High Intensity Interval Training in Patients with CHD and Preserved Ventricular Function

Hochintensives Intervalltraining bei Patienten mit KHK und erhaltener ventrikulärer Pumpfunktion

Summary

Introduction: Applicability and effectiveness of high-intensity interval training currently are discussed and investigated as a possible addition to moderate continuous training (MCT) in cardiac rehabilitation (CR). Meanwhile, prospective multi-centre RCTs and meta-analyses are also available for AIT/HIIT (aerobic interval training / high-intensity interval training) in patients with CHD and CHF / HF/EF.

Method: We conducted a selective literature search until December 2017. This was focussed on studies to evaluate high-intensity interval training modalities in CR both in general as in patients with CHD.

Results: While early (and often small) studies and the following meta-analyses often showed highly significant positive results for high-intensity interval training in comparison to MCT with regards to the maximum oxygen uptake (VO2peak) and other clinically relevant parameters, current prospective multicentre RCTs and meta-analyses show no such significant advantages for high-intensity interval training. Total energy-expenditure (EE) appears to be more relevant for the benefits of such inventions independent of session duration, programme length and training intensity.

Discussion: High-intensity interval training in CR is a safe form of training for CHD patients with preserved left ventricular function showing equivalent improvement of cardiovascular protection factors compared with MCT. It offers a more variable and slightly time saving training option, but requires more intense coaching for the individual patient. Sometimes interval training is not tolerated by CHD-patients. Nevertheless, there is still a need for research in a more precise application and its long-term effects.

Key Words:
Cardiac Rehabilitation, Exercise, Endurance Training, Coronary Arterial Disease, High Intensity Interval Training

Zusammenfassung


Schlüsselwörter:
Kardiologische Rehabilitation, Bewegung, Ausdauertraining, koronare Herzkrankung, Hochintensives Intervalltraining

Definition – History and Primary Prevention
Cardiovascular diseases account for 45% of all deaths, and thus top the list of causes of death in Europe. The total costs resulting from these diseases are about 210 billion € annually in the EU (47). In addition to effective pharmacological and surgical or interventional therapies, training measures to increase the cardiorespiratory performance capacity (VO2peak) are, among others, increasingly in the focus of science and rehabilitative applications (31).

Physical training is a clinically-proven, cost-effective, primary intervention for the prevention and treatment of numerous chronic diseases (11). Results of a meta-analysis on primary prevention show that independent of age and gender, there is
a significant inverse relationship between exercise intensity and overall mortality (23). In elderly people, a higher training intensity is associated with a greater positive effect on the onset incidence of coronary heart disease (CHD) (20).

Interval training is characterized by alternating exercise and recovery phases. These should be so designed that the highest possible oxygen uptake can be maintained over the longest possible time (10, 11, 44). Interval training is performed at various intensities, whereby the "high intensity" interval training used for about 10 years lies at minimum 85 to 90% of the \( \text{VO}_2\text{peak} \) or \( \text{HR}_{\text{max}} \), alternating with recovery phases of the same length, longer, or even shorter, at moderate to low intensity.

High intensity interval training (HIIT) is used for training with rather short (ca 30 sec) intervals, while the current randomized multicenter-studies (RCTs) comprise so-called aerobic interval training (AIT) with longer intervals (4 minutes followed by 3-minute active recovery phases). The latter was designed in Norway and used uniformly in the two current large RCTs in CHD- and CHF-HFrEF patients. (5, 48). Healthy volunteers additionally performed supramaximal exercise (up to 120% \( \text{VO}_2\text{peak} \)) in the sense of "all-out" protocols (5, 43).

Training by the interval method is thus not clearly defined and offers many design possibilities. It can be adapted to individual needs and capacities via duration and intensity of the exercise and recovery intervals as well as via the relationship between exercise and recovery (1:1, 1:2, 2:1) (5).

The most important advantage of high-intensity interval training is the time efficiency of the training form, despite considerable efforts with respect to performance, monitoring and adaptation of this training form. This is important in light of the fact that "lack of time" is the most-often cited barrier to adherence to regular physical exercise (35, 39). According to single studies of athletes and healthy persons, performance of an HIIT is experienced as more pleasant than moderate aerobic endurance training by the continuous exercise method (MCT) (3). Current studies show that, especially in people with a lack of exercise and low cardiorespiratory fitness, the interest and pleasure in physical activity sinks with the degree of intensity, which counters the actual goal of long-term adherence to physical activity (49).

