



REVIEW ARTICLE

## Measurement of physical performance by field tests in programs of cardiac rehabilitation: A systematic review and meta-analysis<sup>☆</sup>



Cristiane Travençolo<sup>a</sup>, Karla Goessler<sup>b</sup>, Roberto Poton<sup>a</sup>, Roberta Ramos Pinto<sup>a</sup>,  
Marcos Doederlein Polito<sup>a,\*</sup>

<sup>a</sup> Departamento de Educação Física, Universidade Estadual de Londrina, Londrina, PR, Brazil

<sup>b</sup> Research Centre for Cardiovascular and Respiratory Rehabilitation, Catholic University of Leuven, Leuven, Belgium

### KEYWORDS

Exercise test;  
Physical conditioning;  
Cardiovascular  
physiology

### Abstract

**Introduction:** The literature concerning the effects of cardiac rehabilitation (CR) on field tests results is inconsistent.

**Purpose:** To perform a systematic review with meta-analysis on field tests results after programs of CR.

**Methods:** Studies published in PubMed and Web of Science databases until May 2016 were analyzed. The standard difference in means correct by bias (Hedges' *g*) was used as effect size (*g*) to measure the amount of modifications in performance of field tests after CR period. Potential differences between subgroups were analyzed by *Q-test* based on ANOVA.

**Results:** Fifteen studies published between 1996 and 2016 were included in the review, 932 patients and age ranged 54.4-75.3 years old. Fourteen studies used the six-minutes walking test to evaluate the exercise capacity and one study used the *Shuttle Walk Test*. The random Hedges's *g* was 0.617 ( $p < 0.001$ ), representing a drop of 20% in the performance of field test after CR. The meta-regression showed significant association ( $p = 0.01$ ) to aerobic exercise duration, i.e., for each 1-min increase in aerobic exercise duration, there is a 0.02 increase in effect size for performance in the field test.

**Conclusion:** Field tests can detect physical modification after CR, and the large duration of aerobic exercise during CR was associated with a better result.

© 2018 Sociedade Portuguesa de Cardiologia. Published by Elsevier España, S.L.U. All rights reserved.

<sup>☆</sup> Please cite this article as: Travençolo C, Goessler K, Poton R, Pinto RR, Polito MD. Medida do desempenho físico por testes de campo em programas de reabilitação cardiovascular: revisão sistemática e meta-análise. Rev Port Cardiol. 2018;37:525–537.

\* Corresponding author.

E-mail address: [marcospolito@uel.br](mailto:marcospolito@uel.br) (M.D. Polito).

**PALAVRAS-CHAVE**

Teste de exercício;  
Condicionamento físico;  
Fisiologia cardiovascular

## Medida do desempenho físico por testes de campo em programas de reabilitação cardiovascular: revisão sistemática e meta-análise

**Resumo**

**Introdução:** A literatura mostra-se inconsistente sobre o efeito da reabilitação cardiovascular (RCV) nos resultados de testes de campo.

**Objetivo:** Fazer uma revisão sistemática com meta-análise sobre os resultados de testes de campo usados em programas de RCV.

**Métodos:** Foram analisados estudos publicados nas bases de dados *PubMed* e *Web of Science* até maio de 2016. O tamanho do efeito (*g*) foi definido como a diferença média padronizada corrigida por viés (*g* de Hedges) e foi usado para medir a quantidade de modificações no desempenho do teste após o período de RCV. Diferenças potenciais entre os subgrupos foram testadas pelo teste Q baseado na análise de variância.

**Resultados:** Compuseram a revisão 15 estudos publicados entre 1996 e 2016, com amostra total de 932 pacientes e idade entre 54,4 e 75,3 anos. Catorze estudos usaram o teste de caminhada de 6 min para avaliar a capacidade de exercício e um estudo usou o *Shuttle Walk Test*. O *g* de Hedges pela análise aleatória foi de 0,617 ( $p < 0,001$ ), representou aumento de 20% no desempenho do teste de campo após a RCV. A metarregressão mostrou associação significativa ( $p = 0,01$ ) para a duração do exercício aeróbio, ou seja, para cada aumento de 1 min na duração do exercício ocorre o aumento de 0,02 no efeito para o desempenho no teste de campo.

**Conclusão:** Testes de campo identificam mudanças após a RCV e a maior duração do exercício aeróbio durante a RCV se associa com um melhor resultado.

© 2018 Sociedade Portuguesa de Cardiologia. Publicado por Elsevier España, S.L.U. Todos os direitos reservados.

**Introduction**

Physical exercise is important in cardiovascular rehabilitation (CR). The physical assessment of patients before starting treatment is thus essential.<sup>1-5</sup> In this respect, cardiopulmonary exercise testing (CPET) measures several variables related to cardiorespiratory function, including peak oxygen consumption ( $VO_{2\max}$ ),<sup>6,7</sup> and is considered the gold standard for determining  $VO_{2\max}$ .<sup>8-13</sup> However, because it is complex and requires maximum effort, CPET is not commonly used in clinical practice.<sup>8,9,11,13-24</sup> For example, 12% of patients with coronary artery disease are unable to perform the test with maximal effort.<sup>25</sup> Therefore, field tests have been developed to predict  $VO_{2\max}$  and to identify functional limitations, enabling  $VO_{2\max}$  to be used more regularly in clinical practice.

