European Journal of Preventive Cardiology
ESC European Society of Cardiology

Review

European Journal of Preventive Cardiology
2017, Vol. 24(16) 1696–1707

DOI: 10.1177/2047487317728370
journals.sagepub.com/home/ejpc
SAGE

High-intensity interval training versus moderate-intensity continuous training on exercise capacity and quality of life in patients with coronary artery disease: A systematic review and meta-analysis

Mansueto Gomes-Neto[1,2,3,4], André R Durães[2], Helena F Correia dos Reis[1,3], Victor R Neves[5], Bruno P Martinez[1,3] and Vitor O Carvalho[3,4,6]

Abstract

Background: Exercise is an effective strategy for reducing total and cardiovascular mortality in patients with coronary artery disease. However, it is not clear which modality is best. We performed a meta-analysis to investigate the effects of high-intensity interval versus moderate-intensity continuous training of coronary artery disease patients.

Methods: We searched MEDLINE, PEDro, LILACS, SciELO and the Cochrane Library (from the earliest date available to November 2016) for controlled trials that evaluated the effects of high-intensity interval versus moderate-intensity continuous training for coronary artery disease patients. Weighted mean differences and 95% confidence intervals were calculated, and heterogeneity was assessed using the I^2 test.

Results: Twelve studies met the study criteria, including 609 patients. High-intensity interval training resulted in improvement in peak oxygen uptake weighted mean difference (1.3 ml/kg/min, 95% confidence interval: 0.6–1.9, $n = 594$) compared with moderate-intensity continuous training. No significant difference in physical, emotional, and social domain of quality of life was found for participants for participants in the high-intensity interval training group compared with the moderate-intensity continuous training group. Sub-analysis of three studies with isocaloric exercise training showed no significant difference in peak oxygen uptake weighted mean difference (0.4 ml/kg/min, 95% confidence interval: –0.1–0.9, $n = 137$) for participants in the high-intensity interval training group compared with moderate-intensity continuous training group.

Conclusions: High-intensity interval training may improve peak oxygen uptake and should be considered as a component of care of coronary artery disease patients. However, this superiority disappeared when isocaloric protocol is compared.

Keywords

Coronary artery disease, exercise, rehabilitation

Received 16 March 2017; accepted 5 August 2017

[1]Physical Therapy Department, Federal University of Bahia, Brazil
[2]Programa de Pós Graduação em Medicina e Saúde, Federal University of Bahia, Brazil
[3]Physiotherapy Research Group, Federal University of Bahia, Brazil
[4]The GREAT Group (GRupo de Estudos em ATividade física), Brazil
[5]Physical Therapy Department, State University of Pernambuco, Brazil
[6]Physical Therapy Department, Federal University of Sergipe, Brazil

Corresponding author:
Mansueto Gomes-Neto, Departamento de Fisioterapia, Universidade Federal da Bahia (UFBA), Instituto de Ciências da Saúde, Av. Reitor Miguel Calmon s/n, Vale do Canela Salvador, BA, CEP 40.110-100, Brazil.
Email: mansueto.neto@ufba.br

Background

Exercise-based cardiac rehabilitation is a safe and well-established intervention to improve aerobic exercise capacity, muscle strength, metabolic parameters, quality of life and survival in patients with coronary artery disease.[1–3]

Despite the well-known benefits of exercise-based cardiac rehabilitation, the most efficient modality and intensity are still under discussion.[4] Traditional exercise prescription includes moderate continuous aerobic exercise training: however, since the recommendation of the American Heart Association in 2007, a strong clinical interest has emerged in high-intensity interval training.[5] Thus, high-intensity interval training, is currently considered as an alternative for moderate continuous exercise within a cardiac rehabilitation program.[6]

A recent systematic review and meta-analysis[7] showed a superiority of the high-intensity interval training in comparison to moderate continuous training on brachial artery vascular function. Other systematic reviews[8–10] also showed the superiority of the high-intensity interval training on exercise capacity in patients engaged with an exercise-based cardiac rehabilitation program. However, these studies performed the search in May 2015[8] and May[9] and December 2013.[10] Since then new studies have been completed and published. In addition, an important aspect to be considered in the comparison of different exercise protocols is the energy expenditure during the training. Isocaloric protocols aim to adjust the energy expenditure within aerobic exercise sessions performed with different intensities.[11]

Vromen et al. performed a meta-regression analysis to determine a ranking of the individual effect of the training characteristics on the improvement in exercise capacity of an aerobic exercise training program in chronic heart failure patients, and concluded that total energy expenditure appeared to be the only training characteristic with a significant effect on improvement in exercise capacity.[12] However, the concept of isocaloric exercise training has never been investigated in meta-analyses involving patients with coronary artery disease.

The aim of this systematic review with meta-analysis was to analyze the published randomized controlled trials (RCTs) that investigated the effects of high-intensity interval versus moderate-intensity continuous training on exercise capacity and quality of life in patients with coronary artery disease. Moreover, this systematic review aims to perform a sub-analysis of the studies that performed an isocaloric exercise training protocol.

Methods

This systematic review was completed in accordance with PRISMA guidelines.[13]

Eligibility criteria

This systematic review included RCTs that studied the effects of high-intensity interval training compared to continuous exercise training in individuals with coronary artery disease (history of coronary artery disease with angina pectoris or myocardial infarction diagnosed by American Heart Association standard criteria,[14] angiographically documented, and/or percutaneous coronary intervention). To be eligible, the trial had to randomize patients with coronary artery disease to a group of high-intensity interval training or to moderate-intensity continuous training.

Studies that enrolled patients with other cardiac or respiratory diseases were excluded. The outcomes of interest were peak oxygen uptake (VO_2; ml/kg/min) and quality of life.

Search methods for identification of studies

We searched for references on MEDLINE, PEDro, LILACS, SciELO and the Cochrane Library up to November 2016 without language restrictions. We used a standard protocol for this search and, whenever possible, used a controlled vocabulary (MeSH term for MEDLINE and Cochrane and Emtree for Embase). In our search strategy, we used three groups of keywords and their synonyms: study design, participants, and interventions.

