Annals of Physical and Rehabilitation Medicine xxx (2016) xxx–xxx

Available online at
ScienceDirect
www.sciencedirect.com

Elsevier Masson France
EM|consulte
www.em-consulte.com

Review

High-intensity interval training in patients with coronary heart disease: Prescription models and perspectives

Paula A.B. Ribeiro [a,b,c], Maxime Boidin [a,b,d], Martin Juneau [a,b,c], Anil Nigam [a,b,c], Mathieu Gayda [a,b,c,*]

[a] Cardiovascular and Prevention and Rehabilitation Centre (ÉPIC), Montreal Heart Institute, University of Montreal, Montreal, Quebec, Canada
[b] Research Center, Montreal Heart Institute, University of Montreal, Montreal, Quebec, Canada
[c] Department of Medicine, University of Montreal, Montreal, Quebec, Canada
[d] Department of Kinesiology, University of Montreal, Montreal, Quebec, Canada

ARTICLE INFO

Article history:
Received 27 January 2016
Accepted 9 April 2016

Keywords:
High-intensity interval training
Continuous aerobic exercise training
Exercise prescription
Coronary heart disease

ABSTRACT

Recently, high-intensity interval training (HIIT) has emerged as an alternative and/or complementary exercise modality to continuous aerobic exercise training (CAET) in CHD patients. However, the literature contains descriptions of many HIIT protocols with different stage durations, nature of recovery and intensities. In this review, we discuss the most recent forms of validated HIIT protocols in patients with coronary heart disease (CHD) and how to prescribe and use them during short- and long-term (phase II and III) cardiac rehabilitation programs. We also compare the superior and/or equivalent short- and long-term effects of HIIT versus CAET on aerobic fitness, cardiovascular function, and quality of life; their efficiency, safety, and tolerance; and exercise adherence. Short interval HIIT was found beneficial for CHD patients with lower aerobic fitness and would ideally be used in initiation and improvement stages. Medium and/or long interval HIIT protocols may be beneficial for CHD patients with higher aerobic fitness, and would be ideally used in the improvement and maintenance stages because of their high physiological stimulus. Finally, we propose progressive individualized models of HIIT programs (phase II to III) for patients with CHD and how to ideally use them according to the clinical status of patients and phase of the cardiac rehabilitation program.

1. Introduction

Older adults represented 13% of the total Canadian population in 2005 and will represent an estimated 24% in 2036 [1]. They represented 19% of the total population in France in 2015 and the proportion is still growing [2]. Aging is associated with increased risk of cardiovascular diseases such as coronary heart disease (CHD) [3]. Cardiovascular diseases are among the leading causes of death today in Canada (29%) and in the world (30%) and can lead to $20 billion/year costs in physician services, hospital costs, lost wages and decreased productivity [3,4] and approximately €196 billion/year in the European Union (€106 billion in healthcare, €44 billion [22%] in informal care, €27 billion [14%] in early mortality and €19 billion in absence from work or early retirement) [5].

Maximal aerobic power $\left(VO_{2_{peak}}\right)$ is an independent predictor of mortality and morbidity in CHD patients [6]. Therefore, cardiac rehabilitation programs with an exercise training component such as continuous aerobic exercise training (CAET) were found to be safe and to improve prognosis in CHD patients [7–11]. The additional clinical benefits of exercise training in CHD patients are well documented and include improvements in cardiovascular, lung and skeletal muscle functions, endurance, quality of life, inflammation, depressive symptoms, stress and cognitive functions [12,13]. Therefore, exercise training such as CAET is now a cornerstone of the non-pharmacological treatment of patients with CHD and is integrated into the North American and European guidelines [12–15].

Recently, a strong clinical interest has emerged in high-intensity interval training (HIIT) in patients with CHD, first mentioned in the American Heart Association recommendations for exercise prescription in 2007 [12]. Actually, HITT is increasingly being mentioned as an exercise modality in the most recent North American and European guidelines for CHD patients [12–14].