Several field tests are used in CR. The 6-minute walk test (6MWT; the longest distance walked in 6 minutes),<sup>26,27</sup> provides firm evidence of response to clinical changes.<sup>10</sup> It correlates with  $VO_{2\max}$  in CPET in patients with heart failure<sup>28-30</sup> and is sensitive to changes in perception of disease symptoms.<sup>31</sup> Moreover, the Shuttle Walk Test (longest distance walked in a 10-meter corridor with gradual increase in intensity) has been used in post-operative coronary artery bypass grafting (CABG) patients,<sup>32</sup> heart failure patients<sup>33</sup> and in Chagas disease.<sup>34</sup>

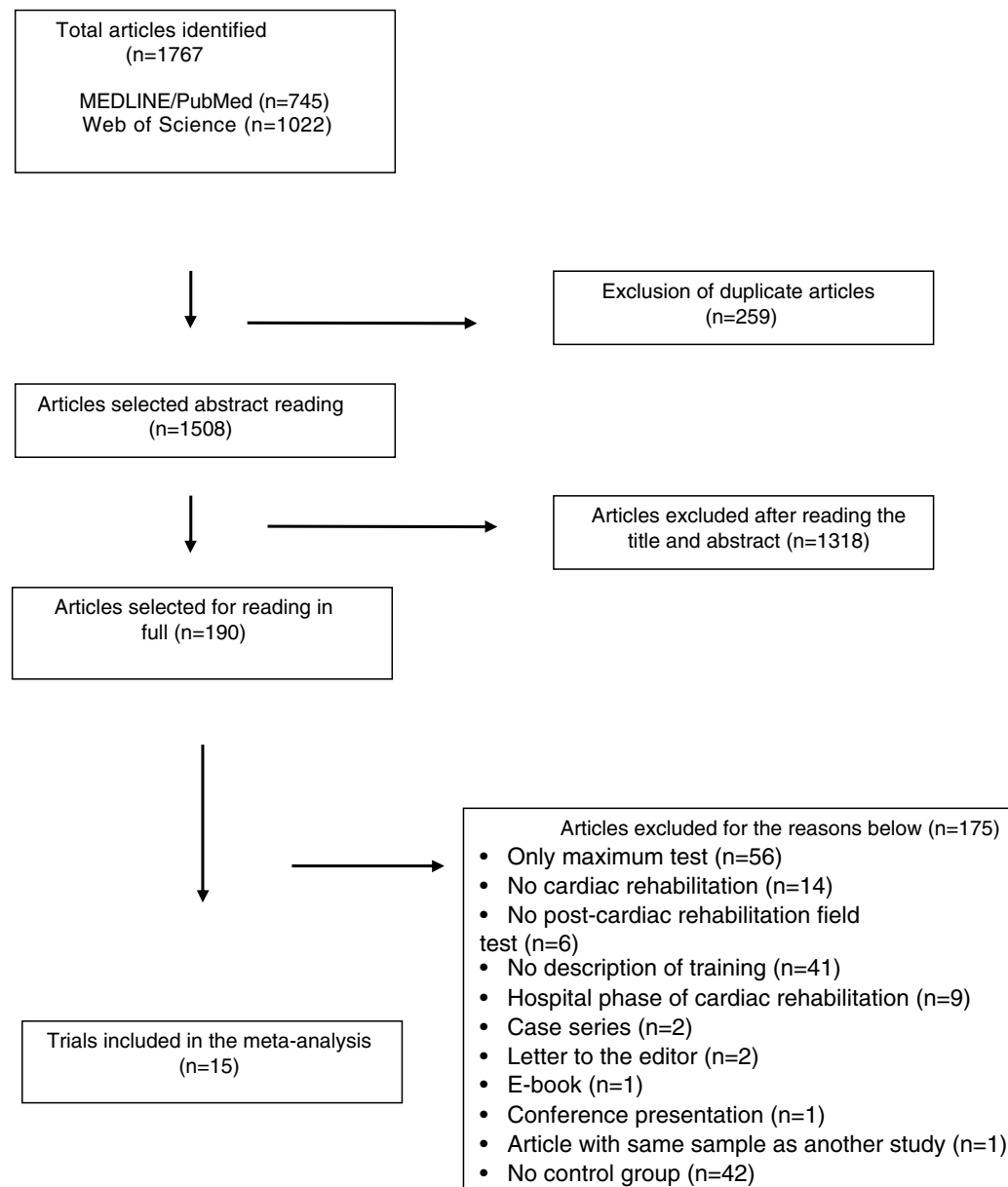
Step tests are also used in patients with respiratory diseases<sup>35</sup> suspected coronary obstruction<sup>36</sup> and in elderly patients with heart failure.<sup>37-39</sup> They require little space and are easy to transport and simple to perform.<sup>40</sup>

However, the literature on the effects of CR programs on field test performance is inconsistent. Conducting further

trials is important and other research models would enable an integrated analysis of published results. In this context, systematically reviewing the literature makes it possible to search for and include references using defined and robust strategies, and a meta-analysis allows a mathematical model to be used to identify potential variables affecting outcome. We did not find any meta-analyses focusing on field tests and CR. As such, the aim of this study was to systematically review the literature on field tests used in CR programs and to perform a meta-analysis to identify (1) the effect of CR on field test performance and (2) training variables that may influence CR effect.

**Methods****Search strategy and selection of trials**

Two researchers (CFT and RRP) independently conducted a literature review in the *MEDLINE/PubMed* and *Web of Science* databases. Articles were selected from their date of publication up to May 2016. Doubts concerning article selection were resolved jointly by the researchers based on the proposed inclusion criteria. Medical descriptors standardized by Medical Subject Heading were used, along with terms and expressions in the title or abstract. The following inclusion criteria were taken into account: (1) articles in English, including randomized and non-randomized clinical trials; (2) human subjects (men and/or women over 18 years of age); (3) diagnosis of heart disease; (4) participants in outpatient CR programs; (5) exercise capacity evaluated by means of exercise tests independently of CPET; (6) presence of training-prescription variables; (7) control group.



**Figure 1** Flowchart of the selection process of articles included in the systematic review.

### Trials included in the systematic review

We initially identified 1767 articles in both databases, of which 259 were excluded because they were duplicates and 1318 were excluded after analysis of the title and abstract. After reading the remaining trials in full, 15 were used for this review (Figure 1).

### Data extraction and quality analysis

The data on trial quality, journal impact factor, year of publication, gender, age, weight, height, body mass index (BMI), ejection fraction (EF),  $VO_{2\ max}$ , training volume, training intensity, type of training, training location, type of field test used and field test results were independently extracted by two evaluators (CFT and RRP) to a specific

spreadsheet. General concordance was 0.92 using Cohen's kappa coefficient. Discordances were resolved by face-to-face discussion. The comparison of field-test values between the experimental and control groups of the trials included was the primary outcome.

Trial quality was assessed using the Physiotherapy Evidence Database (PEDro) scale, which has been reported to be valid<sup>56</sup> and reproducible.<sup>57</sup> Scoring was performed twice and any doubts were resolved jointly. Articles were not excluded based on the quality result.