The beginnings of interval training ("repetition training" or "interrupted exercise") arose in the first decade of the 20th century: in Scandinavia at that time, Holmer introduced the so-called "fartlek" (Swedish for "speedplay") to the training design for endurance athletes. High-intensity interval training is thus not a new form of training in sports. As early as 1976, Saltin et al. described two different interval-training protocols, which can be taken as the models for the further development (38).

The effectiveness of high-intensity interval training in improving the \( \text{VO}_2\text{peak} \) in healthy individuals has been confirmed among other things by two current meta-analyses. In comparison, high-intensity interval training was more effective than MCT (1.2±0.9ml/Kg-1min-1). The greatest improvement was observed in untrained persons with a low fitness level. Training interventions which lasted longer had a greater effect (27, 46).

The primary goal of individually-adapted training interventions in CR is a demonstrable favorable influence on the course and prognosis of an existing cardiovascular disease (2). The secondary goals are improvement in physical performance capacity and exercise tolerance by improving cardiorespiratory, muscular and metabolic fitness, reduction of age or disease-related degenerative processes resulting in an improved quality of life and independence for the patient (42).

The highest attainable oxygen uptake (\( \text{VO}_2\text{peak} \)) is taken as an independent inverse risk marker for morbidity and mortality in cardiovascular and/or metabolic diseases, including CHF-HFrEF (15, 16, 18, 30, 41). Long-term observations of CHD patients show that high cardiovascular performance capacity compared to low capacity is associated on average with a decrease in overall mortality by 65% and cardiovascular lethality by 56% (4). A \( \text{VO}_2\text{peak} \) raised by 1 ml/kg/min on average is associated in men with an 8-17% and in women with a 10-14% reduction in overall mortality and in total with a 10-16% reduction in cardiovascular lethality (4, 15, 16, 17).

A 12-week CR brought improvement in the performance capacity of 5641 CHD patients of 1 metabolic equivalent (MET), accompanied on average by a reduction of overall mortality by 13% (in patients with initially low physical performance capacity even by 30%). An increase by 1 MET in the first year after CR was associated on average with a 25% reduction in overall mortality (24).

Studies to date consistently show that high training intensities are well tolerated, even in patients with high cardiovascular risk or manifest, stable and pharmacologically-adequate therapy of cardiovascular diseases including CHD, and are not associated per se with an elevated risk for the individual patient (31, 37, 48).

AIT has especially been in the scientific focus of CR for nearly 15 years, after a Norwegian group demonstrated significant clinical improvement in patients with CHD and CHF-HFrEF (36, 48).

In CHD patients, participation in interval training (including HIIT/AIT) or moderate training by the continuous exercise method (MCT) in the modern CR setting is basically coupled with a very low risk of relevant episodes, which does not differ significantly between the two training forms (37). A study conducted in a small and inhomogeneous patient collective did, however, reveal adverse effects (nausea, vagovasal reactions, cardiac arrhythmias and myocardial ischemias) in up to 8% of the patients up to 24 hours after a single high-intensity interval session (21).

In the 1990s, Meyer et al. performed the first studies in Germany with interval training forms using short exercise intervals (exercise phase 30, recovery phase 40 sec) in CHD and especially CHF-HFrEF patients during CR. The protocol used here had long been introduced to German CR (25, 26).

Results of a first meta-analysis on high-intensity interval training (10 studies, n=273 patients with CHD, CHF-HFrEF or existing cardiovascular risk factors) showed an advantage of interval training over MCT in the overall collective. On average, significantly greater improvement in \( \text{VO}_2\text{peak} \) was attained in 12- to 16-week interval training (+3.03ml/kg/min) (45).

One protocol with long exercise phases, which is often used in current and scientific studies, is the so-called 4×4 minutes AIT protocol mentioned earlier. After a brief warm-up phase at moderate intensity (60% of maximum heart rate, \( \text{HR}_{\text{max}} \)), four 4-minute exercise intervals (85 to 90% \( \text{VO}_2 \) peak or 90-95% \( \text{HR}_{\text{max}} \)) alternate with 2- to 3-minute recovery phases (60-70% \( \text{HR}_{\text{max}} \)) (48). The effectiveness of this protocol has been tested in numerous studies on cardiac patients, especially CHD and CHF-HFrEF patients (6, 14, 28, 29, 40, 42, 43, 45, 48).
Moreover, the effectiveness has been confirmed in metabolic syndrome and other cardiovascular risk factors (7,11,45). High-intensity interval training is an effective training modality to improve the V\textsubscript{O} peak. Moreover, positive effects have been found on anthropometric parameters, arterial blood pressure, LDL and HDL cholesterol and a decreased prevalence of metabolic syndrome (45). Results of current meta-analyses, by contrast, document advantages of MCT in the reduction of resting heart rate and body weight (22, 31). Vascular improvements (endothelial function or “flow-mediated vasodilatation” (FMD) of the arm arteries) by high-intensity interval training were also observed (7, 13, 34).

