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FULL RESEARCH PAPER
*Physical activity*

# The effect of high-intensity interval training on exercise capacity in post-myocardial infarction patients: a systematic review and meta-analysis

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**Aims** Exercise-based cardiac rehabilitation has been recommended a treatment for patients with cardiovascular disease. Nevertheless, it remains controversial which exercise characteristics are most beneficial for post-myocardial infarction (MI) patients. We performed a systematic review and meta-analysis to investigate the effects of high-intensity interval training (HIIT) in these patients.

**Methods and results** We searched PubMed, Embase, the Cochrane Library, China National Knowledge Infrastructure (CNKI), Chinese Science and Technology Periodical Database (VIP), and Wanfang Dataset (from the earliest date available to February 2021) for randomized controlled trials and cohort studies that evaluated the effects of HIIT on post-MI patients. Studies were selected according to inclusion and exclusion criteria. Data synthesis was performed with R software version 4.0.1. Eight studies met the study criteria, including 387 patients. Compared to the control group [moderate-intensity continuous training (MICT) and/or routine physical activity], HIIT significantly improved peak oxygen uptake (peak $VO_2$) [mean difference = 3.83 mL/kg/min, 95% confidence interval (CI) (3.25, 4.41), $P < 0.01$]. No significant difference in systolic and diastolic blood pressures, peak and resting heart rate, left ventricular ejection fraction, left ventricular end-diastolic volume, and the quality of life was found between HIIT group and control group. The duration of follow-up ranged from 6 to 12 weeks. The incidence of adverse events was similar between groups [risk difference = 0.01, 95% CI (-0.02, 0.04), $P = 0.53$].

**Conclusion** Compared with MICT and routine physical activity, HIIT could significantly improve exercise capacity in post-MI patients, and appears to be safe.

**Keywords** Myocardial infarction • Exercise training • Cardiac rehabilitation

## Introduction

The incidence and mortality of cardiovascular disease (CVD) are on the rise year by year, while coronary artery disease (CAD) has become the major cause of death worldwide.[1] As one of critical CAD, myocardial infarction (MI) is characterized by high lethality and disability, despite the advance of percutaneous coronary intervention technique.[2] As an important intervention for CAD, exercise-based cardiac rehabilitation (CR) was proved to be safe and effective in decreasing CAD mortality and morbidity, as well as improving exercise capacity and quality of life of patients.[3,4] Despite the severity of MI, CR were recommended for patients with MI. Some evidence suggested that CR contributed to decreasing total mortality in patients after acute coronary syndrome, including MI.[5,6]

In the decades, low- to moderate-intensity continuous training (MICT) has shown its benefits in CR and was recommended as an acknowledged safe and efficient intervention in improving exercise capacity, and reducing adverse cardiac events.[7,8] However, it is still under debate whether high-intensity training, as a potential exercise modality in CR, could replace moderate-intensity training.

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High-intensity interval training (HIIT) is characterized by repeated bouts of short to moderate-duration exercise completed at high intensity, interspersed with periods of low-intensity exercise. Derived from competitive sports, HIIT is an emerging modality that requires repeating full-force, fast and explosive exercises.[9] The target intensity of HIIT reaches more than 85% peak heart rate (HR) or 80% peak oxygen uptake (peak $VO_2$), which exceeds the anaerobic threshold. In recent years, growing evidences supported a beneficial effect of HIIT on exercise capacity, cardiovascular function.[10,11] A systematic review and meta-analysis conducted by Gomes-Neto *et al.*[11] compared HIIT with MICT for the effect of exercise capacity in patients with CAD. The overall result of the study showed superior improvement in peak $VO_2$ resulting from HIIT, compared to MICT, in CAD patients. However, there is currently no strong clinical evidence to prove the efficiency of HIIT in post-MI patients.

Thus, we performed a systematic review with meta-analysis to investigate the effect of HIIT on exercise capacity in post-MI patients. In addition, the evaluation for the effects of HIIT on blood pressure, HR, left ventricular function and remodelling, quality of life, and the risk of adverse events (AEs) was also performed.

# Methods

## Study design

The systematic review and meta-analysis were conducted and reported in accordance with Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines.

## Search strategy

We searched references on PubMed, Embase, the Cochrane Library, China National Knowledge Infrastructure (CNKI), Chinese Science and Technology Periodical Database (VIP), and Wanfang Dataset (from the earliest date available to February 2021), with language restrictions to English and Chinese. The search strategy included two categories: 'high-intensity interval training' and 'myocardial infarction'. Keywords and medical subject headings (MeSH) terms relating to these categories were used to optimize the output from the database search, including: 'high-intensity interval training/exercise', 'aerobic interval training/exercise', 'HIIT/HIIE', 'AIT/AIE', 'myocardial infarction', 'acute coronary syndrome', 'MI', and 'ACS'. All included articles had their full-text reviewed. For the articles included in this systematic review, we checked the reference to identify other potentially eligible articles.