* Corresponding author. Cardiovascular Prevention and Rehabilitation Centre (Centre ÉPIC), Montreal Heart Institute, University of Montreal, 5055 St-Zotique Street East, Montreal, Quebec H1T 1N6, Canada. Tel.: +514 374 1480x4208; fax: +514 374 2445.
E-mail address: mathieu.gayda@icm-mhi.org (M. Gayda).

http://dx.doi.org/10.1016/j.rehab.2016.04.004
1877-0657/

Here we review different forms of HIIT, their principles and their potential combination with CAET to optimize exercise training adaptations in CHD patients. We discuss only phase II (short-term) and III (long-term/maintenance) exercise training programs with HIIT and CAET separately or combined. Finally, we propose how HIIT with CAET can be integrated into theoretical/practical progressive exercise training models (phase II/III) for CHD patients.

2. CAET for cardiac patients

CAET is still the cornerstone of exercise training programs for CHD patients and is largely recommended worldwide [12–14,16]. The program improves prognosis, is safe and feasible and has almost no contra-indications for most patients with stable CHD [12–14,16]. CAET programs have shown good short- and long-term clinical benefits, including reduced mortality and/or morbidity [7–10,17–21], improved $VO_{2_{peak}}$ and ventilatory function, relieved clinical symptoms (dyspnea, sleep disorders and depressive symptoms), controlled dyslipidaemia, and reduced endothelial and muscle dysfunction [12–14,16]. The main goal of CAET is to perform longer exercise periods in steady-state, which favours oxidative metabolism. For beginners, walking programs remain the most prescribed modality for CHD patients because of the advantages: walking is safe, appropriate for starting exercising, needs no or little supervision and can be performed anywhere (indoor or outdoor). Exercise modalities for CAET include mostly walking, running, cycling, Nordic walking, rowing, swimming, stepping and stairs climbing [12–14,16]. In general, CAET leads to higher fat oxidation and longer exercising bouts at intensities from 40% to 50% $VO_{2_{peak}}$ for beginners with low physical function/greater cardiac risk (i.e., CHD patients) and 50% to 75% $VO_{2_{peak}}$ for CHD patients with higher fitness level or less cardiac risk [12–14,16].

Traditionally, the exercise intensity for CAET is prescribed using percentage maximal heart rate (%HRmax), heart rate reserve (%HRR) and peak power output (%PPO) and patient's rate of perceived exertion (RPE) (Borg scale: 6–20), with considerable success [12–14,16]. The exercise intensity zones for CAET are usually classified as follows (see review [15] for details): light- to moderate-intensity zone (40–50% $VO_{2_{peak}}$, RPE: 11–12) and moderate- to high-intensity zone (50–75% of $VO_{2_{peak}}$, RPE: 12–15). These zones must be mainly considered with phase II (initiation-improvement) and III (maintenance) cardiac rehabilitation (see progression models in Table 1). Exercise prescription based on the intensity of the ventilatory threshold, measured during maximal cardiopulmonary exercise test, is also often used for CHD patients, especially those receiving beta-blockers, and corresponds to 50% to 60% $VO_{2_{peak}}$ (initial moderate-zone intensity) [13].

3. General principles of HIIT and exercise training implementation for CHD patients

In this section, we review the general principles of HIIT prescription adapted to CHD patients and its place in the context of exercise training implementation. In a second section, we review the available studies comparing HIIT to CAET for CHD patients, an important topic in recent years (Table 2). Finally, we propose a guide for HIIT prescription and implementation combined with CAET for CHD patients (Table 1).