### Statistical analysis

#### Calculation of the effect size

Effect size (g) was used to quantify changes in field test performance following the CR period (aerobic training or

aerobic+resistance training). Effect size was defined as the standardized mean difference, corrected for bias (Hedges's  $g$ ), in field test performance for the experimental and control groups. We initially calculated the paired difference (experimental mean-control mean) and the standard deviation (SD) of the paired difference (experimental  $SD^2$ +control  $SD^2$ - $2 \times$  inter-trial correlation  $\times$  experimental  $SD \times$  control  $SD$ )<sup>1/2</sup> to determine the standardized mean difference (SMD). We then determined the SMD (paired difference  $\times$  (2- $2 \times$  inter-trial correlation))<sup>1/2</sup>  $\div$  (paired difference of SD) and standard error (SE) of the SMD ((1/n+SMD<sup>2</sup>  $\div$  (2  $\times$  n))<sup>1/2</sup>  $\times$  (2- $2 \times$  inter-trial correlation))<sup>1/2</sup>. Finally, the correction factor obtained with the formula  $1 - \{3 - [4 \times (n \text{ total} - 2) - 1]\}$  was multiplied by the SMD to obtain Hedges's  $g$ . When the study reported only the SE, the SD was calculated by multiplying the SE by the square root of the sample number,  $n$ . No study provided inter-trial group data (correlation between data from the experimental and control groups), so this value was assumed to be 0.5 for all studies. Positive  $g$  values indicated increased performance compared to the control group values.

The  $Q$ -statistic was calculated to determine whether the degrees of similarity among the effect sizes were significant. It was converted into a standardized measurement of heterogeneity ( $I^2$  statistic) and values of 25%, 50% and 75% indicated low, moderate or high heterogeneity, respectively. Risk of bias was analyzed by funnel plot vs. SMD. Publication bias was analyzed using Egger's non-parametric regression (two-tailed) and the method proposed by Duval and Tweedie.

### Subset and moderator variable analyses

Meta-analysis and meta-regression were performed using the Comprehensive Meta-Analysis program (version 2.2, Biostat Inc., Englewood, NJ, USA) using a random-effects model and Hedges's  $g$  correction factor. For significant heterogeneity, moderator variable analysis was used to explain the  $g$ -value variability in the outcomes. Potential moderator variables included age, gender, BMI, weight, height, baseline EF, baseline  $VO_2$ , training time, weekly frequency, duration of aerobic exercise, quality of the trials (PEDro scale), journal impact factor and year of publication of the study.

Subset analysis included the variables type of exercise (aerobic, aerobic+resistance), type of aerobic exercise (walking, bicycle, walking and/or bicycle), type of training (continuous, progressive), training place (home or clinic), type of disease and procedure (angina, myocardial infarction, heart failure, angioplasty and coronary artery bypass grafting). Any differences between subsets were analyzed by  $Q$  test based on the analysis of variance (ANOVA).

## Results

### Description of included trials

The general details of the trials included are described in Table 1. We identified 15 trials published between 1996 and 2016. The total sample consisted of 932 patients (701 men and 191 women). In one trial<sup>48</sup> with 40 participants, the number of men and women was not specified. The mean age was

between 54.4 and 75.3 years. Fourteen trials used the 6MWT to assess exercise capacity and one study used the Shuttle Walk Test.<sup>48</sup> For the statistical analysis of subsets and moderator variables, we therefore considered only trials that used the 6MWT. Only seven studies<sup>42,43,45,49,52,54,55</sup> used CPET in combination with field testing.

Ten trials were conducted in patients with heart failure,<sup>41-47,52,54,55</sup> two in patients following myocardial infarction,<sup>51,53</sup> one in patients with angina,<sup>48</sup> one in post-angioplasty and CABG patients<sup>49</sup> and one in pre-operative CABG patients.<sup>50</sup>

CR was unsupervised in only one<sup>47</sup> of the 10 trials conducted in patients with heart failure. Mean training duration lasted from six<sup>44</sup> to 20 weeks<sup>42</sup> in two,<sup>42,43</sup> three,<sup>41,44-46</sup> four,<sup>52</sup> five<sup>54,55</sup> and seven<sup>47</sup> weekly sessions. In one study,<sup>55</sup> patients with functional capacities less than 3 metabolic equivalent of tasks (METs) trained daily (5-10 minutes); those at 3-5 METs trained once or twice a day (15 minutes); and those at >5 METs trained for three to five sessions/week (20-30 minutes). All of the trials used aerobic exercises in the CR program, including walking,<sup>41,47,55</sup> Nordic walking,<sup>54</sup> exercise bicycle,<sup>41-43,45,52</sup> treadmill,<sup>43,45</sup> stair machine,<sup>43</sup> and arm ergometer,<sup>41</sup> while one study<sup>44</sup> did not specify the type of exercise. Seven trials<sup>41,42,46,49,50,52,55</sup> used muscle-strengthening exercises, including three studies with equipment,<sup>41,49,52</sup> three with gym bands<sup>46,50,55</sup> and one with circuit.<sup>42</sup> The duration of aerobic exercise ranged from 10<sup>47</sup> to 90 minutes.<sup>44</sup>

Two trials<sup>51,53</sup> were conducted in patients following myocardial infarction, although CR was unsupervised and the aerobic exercise was walking (four weeks, four times a week). In addition, one trial<sup>48</sup> was conducted in angina patients in a supervised program (circuit, once a week for eight weeks), another was conducted in post-angioplasty and CABG patients (three times a week for 12 weeks; aerobic exercises on bicycle and resistance exercises with body weight and equipment),<sup>49</sup> while a third<sup>50</sup> was conducted in pre-operative CABG patients (twice a week for 16 weeks; aerobic exercises on bicycle and walking and resistance exercises with body weight and gym bands). In general, duration of aerobic exercise ranged from 10<sup>54,55</sup> to 80 minutes.<sup>48</sup>

### Field test and meta-analysis

Figure 2 shows the effect size of the 15 trials. The data were analyzed in meters, taking into account the pre- and post-test means and SDs of the control and experimental groups, as well as the number of subjects in each session. The data were found to be heterogeneous ( $Q=42.0$ ; degrees of freedom=14;  $I^2=66.7\%$ ;  $p<0.001$ ). Hedges's  $g$  using the random model was 0.617 (0.373-0.86;  $p<0.001$ ), which meant a 20% increase in test performance after cardiovascular rehabilitation.