## Criteria for study inclusion

The systematic review included randomized controlled trials (RCTs) and cohort studies that evaluated the effects of HIIT in post-MI patients compared with the control group. HIIT was defined as repeated bouts of high-intensity exercise, interspersed with periods of low-intensity recovery, which of the protocol was described in detail. The control groups include those patients with MICT and/or routine physical activity prescription. Exercise prescription described as regular, recommended or usual physical activity/exercise was considered as routine physical activity. The diagnosis of MI was based on the American Heart Association standard criteria, coronary angiography records, other reliable medical records, and/or percutaneous coronary intervention.[12]

The primary outcome measure was peak $VO_2$, while other outcome measures included systolic blood pressure (SBP) and diastolic blood pressure (DBP), peak and resting HR, left ventricular ejection fraction (LVEF), left ventricular end-diastolic volume (LVEDV), quality of life, and the risk of AEs. AEs were collected from the point of participate enrolment until end of study.

AEs were defined as all-cause mortality, target vessel revascularization, myocardial ischaemic events, and any potential training-related sports injuries.

Single-arm research, animal experiment research, letter, review, or literature with incomplete data were excluded.

## Selection and data collection

Preliminary screening on title and abstracts was independently conducted by two reviewers. Then, the full text was obtained for further consideration. Two reviewers independently performed a detailed assessment on full text based on inclusion or exclusion criteria. The extracted data includes population, training performed, outcomes, intervention period, and the incidence of AEs. When insufficient data were available in the full text or access to full-text articles were not available, the corresponding authors of these literatures were contacted by email once. Any disagreements in the above progression were judged by a third reviewer.

## Quality assessment

Physiotherapy Evidence Database (PEDro) Scale was applied to assess the quality of included literatures, which was scored according to criteria items including random allocation, concealed allocation, similarity baseline between groups, blinding method, adequacy of follow-up, intention-to-treat analysis, and point estimates and variability. This was converted into a score of 0–10 (higher scores indicated greater methodological quality). Two reviewers were responsible for the assessment of study quality independently, and a third reviewer conducted the accuracy.

## Statistical analysis

Statistical analysis was performed with R software version 4.0.1 (R Foundation). Estimates of combined effects were obtained by comparing the least square mean change from baseline to end of the study and were expressed as the mean difference (MD) between groups and 95% confidence interval (CI). Risk differences and its 95% CI were applied for pooled-analysis of the incidence of AEs. If the study was a multiple-arms trial, all relevant groups had data extracted. Subgroup analysis was performed when there were at least three studies in each subgroup.

Pooled-analyses were conducted using a fixed-effects and random-effects model. Heterogeneity among studies was examined with Cochran's $Q$ and $I^2$ statistic. When $I^2$ is greater than 50%, it indicated low heterogeneity, and a fixed-effects model would be chosen; otherwise, a random-effects model was adopted.[13] A $P$-value of <0.05 was regarded as statistically significant.

# Result

## Selection process and study characteristics

The initial search identified 607 articles, of which 265 were eligible for title and abstracts scanning following the exclusion of duplicates. Based on the inclusion and exclusion criteria, 243 literatures were excluded with 22 left. After complete reading full-texts of 22 articles, eight[14–21] articles met the eligibility criteria and were included in the meta-analysis. The process of literature search and study selection was presented in *Figure 1*.