The strategy developed by Higgins and Green[15] was used for the identification of RCTs in PUBMED/MEDLINE. To identify the RCTs in other databases we adopted a search strategy using similar terms. We checked the references of the articles included in this meta-analysis to identify other potentially eligible studies. For ongoing studies, authors were contacted by e-mail for confirmation of any data or obtaining additional information.

Data collection and analysis

Titles and abstracts were independently checked by two reviewers. If at least one of the reviewers considered one reference eligible, the full text was obtained for complete assessment. Then, two reviewers independently assessed the full text of selected articles to verify if they met the criteria for inclusion or exclusion. Two authors independently extracted data from the published reports using standard data extraction forms adapted from Higgins and Green.[15]

Aspects of the study population, intervention performed, follow-up period and rates of missing data, outcome measures, and results were reviewed.

Quality of meta-analysis evidence

The quality of studies included in this systematic review was scored by two researchers using the PEDro scale, which is based on important criteria, such as concealed allocation, intention-to-treat analysis, and the adequacy of follow-up. These characteristics make the PEDro scale a useful tool for assessing the quality of rehabilitation trials.[16–18] Any disagreements in the rating of the studies were resolved by a third reviewer.

Statistical assessment

Pooled-effect estimates were obtained by comparing the least square mean change from baseline to endpoint for each group, and were expressed as the weighted mean difference between groups. When the standard deviation (SD) of change was not available, the SD of the baseline measure was used for the meta-analysis. Calculations were done using a fixed-effects and random-effects model. If the trial was a multiple-arm RCT, all relevant experimental intervention groups (high-intensity interval versus moderate-intensity continuous training) had data extracted. In follow-up reports with multiple endpoints, only data closest to the end of the exercise program were included. In cross-over trials, size effects were only extracted at the first cross-over point.

We compared high-intensity interval versus moderate-intensity continuous training, and also performed a sub-analysis of the studies that compared an isocaloric exercise training protocol. An α value ≤ 0.05 was considered significant. Heterogeneity among studies was examined with Cochran's Q and I^2 statistic, in which values greater than 50% were considered indicative of high heterogeneity[19] and the random-effects model was chosen. Analyses were performed with Review Manager (Version 5.3).[20]

Results

Description of selected studies

The initial search led to the identification of 609 abstracts, from which 23 studies were considered as potentially relevant and were retrieved for detailed analysis. After a complete reading of 23 articles, eight were excluded and 15[21–34] met the eligibility criteria. Of these, three were duplicates (studies that used the same participants). The study by Pattyn et al.[33] used the same participants as the study by Conraads et al.;[32] the study by Moholdt et al. in 2012[27] used the same participants as the study by Moholdt et al. in 2011,[26] and the study by Rognmo et al.[22] used the same participants as the study by Amundsen et al.[21] Finally, 12 studies met the eligibility criteria. Figure 1 shows the PRISMA flow diagram of studies in this review. Each of the papers was scored using the PEDro scale methodology by both reviewers. The results of the assessment of the PEDro scale, with a mean value of 5.1, are presented individually in Table 1.

Study characteristics

The number of participants randomized in this meta-analysis ranged from 14[24] to 200.[33] The mean age of participants ranged from 58–65 years. Twelve studies included patients of both genders and two studies included only men.[24,31] Sample size, outcomes, and results of included studies are summarized in Table 1.

Characteristics of intervention programs

The characteristics of the high-intensity interval training and moderate-intensity continuous training have been reported in most studies (Table 2). Only five studies used isocaloric exercise training.[22,23,29,33,34]

Peak VO2. Twelve studies assessed peak VO_2 as outcome. The studies showed a baseline average of 24 ml/kg/min and a post-intervention average of 28 ml/kg/min. The meta-analyses showed (Figure 2(a)) a significant improvement in peak VO_2 of 1.3 ml/kg/min (95% confidence interval (CI): 0.6–1.9, $n = 594$) for participants in the high-intensity interval training group compared with the moderate-intensity continuous training group. The meta-analyses of studies that did not use isocaloric exercise training showed (Figure 2(b)) a significant improvement in peak VO2 of 1.9 ml/kg/min (95% CI: 1.1–2.6, $n = 446$) for participants in the high-intensity interval training group compared with the moderate-intensity continuous training group.

Five studies used isocaloric exercise training.[22,23,29,33,34] However, the Madssen et al. study[34] presented data as median (CI) and was not included in the meta-analysis. Our sub-analysis of four studies with isocaloric exercise training showed (Figure 2(c)) a no significant difference in peak VO_2 of 0.7 ml/kg/min (95% CI: –0.1–0.9, $n = 137$) for participants in the high intensity interval training group compared with moderate intensity continuous training group.

