×) and interval at 70–80% (1×). They kept a diary	Usual care	PF: symptom-limited CPET on a bicycle (METs) – PA: Saltin–Grimby physical activity level scale	Not reported
Oerkild et al.[21]	Denmark	Randomised clinical trial – parallel design	12 months	$n = 75$ at baseline – 36 HB (74.4 ± 5.8 years, 19 men, 10 MI, 7 PCI, 6 CABG, 14 HF) – 39 CB (74.7 ± 5.9 years, 26 men, 12 MI, 7 PCI, 6 CABG, 12 HF)	3 months: 2 visits by a physiotherapist with a 6–week interval to develop a training programme that could be done at home and in the surroundings. 6 × 30 minutes/week, 11–13 Borg. A telephone call in between the 6 weeks	CB: 3 months, 2 × 60 minutes/week and were encouraged to exercise at home	PF: symptom-limited CPET on a bicycle (peak oxygen consumption) and a 6MWT – PA: Saltin–Grimby physical activity level scale	7 patients died. Other adverse events were equally distributed at 12–months follow-up but data were not shown
Smith et al.[27]	Canada	Randomised clinical trial – parallel design	12 months	$n = 198$ in final analysis – 96 HB CABG patients (65.1 ± 9.0 years, 16 women, 57 MI history) – 102 CB CABG	6 months 2 × 1–hour session + train 5 × 60–70 minutes/week. After 6 months: instruction to train 5 × 50–	CB: 6 months of hospital-based CR 3 × 60–70 minutes/week + advised to	PF: symptom-limited CPET on a bicycle (peak oxygen consumption) PA: Physical Activity	Between the end of CR and 12–month follow-up, 5 people died and 10 became ill

(continued)

Table 1. Continued

Study (year)	Origin	Design	Follow-up	Participants	Home-based exercise intervention	Control	PF and PA assessment	Adverse events
				patients (63.4 ± 8.8 years, 21 women, 58 MI history)	75 minutes/week at 65–70% of HRR. Logbook and Telephone calls every other week	do 2 more times on their own. After the 6 months: instruction to train 5 × 50–75 minutes/week at 65–70% of HRR	Scale for the Elderly (PASE), but only at 12 months after CR discharge	
Lear et al.[20]	Canada	RCT – parallel design	12 months	$n = 302$ at baseline – 151 HB (64.8 ± 8.8 years, 125 men, 83 MI, 46 CABG, 66 PTCA, 24 other IHD, 43 angina) – 151 UC (63.4 ± 10.2 years, 124 men, 77 MI, 62 CABG, 47 PTCA, 28 other IHD, 35 angina)	2 × 75 minutes/week for 16 weeks CR + lifestyle management. Establish a HB exercise programme. Logbook and Called once per month. 2 counselling sessions were held at months 6 and 9	Usual care	PF: symptom-limited treadmill CPET (METs) PA: 4-week Minnesota Leisure Time Physical Activity questionnaire (MLTPAQ) in kcal/week	HB: 1 sore back, 2 cancer, 1 broken arm, 1 died. UC: 3 died
Marchionni et al.[22]	Italy	RCT – parallel design	12 months	$n = 270$ post-MI patients at baseline (46–86 years, 183 men) 90 HB, 90 UC, 90 CB	4–8 instruction sessions on how to perform training at home + 2 months cycling, 5 × 30 minutes/week at 70–85% HRmax. Logbook and Home visits every other week to adjust prescription and enhance adherence	Usual care – CB: 40 supervised exercise sessions in 2 months. 3 × 30 minutes/week endurance training + 2 × 60 minutes/week stretching and flexibility at 70–85% HRmax	PF: symptom-limited CPET on a bicycle (TWC)	10 died, 7 nonfatal events
Madssen et al.[28]	Norway	RCT – parallel design	12 months	$n = 49$ in final analysis – 24 HB (64.4 years, 15 PCI, 7 CABG, 2 valve) – 25 UC (58.5 years, 15 PCI, 7 CABG, 1 valve, 2 cardiomyopathy)	Written exercise prescription following completion of CR of 3 × HIIT/week of 36–38 minutes at 85–95% HRmax during HIIT blocks and 70% HRmax during active rest. 1 supervised session/month as follow-up	Usual care	PF: symptom-limited CPET on a treadmill (peak oxygen consumption) PA: questionnaire and, in a subgroup of patients ($n = 18$), a SenseWear Pro2 Armband	HB: 1 duodenal cancer and AF, 1 chronic lymphatic leukaemia. UC: 1 tibial fracture, 1 breast carcinoma
Aamot et al.[30]	Norway	Randomised clinical trial – parallel design	12 months	$n = 76$ in final analysis – 23 HB (59 years, 22 men, 16 MI, 5 CABG, 2 ACS) – 24 CB group exercise (59 years, 21 men, 16 MI, 6 CABG, 2 ACS) – 29 CB treadmill exercise (58 years, 25 men, 21 MI, 6 CABG, 2 ACS)	12 weeks of HIIT twice per week. 4 × 4 minutes at 85–95% HRmax, interspersed with active rest at 70% HRmax	CB: both groups did the same 12–week programme as the HB group, but under supervision on a treadmill or by means of group exercise	PF: symptom-limited CPET on a treadmill (peak oxygen consumption) PA: International Physical Activity Questionnaire (IPAQ) and SenseWear Pro2 Armband for 7 days	3 new cardiac events, 2 hospitalised with chest pain, 7 orthopaedic problems, 1 clavicle fracture