Table 2 shows a summary of the results of current studies in which the effectiveness of high-intensity interval training was compared to MCT in CHD patients.

Table 3 shows a summary of the results of current meta-analyses, in which the effectiveness of high-intensity interval training versus MCT is compared in healthy individuals and CHD patients.

After performance of many smaller and inhomogeneous studies, the first meta-analysis comprising exclusively training studies on CHD patients with preserved systolic ejection fraction (9 studies, n=206 patients) revealed a significantly greater improvement in V\textsubscript{O} peak (+1.60ml/kg/min) in high-intensity interval training compared to MCT. A significant weight loss (-0.78kg) and a reduction of resting pulse were more likely attained with MCT (31). The results of two Australian meta-analyses (6, resp. 10 studies, n=229, resp. n=472), likewise show a significantly greater improvement in V\textsubscript{O} peak on average by high-intensity interval training (+1.53, resp. +1.78ml/kg/min) compared to MCT (9, 22).

Moholdt et al. were able to confirm in a retrospective univariate “general linear model” that in high-intensity interval training, the actual training intensity (%HR\textsubscript{max}) is decisive for the efficiency of the training. In 112 CHD patients who trained for 12 weeks with the 4x4 min. protocol, significantly greater improvements in V\textsubscript{O} peak were achieved in the group which trained on average at the highest intensity (>92% HR\textsubscript{max}) (29).

A randomized pilot study (n=91) performed in a German rehabilitation clinic examined the effect of the 4x4 min. protocol (AIT) during a 3-week CR compared to MCT (70-75% HR\textsubscript{max}) in the same training scope. In both groups, the physical exercise capacity was significantly improved (Watt\textsubscript{max} in AIT +11.9% vs. MCT +8.15%). No advantage was observed for AIT (14).

In Austria, Tschentscher et al. compared two different forms of high-intensity interval training including AIT with MCT. The study group (n=66) was randomized to three different training forms during a 6-week outpatient CR: 1. MCT at 65-85% HR\textsubscript{max}, 2. “classical” AIT with 4x4 min at 85-95% HR\textsubscript{max} or 3. so-called pyramidal training (PYR) with 3x8 min at 65-95-65% HR\textsubscript{max}. In all groups, a significant improvement in the maximum attained performance in watts was achieved with 18 training sessions. No difference was determined between the groups (40).

The customary duration of CR in the German-speaking region of three to six weeks does not appear to be long enough to demonstrate differences in the effectiveness of the two training methods. In all of the studies integrated in the meta-analyses, training was conducted over at least 12 weeks. A Norwegian study (n=59 CHD patients) confirms this assumption: after 4-week training, (5/week) the results of AIT and MCT were comparable with respect to improvement in V\textsubscript{O} peak (28).

In the first large (n=200) multicenter prospective randomized study on CHD patients (SAINTEX-CAD), contrary to the results of earlier studies and meta-analyses, comparable positive effects of AIT and MCT were determined after 12-week training. This was also the case for improvement in V\textsubscript{O} peak, peripheral endothelial function (FMD of the A. brachialis), for the influence on CV risk factors, quality of life (QoL) and safety aspects (6).

Another meta-analysis with 11 studies and n=594 patients was performed including SAINTEX-CAD, which again found significantly better results for AIT (+1.25ml/min/kg) with respect to improvement in V\textsubscript{O} peak (12).

Of particular interest in this meta-analysis is a subgroup analysis, in which the authors examined the data of studies which initially matched the training with respect to energy expenditure or isocaloricity. It was proven within studies on AIT that the total energy expenditure (EE) and not the training modality resp. intensity apparently determines the improvement in performance capacity (8, 12). Comparable results were found in another meta-analysis in CHD patients. After correlation to the (total) EE, the influence of the three parameters total training time, duration of training sessions and training intensity no longer showed independent effect strengths (8, 19).