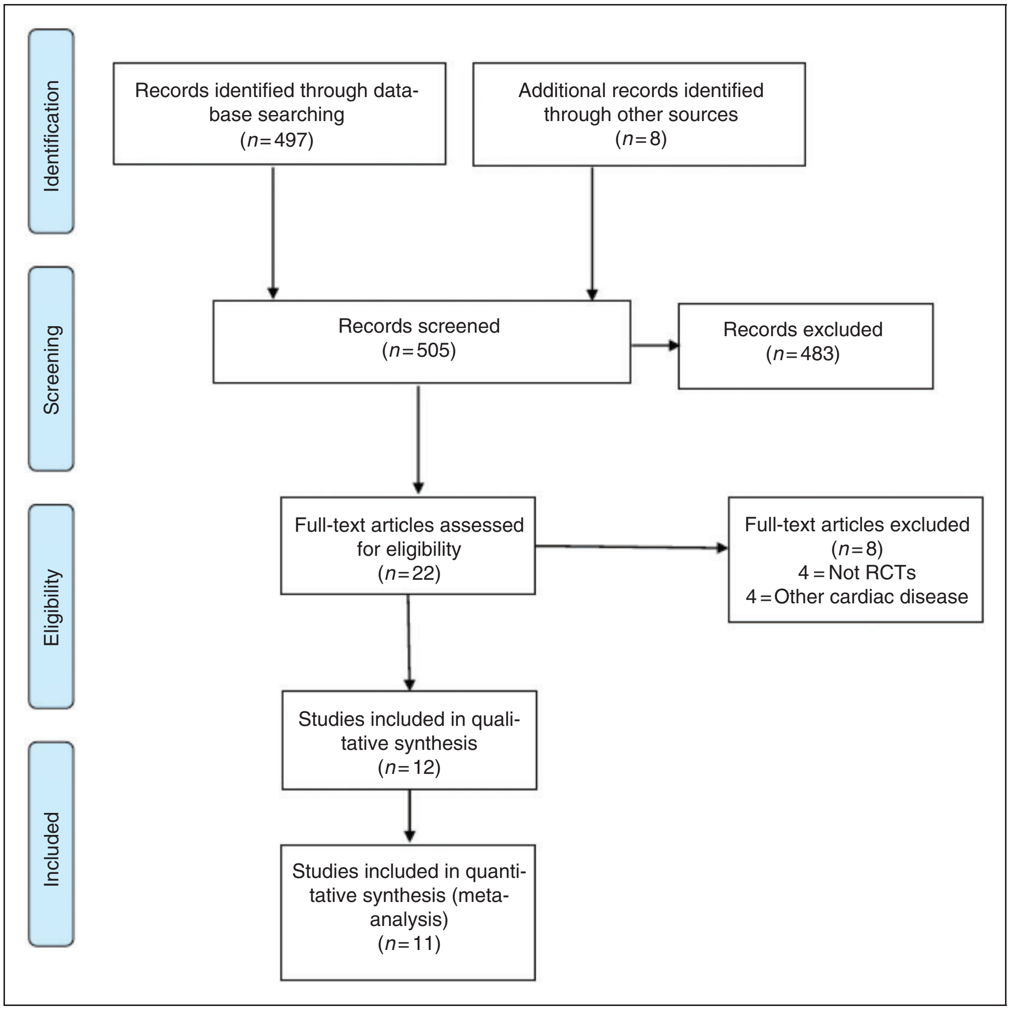

Figure 1. Search and selection of studies for systematic review according to Preferred reporting items for systematic reviews and meta-analyses (PRISMA). RCT: randomized controlled trial.

Quality of life. Four studies assessed quality of life (a total of 394 patients).[22,27,31,32] In the study by Conraads et al.[32] the quality of life, assessed by SF-12 questionnaire, improved significantly on the physical and mental domains in the high-intensity interval training group. In the studies by Moholdt et al.[23,27] the quality of life, assessed by the MacNew questionnaire, showed improvements in both groups. The study by Jaureguizar et al.[31] assessed the quality of life by SF-36 and MacNew questionnaires and showed no difference between groups. Due to the difference between the instruments on the assessment of quality of life, we performed a meta-analysis for the physical component and mental component of SF-12 and SF-36 with standardized mean difference. No significant difference in the physical, emotional, and social domains of quality of life of the MacNew questionnaire was found for participants in the high-intensity interval training group compared with moderate-intensity continuous training group (Figure 3(a)). No significant difference in the physical component and mental component was found for participants in the high-intensity interval training group compared with moderate-intensity continuous training group (Figure 3(b)).

Discussion

Our meta-analyses showed that high intensity interval training was more efficient than moderate intensity continuous training on peak VO_2 gain of patients with coronary artery disease. However, when we analyzed the studies with an isocaloric exercise training protocol, the superiority of the high-intensity exercise training on peak VO_2 disappeared. (Figure 1(b)) The quality of life showed no difference on physical, emotional, and social domains between groups.

Exercise training is well established as an important non-pharmacological therapy in adults with chronic diseases, and it is endorsed by the main guidelines around the world.[35–37] Although the overall level of

Table 1. Characteristics of included studies.

Study	Disease	Sample size	Gender	Age (y)	Outcomes	Key findings	Dropouts %	Dropouts pre and post intervention	PEDro score
Conraads et al., 2015[32]	CAD or previous MI	200 (174)	M/F	58.4	Peak VO_2 Peripheral endothelial function Cardiovascular risk factors Quality of life	No difference between the groups ($p > 0.05$)	All–26 (13%)	HIIT–15 (15%) MCT–11 (11%)	7
Moholdt et al., 2012[27]	Post MI	107 (89)	M/F	57.2	Peak oxygen uptake Endothelial function Blood markers Quality of life	There was a larger increase in peak VO_2 after HIIT compared to MICT ($p < 0.014$)	All–18 (16.8%)	HIIT–13 (18%) MCT–5 (14%)	6
Moholdt et al., 2009[23]	Post CABG	69 (78)	M/F	61.1	Peak oxygen uptake Left ventricular function Quality of life Blood markers	HIIT group showed a further increase in peak VO_2 compared MICT ($p < 0.05$)	All–21 (30.4%)	HIIT–10 (30%) MCT–11 (31%)	6
Rocco et al., 2012[29]	CAD	37 (37)	M/F	59.7	Peak oxygen uptake $PETCO_2$ Ventilatory anaerobic limiar	No difference between the groups	NR	NR	3
Jaureguizar et al., 2016[31]	CAD	72 (72)	M	58	Functional capacity Quality of life Safety	HIIT resulted in a significantly greater increase in peak VO_2 and 6-minute walk distance compared with MICT ($p < 0.05$)	NR	NR	5
Warburton et al., 2005[24]	CAD	14(14)	M	56	Exercise capacity Anaerobic capacity	No difference between the groups	NR	NR	4
Cardozo et al., 2015[30]	CAD	92 (71)	M/F	64	Peak VO_2 (exercise capacity) VE/VCO slope O_2P (oxigeny pulse)	After training the peak VO_2 increasing in HIIT and remaining stable in MICT ($p < 0.04$)	NR	NR	5
Keteyian et al., 2014[28]	MI, CABG, CAD	39 (28)	M/F	59	Peak VO2 (cardiorespiratory fitness)	The improvement in peak VO_2 was greater among patients randomized to HIIT versus MICT ($p < 0.043$)	All–39 (28.2%)	HIIT–6 (29%) MCT–5 (28%)	6
Rognmo et al., 2004[22]	CAD	24 (17)	M/F	62	Peak VO_2 (exercise capacity)	The peak VO_2 in HIIT group was grater than MICT ($p < 0.011$)	All–7 (29.1%)	HIIT–3 (27%) MCT–1 (10%)	5