Table 2 shows the continuous variables analyzed by meta-regression. Only three variables showed significant results: duration of aerobic exercise ( $p=0.01$ ), baseline  $VO_{2 \text{ max}}$  ( $p<0.01$ ) and final  $VO_{2 \text{ max}}$  ( $p=0.01$ ). In this context, for each 1-minute increase in duration of aerobic exercise,  $g$  increased by 0.02 in field test performance. This did not occur for baseline and final  $VO_{2 \text{ max}}$ . Instead, for each 1

**Table 1** Trials included in the systematic review of the literature.

Author and year	Country	Sample	Training characteristic – CR at clinic and at home	Test result
McKelvie et al. <sup>41</sup>	Canada	HF EG=90 M and W (64.8 years)	EG=supervised CR at clinic, walking, stationary bicycle, arm ergometer, 60-70% max. HR, 30 min, resistance exercises with equipment 40-60% of 1RM, 1-3 sets, 10-15 reps, 3 times/wk, 12 wk	6MWT EG baseline=434±66.5 m, EG final=456±71 m
		CG=91 M and W (66.1 years)	CG=monthly visits and encouragement to continue usual physical activity	CG baseline=421±75.84 m, CG final=436±70 m
Jónsdóttir et al. <sup>42</sup>	Iceland	HF EG=21 M and W (68 years)	EG=supervised CR at clinic, bicycle, 50% maximum load (W), 15 min, muscle strengthening with circuit, 20-25% of 1RM, 2 times/wk, 20 wk	6MWT EG baseline=489.3±75 m, EG final=526.4±71.9 m
		CG=22 M and W (69 years)	CG=not reported in the text	CG baseline=489.2±66.33 m, CG final=494.6±66.4 m
Freimark et al. <sup>43</sup>	Israel	HF EG=44 M and W (62 years)	EG=supervised CR at clinic, treadmill, stair machine and bicycle, 45 min, 60-70% of max HR, 2 times/wk, 18 wk	6MWT EG baseline=316.0±84.5 m, EG final=443.6±83.8 m
		CG=12 M and W (61 years)	CG=not reported in the text	CG baseline=320.0±99.6 m, CG final=281.7±126.6 m

Table 1 (Continued)

Author and year	Country	Sample	Training characteristic – CR at clinic and at home	Test result
Chan et al. <sup>44</sup>	China	HF EG=30 M and W (75.3 years)	EG=supervised CR at clinic, aerobic exercises 90 min, 60-80% of heart-rate reserve, 3 times/wk, 6 wk CG=medical recommendation	6MWT EG baseline=232.7±110.1 m, EG final=360.2±106.9 m
		CG=28 M and W (73.5 years)		CG baseline=205.8±87.7 m, CG final=299.9±56.2 m
Brubaker et al. <sup>45</sup>	USA	HF EG=30 M and W (70.4 years)	EG=supervised CR at clinic, treadmill or bicycle, 30-40 min, 40-70% of heart-rate reserve, 3 times/wk, 16 wk CG=telephone calls from investigators asking about changes in drug treatment every 2 weeks for 16 weeks. They were not asked about exercising	6MWT EG baseline=406.3±30.6 m, EG final=461.77±29.9 m
		CG=29 M and W (69.9 years)		CG baseline=375.51±39.68 m, CG final=423.06±23.8 m
Gary et al. <sup>46</sup>	USA	HF EG=12 M and W (59 years)	EG=supervised CR at clinic, 30-60 min, 50-70% heart-rate reserve, 3 times/wk, 12 wk, muscle strengthening with TheraBand, 2-3 sets, 12-15 reps CG=5 to 6 home visits in the 12-wk period	6MWT EG baseline=364.3±80 m, EG final=410.7±91.5 m
		CG=12 M and W (61 years)+24		CG baseline=306.6±121.3 m, CG final=309.7±135.4 m

Table 1 (Continued)

Author and year	Country	Sample	Training characteristic – CR at clinic and at home	Test result
Babu et al. <sup>47</sup>	India	HF EG=14 M and W (56.9 years)	EG=unsupervised CR at home, walking 10-80 min, between 4 and 6 on the Modified Borg Scale, 7 times/wk, 8 wk	6MWT EG baseline=429.33±125.15 m, EG final=514.53±135.12 m
		CG=13 M and W (58.8 years)	CG=medical recommendations at hospital discharge	CG baseline=310.23±121.11 m, CG final=357.15±147.95 m
Asbury et al. <sup>48</sup>	England	Angina EG=20 (65.1 years)	EG=supervised CR at clinic, circuit, 40-75% of heart-rate reserve, 80 min, 1 time/wk, 8 wk	ISWT EG baseline=248.2±121.7 m, Final=305±115.8 m
		CG=20 (65.1 years)	CG=monitoring of symptoms for 8 wk	CG baseline=222±78.4 m, Final=248.5±80 m
Chen et al. <sup>49</sup>	Taiwan	Angioplasty and CABG EG=21 M and W (69.7 years)	EG=supervised CR at clinic, bicycle, 30 min, 60-80% of heart-rate reserve, 3 times/wk, 12 wk, muscle strengthening with free weights and equipment, 30 min, 40-60% of 1RM, 12-15 reps	6MWT EG baseline=354.6±63.7 m, EG final=373.3±62.4 m
		CG=15 M and W (65.1 years)	CG=drug treatment and medical appointments if needed	CG baseline=329.7±47 m, CG final=323.9±146.2 m
Sawatzky et al. <sup>50</sup>	Canada	pre-operative CABG EG=8 M and W (64 years)	EG=supervised CR at clinic, walking and bicycle, 60 min, 85% VO <sub>2 max</sub> , muscle strengthening with body weight and TheraBand, 2 times/wk, 16 wk	6MWT EG baseline=342±79 m, EG final=474±101 m
		CG=7 M and W (63 years)	CG=3-hour meeting with nurse and anesthesiologist, recommendations for healthy lifestyle habits	CG baseline=337±52 m, CG final=357±27 m