The main principle of HIIT is to perform brief periods of high-intensity exercise (e.g. > 85% $VO_{2_{peak}}$ or PPO), interspersed with periods of low-intensity exercise or passive rest, to allow patients to accumulate greater time at a higher-intensity than they would otherwise perform with continuous exercise [22,23]. In CHD patients, HIIT can be considered a time-efficient substitute and/or alternative to traditional continuous exercise training [22,23]. Different HIIT protocols (intensity, stage duration, nature of recovery, number of intervals) have been tested and used for CHD patients (see reviews [22,23] for details and Table 2 for protocols). Three different categories of HIIT have been described for CHD patients:

- long intervals: 3 to 15 min at 85% to 90% $VO_{2_{peak}}$;
- medium intervals: 1 to 3 min at 95% to 100% $VO_{2_{peak}}$;
- short intervals: 10 sec to 1 min at 100% to 120% $VO_{2_{peak}}$ [22,23].

Furthermore, HIIT can be performed with different exercise modes such as cycling, running, walking with inclination, rowing, swimming or other activities. Exercise intensity is generally determined with % $VO_{2_{peak}}$, %HRmax, percentage maximal aerobic power, percentage maximal short exercise capacity or RPE (Borg scale) [22,23]. The HIIT choice in terms of exercise intensity, duration of intervals and use of active or passive recovery has a profound effect on acute physiological responses, exercise tolerance and RPE for CHD patients [22,23].

3.1. HIIT with short intervals

The acute physiological responses to different HIIT with short interval protocols have been studied in patients with CHD [22–26]. Our group investigated an optimal protocol that would allow CHD patients to spend more time near the $VO_{2_{peak}}$ values and exercise for a longer total time with less feeling of fatigue and dyspnea [24–26]. We compared the acute cardiovascular

Table 1
Progression models for aerobic exercise training–continuous aerobic exercise training (CAET) or high-intensity interval training (HIIT) – for patients with coronary heart disease (CHD) by functional status.

Patient profile	Stage of training	Prescription (weekly)	CAET	HIIT
Low functional status (< 5 METs)	Initiation (week 0–4)	2–3 × CAET	50–70% PPO (RPE: 11–15)	Not recommended
	Improvement (week 4–12)	2 × CAET and 1 × HIIT (SI)	50–70% PPO (RPE: 11–15)	HIIT-SI: 15 s to 1 min at 70–100% PPO (RPE: 15–18)
	Maintenance (week > 12)	2 × CAET and 1 × HIIT (SI + MI)	50–70% PPO (RPE: 11–15)	HIIT-MI: 1–3 min at 90–110% PPO (RPE > 15) HIIT-SI: 15 s to 1 min at 100–120% PPO (RPE: 15–18)
Normal and high functional status (≥ 5 METs)	Initiation (week 0–4)	2 × CAET and 1 × HIIT (SI)	50–70% PPO (RPE: 11–15)	HIIT-SI: 15 s to 1 min at 80–100% PPO (RPE: 15–18)
	Improvement (week 4–12)	1 × CAET and 2 × HIIT (SI + MI)	50–70% PPO (RPE: 11–15)	HIIT-MI: 1–3 min at 95–100% $VO_{2_{peak}}$ (RPE > 15) HIIT-SI: 10 sec to 1 min at 100–120% $VO_{2_{peak}}$ (RPE: 15–18)
	Maintenance (week > 12)	3 × CAET or HIIT (MI + LI)	50–70% PPO (RPE 14–16)	HIIT-MI: 1–3 min at 95–100% $VO_{2_{peak}}$ (RPE > 15) HIIT-LI: 3–4 min at 80–85% $VO_{2_{peak}}$ (RPE > 15)

HRR: heart rate reserve; PPO: peak power output; RPE: rate of perceived exertion; METS: metabolic equivalents; SI: short intervals; MI: medium intervals; LI: long intervals. HIIT proposal (SI, MI and LI) was based on references [27,29,31,37–52].

Please cite this article in press as: Ribeiro PAB, et al. High-intensity interval training in patients with coronary heart disease: Prescription models and perspectives. Ann Phys Rehabil Med (2016), http://dx.doi.org/10.1016/j.rehab.2016.04.004