(continued)

Table 1. Continued

Study	Disease	Sample size	Gender	Age (y)	Outcomes	Key findings	Dropouts %	Dropouts pre and post intervention	PEDro score
Amundsen et al., 2008[21]	CAD	21 (17)	M/F	62	VO_2 peak Left ventricular function	VO_{2peak} increased more in the HIIT than in the MICT ($p < 0.01$)	4 (19%)	NR	4
Moholdt et al., 2011[26]	MI	107 (69)	M/F	57	Aerobic capacity	$VO2_{peak}$ increased significantly more after HIIT than after usual care exercise ($p < 0.005$)	38 (35.5%)	HIIT–27 (38%) MCT–11 (31%)	4
Currie et al., 2013[25]	CAD	30 (22)	M/F	65	Brachial artery flow-mediated dilation Cardiorespiratory fitness	No difference between the groups ($p > 0.05$)	8 (26.7%)	NR	5
Pattyn et al., 2016[33]	CAD	200 (163)	M/F	59	Physical fitness Physical activity Peripheral endothelial function Cardiovascular risk factors Quality of life	No difference between the groups ($p > 0.05$)	37 (18.5%)	HIIT–20 (20%) MCT–17 (17%)	6
Prado et al., 2016[44]	CAD	35 (35)	M/F	59	Cardiorespiratory fitness	No difference between the groups ($p > 0.05$)	NR	NR	6

CAD: coronary artery disease; M/F: male/female; MI: myocardial infarction; HIIT: high-intensity interval training; MICT: moderate-intensity continuous training; VO_2: oxygen uptake; PETCO2: Partial pressure of exhaled carbon dioxide; CABG: Coronary artery bypass grafting; VE: minute ventilation; VCO: carbon dioxide production, CEPT: cardiopulmonary exercise test; NI: Not informed.

Table 2. Characteristics of the high-intensity interval training (HIIT) versus moderate-intensity continuous training (MICT) intervention in the trials included in the review.

Study	Type of exercise	VO_2 measurement	Intensity	Trained intensity	Volume	Frequency (×per wk)	Time (min)	Length (wk)	Supervision
Conraads et al., 2015[32]	HIIT	Cardiopulmonary exercise testing	90–95% Peak HR	88% Peak HR or 86% Peak workload	10 min warm up 38 min exercise 0 min cool down	3	38	12	Yes
	MICT	Cardiopulmonary exercise test	70–75% Peak HR	80% Peak HR or 63% Peak workload	5 min warm up 37 min exercise 5 min cool down	3	47	12	Yes
Moholdt et al., 2009[23]	HIIT	Cardiopulmonary exercise test	90% HR_{max}	92% HR_{max}	8 min warm up 25 min exercise 5 min cool down	5	NR	4	NR
	MICT	Cardiopulmonary exercise test	70% HR_{max}	74% HR_{max}	NR warm up 46 min exercise NR cool down	5	46	4	NR
Rocco et al., 2012[29]	HIIT	Cardiopulmonary exercise test	HR at RCP	80–90% VO_2 peak	NR warm up 42 min exercise NR cool down	3	42	12	Yes
	MICT	Cardiopulmonary exercise test	HR at VAT		5 min warm up 50 min exercise 5 min cool down	3	60	12	Yes
Jaureguizar et al., 2016[31]	HIIT	Cardiopulmonary exercise test	SRT_{max}	134.5% ± 29.7% (second month) of the maximum load reached in the initial CPET corresponding to 50% of the SRT in both months. The resulting HR during the first and second months in the HIIT group was between VT1 and VT2.	5–12 min warm up 15–30 min exercise 5–12 min cool down	3	40	8	NR
	MICT	Cardiopulmonary exercise test	HR at VT1 at (2nd month + 10% HR at VT1	First month; 64.2% ± 8.5% of the VO_2 peak. Second month: 69.5% ± 8.7% of the VO_2 peak	5 min warm up 15–30 min exercise 5 min cool down	3	40	8	NR
Warburton et al., 2005[24]	HIIT	Cardiopulmonary exercise test	85–95% HR/VO_2 reserve	NI	10 min warm up 30 min exercise 5 min cool down	2	30	16	NR
	MICT	Cardiopulmonary exercise test	65% HR/VO_2 reserve	NI	10 min warm up 30 min exercise 10 min cool down	2	30	16	NR
Cardozo et al., 2015[30]	HIIT	Cardiopulmonary exercise test	90% HR peak	NI	5 min warm up 30 min exercise 5 min cool down	3	40	16	Yes
	MICT	Cardiopulmonary exercise test	70–75% HR peak	NI	5 min warm up 30 min exercise 5 min cool down	3	40	16	Yes

(continued)