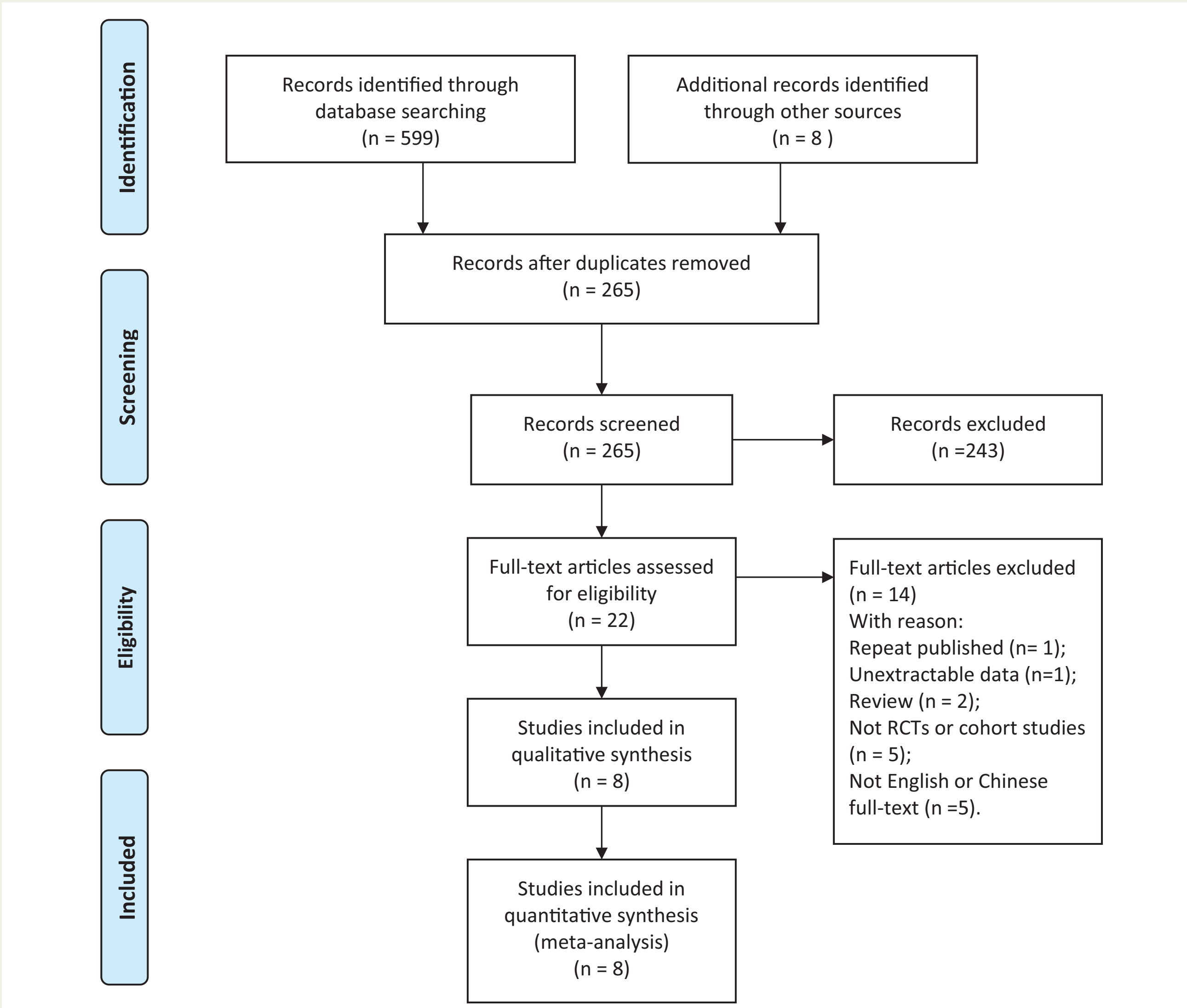


**Figure 1** The literature search and selection process.

*Table 1* lists the general characteristics of the included studies, which consisted of seven RCTs and one retrospective cohort study. A total of eight studies comprising 387 patients were included for analysis, and 205 patients underwent HIIT. The number of included participants in each study in our meta-analysis ranged from 27 to 89, and the mean age of included participants ranged from 55.1 to 75.5 years. In six[14,15,17–19,21] of included study, MICT was applied for the intervention of control group, while participates in control group of three[16,20,21] studies were given routine physical activities. Two[16,20] studies had a three-arm parallel group design. The duration of the interventions ranged between 6 and 12 weeks. The quality assessment for these studies showed a mean PEDro score of 5.5 (range from 4 to 7). Other characteristics like training protocol and outcome measures were summarized in *Table 1*.

## Peak oxygen uptake

Eight studies reported peak $VO_2$ measured by cardiopulmonary exercise test. We did not include the Eser *et al.*[14] study in the pooled-analysis of change of peak $VO_2$, as only percentages were provided. Thus, seven studies that included 340 patients were available for the meta-analysis. Test among studies indicated low heterogeneity ($I^2$ = 0%, $P$ = 0.25). The meta-analysis showed a significant improvement in peak $VO_2$ [MD = 3.83 mL/kg/min, 95% CI (3.25, 4.41), $P < 0.01$] for patients in the HIIT group compared with the control group (*Figure 2A*).

Subgroup analyses of HIIT vs. MICT and HIIT vs. routine physical activities were performed base on exercise prescription of the control group. The subgroup analyses showed a significant improvement in peak $VO_2$ [MD = 3.73 mL/kg/min, 95% CI (3.06, 4.40), $P < 0.01$] for patients in the HIIT group compared with the MICT group. The