Table 1 (Continued)

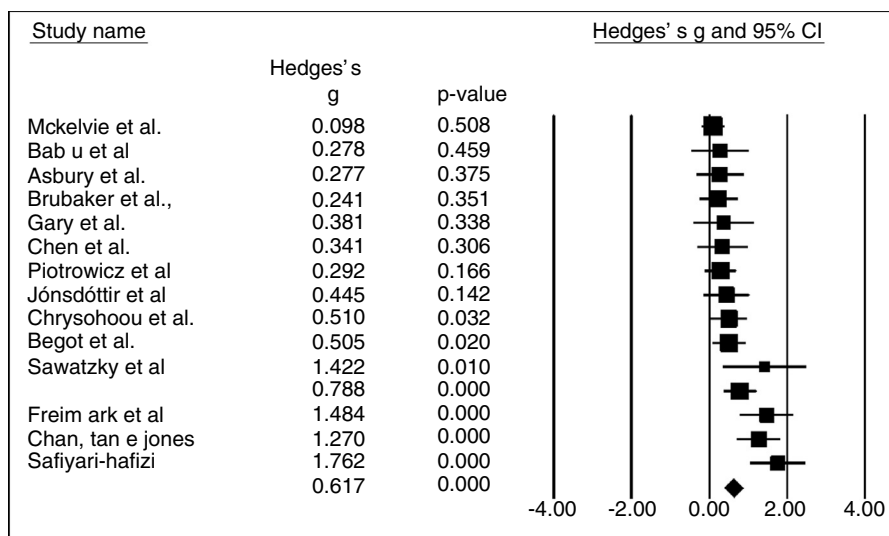
Author and year	Country	Sample	Training characteristic – CR at clinic and at home	Test result
Begot et al. <sup>51</sup>	Brazil	MI EG=41 M and W (59 years)	EG=unsupervised CR at home, walking 20-40 min, 4 times/wk, 4 wk CG=General information on healthy lifestyle habits and importance of continuing the physical activity started at the hospital	6MWT EG baseline=460±106 m, EG final=536±106 m
		CG=45 M and W (57 years)		CG baseline=457±73 m, CG final=487±73 m
Chrysohoou et al. <sup>52</sup>	Greece	HF EG=33 M and W (63 years)	EG=supervised CR at clinic, bicycle, 45 min, 80-100% VO <sub>2</sub> , 3 times/wk, 12 wk, muscle strengthening with equipment, 30-90% of 1RM, 3 sets, 10-15 reps CG=usual medical treatment	6MWT EG baseline=422±77 m, EG final=476±82 m
		CG=39 M and W (56 years)		CG baseline=406±64 m, CG final=423±65 m
Peixoto et al. <sup>53</sup>	Brazil	MI EG=45 M and W (56.8 years)	EG=unsupervised CR at home, walking, 20-40 min, 4-5 on the Modified Borg Scale, 4 times/wk, 4 wk CG=standard treatment and instructions to continue physical activity started during hospitalization	6MWT EG baseline=434.2±86.3 m, EG final=519.7±79.3 m
		CG=43 M and W (56 years)		CG baseline=439.1±78.4 m, CG final=452.1±111.2 m



Table 1 (Continued)

Author and year	Country	Sample	Training characteristic – CR at clinic and at home	Test result
Piotrowicz et al. <sup>54</sup>	Poland	HF EG=75 M and W (54.4 years)	EG=CR with remote clinical monitoring, Nordic walking, starting with 10 min ( $VO_2 < 14$ ml/kg/min); 15 min ( $VO_2 = 14-20$ ); 20 min ( $VO_2 > 20$ ) progressing to 45-60 min, 5 times/wk, 8 wk	6MWT EG baseline=428±93 m, EG final=480±87 m
		CG=32 M and W (62.1 years)	CG=standard treatment and recommendations on changes in lifestyle and self-care	CG baseline=439±76 m, CG final=465±91 m
Safiyari-Hafizi et al. <sup>55</sup>	Canada	HF EG=20 M and W (57.8 years)	EG=supervised CR at home, interval walking, 10-50 min, 80-85% peak $VO_2$ followed by active recovery of 40-50% peak $VO_2$ , 2 times/day to 5 times/wk, 12 wk; muscle strengthening with gym bands, 10 exercises, resistance by length of band, 1-3 sets, 15 reps, 1-3/wk.	6MWT EG baseline=275±37.9 m, EG final=312.2±42.1 m
		CG=20 M and W (58.9 years)	CG=encouragement to practice moderate exercise	CG baseline=259.6±25.1 m, CG final=235.2±28.6 m

Legend: 1RM: one-repetition maximum; 6MWT: 6-minute walk test; CABG: coronary artery bypass grafting; CG: control group; CR: cardiovascular rehabilitation; EG: experimental group; HF: heart failure; HR: heart rate; ISWT: Incremental Shuttle Walk Test; M: men; m: meters, max: maximum; MI: myocardial infarction; min: minute(s);  $VO_2$ : oxygen consumption; W: women; wk: week(s).



**Figure 2** Forest plot of the 15 trials included in the meta-analysis.

**Table 2** Variables analyzed by meta-regression.

Variable	Number of trials	Slope	p
Study quality	15	-0.11	NS
Impact factor	14	-0.05	NS
Year of publication	15	0.02	NS
Gender	14	-0.01	NS
Age (years)	15	0.003	NS
BMI (kg/m <sup>2</sup> )	9	0.04	NS
Weight (kg)	6	-0.0003	NS
Height (m)	3	0.005	NS
Baseline ejection fraction	10	0.01	NS
Baseline VO <sub>2 max</sub> (ml/kg/min)	6	-0.23	<0.01
Final VO <sub>2 max</sub> (ml/kg/min)	6	-0.08	0.01
Training duration (weeks)	15	0.01	NS
Weekly frequency (days)	14	-0.07	NS
Duration of aerobic exercise (minutes)	12	0.02	0.01

BMI: body mass index; NS: not significant; VO<sub>2 max</sub>: maximum oxygen consumption.

ml/kg/min reduction in baseline VO<sub>2 max</sub>, g increased by 0.23, and for each 1 ml/kg/min reduction in final VO<sub>2 max</sub>, g increased by 0.08. Continuous variables, such as the intensity of aerobic and resistance training, and the number of sets and reps, were not subjected to meta-regression, since the data were presented in broad ranges, hindering meta-regression analysis and stratification for analysis by categorical variables.