Table 2. Continued

Study	Type of exercise	VO_2 measurement	Intensity	Trained intensity	Volume	Frequency (×per wk)	Time (min)	Length (wk)	Supervision
Keteyian et al., 2014[28]	HIIT	Cardiopulmonary exercise test	80–90% HR reserve	NI	5 min warm up 30 min exercise 5 min cool down	3	40	NR	Yes
	MICT	Cardiopulmonary exercise test	60–80% HR reserve	NI	5 min warm up 30 min exercise 5 min cool down	3	40	NR	Yes
Rognmo et al., 2004[22]	HIIT	Cardiopulmonary exercise test	80–90% of VO_{2peak} (85–95% of HR_{peak})	NI	5 min warm up 25 min exercise 3 min cool down	3	33	10	Yes
	MICT	Cardiopulmonary exercise test	50–60% of $VO2_{peak}$	NI	NR warm up 41 min exercise NR cool down	3	41	10	Yes
Madssen et al., 2014[34]	HIIT	Cardiopulmonary exercise test	85–95% of HR_{peak}	NI	10 min warm up 4 times 4 min active pause of 3 min	3	38	12	Yes
	MICT	Cardiopulmonary exercise test	70% HR_{max}	NI	46 min	3	46	12	Yes
Moholdt et al., 2011[26]	HIIT	Cardiopulmonary exercise test	90% HR_{max}	87% HR_{max}	NR warm up NR min exercise NR cool down	2	NR	12	NR
	MICT	Cardiopulmonary exercise test	Moderate-to-high	79% HR_{max}	NR warm up NR min exercise NR cool down	2	50	12	NR
Currie et al., 2013[25]	HIIT	Cardiopulmonary exercise test	80–104% at PPO	73% ± 10% HR_{max}	10–15 min warm up 19 min exercise 10–15 min cool down	2	NR	12	Yes
	MICT	Cardiopulmonary exercise test	51–56% at PPO	65% ± 4% HR_{max}	10–15 min warm up 30–50 min exercise 10–15 min cool down	2	NR	12	Yes
Prado et al., 2016[44]	HIIT	Cardiopulmonary exercise test	At RCP	NI	5 min warm up 42 min exercise 5 min cool down	3	52	12	Yes
	MICT	Cardiopulmonary exercise test	At VAT	NI	5 min warm up 50 min exercise 5 min cool down	3	60	12	Yes

CAD: coronary artery disease; HR: heart rate, HR_{max}: maximum heart rate; MI: myocardial infarction; NR: not reported; PPO: peak power output; RCP: respiratory compensation point; SRT: steep ramp test; VAT: ventilatory anaerobic threshold; VO_2: oxygen uptake.

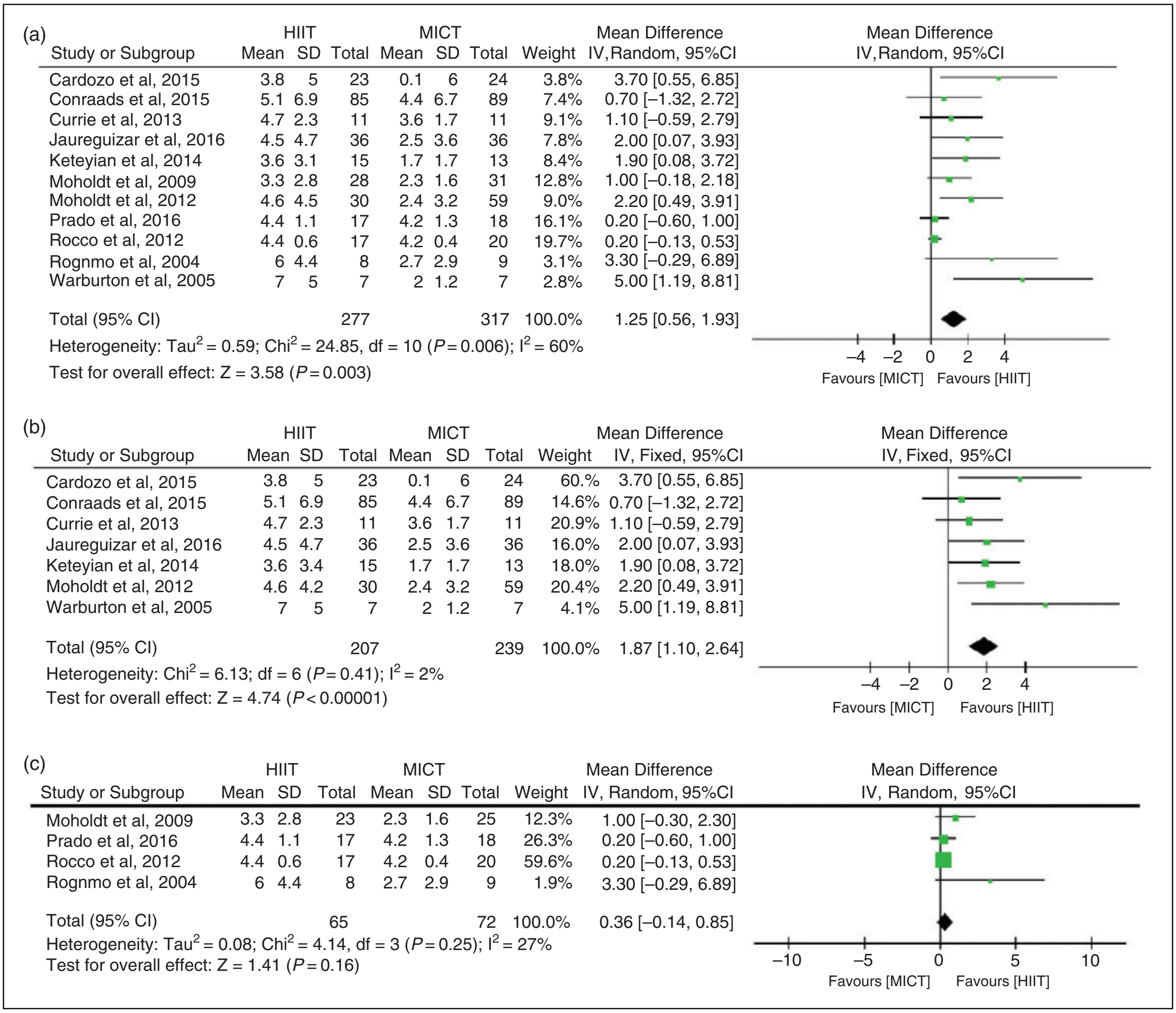

Figure 2. Change in peak oxygen uptake (peak VO_2) – high-intensity interval training (HIIT) versus moderate-intensity continuous training (MICT). (a) Change in peak VO_2 – all studies; (b) change in peak VO_2 - non-isocaloric studies; (c) change in peak VO_2 – isocaloric studies. Review Manager (RevMan). Version 5.3 The Cochrane Collaboration, 2013. CI: confidence interval; SD: standard deviation.