**Table 1 Characteristics of included studies**

| Study | Design | Sample size (HIIT/control) | Gender | Mean age (years) | Training characteristics: HIIT | Training characteristics: Control | Training duration | Outcomes | PEDro score |
|---|---|---|---|---|---|---|---|---|---|
| Eser *et al.* (2020)[14] | RCTs | 34/35 | M/F | 56.0 | HIT: 4 bouts × 4 min (VT2).<br>Each interval: 3 min (0-VT1). | MICT: 30 min of continuous training (VT1) | 9 weeks | Peak $VO_2$<br>Blood pressure<br>Heart rate | 7 |
| Choi *et al.* (2018)[15] | RCTs | 23/21 | M/F | 55.1 | HIT: 4 bouts × 4 min (85–100% max HR).<br>Each interval: 3 min (50–60% max HR). | MICT: 28 min of continuous training (60–70% max HR) | 9–10 weeks | Exercise tolerance test<br>6MWT<br>METs<br>Quality of life | 5 |
| Jayo-Montoya *et al.* (2019)[16] | RCTs | 44/11 | M/F | | HIT: 4 bouts × 2∼4 min (90% Peak $VO_2$).<br>Intervals: a total of 12∼24 min (70% peak $VO_2$). | Regular physical activity: NA | 12 weeks | Cardiopulmonary exercise test<br>Body composition<br>METs | 6 |
| Kim *et al.* (2015)[17] | RCTs | 14/14 | M/F | 58.6 | HIT: 4 bouts × 4 min (85–95% max HR).<br>Each interval: 3 min (50–70% max HR). | MICT: 25 min of continuous training (70–85% max HR) | 6 weeks | Peak $VO_2$<br>Heart rate<br>Blood biomarkers | 5 |
| Dun *et al.* (2019)[18] | Retrospective cohort study | 42/14 | M/F | 68.3 | First part:<br>HIT: 4 bouts × 30∼60 s (RPE: 15–17).<br>Each interval: 1∼5 min (RPE: 14).<br>Second part:<br>HIT: 5∼8 bouts × 30∼60 s (RPE: 15–17).<br>Each interval: 2∼4 min (RPE: 14). | MICT: 20∼45 min of continuous training (RPE: 12–14) | 12 weeks | Peak $VO_2$<br>Blood pressure<br>Body composition<br>Quality of life | 4 |
| Trachsel *et al.* (2019)[19] | RCTs | 9/10 | M/F | 58.4 | HIT: 2∼3 bouts × 6∼8 min (RPE: 15).<br>Each interval: 5 min (RPE: 5). | MICT: encouraged for 30∼60 min of continuous training (RPE of 12–14) | 12 weeks | Cardiopulmonary exercise test<br>Blood pressure<br>Heart rate<br>Echocardiography | 5 |

*Continued*

**Table 1** *Continued*

| Study | Design | Sample size (HIIT/control) | Gender | Mean age (years) | Training characteristics: HIIT | Training characteristics: Control | Training duration | Outcomes | PEDro score |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Blood biomarkers | |
| Wisløff et al. (2007)[20] | RCTs | 9/18 | M/F | 75.5 | HIT: 4 bouts × 4min (90–95% max HR). Each interval: 3 min (50–70% max HR). | MICT: 47 min of continuous training (70–75% max HR) Recommended physical activity group: NA | 12 weeks | Exercise testing<br>Heart rate<br>Endothelial function<br>Echocardiography<br>Muscle biopsy<br>Blood biomarkers<br>Quality of life | 6 |
| Moholdt et al. (2012)[21] | RCTs | 30/59 | M/F | 57.4 | HIT: 4 bouts × 4min (85–95% max HR). Each interval: 1 min (70% max HR). | Usual care exercise: 60 min of aerobic exercises | 12 weeks | Exercise testing<br>Heart rate<br>Endothelial function<br>Blood biomarkers<br>Quality of Life | 6 |

200-mFWT, 200-m fast walk test; 6MWT, 6-min walk test; HIIT, high-intensity interval training; HIT, high-intensity training; M/F, male/female; max HR, maximum heart rate; METs, metabolic equivalents; MICT, moderate-intensity continuous training; min, minute(s); NA, not available; peak $VO_2$, peak oxygen uptake; RCTs, randomized controlled trials; RPE, rating of perceived exertion; s, second(s); VT, ventilatory threshold.

subgroup analyses of HIIT versus routine physical activities showed that HIIT had a significantly greater effect on peak $VO_2$ [MD = 4.13 mL/kg/min, 95% CI (2.99, 5.26), $P < 0.01$] than usual physical activities. Results of subgroup analyses were presented in Figure 2B.

## Blood pressure

Blood pressure, including SBP and DBP, was measured for three[14,18,19] studies with a total of 144 patients. MICT was applied for exercise training of the control group in these three studies. Results of our meta-analysis indicated no significantly greater effect on SBP [MD = 3.45 mmHg, 95% CI (-1.66, 8.57), $P = 0.19$] (Figure 3A) and DBP [MD = -0.21 mmHg, 95% CI (-7.74, 7.31), $P = 0.96$] (Figure 3B) for HIIT, compared with MICT.

## Heart rate

Heart rates, including peak and resting HR, were available for five studies[14,17,19–21] with a total of 232 patients. Results of meta-analysis indicated no significantly greater effect on peak HR [MD = 0.74 $min^{-1}$, 95% CI (-2.82, 4.30), $P = 0.68$] (Figure 3C) and resting HR [MD = 1.60 $min^{-1}$, 95% CI (-0.27, 3.47), $P = 0.09$] (Figure 3D) for HIIT, compared with MICT and usual physical activities.

## Left ventricular function and remodelling

Left ventricular function and remodelling data measured as LVEF and LVEDV were available for two[19,20] studies (a total of 54 patients). Results of meta-analysis indicated no significantly greater effect on LVEF [MD = 4.46%, 95% CI (-5.75, 14.68), $P = 0.39$] (Figure 3E) and LVEDV [MD = -8.89 mL, 95% CI (-21.93, 4.16), $P = 0.18$] (Figure 3F) for HIIT, compared with MICT and routine physical activities.