RCT: randomised controlled trial; PA: physical activity; PF: physical fitness; HB: home-based; PCI: percutaneous coronary intervention; UC: usual care; MI: myocardial infarction; AMI: acute myocardial infarction; CABG: coronary artery bypass grafting; AP: angioplasty; HF: heart failure; CHF: chronic heart failure; PCI: percutaneous coronary intervention; HRR: heart rate reserve; CR: cardiac rehabilitation; CB: centre-based; CPET: cardiopulmonary exercise test; MET: metabolic equivalent; CAD: coronary artery disease; T2D: type 2 diabetes mellitus; 6MWT: 6–minute walking test; PTCA: percutaneous transluminal coronary angioplasty; IHD: ischaemic heart disease; HRmax: maximum heart rate; TWC: total work capacity; HIIT: high-intensity interval training; AF: atrial fibrillation; ACS: acute coronary syndrome.

No further contact was provided except for the follow-up measurements. Not one study reported specifically about the parameters of the exercise performed by participants in the UC group during the follow-up period; however, Brubaker et al.[30] suggested that knowledge of follow-up testing alone was sufficient motivation for continuing PA.

Assessment of outcomes

A description of the assessments of physical fitness and PA is shown in Table 1. All nine studies assessed maximal EC, but only seven could be included in the meta-analysis, representing 10 study groups.[20,26–31] EC was evaluated by means of a symptom-limited exercise test on a bicycle ($n = 5$) or a treadmill ($n = 4$). PA was measured using time quotas[26,30] or by means of questionnaires (Saltin–Grimby scale,[21,27] Physical Activity Scale for the Elderly (PASE),[28] Minnesota Leisure Time Physical Activity Questionnaire (MLTPAQ), International Physical Activity Questionnaire (IPAQ) and one not specified).[20,29,31] One study did not evaluate PA.[22]

Quantitative data synthesis

Figures 2 and 3 show the forest plots of the main effects for EC. Overall, we observed no statistically significant difference in EC between the HB intervention group versus the UC group (SMD 0.10, 95% CI –0.13 to 0.33, $I^2 = 59\%$). However, there was high heterogeneity across studies. Leave-one-out sensitivity analysis showed that when we removed the study of Madssen et al.,[29] the overall effect changed into a small but significant difference in favour of the HB exercise group (SMD 0.17, 95% CI 0.03–0.32, $I^2 = 7\%$). This was expected as all studies except Madssen et al.[29] reported a trend[20,26,27,30] or a significant effect[27] in favour of HB exercise. No change was found when the CAD plus type 2 diabetes mellitus (T2D) group from the study of Karjalainen et al.[27] was excluded (SMD 0.05, 95% CI –0.22 to 0.32, $I^2 = 64\%$).

A small but significant effect was also seen between the HB intervention group and the CB group in favour of the HB group (SMD 0.25, 95% CI 0.02–0.48, $I^2 = 0\%$). Heterogeneity was low, although only three studies (four groups) could be included.