evidence is moderate, high-intensity interval training is a safe and simple intervention that could potentially be beneficial for patients with coronary artery disease.[38] In a large meta-analysis of patients with heart failure, no deaths were attributed to exercise training regardless of intensity.[12] Rognmo et al., examined the risk of cardiovascular events during organized high-intensity interval exercise training and moderate-intensity training among 4846 patients with coronary heart disease in three Norwegian cardiac rehabilitation centers and concluded that the risk of a cardiovascular event was low.[39]

The strength of the present study is the update of the systematic review and a sub-analysis of the studies that used an isocaloric exercise training protocol. In addition, the eligibility of peak VO_2 and quality of life as outcomes is relevant because peak VO_2 is the gold standard method to assess aerobic exercise capacity and is related to quality of life and prognosis in patients with chronic conditions.[38,40,41] However, the result of this meta-analysis is limited by the lack of high-quality studies and we are not able to make judgments about the best method of exercise-based cardiac rehabilitation.

Determining the most appropriate exercise prescription (intensity, frequency, duration, and timing) is important to achieve the best results of peak VO_2 and quality of life. The results of our meta-analyses are in accordance with previous systematic reviews that investigated the effect of high-intensity interval training versus moderate-intensity continuous training on peak

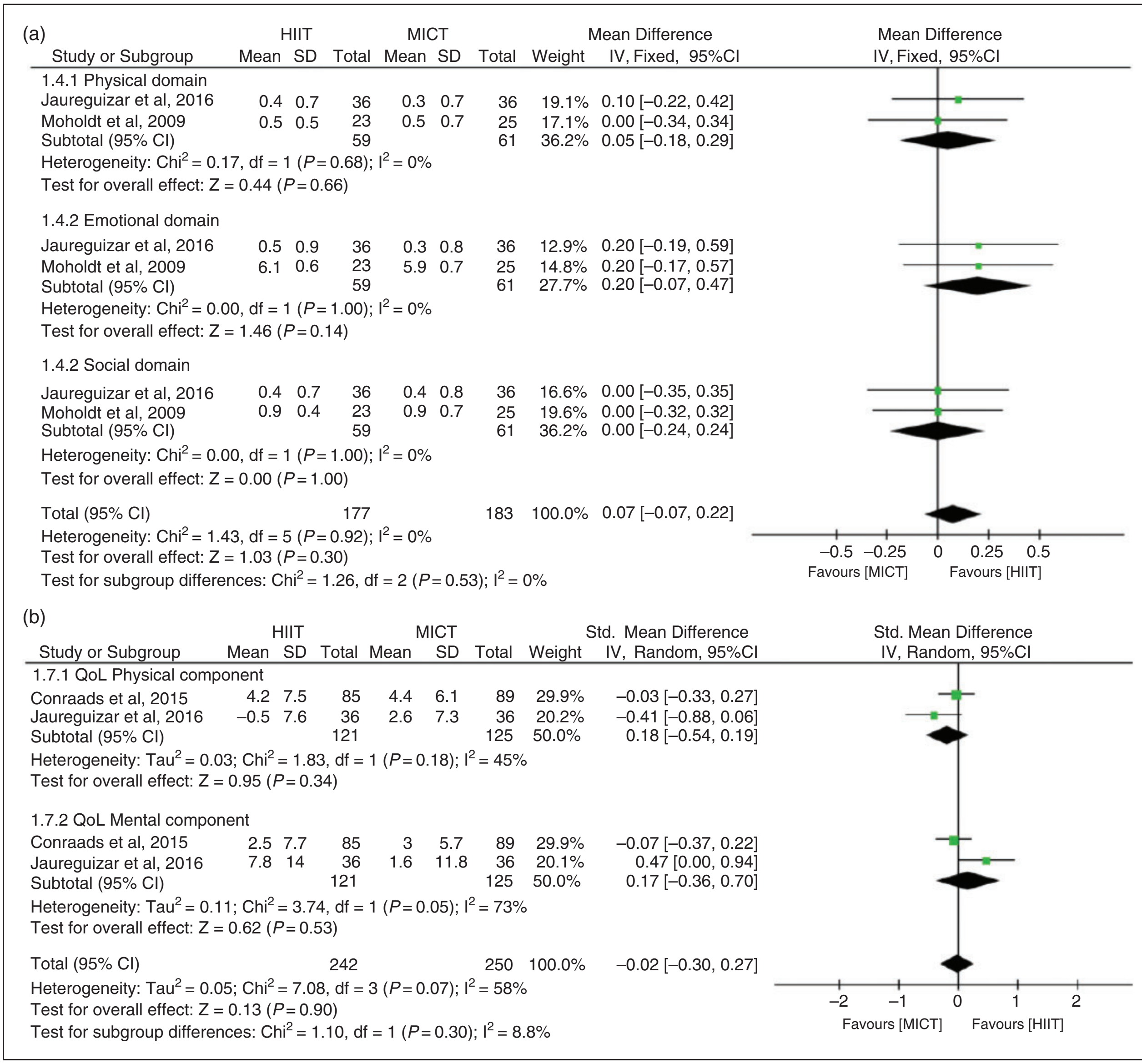

Figure 3. Change in quality of life – high-intensity interval training (HIIT) versus moderate-intensity continuous training (MICT). (a) Change in MacNew domains of quality of life; (b) change in physical and mental component. Review Manager (RevMan). Version 5.3 The Cochrane Collaboration, 2013. CI: confidence interval; SD: standard deviation.