## Quality of life

Quality of life data was available for four[15,18,20,21] studies (a total of 261 patients). In the study by Choi *et al.*,[15] the quality of life was assessed by PHQ-9, HADS-A, HADS-A, ISI, FSS questionnaire and showed significant improvements in PHQ-9, HADS-D, FSS for the patients in the HIIT group compared with the MICT group. In the study by Dun *et al.*,[18] the quality of life was assessed by the PHQ-9 questionnaire, and the result showed no significantly greater improvement for HIIT compared with MICT. In studies of Wisløff *et al.*[20] and Moholdt *et al.*,[21] the quality of life was assessed by the MacNew questionnaire. The meta-analysis of the quality of life assessed by the MacNew questionnaire did not show a significantly greater improvement [MD = 0.62, 95% CI (-0.14, 1.37), $P = 0.11$] for the HIIT group compared with the control group (Figure 3G).

## Safety of high-intensity interval training

The safety of HIIT measured as the incidence of AEs was reported in six[15,17–21] studies. In studies of Dun *et al.*[18] and Trachsel *et al.*,[19] no AEs occurred during the trials. The meta-analysis showed no significant difference [risk difference = 0.01, 95% CI (-0.02, 0.04), $P = 0.53$] in the incidence of AEs between the HIIT group and the control group (Figure 4).