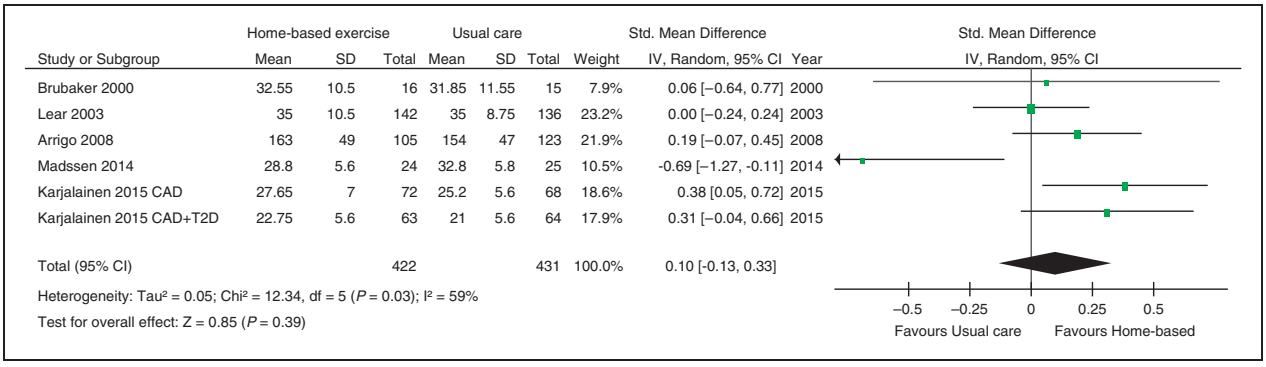

Figure 2. Synthesis of results: exercise capacity, home-based vs. usual care.
CI: confidence interval.

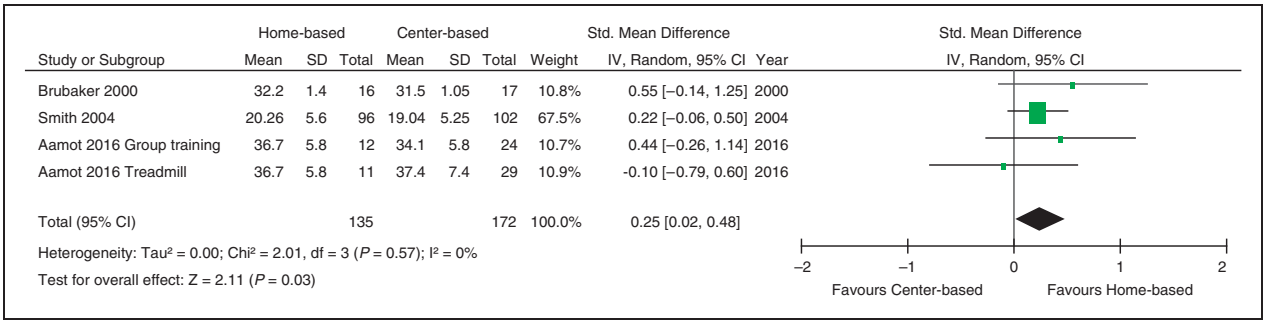

Figure 3. Synthesis of results: exercise capacity, home-based vs. centre-based.
CI: confidence interval.

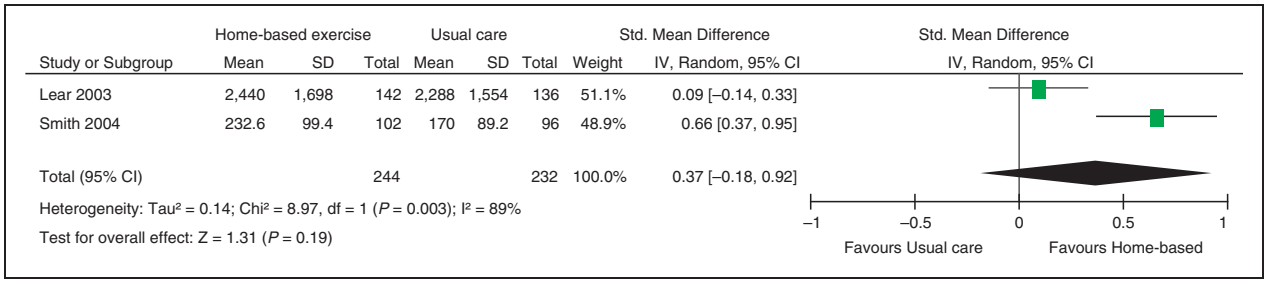

Figure 4. Synthesis of results: physical activity, home-based vs. usual care.
CI: confidence interval.