VO_2 in patients with coronary artery disease.[8–10] However, the novelty of this systematic review is the lack of superiority of the interval exercise training on peak VO_2, when the studies with isocaloric exercise protocols were considered.

A previous systematic review involving exercise training parameters in patients with heart failure suggests the use of high total energy expenditure as a main goal for exercise-based cardiac rehabilitation.[12] The authors showed that total energy expenditure was the strongest variable associated with gain in peak VO_2 in patients with heart failure.[12] Considering our results, its plausible to speculate that the total energy spent on exercise training is more important than exercise intensity in patients with coronary disease. The conclusion from the studies on high-intensity interval training that we found is in accordance with the results found by other systematic reviews regarding the effectiveness of high-intensity interval training in healthy young to middle-aged adults[42] and patients with cardiac disease.[43,44]

This review highlights the paucity of high-quality research addressing high-intensity interval training in patients with coronary artery disease. Given the significant heterogeneity found in the primary analyses due the variance in exercise protocols (variable intensities and different durations of the exercise programs), caution is warranted when interpreting our results.

Further investigations into the prescription of the exercise training variables (e.g. intensity, bouts, frequency, duration, etc.) are recommended to enhance our understanding of the real positive effects of high-intensity interval training.

Conclusion

This systematic review found that the high-intensity interval training was superior to continuous exercise training on peak VO_2 gain. However, this superiority disappeared in our sub-analysis of isocaloric protocols in patients with coronary artery disease. Moreover, there was no difference between high-intensity interval training and continuous exercise training effects on quality of life.

Author contribution

MGN, AD, VN, and VC contributed to the conception and design of the work. VN, AD, BM, HR contributed to the acquisition, analysis, or interpretation of data for the work. MGN, VN, BM, and HR drafted the manuscript. MGN, AD, and VC critically revised the manuscript. All authors gave final approval and agree to be accountable for all aspects of work ensuring integrity and accuracy.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

References

1. Taylor RS, Brown A, Ebrahim S, et al. Exercise-based rehabilitation for patients with coronary heart disease: Systematic review and meta-analysis of randomized controlled trials. *Am J Med* 2004; 116: 682–692.
2. 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.
3. Mezzani A, Hamm LF, Jones AM, et al. Aerobic exercise intensity assessment and prescription in cardiac rehabilitation: A joint position statement of the European Association for Cardiovascular Prevention and Rehabilitation, the American Association of Cardiovascular and Pulmonary Rehabilitation and the Canadian Association of Cardiac Rehabilitation. *Eur J Prev Cardiol* 2013; 20: 442–467.
4. Garber CE, Blissmer B, Deschenes MR, et al. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: Guidance for prescribing exercise. *Med Sci Sports Exerc* 2011; 43: 1334–1359.
5. Balady GJ, Williams MA, Ades PA, et al. Core components of cardiac rehabilitation/secondary prevention programs: 2007 Update: A scientific statement from the American Heart Association Exercise, Cardiac Rehabilitation, and Prevention Committee, the Council on Clinical Cardiology; the Councils on Cardiovascular Nursing, Epidemiology and Prevention, and Nutrition, Physical Activity, and Metabolism; and the American Association of Cardiovascular and Pulmonary Rehabilitation. *Circulation* 2007; 115: 2675–2682.
6. Gayda M, Ribeiro PA, Juneau M, et al. Comparison of different forms of exercise training in patients with cardiac disease: Where does high-intensity interval training fit? *Can J Cardiol* 2016; 32: 485–494.
7. Ramos JS, Dalleck LC, Tjonna AE, et al. The impact of high-intensity interval training versus moderate-intensity continuous training on vascular function: A systematic review and meta-analysis. *Sports Med* 2015; 45: 679–692.
8. Liou K, Ho S, Fildes J, et al. High intensity interval versus moderate intensity continuous training in patients with coronary artery disease: A meta-analysis of physiological and clinical parameters. *Heart Lung Circ* 2016; 25: 166–174.
9. Pattyn N, Coeckelberghs E, Buys R, et al. Aerobic interval training vs. moderate continuous training in coronary artery disease patients: A systematic review and meta-analysis. *Sports Med* 2014; 44: 687–700.
10. Elliott AD, Rajopadhyaya K, Bentley DJ, et al. Interval training versus continuous exercise in patients with coronary artery disease: A meta-analysis. *Heart Lung Circ* 2015; 24: 149–157.
11. Swain DP and Franklin BA. Comparison of cardioprotective benefits of vigorous versus moderate intensity aerobic exercise. *Am J Cardiol* 2006; 97: 141–147.
12. Vromen T, Kraal JJ, Kuiper J, et al. The influence of training characteristics on the effect of aerobic exercise training in patients with chronic heart failure: A meta-regression analysis. *Int J Cardiol* 2016; 208: 120–127.
13. Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *BMJ* 2009; 339: b2535.
14. Scanlon PJ, Faxon DP and Audet A. ACC/AHA guidelines for coronary angiography: Executive summary and recommendations. *Circulation* 1999; 99: 2345–2357.
15. Higgins JPT and Green S. *The Cochrane Library. Cochrane handbook for systematic reviews of interventions 4.2.6. Issue 4*. Update September 2006. Chichester: John Wiley & Sons, 2006.
16. Olivo SA, Macedo LG, Gadotti IN, et al. Scales to assess the quality of randomized controlled trials: A systematic review. *Phys Ther* 2008; 88: 156–175.
17. Verhagen AP, de Vet HCW, de Bie RA, et al. The Delphi list: A criteria list for quality assessment of randomized clinical trials for conducting systematic reviews developed by Delphi Consensus. *J Clin Epidemiol* 1998; 51: 1235–1241.