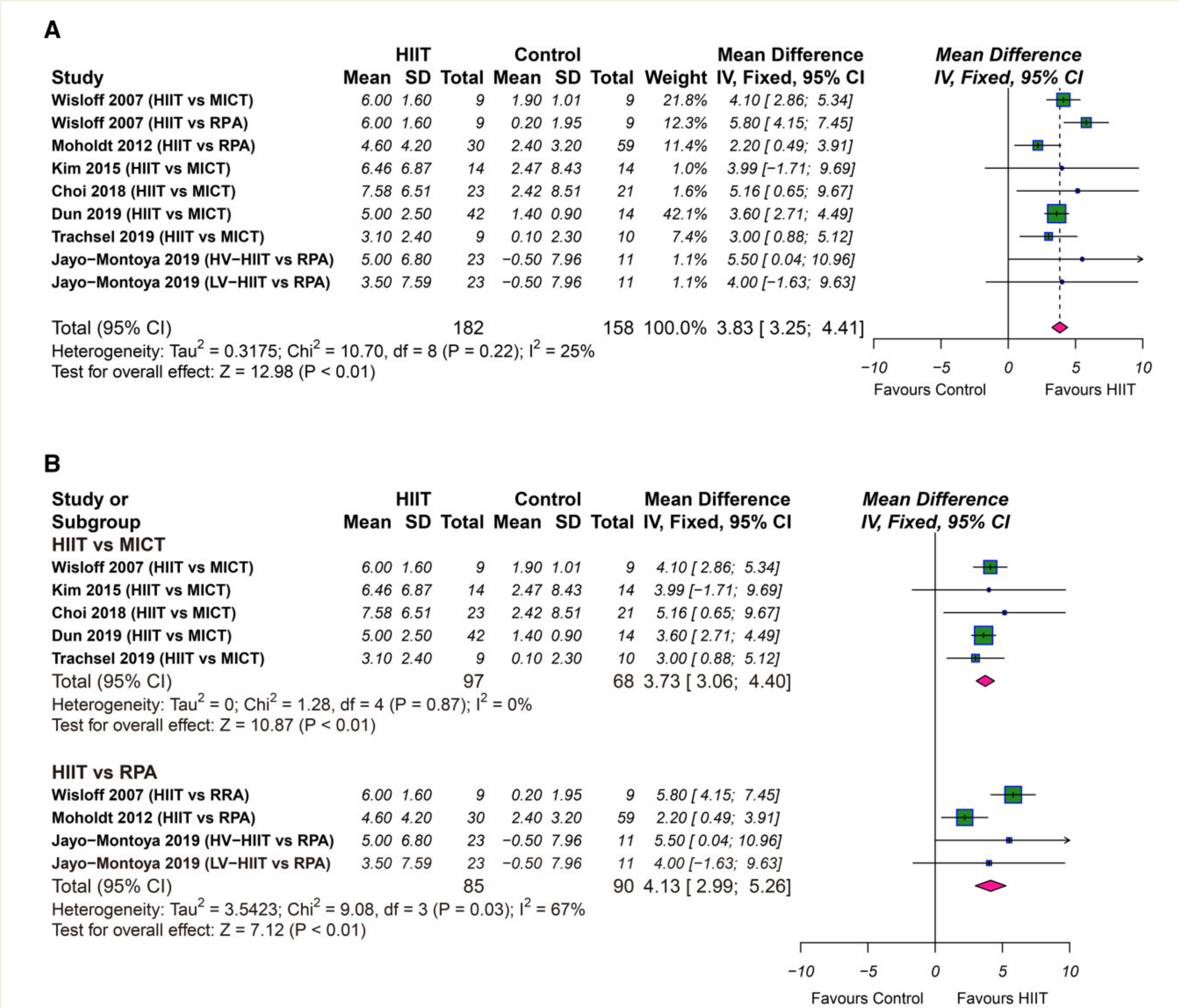


**Figure 2** Forest plot comparing the change in peak oxygen uptake (peak $VO_2$) between high-intensity interval training and control group (moderate-intensity continuous training and/or routine physical activity). (*A*) High-intensity interval training vs. moderate-intensity continuous training and routine physical activity. (*B*) Subgroup analysis of high-intensity interval training vs. moderate-intensity continuous training and high-intensity interval training vs. routine physical activity. CI, confidence interval; HV, high volume; LV, low volume; SD, standard deviation.

# Discussion

For the past years, CR programmes of post-MI were mostly based on MICT protocol.[22] With the advance of CVD prevention and treatment concepts, whether MICT is still the most recommended CR programmes for post-MI patients is worth discussing. Previous studies showed the superiority of HIIT in clinical efficacy compared with MICT in cardiac patients.[23,24] Moreover, results of long-term follow-up of several studies suggested no significant difference in the risk of AEs between HIIT and MICT.[25,26] These evidences support that HIIT could be used as an alternative and/or complimentary to MICT, for stable CAD patients. However, the utility and safety of HIIT in severe CAD requiring further evidences.[8]

Our meta-analysis showed that HIIT was more effective than control groups in improving peak $VO_2$ of post-MI patients without increasing the incidence of AEs. Subgroup analyses of HIIT vs. MICT and HIIT versus routine physical activity showed that there were both significant improvements in favour of HIIT. However, results of our meta-analysis indicated no significant effect on SBP and DBP, peak and resting HR, LVEF, LVEDV, and quality of life for HIIT compared with MICT and/or usual physical activity.

## Peak oxygen uptake

Peak $VO_2$ was considered as an effective indicator of exercise capacity.[27] Previous studies indicated that exercise intensity was an important predictor of efficiency of CR programmes, and peak $VO_2$ improved in parallel with the increase of intensity.[28,29]