Table 3 shows categorical variable subsets analyzed by the Q test based on ANOVA. In this group of variables, the duration of aerobic exercise was stratified into three categories (30-35 minutes, 45 minutes; >60 minutes). Duration of over 60 minutes had a significantly larger g than the 30-35 minute duration. In addition, a difference was noted in relation to the type of training; effect size was greater for progressive training than for continuous training.

No publication bias was identified using Egger's regression (p=0.06) and the method proposed by Duval and Tweedie (K=15; Q=31.38).

## Discussion

The aim of this study was to determine the effect size and the variables that influence the results of field tests used in CR programs. The results showed a predominance of 6MWT, which was used in 14 of the 15 trials. The primary outcome was a 20% increase in final vs. baseline field test performance. In addition, performance was associated with progressive aerobic exercise training, longer duration of exercise, and baseline and final VO<sub>2 max</sub> values.

Aerobic exercise has been established as beneficial to patients with heart failure, through central (increased cardiac output, ventricular remodeling and modulation of the sympathetic nervous system) and peripheral mechanisms (increased peripheral muscle perfusion and increased extraction and use of oxygen).<sup>58</sup> In patients with preserved EF, there was an increase in VO<sub>2 max</sub> due to improved muscle and microvascular function.<sup>59</sup> In patients with coronary artery disease, aerobic exercise slows progression

**Table 3** Subset analysis by categorical variables.

Variable	Category	No. of trials	Effect size (95% CI)	Comparison (Q test based on analysis of variance)
Type of training	Continuous	4	0.27 (-0.11 to 0.65)	Progressive>continuous (p=0.03)
	Progressive	6	0.64 (0.3 to 0.98)	
Type of exercise	Walking	6	0.66 (0.23 to 1.10)	NS
	Bike	3	0.45 (-0.15 to 1.04)	
	Walking+bike	4	0.66 (0.13 to 1.19)	
Place of training	Home	5	0.74 (0.30-1.18)	NS
	Outpatient	10	0.56 (0.27-0.85)	
Disease	MI	3	0.80 (0.21 to 1.40)	NS
	HF	10	0.64 (-0.33 to 0.96)	
	ANGIO/CABG	2	0.32 (-0.42 to 1.05)	
Training combination	Aerobics	8	0.64 (0.30 to 0.98)	NS
	Aerobics+resistance	7	0.62 (0.24 to 1.01)	

95% CI: 95% confidence interval; ANGIO: angioplasty; Bike: exercise bicycle; CABG: coronary artery bypass grafting; HF: heart failure; MI: myocardial infarction; NS: not significant.

and reduces the size of atherosclerotic plaques, improves endothelial function and increases left ventricular EF after myocardial infarction.<sup>60</sup> Therefore, our results in relation to the recommendation for aerobic exercise reinforce the data in the literature. Moreover, our study found that better field test performance was obtained based on progressive aerobic exercise, rather than maintaining the same load effort throughout the training period. In this context, as long as physical and clinical conditions allow the patient to handle relatively greater effort after a training period, a gradual increase in intensity may help improve performance. However, data from the references in this study were not conclusive about the best effort intensity or the progression model, because in most of the trials these data were given in broad ranges that did not enable suitable statistical analyses.

Regarding the duration of aerobic exercise, our results showed that the greatest effect occurred in direct relation to the duration of exercise. However, of the 15 trials included, nine used exercise duration of between 30 and 45 minutes; only two studies used one exceeding 60 minutes. Although our results showed that for every 1-minute increase in exercise duration, there was a 0.02 increase in g, this does not necessarily mean that extremely long exercise durations would be positive for the patient. Thus, it is hasty to assume that heart disease patients should perform aerobic exercise for more than 60 minutes. Other trials should therefore be conducted with durations greater than 60 minutes to better analyze results.

Regarding  $VO_{2\max}$ , the meta-regression showed a significant relationship between both baseline and final values and field test performance. This suggests that patients with a lower physical fitness level at the start of CR respond better than patients with a higher level. Similarly, patients with a lower fitness level at the end of the CR had a better effect size. These patients tended to have a better response in the field test after CR. In line with our findings, a meta-analysis study<sup>61</sup> demonstrated that baseline  $VO_{2\max}$  was a predictor of exercise capacity after CR. In addition, the trial found

that exercise intensity was another predictive variable of exercise capacity at the end of the rehabilitation program.

However, some other variables did not correlate with increased performance, such as gender, height, weight and BMI. Considering that 6MWT was predominantly used and can be affected by anthropometric differences, we could assume that being taller or heavier affected performance. However, one possible reason that this assumption was not confirmed may be due to the clinical characteristics of the samples. Because we included only trials with patients and not healthy individuals, differences in height, weight and gender did not have the statistical power to influence results. However, the trials did not report separate outcomes for gender or BMI cutoff points when they were present. Therefore, even though our study did not detect a relationship between these variables and test performance, confirmation is still needed. In addition to anthropometric variables, CR duration and weekly treatment frequency did not affect final performance. This may be explained by the difficulty of analysis due to the heterogeneity of protocols regarding the type of supervision, type of aerobic exercise, and duration and intensity of training.

In addition to the physiological variables or training variables, data related to journal impact factor, trial quality and year of publication were also analyzed. These analyses were included to detect bias in trials with different qualities, published in periodicals with different impact factors or published in different years. However, no relationships between these variables and the final outcome were identified.

## Conclusions

The primary outcome of this systematic review with meta-analysis was increased field test performance following CR, and that a longer duration of aerobic exercise equates to better performance. These results may contribute to the prescription of CR exercise sessions.

## Sources of funding

This study was partially funded by the Conselho Nacional de Desenvolvimento Científico e Tecnológico [Brazilian National Council for Scientific and Technological Development] – CNPq – Brazil (process 303566/2013-2).