In contrast to this, the influence of training intensity and modality in the studies not matched by EE remains speculation with a hypothetical advantage for high-intensity interval training including HIIT and AIT.

The authors of the SAINTEX-CAD study report that the patients in the AIT group had a tendency to train less intensively than predetermined (88% instead of 90-95% HR\textsubscript{max}), while the MCT group tended to perform their training more intensively (80% instead of 70-75% HR\textsubscript{max}) (32). The targeted very high intensity of 90-95% HR\textsubscript{max} could only be achieved by some of the CHD patients. Results of a subsequent analysis of a small study collective (n=18) of the SAINTEX-CAD study showed significantly higher energy expenditures for MCT compared to AIT (352±90.8 kcal vs. 269±70.7kcal pro session), which may explain the neutral results in the SAINTEX-CAD given above. By contrast, in the originally defined 4x4min protocol isocaloricity (as originally intended by Wisloff et al. in the implementation of this protocol) could be demonstrated – even though here with a trend “in favor of” MCT (317±85.2 vs. 273±65.3kcal) (32). In an editorial on the current meta-analysis, the authors of the SAINTEX-CAD study emphasize that further randomized studies which take EE into account are needed to answer the question whether the EE or the training modalities are the more important. The discussion about the advantages of AIT/ HIIT resp. MCT thus remains open and exciting (8).

The maintainability and long-term effects of high-intensity interval training for CHD patients have hardly been studied thus far. A Norwegian study examined the effect of 6-month home-training in 51 patients following an initial 4-week CR (28). The home-training led in the observation period to a significant further increase in V\textsubscript{O} peak only in the interval group. The authors assume that this effect resulted from the higher intensity of home-training in the group. This could indicate that the patients gain greater confidence in their own performance capacity thanks to the high-intensity training and attempt more at home. A comparable effect was observed in the 1-year follow-up of the AIT group in the SAINTEX-CAD study (33).
Conclusions

Conclusions concerning high-intensity interval training including AIT and HIIT in CHD (with preserved left-ventricular ejection fraction):

1. High-intensity interval training can be optionally integrated in addition to MCT in a training program during CR on an individual basis taking into account the preferences and physical exercise capacity of the individual patient with stable and optimally-treated CHD. It has no greater general risk for stable patients than MCT.

2. But within Phase II CR, the target group appears rather small, especially for AIT and HIIT. The studies confirm that many patients cannot follow the predetermined high-intensity training guidelines. This means that considerable effort is needed for individually adapted implementation and supervision of training in the application of interval training. As part of Phase II CR, high-intensity interval training appears to be suitable for more resilient patients who are willing and motivated to exert themselves more.

3. In the clinical setting, the postulated time advantage of about 30 min/week by isocaloric expenditure in AIT/HIIT compared to MCT is not relevant. HIIT appears to be interesting as part of outpatient or home-based CR, or for independent continuation of effective training in Phase III.

4. High-intensity interval training appears to be counterproductive in patients with pre-existing lack of exercise and low fitness level, particularly at the start, considering the long-lasting adherence to physical exercise to be achieved by the CR.

5. One-year data are only available for SAINTEX-CAD (for AIT positive), in general, however long-term observations which confirm the prognostic importance of this form of training are also missing in all meta-analyses.

6. Through high-intensity interval training in CHD patients, especially as part of CR, there has been increased focus in MCT as well on training intensity and EE, whereby the latter currently appears to have the greatest impetus for improvement of the $\dot{V}_{O_2}$ peak.

Conflict of Interest
The authors have no conflict of interest.
References


Summary of the results of current randomized studies (RCTs) comparing the effectiveness of high-intensity interval training versus moderate training by the continuous exercise method (MCT) in CHD patients. (CAD: coronary artery disease; CABG: coronary artery bypass grafting; CEPT: cardiopulmonary exercise test; M/F=male/female; MI=myocardial infarction;