PA was reported as a percentage of people remaining active above a certain threshold[26] or as the mean number of days or minutes per week someone was physically active.[27,30] Two studies used the Saltin–Grimby questionnaire in order to classify patients into four PA categories.[21,27] Aamot et al.[31] used both the IPAQ and a SenseWear Pro2 Armband, but reported only the median and interquartile ranges of the IPAQ scores. They found no group differences between HB, CB treadmill and CB group exercise in PA, both with the IPAQ and SenseWear Pro2 Armband. The only two studies that could be included in our meta-analysis made use of the PASE[28] or the MLTPAQ[20] (see Figure 4). In general, the HB group was more active than the control group, but this could not be statistically confirmed in the meta-analysis. In the study of Arrigo et al.,[26] 73% of the intervention group did moderately intense activity three or more times per week for ≥ 30 minutes in comparison with 40% in the control group. Brubaker et al.[30] reported an exercise frequency of 4.2 ± 0.6 days/week for the HB group, but did not measure the frequency of the UC group out of fear that it would influence their PA behaviour. Karjalainen et al.[27] found an increase in exercise minutes per week for both the CAD and CAD plus T2D group (164 ± 96 to 179 ± 91 minutes/week and 141 ± 50 to 146 ± 69 minutes/week, respectively). A difference of –4 points on the Saltin–Grimby scale was reported by Oerkild et al.[21] The HB group was significantly more active in the study of Smith et al.,[28] as was seen in the PASE scores (232.6 ± 99.4 vs. 170 ± 89.2; $p = 0.005$). Lear et al.[20] found a significant decrease in PA both in the Extensive Lifestyle Management Intervention (ELMI) group (3134 ± 2294 to 2440 ± 1698 kcal/week; $p < 0.01$) and in the UC group (3022 ± 2308 to 2288 ± 1554 kcal/week; $p < 0.001$), with the intervention group remaining active at a higher level. Although Madssen et al.[29] reported PA after the intervention period, no between-group comparisons were made and data were reported in steps and time spent in sedentary, moderate and vigorous PA zones.

Finally, seven studies reported on adverse events.[20–22,26,28,29,31] Twenty-six patients died during follow-up: one cancer, one sudden death, two re-infarction, three neoplasm, one pulmonary embolism, one perioperatively during CABG and 17 undefined. None of the studies reported a significant difference between groups, and none reported whether death was related to exercise.

Study quality

The TESTEX score was used to evaluate study quality. A median score of 8 out of 15 was obtained (range: 5–10), which indicated low to medium quality. Details on randomisation method and procedure, blinding of assessors, activity monitoring of controls, relatively adjusting exercise intensity and exercise energy expenditure were the most frequently lacking items. In particular, this last shortcoming is of major importance since it has been documented before that a direct comparison of training effects is only possible if programmes are isocaloric.[34] A detailed overview of the study quality of each of the trials can be found in Supplemental File 3.

Publication bias

The slight asymmetry of the funnel plot (Figure 5) for the comparison of HB and UC suggested small publication bias. However, the Egger regression coefficient was not significant (one-tailed p-value $= 0.27$) and, using the trim-and-fill method, no additional studies were added. Visual inspection of the funnel plot (Figure 6) for the comparison of HB and CB showed no asymmetry. This was confirmed by a non-significant (one-tailed p-value $= 0.40$) Egger regression coefficient and the fact that no studies were added by the trim-and-fill method.

Discussion

Despite the well-known benefits on EC, CR remains seriously underused. Moreover, participation in

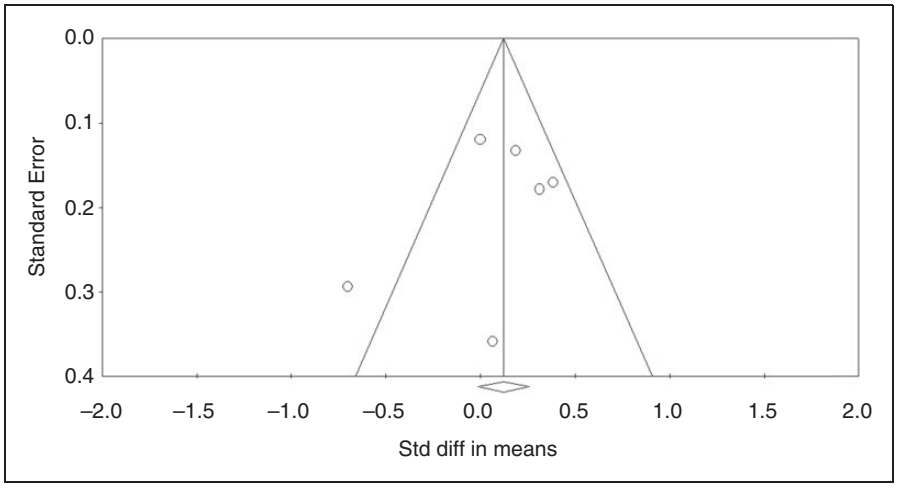

Figure 5. Funnel plot of included studies assessing exercise capacity, home-based vs. usual care.
Std. diff.: standardised difference.