## Conflicts of interest

The authors have no conflicts of interest to declare.

## References

- Shepherd CW, While AE. Cardiac rehabilitation and quality of life: a systematic review. *Int J Nurs Stud.* 2012;49:755–71.
- Herdy AH, López-Jiménez F, Terzic CP, et al. South American guidelines for cardiovascular disease prevention and rehabilitation. *Arq Bras Cardiol.* 2014;103:1–31.
- Gremeaux M, Hannequin A, Laurent Y, et al. Usefulness of the 6-minute walk test and the 200-metre fast walk test to individualize high intensity interval and continuous exercise training in coronary artery disease patients after acute coronary syndrome: a pilot controlled clinical study. *Clin Rehabil.* 2011;25:844–55.
- Piotrowicz R, Wolszakiewicz J. Cardiac rehabilitation following myocardial infarction. *Cardiol J.* 2008;15:481–7.
- Ricardo DR, Araújo CGS. Reabilitação cardíaca com ênfase no exercício: uma revisão sistemática. *Rev Bras Med Esporte.* 2006;12:279–85.
- Arena R, Sietsema KE. Cardiopulmonary exercise testing in the clinical evaluation of patients with heart and lung disease. *Circulation.* 2011;123:668–80.
- Balady GJ, Arena R, Sietsema K, et al. Clinician's guide to cardiopulmonary exercise testing in adults: a scientific statement from the American heart association. *Circulation.* 2010;122:191–225.
- Sartor F, Vernillo G, De Morree HM, et al. Estimation of maximal oxygen uptake via submaximal exercise testing in sports, clinical, and home settings. *Sports Med.* 2013;43:865–73.
- Guazzi M, Adams V, Conraads V, et al. EACPR/AHA Joint Scientific Statement Clinical recommendations for cardiopulmonary exercise testing data assessment in specific patient populations. *Eur Heart J.* 2012;33:2917–27.
- Bellet RN, Francis RL, Jacob JS, et al. Repeated six-minute walk tests for outcome measurement and exercise prescription in outpatient cardiac rehabilitation: a longitudinal study. *Arch Phys Med Rehabil.* 2011;92:1388–94.
- Ross RM, Murthy JN, Wollak ID, et al. The six minute walk test accurately estimates mean peak oxygen uptake. *BMC Pulm Med.* 2010;10:2–9.
- de Freitas PE. Ergometria: conceitos para o clínico. *Rev Méd Minas Gerais.* 2008;18:41–8.
- Huggett DL, Connelly DM, Overend TJ. Maximal aerobic capacity testing of older adults: a critical review. *J Geront Med Sci.* 2005;60:57–66.
- Casillas JM, Hannequin A, Besson D, et al. Walking tests during the exercise training: specific use for the cardiac rehabilitation. *Ann Phys Rehabil Med.* 2013;56:561–75.
- Noonan V, Dean E. Submaximal exercise testing: clinical application and interpretation. *Phys Ther.* 2000;80:782–807.
- Tebexreni A, Lima E, Tambeiro V. Protocolos tradicionais em ergometria, suas aplicações práticas "versus" protocolo de rampa. *Rev Soc Cardiol Estado de São Paulo.* 2001;11:1–9.
- Gayda M, Temfemo A, Choquet D, et al. Cardiorespiratory requirements and reproducibility of the six-minute walk test in elderly patients with coronary artery disease. *Arch Phys Med Rehabil.* 2004;85:1538–43.
- Du HY, Newton PJ, Salamonson Y, et al. A review of the six-minute walk test: its implication as a self-administered assessment tool. *Eur J Card Nurs.* 2009;8:2–8.
- Hansen D, Jacobs N, Bex S, et al. Are fixed-rate step tests medically safe for assessing physical fitness? *Eur J Appl Physiol.* 2011;111:2593–9.
- Pichurko BM. Exercising your patient: which test(s) and when? *Respir Care.* 2012;57:100–13.
- da Costa JNF, Arcuri JF, Gonçalves IL, et al. Reproducibility of cadence free six-minute step test in subjects with COPD. *Respir Care.* 2014;59:538–42.
- Guazzi M. Reproducibility of cardiopulmonary exercise test variables: getting into an additional strength of the test. *Eur J Prev Cardiol.* 2014;21:442–4.
- Pollentier B, Irons SL, Benedetto CM, et al. Examination of the six minute walk test to determine functional capacity in people with chronic heart failure: a systematic review. *Cardiopulm Phys Ther J.* 2010;21:13–21.
- Arena R, Myers J, Williams MA, et al. Assessment of functional capacity in clinical and research settings: a scientific statement from the American Heart Association Committee on Exercise Rehabilitation, and Prevention of the Council on Clinical Cardiology and the Council on Cardiovascular Nursing. *Circulation.* 2007;116:329–43.
- Coeckelberghs E, Buys R, Goetschalckx K, et al. Prognostic value of the oxygen uptake efficiency slope and other exercise variables in patients with coronary artery disease. *Eur J Prev Cardiol.* 2016;23:237–44.
- Crapo RO, Casaburi R, Coates AL, et al. ATS statement: guidelines for the six-minute walk test. *Am J Respir Crit Care Med.* 2002;166:111–7.
- Holland AE, Spruit MA, Troosters T, et al. An official European respiratory society/American thoracic society technical standard: field walking tests in chronic respiratory disease. *Eur Respir J.* 2014;44:1428–46.
- Carvalho LP, Di Thommazo-Luporini L, Aubertin-Leheudre M, et al. Prediction of cardiorespiratory fitness by the six-minute step test and its association with muscle strength and power in sedentary obese and lean young women: a cross-sectional study. *PLOS ONE.* 2015;10:1–16.
- Zugck C, Krüger C, Dürr S, et al. Is the 6-minute walk test a reliable substitute for peak oxygen uptake in patients with dilated cardiomyopathy? *Eur Heart J.* 2000;21:540–9.
- Cahalin LP, Mathier MA, Semigran MJ, et al. The six-minute walk test predicts peak oxygen uptake and survival in patients with advanced heart failure. *Chest.* 1996;110:325–32.
- Ingle L, Shelton RJ, Rigby AS, et al. The reproducibility and sensitivity of the 6-min walk test in elderly patients with chronic heart failure. *Eur Heart J.* 2005;26:1742–51.
- Fowler SJ, Singh SJ, Revill S. Reproducibility and validity of the incremental shuttle walking test in patients following coronary artery bypass surgery. *Physiotherapy.* 2005;91:22–7.
- Pulz C, Diniz RV, Alves ANF, et al. Incremental shuttle and six-minute walking tests in the assessment of functional capacity in chronic heart failure. *Can J Cardiol.* 2008;24:131–5.
- Alves R, Lima MM, Fonseca C, et al. Peak oxygen uptake during the incremental shuttle walk test in a predominantly female population with Chagas heart disease. *Eur J Phys Rehabil Med.* 2016;52:20–7.
- de Andrade CH, de Camargo AA, de Castro BP, et al. Comparison of cardiopulmonary responses during 2 incremental step tests in subjects with COPD. *Respir Care.* 2012;57:1920–6.
- Master AM. The two-step test of myocardial function. *Am Heart J.* 1935;10:495–510.