18. Maher CG, Sherrington C, Herbert RD, et al. Reliability of the PEDro scale for rating of quality randomized controlled trials. *Phys Ther* 2003; 83: 713–721.
19. Higgins JP, Thompson SG, Deeks JJ, et al. Measuring inconsistency in meta-analyses. *BMJ* 2003; 327: 557–560.
20. Collaboration TC. http://community.cochrane.org/tools/review-production-tools/revman-5/revman-5-download, 2017.
21. Amundsen BH, Rognmo O, Hatlen-Rebhan G, et al. High-intensity aerobic exercise improves diastolic function in coronary artery disease. *Scand Cardiovasc J* 2008; 42: 110–117.
22. Rognmo Ø, Hetland E, Helgerud J, et al. High intensity aerobic interval exercise is superior to moderate intensity exercise for increasing aerobic capacity in patients with coronary artery disease. *Eur J Cardiovasc Prev Rehabil* 2004; 11: 216–222.
23. Moholdt TT, Amundsen BH, Rustad LA, et al. Aerobic interval training versus continuous moderate exercise after coronary artery by pass surgery: A randomized study of cardiovascular effects and quality of life. *Am Heart J* 2009; 158: 1031–1037.
24. Warburton DER, McKenzie DC, Haykowsky MJ, et al. Effectiveness of high-intensity interval training for the rehabilitation of patients with coronary artery disease. *Am J Cardiol* 2005; 95: 1080–1084.
25. Currie KD, Dubberley JB, McKelvie RS, et al. Low-volume, high-intensity interval training in patients with CAD. *Med Sci Sports Exerc* 2013; 45: 1436–1442.
26. Moholdt T, Aamot IL, Granøien 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.
27. Moholdt T, Aamot IL, Granøien I, et al. Aerobic interval training increases peak oxygen uptake more than usual care exercise training in myocardial infarction patients: A randomized controlled study. *Clin Rehabil* 2012; 26: 33–44.
28. Keteyian SJ, Hibner BA, Bronsteen K, et al. Greater improvement in cardiorespiratory fitness using higher-intensity interval training in the standard cardiac rehabilitation setting. *J Cardiopulm Rehabil Prev* 2014; 34: 98–105.
29. Rocco EA, Prado DM, Silva AG, et al. Effect of continuous and interval exercise training on the PETCO2 response during a graded exercise test in patients with coronary artery disease. *Clinics* 2012; 67: 623–627.
30. Cardozo GG, Oliveira RB and Farinatti PT. Effects of high intensity interval versus moderate continuous training on markers of ventilatory and cardiac efficiency in coronary heart disease patients. *Scientific World Journal* 2015; 2015: 192479.
31. Jaureguizar KV, Vicente-Campos D, Bautista LR, et al. Effect of high-intensity interval versus continuous exercise training on functional capacity and quality of life in patients with coronary artery disease: A randomized clinical trial. *J Cardiopulm Rehabil Prev* 2016; 36: 96–105.
32. Conraads VM, Pattyn N, De Maeyer C, et al. Aerobic interval training and continuous training equally improve aerobic exercise capacity in patients with coronary artery disease: The SAINTEX-CAD study. *Int J Cardiol*, 2015 20; 179: 203–210.
33. Pattyn N, Vanhees L, Cornelissen VA, et al. The long-term effects of a randomized trial comparing aerobic interval versus continuous training in coronary artery disease patients: 1-Year data from the SAINTEX-CAD study. *Eur J Prev Cardiol* 2016; 23: 1154–1164.
34. Madssen E, Moholdt T, Videm V, et al. Coronary atheroma regression and plaque characteristics assessed by grayscale and radiofrequency intravascular ultrasound after aerobic exercise. *Am J Cardiol*, 2014 15; 114: 1504–1511.
35. Ismail H, McFarlane JR, Nojoumian AH, et al. Clinical outcomes and cardiovascular responses to different exercise training intensities in patients with heart failure: A systematic review and meta-analysis. *JACC Heart Fail* 2013; 1: 514–522.
36. Dickstein K, Cohen-Solal A, Filippas G, et al. ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure 2008: The Task Force for the Diagnosis and Treatment of Acute and Chronic Heart Failure 2008 of the European Society of Cardiology. Developed in collaboration with the Heart Failure Association of the ESC (HFA) and endorsed by the European Society of Intensive Care Medicine (ESICM). *Eur Heart J* 2008; 29: 2388–2442.
37. Garvey C, Fullwood MD and Rigler J. Pulmonary rehabilitation exercise prescription in chronic obstructive lung disease: US survey and review of guidelines and clinical practices. *J Cardiopulm Rehabil Prev* 2013; 33: 314–322.
38. Frankenstein L, Nelles M, Hallerbach M, et al. Prognostic impact of peak VO2-changes in stable CHF on chronic beta-blocker treatment. *Int J Cardiol* 2007; 122: 125–130.
39. Rognmo Ø, Moholdt T, Bakken H, et al. Cardiovascular risk of high- versus moderate-intensity aerobic exercise in coronary heart disease patients. *Circulation* 2012; 126: 1436–1440.
40. Diller GP, Dimopoulos K, Okonko D, et al. Exercise intolerance in adult congenital heart disease: Comparative severity, correlates, and prognostic implication. *Circulation* 2005; 112: 828–835.
41. Achttien RJ, Staal JB, van der Voort S, et al. Exercise-based cardiac rehabilitation in patients with coronary heart disease: A practice guideline. *Neth Heart J* 2013; 21: 429–438.
42. Milanović Z, Sporiš G and Weston M. Effectiveness of high-intensity interval training (HIT) and continuous endurance training for VO2max improvements: A systematic review and meta-analysis of controlled trials. *Sports Med* 2015; 45: 1469–1481.
43. Fleg JL. Salutary effects of high-intensity interval training in persons with elevated cardiovascular risk. *F1000Res*, E-publication on 7 September 2016. DOI: 10.12688/f1000research.8778.1.
44. Prado DM, Rocco EA, Silva AG, et al. Effects of continuous vs interval exercise training on oxygen uptake efficiency slope in patients with coronary artery disease. *Braz J Med Biol Res* 2016; 49: e4890.