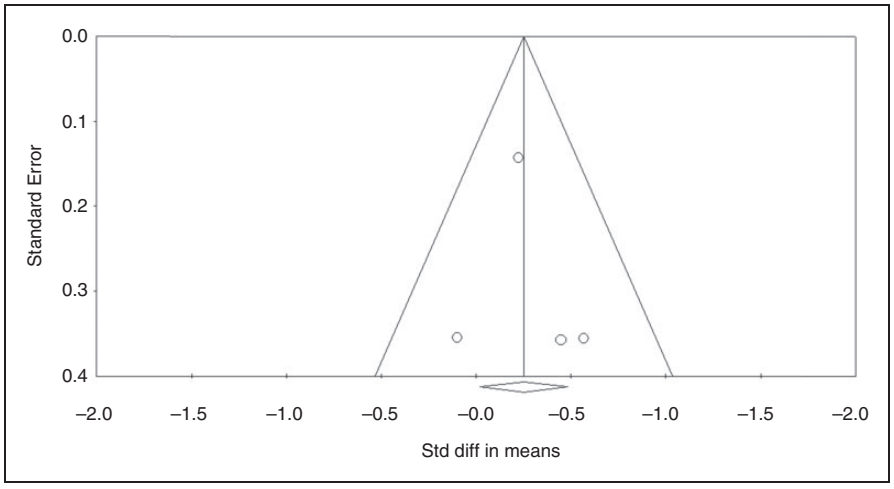

Figure 6. Funnel plot of included studies assessing exercise capacity, home-based vs. centre-based.
Std. diff.: standardised difference.

supervised CR programmes does not necessarily lead to a sustained change in PA levels in daily life.[11,35,36] The results of this meta-analysis show that when CR is offered to stable, low-risk patients in the HB setting, the longer-term results seem better when compared to CB rehabilitation. This implies that implementation of an exercise routine in the daily lives of the patients after a cardiac event is necessary in order to obtain lasting lifestyle changes. Surprisingly, we could not document a larger effect on EC between HB rehabilitation and UC when both were offered after completion of a phase II CB CR programme.

Currently, a clear definition for 'HB CR' is lacking. As such, the contents of these interventions varied widely and ranged from the use of manuals for a healthier lifestyle to personalised exercise prescriptions.[17,37] However, as exercise should be the key component of a CR programme, we opted to only include those studies that investigated the long-term effects on EC and PA of well-defined exercise prescriptions delivered in the home environment of the patient.

There were only three studies that compared the longer-term effects of HB exercise with CB rehabilitation. Two interventions were performed as phase II programmes, whereas the third study evaluated patients 1 year after enrolment, instead of 1 year after completion of the phase II CR.[30] Our results indicated a small but significant difference in EC in favour of the HB group. This is in line with the study of Smith et al.[38] comparing HB with CB rehabilitation over a 6-year follow-up period. These authors observed a significantly higher EC in the HB group compared to the

CB group at 6–year follow-up. However, in contrast to our results, they also reported a significantly higher self-reported PA score in the HB group.

Unexpectedly, we did not observe a significant difference in EC between HB exercise and UC. Previously, Hansen et al.[39] showed that only 27% of patients that participated in an in-hospital programme adhered to the minimal PA level that is required to obtain significant health benefits at 18 months of follow-up. This level was defined as doing more than 5 days of moderate-intensity activities or walking per week. However, when looking at our data in more detail, all but one of the included studies reported a trend for a higher EC in favour of HB exercise. When we subsequently omitted this one study[29] by means of a leave-one-out sensitivity analysis, the results changed into a significant difference in favour of HB exercise (SMD 0.17, 95% CI 0.03–0.32). One of the potential explanations for this is that participants in the HB group of Madssen et al.[29] received a high-intensity interval exercise prescription. However, only a third of their patients reported exercising at high intensity two to three times/week, demonstrating that adherence to their exercise prescription was low. This suggests that it might be more difficult to implement high-intensity interval training as a routine practice, and if patients are not given any proper alternative, they seem to opt not to do any PA at all. Given the limited amount of data, more research is needed in order to confirm this.

Only two studies compared the effect of HB exercise on PA behaviour. Although both studies showed a tendency towards higher levels of PA following HB exercise, this was not shown by a significant effect size following HB training. However, given the scarcity of data, more high-quality studies are needed in order to evaluate the potential superiority of HB interventions in phase III programmes.

Further, the approaches to follow-up during the interventions were very diverse, involving telephone calls, occasional group sessions, home visits or any combination of these methods. There is no doubt that the way of contact during the intervention has an influence on adherence and motivation. However, the clinical effectiveness and cost-effectiveness of each of these different interactions remains to be elucidated. In addition, although we tried to focus on the exercise component of delivered HB programmes only, we did not exclude studies in which some kind of supplementary BCT was implemented. This was the case in half of the included studies. BCT on its own is known to influence PA behaviour,[40] and thus EC,[41] and could have affected the results.