37. Rikli R, Jones C. Development and validation of a functional fitness test for community-residing older adults. *J Aging Phys Act.* 1999;7:129–61.
38. Garcia S, Alosco ML, Spitznagel MB, et al. Cardiovascular fitness associated with cognitive performance in heart failure patients enrolled in cardiac rehabilitation. *BMC Cardiovasc Disord.* 2013;13:2–7.
39. Alosco ML, Brickman AM, Spitznagel MB, et al. Poorer physical fitness is associated with reduced structural brain integrity in heart failure. *J Neurol Sci.* 2013;328:51–7.
40. American College of Sports Medicine. *Diretrizes do ACSM para os testes de esforço e sua prescrição.* 7th ed. Rio de Janeiro: Guanabara-Koogan; 2007.
41. McKelvie RS, Teo KK, Roberts R, et al. Effects of exercise training in patients with heart failure: the Exercise Rehabilitation Trial (EXERT). *Am Heart J.* 2002;144:23–30.
42. Jónsdóttir S, Andersen KK, Sigurosson AF, et al. The effect of physical training in chronic heart failure. *Eur J Heart Fail.* 2006;8:97–101.
43. Freimark D, Shechter M, Schwammenthal E, et al. Improved exercise tolerance and cardiac function in severe chronic heart failure patients undergoing a supervised exercise program. *Int J Cardiol.* 2007;116:309–14.
44. Chan C, Tang D, Jones A. Clinical outcomes of a cardiac rehabilitation and maintenance program for Chinese patients with congestive heart failure. *Disabil Rehabil.* 2008;30:1245–53.
45. Brubaker PH, Moore JB, Stewart KP, et al. NIH public access. *J Am Geriatr Soc.* 2010;57:1982–9.
46. Gary RA, Cress ME, Higgins MK, et al. Combined aerobic and resistance exercise program improves task performance in patients with heart failure. *Arch Phys Med Rehabil.* 2011;92:1371–81.
47. Babu AS, Maiya AG, George MM, et al. Effects of combined early in-patient cardiac rehabilitation and structured home-based program on function among patients with congestive heart failure: a randomized controlled trial. *Heart Views.* 2011;12:99–103.
48. Asbury EA, Webb CM, Probert H, et al. Cardiac rehabilitation to improve physical functioning in refractory angina: a pilot study. *Cardiology.* 2012;122:170–7.
49. Chen CH, Chen YJ, Tu HP, et al. Benefits of exercise training and the correlation between aerobic capacity and functional outcomes and quality of life in elderly patients with coronary artery disease. *Kaohsiung J Med Sci.* 2014;30:521–30.
50. Sawatzky JAV, Kehler DS, Ready AE. Prehabilitation program for elective coronary artery bypass graft surgery patients: a pilot randomized controlled study. *Clin Rehabil.* 2014;28:648–57.
51. Begot I, Peixoto TC, Gonzaga LR, et al. A home-based walking program improves erectile dysfunction in men with an acute myocardial infarction. *Am J Cardiol.* 2015;115:571–5.
52. Chrysohoou C, Angelis A, Tsitsinakis G, et al. Cardiovascular effects of high-intensity interval aerobic training combined with strength exercise in patients with chronic heart failure. A randomized phase III clinical trial. *Int J Cardiol.* 2015;179:269–74.
53. Peixoto TCA, Begot I, Bolzan DW. Early exercise-based rehabilitation improves health-related quality of life and functional capacity after acute myocardial infarction: a randomized controlled trial. *Can J Cardiol.* 2015;31:308–13.
54. Piotrowicz E, Zieliński T, Bodalski R, et al. Home-based telemonitored Nordic walking training is well accepted, safe, effective and has high adherence among heart failure patients, including those with cardiovascular implantable electronic devices: a randomized controlled study. *Eur J Prev Cardiol.* 2015;22:1368–77.
55. Safiyari-Hafizi H, Taunton J, Ignaszewski A, et al. The health benefits of a 12-week home-based training cardiac rehabilitation program in patients with heart failure. *Can J Cardiol.* 2016:561–7.
56. de Morton NA. The PEDro scale is a valid measure of the methodological quality of clinical trials: a demographic study. *Aust J Physiother.* 2009;55:129–33.
57. Maher CG, Sherrington C, Herbert RD, et al. Reliability of the PEDro scale for rating quality of randomized controlled trials. *Phys Ther.* 2003;83:713–21.
58. Vigorito C, Giallauria F. Effects of exercise on cardiovascular performance in the elderly. *Front Physiol.* 2014;5:1–8.
59. Haykowsky MJ, Brubaker PH, Stewart KP, et al. Effect of endurance training on the determinants of peak exercise oxygen consumption in elderly patients with stable compensated heart failure and preserved ejection fraction. *J Am Coll Cardiol.* 2012;60:120–8.
60. Gielen S, Laughlin MH, O'Conner C, et al. Exercise training in patients with heart disease: review of beneficial effects and clinical recommendations. *Prog Cardiovasc Dis.* 2015;57:347–55.
61. 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;23:683–93.