<table>
<thead>
<tr>
<th>STUDY</th>
<th>DISEASE</th>
<th>SAMPLE SIZE</th>
<th>GENDER</th>
<th>AGE (YRS)</th>
<th>OUTCOME PARAMETER</th>
<th>MAJOR FINDINGS</th>
<th>DROPOUT RATES</th>
<th>VO2 MEASUREMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rognmo et al., 2004; Amundsen et al., 2008 (36, 50)</td>
<td>CAD</td>
<td>17 (INT 8)</td>
<td>M/F</td>
<td>62</td>
<td>Peak VO2 (exercise capacity)</td>
<td>peak VO2, greater in HIIT versus MCT (p&lt;0.011)</td>
<td>7 (29.2%)</td>
<td>CPET</td>
</tr>
<tr>
<td>Warburton et al., 2005 (51)</td>
<td>CAD (post CABG or MI)</td>
<td>14 (INT 7)</td>
<td>M/F</td>
<td>56</td>
<td>Exercise capacity</td>
<td>Anaerobic capacity</td>
<td>No difference between groups</td>
<td>NR</td>
</tr>
<tr>
<td>Moholdt et al., 2009 (28)</td>
<td>Post CABG</td>
<td>59 (INT 28)</td>
<td>M/F</td>
<td>61.1</td>
<td>Peak oxygen uptake</td>
<td>Left ventricular function</td>
<td>Quality of life Blood markers</td>
<td>HIIT showed further increase in peak VO2 compared to MCT (p&lt;0.05)</td>
</tr>
<tr>
<td>Moholdt et al., 2011 Moholdt et al., 2012 (52, 53)</td>
<td>Post MI</td>
<td>89 (INT 30)</td>
<td>M/F</td>
<td>57</td>
<td>Aerobic capacity</td>
<td>peak VO2, greater in HIIT versus usual care exercise (p&lt;0.005)</td>
<td>38 (35.5%)</td>
<td>CPET</td>
</tr>
<tr>
<td>Rocco et al., 2012 (54)</td>
<td>CAD</td>
<td>37 (INT 17)</td>
<td>M</td>
<td>59.7</td>
<td>Peak oxygen uptake</td>
<td>PETCO2 Ventilatory anaerobic limiar</td>
<td>No difference between groups</td>
<td>NR</td>
</tr>
<tr>
<td>Currie et al., 2013 (55)</td>
<td>recent CAD event</td>
<td>22 (INT 11)</td>
<td>M/F</td>
<td>65</td>
<td>Brachial artery flowmediated dilation</td>
<td>Cardiorespiratory fitness</td>
<td>No difference between groups</td>
<td>8 (26.7%)</td>
</tr>
<tr>
<td>Keteyian et al., 2014 (56)</td>
<td>MI, CABG, CAD</td>
<td>28 (INT 11)</td>
<td>M/F</td>
<td>59</td>
<td>Peak VO2 (cardiorespiratory fitness)</td>
<td>peak VO2, greater in HIIT versus MCT (p&lt;0.043)</td>
<td>39 (28.2%)</td>
<td>CPET</td>
</tr>
<tr>
<td>Conraads et al., 2015 (6)</td>
<td>CAD (post CABG or MI and/or PCI)</td>
<td>174 (INT 85)</td>
<td>M/F</td>
<td>58.4</td>
<td>Peak VO2 Peripheral endothelial function</td>
<td>Cardiovascular risk factors</td>
<td>Quality of life</td>
<td>No difference between the groups (p&gt;0.05)</td>
</tr>
<tr>
<td>Cardozo et al., 2015 (57)</td>
<td>CAD</td>
<td>71 (INT 23)</td>
<td>M/F</td>
<td>64</td>
<td>Peak VO2 (exercise capacity)</td>
<td>VE/VCO slope O2 pulse</td>
<td>peak VO2, increasing in HIIT and remaining stable in MCT (p&lt;0.04)</td>
<td>none (0%)</td>
</tr>
<tr>
<td>Jaureguizar et al., 2016 (58)</td>
<td>CAD</td>
<td>72 (INT 36)</td>
<td>M</td>
<td>58</td>
<td>Functional capacity</td>
<td>Quality of life Safety</td>
<td>HIIT significantly greater increase in peak VO2 and 6-minute walk distance compared to MCT (p&lt;0.05)</td>
<td>NR</td>
</tr>
<tr>
<td>Prado et al., 2016 (59)</td>
<td>CAD</td>
<td>35 (INT 17)</td>
<td>M/F</td>
<td>59</td>
<td>Cardiorespiratory fitness</td>
<td>No difference between groups (p&gt;0.05)</td>
<td>NR</td>
<td>CPET</td>
</tr>
<tr>
<td>Tschentscher et al., 2016 (40)</td>
<td>CAD</td>
<td>60 (INT 20 AIT and 20 PYR)</td>
<td>M/F</td>
<td>62</td>
<td>Peak work capacity</td>
<td>No difference between all 3 groups (p n.s.) with isocaloric exercise training protocols</td>
<td>6 (9.1%)</td>
<td>no CPET</td>
</tr>
</tbody>
</table>
### Table 2 – 2nd part