Finally, adverse events included cardiovascular problems, but also musculoskeletal and metabolic issues. In case of the 26 reported deaths, underlying causes were poorly documented. Not a single study stated whether adverse events were exercise induced or not.

Limitations

This study has some limitations, which mainly reflect the lack of high-quality research in the field to date. The first limitation is the large variability and complexity of the interventions. The different FITT parameters of the prescribed exercise programmes make a direct comparison of interventions extremely difficult. It is impossible to know which factor contributes most to the observed differences, not only between the groups of the same trial, but also between trials. Furthermore, some trials applied BCT on top of the exercise prescription, and there was a broad use of follow-up methods. Both BCT and the choice of follow-up method have independent effects on our outcome measures, as indicated before. Second, as long-term adaptations are the ultimate goal of CR, the number of studies available evaluating the longer-term effects of CR interventions was disappointingly low. Third, there were almost no studies reporting on PA, and the objective measurement of PA was extremely poor; that is, PA was often reported as a percentage of people achieving a threshold based on time or as raw values in minutes or days per week. Although it is feasible to obtain valid and reliable measures of PA (PASE,[42] MLTPAQ,[43] SenseWear Armband,[44] etc.), these measures remain generally underemployed. More uniformity and objectivity are warranted in measuring PA behavior.[45] Fourth, given the secondary prevention goal of CR, a follow-up period of 1 year is negligible, and there is an urgent need for studies evaluating the effect of CR over even longer periods of time. Fifth, there was a high amount of missing gender specifications, which could affect adherence rates, and thus EC results, as studies have shown that men are more adherent to exercise programmes.[46,47] Sixth, overall, study quality was low to moderate, which indicates the need for further well-designed RCTs that take into account EC and PA. More attention should be given to relatively easy aspects such as providing details of the randomisation procedure, blinding of assessors and determining whether HB and CB programmes are isocaloric.

Conclusions

Only a low number of studies and thus a scarcity of evidence are currently available on HB exercise interventions and their effects on EC and PA in the longer term in cardiac patients. Our results demonstrated no significant differences between HB exercise rehabilitation and UC, but a small significant difference between

HB exercise and CB rehabilitation in favour of the former. Our results were influenced by the large variety that was present in different exercise prescriptions, measuring instruments and follow-up methods, making a direct comparison of interventions difficult. Future research involving exercise interventions for cardiac patients should aim to apply a longer follow-up period and methods that are easily interpretable, as well as to show any results in the most convenient units of measurement. Researchers should try to establish transparent protocols with an emphasis on the use of widespread criterion methods for means of follow-up and outcome measures. According to us, the current state of technology is sufficient to provide the patient with effective and objective means of monitoring their exercise parameters and adherence in a HB setting.

Author contribution

JC contributed to conception and design, acquisition, analysis, interpretation and drafted the manuscript. RB and VAC contributed to conception and design, acquisition, analysis, interpretation, drafted the manuscript and critically revised the manuscript. WB contributed to the interpretation and critically revised the manuscript. NS contributed to quality assessment, interpretation and critically revised the manuscript. All authors gave final approval.