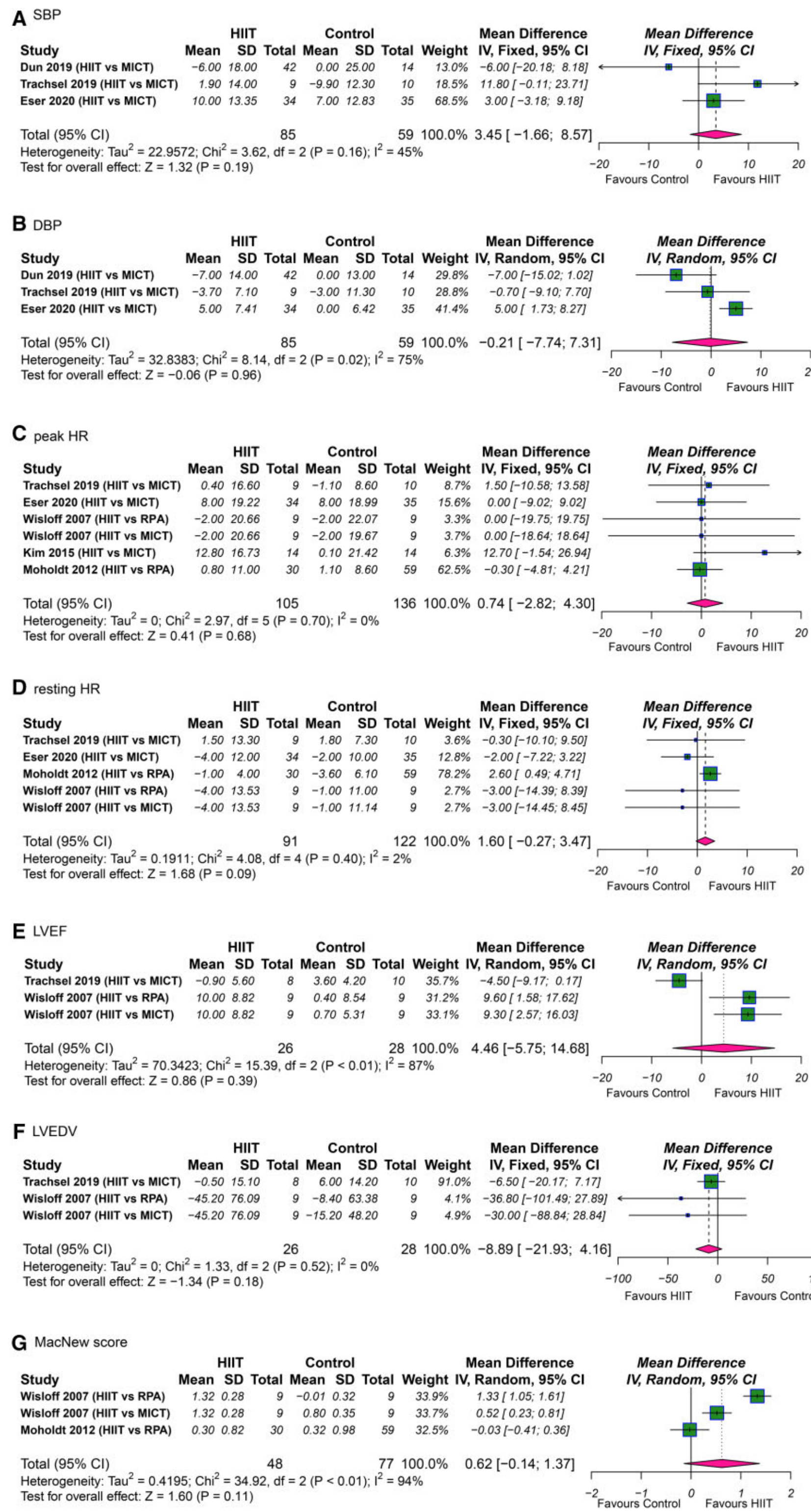


**Figure 3** Forest plot comparing the change in other outcome measures between high-intensity interval training and control group (moderate-intensity continuous training and/or routine physical activity). (*A*) change in systolic blood pressure. (*B*) Change in diastolic blood pressure. (*C*) Change in peak heart rate. (*D*) Change in resting heart rate. (*E*) Change in left ventricular ejection fraction. (*F*) Change in left ventricular end-diastolic volume. (*G*) Change in MacNew questionnaire score. CI, confidence interval; HV, high volume; LV, low volume; SD, standard deviation.

| Study | HIIT Events | HIIT Total | Control Events | Control Total | Weight | Risk Difference IV, Fixed, 95% CI |
|---|---|---|---|---|---|---|
| Wisloff 2007 (HIIT vs MICT) | 0 | 9 | 1 | 9 | 1.5% | −0.11 [−0.37; 0.15] |
| Wisloff 2007 (HIIT vs RPA) | 0 | 9 | 0 | 9 | 2.8% | 0.00 [−0.19; 0.19] |
| Moholdt 2012 (HIIT vs RPA) | 3 | 35 | 2 | 72 | 10.2% | 0.06 [−0.04; 0.16] |
| Kim 2015 (HIIT vs MICT) | 1 | 16 | 0 | 16 | 4.2% | 0.06 [−0.09; 0.22] |
| Choi 2018 (HIIT vs MICT) | 1 | 24 | 0 | 22 | 8.4% | 0.04 [−0.07; 0.15] |
| Dun 2019 (HIIT vs MICT) | 0 | 92 | 0 | 38 | 69.8% | 0.00 [−0.04; 0.04] |
| Trachsel 2019 (HIIT vs MICT) | 0 | 9 | 0 | 10 | 3.1% | 0.00 [−0.18; 0.18] |
| Total (95% CI) | | 194 | | 176 | 100.0% | 0.01 [−0.02; 0.04] |

Heterogeneity: $Tau^2 = 0$; $Chi^2 = 2.75$, df = 6 ($P = 0.84$); $I^2 = 0\%$
Test for overall effect: $Z = 0.63$ ($P = 0.53$)

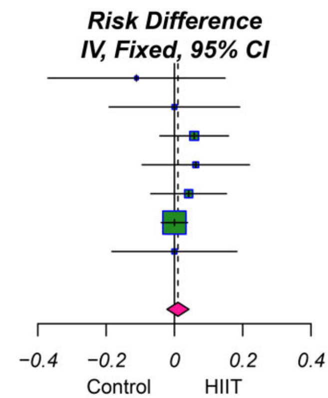


**Figure 4** Forest plot comparing the incidence of adverse events between high-intensity interval training and control group (moderate-intensity continuous training and/or routine physical activity). CI, confidence interval; HV, high volume; LV, low volume.

A number of studies have found that HIIT could significantly increase the peak $VO_2$ of patients with CAD. Nilsson *et al.*[26] conducted a trial include 86 patients with CAD for 12-week CR programme, and the study showed that HIIT improved Peak $VO_2$ 15 months after CR entry. Taylor *et al.*[30] found a significant improvement of peak $VO_2$ in the HIIT group after 12 months compared with MICT after a 1-years follow-up. In a meta-analysis of patients with CAD, HIIT showed a superiority in improving peak $VO_2$ of patients compared with MICT.[11] However, the superiority of HIIT disappeared when analysing with an isocaloric exercise protocol. The similar design of matching total energy expenditure was not observed in included studies. Accordingly, whether isocaloric training protocol might have a major impact on our conclusion could not be determined.

It is worth noting that participants in Wisløff *et al.*[20] were characterized with heart failure after MI. For patients with heart failure, HIIT proved to be an effective training protocol for improving exercise capacity.[23,24,31] The efficiency of HIIT in patients of heart failure after MI require more evidences.