<table>
<thead>
<tr>
<th>VO$_2$ MEASUREMENT</th>
<th>HIIT INTENSITY PRESCRIBED</th>
<th>HIIT INTENSITY TRAINED</th>
<th>MCT INTENSITY PRESCRIBED</th>
<th>MCT INTENSITY TRAINED</th>
<th>HIIT TIME TRAINED (MIN)</th>
<th>MCT TIME TRAINED (MIN)</th>
<th>FREQUENCY PER WEEK</th>
<th>DURATION (WEEKS)</th>
<th>SUPERVISION</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPET</td>
<td>80–90% VO$_2$peak (85–95% HRpeak)</td>
<td>NR</td>
<td>50–60% of VO$_2$peak</td>
<td>NR</td>
<td>33</td>
<td>41</td>
<td>2</td>
<td>10</td>
<td>Yes</td>
</tr>
<tr>
<td>CPET</td>
<td>85–95% HR/VO$_2$ reserve</td>
<td>NR</td>
<td>65% HR/VO$_2$ reserve</td>
<td>NR</td>
<td>30</td>
<td>30</td>
<td>2</td>
<td>16</td>
<td>NR</td>
</tr>
<tr>
<td>CPET</td>
<td>90% HR$_{max}$</td>
<td>92% HR$_{max}$</td>
<td>70% HR$_{max}$</td>
<td>74% HR$_{max}$</td>
<td>46</td>
<td>5</td>
<td>4</td>
<td></td>
<td>NR</td>
</tr>
<tr>
<td>CPET</td>
<td>90% HR$_{max}$</td>
<td>79% HR$_{max}$</td>
<td>Moderate-to-high</td>
<td>73% ± 10% HR$_{max}$</td>
<td>NR</td>
<td>NR</td>
<td>2</td>
<td>12</td>
<td>NR</td>
</tr>
<tr>
<td>CPET</td>
<td>HR at RCP</td>
<td>80–90% VO$_2$peak</td>
<td>HR at VAT</td>
<td>NR</td>
<td>42</td>
<td>60</td>
<td>3</td>
<td>12</td>
<td>Yes</td>
</tr>
<tr>
<td>CPET</td>
<td>80–104% at PPO</td>
<td>73% ± 10% HR$_{max}$</td>
<td>51–56% at PPO</td>
<td>65% ± 4% HR$_{max}$</td>
<td>NR</td>
<td>NR</td>
<td>2</td>
<td>12</td>
<td>Yes</td>
</tr>
<tr>
<td>CPET</td>
<td>80–90% HR reserve</td>
<td>NR</td>
<td>60–80% HR reserve</td>
<td>NR</td>
<td>40</td>
<td>40</td>
<td>3</td>
<td>10</td>
<td>Yes</td>
</tr>
<tr>
<td>CPET</td>
<td>90–95% HR$_{peak}$</td>
<td>88% HR$_{peak}$ or 85% Peak workload</td>
<td>70–75% HR$_{peak}$</td>
<td>80% HR$_{peak}$ or 63% Peak workload</td>
<td>38</td>
<td>47</td>
<td>3</td>
<td>12</td>
<td>Yes</td>
</tr>
<tr>
<td>CPET</td>
<td>90% HR$_{peak}$</td>
<td>NR</td>
<td>70–75% HR$_{peak}$</td>
<td>NR</td>
<td>40</td>
<td>40</td>
<td>3</td>
<td>16</td>
<td>Yes</td>
</tr>
<tr>
<td>CPET</td>
<td>SRT$_{max}$</td>
<td>Second month: HR at VT1 (2nd month: +10% HR at VT1)</td>
<td>First month: 64.2%±8.5% of VO$_2$peak</td>
<td>Second month: 69.5%±7.7% of VO$_2$peak</td>
<td>40</td>
<td>40</td>
<td>3</td>
<td>8</td>
<td>NR</td>
</tr>
<tr>
<td>CPET</td>
<td>HR at RCP</td>
<td>NR</td>
<td>At VAT</td>
<td>NR</td>
<td>52</td>
<td>60</td>
<td>3</td>
<td>12</td>
<td>Yes</td>
</tr>
<tr>
<td>no CPET</td>
<td>85–95% HR$_{peak}$</td>
<td>Start: 77.4±4.5% HR$_{peak}$</td>
<td>End: 75.8±57% HR$_{peak}$</td>
<td>Start: 80.5±6.1% HR$_{peak}$</td>
<td>End: 73.6±7.3% HR$_{peak}$</td>
<td>25</td>
<td>33</td>
<td>3</td>
<td>6</td>
</tr>
</tbody>
</table>