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References

1. Mendis S, Puska P and Norrving B. WHO global atlas on cardiovascular disease prevention and control. World Health Organization, Geneva, 2011.
2. Vanhees L, De Sutter J, Gelada SN, et al. Importance of characteristics and modalities of physical activity and exercise in defining the benefits to cardiovascular health within the general population: recommendations from the EACPR (part I). *Eur J Prev Cardiol* 2012; 19: 670–686.
3. Vanhees L, Stevens A, Schepers D, et al. Determinants of the effects of physical training and of the complications requiring resuscitation during exercise in patients with cardiovascular disease. *Eur J Cardiovasc Prev Rehabil* 2004; 11: 304–312.
4. Arbit B, Azarbal B, Hayes SW, et al. Prognostic contribution of exercise capacity, heart rate recovery, chronotropic incompetence, and myocardial perfusion single-photon emission computerized tomography in the prediction of cardiac death and all-cause mortality. *Am J Cardiol* 2015; 116: 1678–1684.
5. Myers J, Prakash M, Froelicher V, et al. Exercise capacity and mortality among men referred for exercise testing. *N Engl J Med* 2002; 346: 793–801.
6. Piepoli MF, Corra U, Adamopoulos S, et al. Secondary prevention in the clinical management of patients with cardiovascular diseases. Core components, standards and outcome measures for referral and delivery: a policy statement from the cardiac rehabilitation section of the European Association for Cardiovascular Prevention & Rehabilitation. Endorsed by the Committee for Practice Guidelines of the European Society of Cardiology. *Eur J Prev Cardiol* 2014; 21: 664–681.
7. Anderson L, Thompson DR, Oldridge N, et al. Exercise-based cardiac rehabilitation for coronary heart disease. *Cochrane Database Syst Rev* 2016; 1: CD001800.
8. Heran BS, Chen JM, Ebrahim S, et al. Exercise-based cardiac rehabilitation for coronary heart disease. *Cochrane Database Syst Rev* 2011; 7: CD001800.
9. Uddin J, Zwisler AD, Lewinter C, et al. Predictors of exercise capacity following exercise-based rehabilitation in patients with coronary heart disease and heart failure: a meta-regression analysis. *Eur J Prev Cardiol* 2016; 23: 683–693.
10. Barber K, Stommel M, Kroll J, et al. Cardiac rehabilitation for community-based patients with myocardial infarction: factors predicting discharge recommendation and participation. *J Clin Epidemiol* 2001; 54: 1025–1030.
11. Karmali KN, Davies P, Taylor F, et al. Promoting patient uptake and adherence in cardiac rehabilitation. Cochrane Database Syst Rev. 2014; 6: CD007131.
12. Vanhees L, Rauch B, Piepoli M, et al. Importance of characteristics and modalities of physical activity and exercise in the management of cardiovascular health in individuals with cardiovascular disease (part III). *Eur J Prev Cardiol* 2012; 19: 1333–1356.
13. Fernandez RS, Davidson P and Griffiths R. Cardiac rehabilitation coordinators' perceptions of patient-related barriers to implementing cardiac evidence-based guidelines. *J Cardiovasc Nurs* 2008; 23: 449–457.
14. Dunlay SM, Witt BJ, Allison TG, et al. Barriers to participation in cardiac rehabilitation. *Am Heart J* 2009; 158: 852–859.
15. Poortaghi S, Baghernia A, Golzari SE, et al. The effect of home-based cardiac rehabilitation program on self efficacy of patients referred to cardiac rehabilitation center. *BMC Res Notes* 2013; 6: 287.