In addition to exercise intensity, Peak $VO_2$ gaining was also related to other elements of exercise prescription, including frequency, duration, and timing.[11] In the study of Jayo-Montoya *et al.*,[16] a greater improvement of Peak $VO_2$ was observed in high-volume HIIT group than low-volume group. Then, the exercise intervention duration of included studies in our meta-analysis was ranged from 6 to 12 weeks. The 30-month follow-up study of Moholdt *et al.*[21,32] suggested that peak $VO_2$ deteriorated significantly without exercise persisting. However, Nilsson *et al.*[26] found HIIT could persistently improve Peak $VO_2$ after 15-month follow-up. The long-term effect of HIIT requires more evidences to confirm. But longer-term and persistent exercise may result in potential longer benefits.

The results of our meta-analysis are consistent with the systematic review which evaluated the effect of HIIT on improving peak $VO_2$ in CAD patients compared with MICT (MD = 1.3 mL/kg/min).[11] The subgroup analysis in our research showed that HIIT resulted in a greater improvement in Peak $VO_2$ by 3.73 mL/kg/min in MD than MICT did. It indicated that the post-MI patients might benefit more from HIIT in improving exercise capacity.

## Blood pressure

Molmen-Hansen *et al.*[33] found the effect of HIIT on lowering blood pressure, which was intensity-dependent. However, there existed different view that the impact of HIIT on blood pressure was not noticeable, compared to MICT.[23,31] In our meta-analysis, change of neither SBP nor DBP, was found no significant difference between the HIIT and the control group. However, only three studies that measured blood pressure were available for our meta-analysis. Due to significant heterogeneity among studies, whether there was a significantly greater effect on blood pressure in HIIT compared with MICT was still uncertain.

## Heart rate

Heart rate was an indicator of autonomic nerve activity. Heart rate has been considered as a valuable mortality predictor for patients with CVD.[34] Lowering resting HR can reduce cardiovascular risk for patients with CAD or heart failure.[35] Guiraud *et al.*[36] found that HIIT could significantly reduce HR and arrhythmic events. Our meta-analysis indicated there was no significant effect on peak and resting HR between HIIT and the control group. The effect of HIIT on HR need to be confirmed in large sample RCTs in the future.

## Left ventricular function and remodelling

Ghardashi *et al.*[37] suggested that HIIT could reduce the area of necrotic myocardium and improve heart function in rats. However, the effect of HIIT on left ventricular function and remodelling in cardiac patients tends to be not positive in the current study.[23,38] Our meta-analysis also showed that there was no significant difference in LVEF and LVEDV for post-MI patients between two groups. Due to significant heterogeneity among studies ($I^2 = 87\%$ for LVEF) and a limitation of the amount of available studies, the above conclusion needs further consideration.

## Quality of life

Improving the quality of life is another major goal of CR. To our knowledge, exercise may result in better quality of life, which was paralleled with physiological improvements.[18,20] The evaluation methods of quality of life among the included studies were varied. Our meta-analysis found that there was no significant improvement in the quality of life assessed by MacNew questionnaire. Nevertheless, it is still unable to draw a valid conclusion due to lacking a unified evaluating method.

## Safety of HIIT

There is a potential risk for patients with CVD when performing high-intensity exercise. However, most current clinical evidences indicated a low risk of cardiac events for HIIT and hold the opinion that HIIT seemed to be safe for CR.[26,30,38,39] As might be expected, no significant higher incidence of cardiovascular events and sports-related injury was observed in HIIT groups among the included studies. The pooled-analysis showed that HIIT and current mainstream training protocol appeared to be equally safe in the CR programme of post-MI patients. Nonetheless, our findings and conclusions may not be rigorous owning to a very low incidence of AEs in HIIT groups and control groups among the included studies. Moreover, most of the studies included in this article did not stratify patients for CR risk. Thus, the safety-related concern of HIIT in post-MI patients requires evaluation by further studies in the future.

In the present study, reporting bias was unable to assess owing to the limit of the amount of included studies. Then, we did not include the study by Eser *et al.*[14] in the pooled-analysis of peak $VO_2$, because its data were given in percentage. We attempted to contact the authors for more information; however, no response has been received yet. It is unclear whether these data may have a significant impact on the results of our meta-analysis. Data under isocaloric conditions were not observed in included studies. Moreover, this study was limited by the small sample size and short follow-up period. The follow-up period of 87.5% of include studies ended with the termination of training, and the duration of the training ranged from 6 to 12 weeks. The long-term effects and safety after training were not known. In addition, we did not consider the effect of cardiac medications on outcomes, although several studies mentioned the administration of these medications, like β-blockers, angiotensin-converting enzyme inhibitors, etc. Another limitation was that our analysis consisted of RCTs and cohort studies; however, data from cohort studies were less efficient than that obtained from RCTs.

# Conclusion

The systematic review found the superiority of HIIT in improving peak $VO_2$ in post-MI patients compared with MICT or other current exercise prescription. Moreover, HIIT appears to be safe. In summary, HIIT shows promising application value and prospects in the rehabilitation of MI patients.

**Conflict of interest:** All authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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