INT=interval training; HIIT=high-intensity interval training; MCT=moderate continuous training; PETCO$_2$=Partial pressure of exhaled carbon dioxide; NR=not reported. PPO=peak power output; PYR=Pyramid training; RCP=respiratory compensation point; SRT=steep ramp test; VAT=ventilatory anaerobic threshold; VO$_2$=carbon dioxide production; VE=minute ventilation; VO$_2$=oxygen uptake.) (modified from 9, 12, 22).
### Review

Interval training in patients with CHD and preserved ventricular function

**Table 3**

Summary of the results of current meta-analyses, in which the effectiveness of high-intensity interval training (HIIT) is compared to moderate continuous training (MCT) in healthy individuals and in CHD patients. (CAD = coronary artery disease; CHF = chronic heart failure; AHT = arterial hypertension; INT = interval training; HIIT = high-intensity interval training; MCT = moderate continuous training; NR = not reported; QoL = quality of life.

<table>
<thead>
<tr>
<th>METALYSIS</th>
<th>DISEASE</th>
<th>STUDIES INCLUDED</th>
<th>SUBJECTS</th>
<th>AGE (YRS)</th>
<th>STUDY SELECTION</th>
<th>OBJECTIVES</th>
<th>TRAINING SESSIONS</th>
<th>RESULTS</th>
<th>CONCLUSION (ABSTRACT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weston et al. 2014 (46)</td>
<td>healthy subjects</td>
<td>38</td>
<td>567</td>
<td>19-34</td>
<td>fitness assessed pre- and post-training period ≥2 weeks repetition duration 30-60s work/rest ratio &lt;1.0 exercise intensity max. or near max.</td>
<td>VO&lt;sub&gt;2&lt;/sub&gt;&lt;sup&gt;max&lt;/sup&gt; (%)</td>
<td>Peak sprint power – in 30-s Wingate test (%)</td>
<td>Mean sprint power – in 30-s Wingate test (%)</td>
<td>13 training sessions</td>
</tr>
<tr>
<td>Milanovic et al. 2015 (27)</td>
<td>healthy subjects</td>
<td>28</td>
<td>732</td>
<td>18-45</td>
<td>VO&lt;sub&gt;2&lt;/sub&gt;&lt;sup&gt;max&lt;/sup&gt; assessed pre- and post-training period ≥2 weeks</td>
<td>VO&lt;sub&gt;2&lt;/sub&gt;&lt;sup&gt;max&lt;/sup&gt; (mL/kg/min)</td>
<td>NR</td>
<td>ET +4.9mL/kg/min</td>
<td>HIIT +5.5mL/kg/min</td>
</tr>
<tr>
<td>Weston et al. 2014 (45)</td>
<td>CAD, CHF, AHT, MBS, Obesity</td>
<td>10</td>
<td>273 (HIIT NR)</td>
<td>25.1±5</td>
<td>randomized trials comparing HIIT and MCT in cardiac, hypertensive or metabolic patients ≥4 weeks</td>
<td>VO&lt;sub&gt;2&lt;/sub&gt;&lt;sup&gt;peak&lt;/sup&gt; (mL/kg/min) and (%)</td>
<td>4-16 weeks with 3-6 training sessions/week</td>
<td>MCT +5.4mL/kg/min (19.4%)</td>
<td>HIIT +2.6mL/kg/min (10.3%)</td>
</tr>
<tr>
<td>Pattyn et al. 2014 (31)</td>
<td>CAD</td>
<td>9</td>
<td>206 (HIIT 100)</td>
<td>NR</td>
<td>randomized trials comparing HIIT and MCT in CAD patients ≥4 weeks</td>