16. Bergstrom G, Borjesson M and Schmidt C. Self-efficacy regarding physical activity is superior to self-assessed activity level, in long-term prediction of cardiovascular events in middle-aged men. *BMC Public Health* 2015; 15: 820.
17. Taylor RS, Dalal H, Jolly K, et al. Home-based versus centre-based cardiac rehabilitation. *Cochrane Database Syst Rev* 2015; 8: CD007130.
18. ter Hoeve N, Huisstede BM, Stam HJ, et al. Does cardiac rehabilitation after an acute cardiac syndrome lead to changes in physical activity habits? Systematic review. *Phys Ther* 2015; 95: 167–179.
19. Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *BMJ* 2009; 339: b2535.
20. Lear SA, Ignaszewski A, Linden W, et al. The Extensive Lifestyle Management Intervention (ELMI) following cardiac rehabilitation trial. *Eur Heart J* 2003; 24: 1920–1927.
21. Oerkild B, Frederiksen M, Hansen JF, et al. Home-based cardiac rehabilitation is as effective as centre-based cardiac rehabilitation among elderly with coronary heart disease: results from a randomised clinical trial. *Age Ageing* 2011; 40: 78–85.
22. Marchionni N, Fattirolli F, Fumagalli S, et al. Improved exercise tolerance and quality of life with cardiac rehabilitation of older patients after myocardial infarction: results of a randomized, controlled trial. *Circulation* 2003; 107: 2201–2206.
23. Smart NA, Waldron M, Ismail H, et al. Validation of a new tool for the assessment of study quality and reporting in exercise training studies: TESTEX. *Int J Evid Based Healthc* 2015; 13: 9–18.
24. Knol MJ, Groenwold RH and Grobbee DE. P-values in baseline tables of randomised controlled trials are inappropriate but still common in high impact journals. *Eur J Prev Cardiol* 2012; 19: 231–232.
25. Cohen J. *Statistical power analysis for the behavioral sciences*. Oxford: Routledge, 1988.
26. Arrigo I, Brunner-LaRocca H, Lefkovits M, et al. Comparative outcome one year after formal cardiac rehabilitation: the effects of a randomized intervention to improve exercise adherence. *Eur J Cardiovasc Prev Rehabil* 2008; 15: 306–311.
27. Karjalainen JJ, Kiviniemi AM, Hautala AJ, et al. Effects of physical activity and exercise training on cardiovascular risk in coronary artery disease patients with and without type 2 diabetes. *Diabetes Care* 2015; 38: 706–715.
28. Smith KM, Arthur HM, McKelvie RS, et al. Differences in sustainability of exercise and health-related quality of life outcomes following home or hospital-based cardiac rehabilitation. *Eur J Cardiovasc Prev Rehabil* 2004; 11: 313–319.
29. Madssen E, Arbo I, Granoien I, et al. Peak oxygen uptake after cardiac rehabilitation: a randomized controlled trial of a 12-month maintenance program versus usual care. *PLoS ONE* 2014; 9: e107924.
30. Brubaker PH, Rejeski WJ, Smith MJ, et al. A home-based maintenance exercise program after center-based cardiac rehabilitation: effects on blood lipids, body composition, and functional capacity. *J Cardiopulm Rehabil* 2000; 20: 50–56.
31. Aamot IL, Karlsen T, Dalen H, et al. Long-term exercise adherence after high-intensity interval training in cardiac rehabilitation: a randomized study. *Physiother Res Int* 2016; 21: 54–64.
32. Ohmura N, Nakada I, Fujii M, et al. [Effects and indication of non-supervised home exercise program in patients following coronary bypass surgery and acute myocardial infarction]. *Jpn Circ J* 1994; 58(Suppl. 4): 1351–1355.
33. Bubnova MG, Aronov DM, Krasnitskii VB, et al. [A home exercise training program after acute coronary syndrome and/or endovascular coronary intervention: efficiency and a patient motivation problem]. *Ter Arkh* 2014; 86: 23–32.
34. Pattyn N, Cornelissen VA, Buys R, et al. Are aerobic interval training and continuous training isocaloric in coronary artery disease patients? *Eur J Prev Cardiol* 2016; 23: 1486–1495.
35. Myers J, McAuley P, Lavie CJ, et al. Physical activity and cardiorespiratory fitness as major markers of cardiovascular risk: their independent and interwoven importance to health status. *Prog Cardiovasc Dis* 2015; 57: 306–314.
36. Moholdt T, Aamot IL, Granoien I, et al. Long-term follow-up after cardiac rehabilitation: a randomized study of usual care exercise training versus aerobic interval training after myocardial infarction. *Int J Cardiol* 2011; 152: 388–390.
37. Clark AM, Haykowsky M, Kryworuchko J, et al. A meta-analysis of randomized control trials of home-based secondary prevention programs for coronary artery disease. *Eur J Cardiovasc Prev Rehabil* 2010; 17: 261–270.
38. Smith KM, McKelvie RS, Thorpe KE, et al. Six-year follow-up of a randomised controlled trial examining hospital versus home-based exercise training after coronary artery bypass graft surgery. *Heart* 2011; 97: 1169–1174.
39. Hansen D, Dendale P, Raskin A, et al. Long-term effect of rehabilitation in coronary artery disease patients: randomized clinical trial of the impact of exercise volume. *Clin Rehabil* 2010; 24: 319–327.
40. Ghisi GL, Abdallah F, Grace SL, et al. A systematic review of patient education in cardiac patients: do they increase knowledge and promote health behavior change? *Patient Educ Couns* 2014; 95: 160–174.
41. Archer E and Blair SN. Physical activity and the prevention of cardiovascular disease: from evolution to epidemiology. *Prog Cardiovasc Dis* 2011; 53: 387–396.
42. Washburn RA, McAuley E, Katula J, et al. The physical activity scale for the elderly (PASE): evidence for validity. *J Clin Epidemiol* 1999; 52: 643–651.
43. Richardson MT, Leon AS, Jacobs DR Jr, et al. Comprehensive evaluation of the Minnesota Leisure Time Physical Activity Questionnaire. *J Clin Epidemiol* 1994; 47: 271–281.
44. Cole PJ, LeMura LM, Klinger TA, et al. Measuring energy expenditure in cardiac patients using the Body

Media Armband versus indirect calorimetry. *A validation study*. J Sports Med Phys Fitness 2004; 44: 262–271.
45. Helmerhorst HJ, Brage S, Warren J, et al. A systematic review of reliability and objective criterion-related validity of physical activity questionnaires. *Int J Behav Nutr Phys Act* 2012; 9: 103.
46. Masuki S, Mori M, Tabara Y, et al. The factors affecting adherence to a long-term interval walking training program in middle-aged and older people. *J Appl Physiol (1985)* 2015; 118: 595–603.
47. Pavey T, Taylor A, Hillsdon M, et al. Levels and predictors of exercise referral scheme uptake and adherence: a systematic review. *J Epidemiol Community Health* 2012; 66: 737–744.