<td>VO&lt;sub&gt;2&lt;/sub&gt;&lt;sup&gt;peak&lt;/sup&gt; (mL/kg/min) and (%) Body weight (kg)</td>
<td>4-16 weeks with 2-6 training sessions/week</td>
<td>HIIT vs MCT +1.60 mL/kg/min (p=0.03)</td>
<td>MCT vs. HIIT -0.78kg (p=0.05)</td>
</tr>
<tr>
<td>Elliott et al. 2015 (9)</td>
<td>CAD</td>
<td>6</td>
<td>229 (HIIT 99)</td>
<td>65</td>
<td>randomized trials comparing HIIT and MCT in CAD patients ≥4 weeks</td>
<td>VO&lt;sub&gt;2&lt;/sub&gt;&lt;sup&gt;peak&lt;/sup&gt; (mL/kg/min) at AT Systolic blood pressure (mmHg)</td>
<td>4-16 weeks with 2-6 training sessions/week</td>
<td>VO&lt;sub&gt;2&lt;/sub&gt;&lt;sup&gt;peak&lt;/sup&gt;: HIIT vs MCT +1.60 mL/kg/min (p=0.0001) VO&lt;sub&gt;2&lt;/sub&gt;&lt;sup&gt;peak&lt;/sup&gt;: HIIT vs. Traditional ET +1.23 mL/kg/min (p=0.0001) RR systol: MCT vs HIIT -3.44mmHg (p=0.077)</td>
<td>In CAD patients HIIT appears more effective than MCT in improvement of aerobic capacity but not for systolic blood pressure</td>
</tr>
<tr>
<td>Liou et al. 2016 (22)</td>
<td>CAD</td>
<td>10</td>
<td>472 (HIIT 218)</td>
<td>59</td>
<td>randomized trials comparing HIIT and MCT in CAD patients ≥4 weeks</td>
<td>VO&lt;sub&gt;2&lt;/sub&gt;&lt;sup&gt;peak&lt;/sup&gt; (mL/kg/min) Body weight (kg) Resting heart rate (min-1)</td>
<td>4-16 weeks with 2-6 training sessions/week</td>
<td>VO&lt;sub&gt;2&lt;/sub&gt;&lt;sup&gt;peak&lt;/sup&gt;: HIIT vs MCT +1.78mL/kg/min (p=0.009) Body weight: MCT vs HIIT -0.48 kg (p=0.004) HRrest: MCT vs HIIT -1.80 min-1 (p=0.001)</td>
<td>HIIT improves the mean VO&lt;sub&gt;2&lt;/sub&gt;&lt;sup&gt;peak&lt;/sup&gt; in CAD patients more than MCT. MCT shows a more pronounced numerical decline in patients’ resting heart rate and body weight</td>
</tr>
<tr>
<td>Gomes-Nato et al. 2017 (12)</td>
<td>CAD</td>
<td>12</td>
<td>609 (HIIT 218)</td>
<td>58.4</td>
<td>randomized trials comparing HIIT and MCT in CAD patients ≥4 weeks</td>
<td>VO&lt;sub&gt;2&lt;/sub&gt;&lt;sup&gt;peak&lt;/sup&gt; (mL/kg/min) VO&lt;sub&gt;2&lt;/sub&gt;&lt;sup&gt;peak&lt;/sup&gt; (mL/kg/min) non-isocaloric VO&lt;sub&gt;2&lt;/sub&gt;&lt;sup&gt;peak&lt;/sup&gt; (mL/kg/min) isocaloric Change in quality of life (QoL)</td>
<td>4-16 weeks with 2-6 training sessions/week</td>
<td>VO&lt;sub&gt;2&lt;/sub&gt;&lt;sup&gt;peak&lt;/sup&gt;: HIIT vs MCT +1.25mL/kg/min (p=0.003) VO&lt;sub&gt;2&lt;/sub&gt;&lt;sup&gt;peak&lt;/sup&gt; non-isocaloric: HIIT vs MCT +1.87mL/kg/min (p=0.0001) VO&lt;sub&gt;2&lt;/sub&gt;&lt;sup&gt;peak&lt;/sup&gt; isocaloric HIIT vs MCT +0.36 mL/kg/min (p=0.16) QoL: HIIT vs MCT -0.02 (p=0.90)</td>
<td>HIIT may improve VO&lt;sub&gt;2&lt;/sub&gt;&lt;sup&gt;peak&lt;/sup&gt; and should be considered in CAD patients. This superiority disappeared when isocaloric protocol is compared.</td>
</tr>
</tbody>
</table>