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RESEARCH ARTICLE

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Effects of high-intensity interval training in patients with coronary artery disease after percutaneous coronary intervention: A systematic review and meta-analysis

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Abstract

Aim: To evaluate whether high-intensity interval training (HIIT) was superior to low-intensity training or usual care among patients after percutaneous coronary intervention. The hypothesis was that HIIT would help patients after percutaneous coronary intervention (PCI) improve cardiopulmonary function, lipid profiles and in-stent restenosis.

Design: A systematic review and meta-analysis were conducted according to the Preferred Reporting Items for Systematic Review and Meta-analysis (PRISMA)2009 Checklist.

Methods: Randomized controlled trials (RCTs) focusing on HIIT programme in patients after PCI were searched in Cochrane Library, Web of Science Core Collection, EMbase, PubMed, China National Knowledge Infrastructure (CNKI) and SinoMed from the inception to 24 March 2020. Standard Mean difference (SMD) and 95% confidence intervals (CI) were performed to summarize the effect sizes.

Results: Six RCTs (247 patients) met the criteria. HIIT programme had a statistically significant effect on raising left ventricular ejection function (LVEF) (SMD = 0.38, 95%CI [0.03, 0.73], $I^2 = 3\%$), VO_{2peak} (SMD = 0.94, 95%CI [0.61, 1.28], $I^2 = 0\%$), as well as improving the serum level of high-density lipoprotein (SMD = 0.55, 95%CI [0.06, 1.03], $I^2 = 0\%$) and late luminal loss (SMD = −0.65, 95%CI [−1.07, −0.23], $I^2 = 0\%$). But HIIT had no prominent effect on improving heart rate (SMD = −0.04, 95%CI [−0.29, 0.21], $I^2 = 0\%$). Summarily, HIIT programme appears to be favourable for CAD patients after PCI by improving cardiopulmonary function, such as LVEF and VO_{2peak}, as well as reducing late luminal loss in per stented arteries. Nevertheless, HIIT has no advantage for adjusting heart rate. More researches with rigorous methods are warranted to explore the controversy about lipid profiles.

Xinyue Zhang and Dongmei Xu contributed equally to this research.

KEYWORDS
coronary artery disease, high-intensity interval training, meta-analysis, percutaneous coronary intervention

1 | INTRODUCTION

Percutaneous coronary intervention (PCI) has become the most effective treatment of coronary artery disease (CAD). Although PCI plays a significant role in decreasing the rate of vascular restenosis and recurrent ischaemia, the use of antithrombotic remains an intractable clinical problem on account of the complicated vascular endothelial condition, chronic atherosclerotic disease, etc. (Saito & Kobayashi, 2020). Additionally, effective cardiac rehabilitation can be viewed as another improvement of prognosis, which is a form of comprehensive and long-term exercise composed of risk factor analysis, physical activities, mental support, life-style behaviour interventions (Olsen et al., 2018; Perk et al., 2012; Zhang & Chang, 2019). The World Health Organization deems that exercise-based cardiac rehabilitation can influence patient's physical, psychological and social condition, benefit their quality of life and control potential complications (WHO, 1993). Furthermore, safe exercise at different intensity can affect the training endurance, oxygen capacity and intervention effects (Che & Wang, 2012).

It is recommended that moderate-intensity continuous training(MICT) at the intensity of 50%–75% heart rate (Gayda et al., 2016) or vigorous-intensity interval exercise are both beneficial to maintain people's health and prevent from the occurrence of disease (Norton et al., 2010; WHO, 2010). In spite of these advantages, around 30% adults fail to meet the demand because of lacking of time and hard to persist (Hallal et al., 2012). More importantly, the long period and complexity of exercise lead to patients giving up these activities (Reichert et al., 2007). Therefore, the HIIT is referred as an alternative cardiac rehabilitation to medium/low-intensity activities, which is short-time high oxygen-consumption exercise interphase with periods of low-intensity training or rest for recovery (Norton et al., 2010). To be specific, a maximal or symptom-limited exercise test with the highest heart rate ranging from 85%–100% is the most common HIIT method.

As for the intervention effects of the 2 approaches, systematic reviews indicate HIIT improved cardiopulmonary function, blood glucose, lipid and cholesterol profiles and some inflammatory markers in patients with chronic disease (Perrier-Melo et al., 2018; Qiu et al., 2017; Wen et al., 2019). And, the severity of anxiety and depression are markedly declined after HIIT (Beauchamp et al., 2010; Weston et al., 2014). Especially for CAD patients, compared with MICT, HIIT is more predominant on exercise capacity and quality of life. Despite HIIT outperforms MICT in physical and psychological status for CAD patients, some indicators of cardiac performance were not included in the published studies no matter by direct or indirect ways (Quindry et al., 2019). Besides these uncertainties, some performance variables of aerobic capacity in cardiac patients showed no difference in terms of systolic or diastolic blood pressure, maximal heart rate, peak minute ventilation and left ventricular ejection fraction (Amundsen et al., 2008; Xie et al., 2017). Although the effect of HIIT was gradually explicit, little is explored about the role and the validity of HIIT on patients following PCI. Combined with regular exercise, CAD patients after PCI recover better than PCI alone (Zhang & Chang, 2019). The objective of this study is to analyse the effect of HIIT compared with low-intensity training or usual care among post-PCI patients in aspect of heart function and prognosis.

RELEVANCE TO CLINICAL PRACTICE

According to the result of meta-analysis, HIIT programme plays an instructional role in promoting the effect of cardiac rehabilitation on post-PCI patient in terms of physical exercise and health education. In other ways, this result is conducive to provide advice to nurses in making clinical decisions that how to carry out postoperative rehabilitation of patients.

WHAT DOES THIS PAPER CONTRIBUTE TO THE WIDER GLOBAL CLINICAL COMMUNITY?

1. Provide advice on cardiac rehabilitation for post-PCI patients.
2. Underline the role of cardiovascular nurses in promoting evidence-based cardiac rehabilitation.

2 | METHODS

This meta-analysis was investigated according to the Preferred Reporting Items for Systematic Review and Meta-analysis(PRISMA)2009 Checklist (Moher et al., 2009).

2.1 | Search strategy

Relevant electronic databases were searched such as Cochrane Library, Web of Science Core Collection, Medline, EMbase, PubMed, China National Knowledge Infrastructure (CNKI) and SinoMed from the inception to 24 March 2020. Those databases were retrieved by two researchers using the following strategies independently. Keywords were set as: percutaneous coronary intervention/coronary arteriography/stent implantation/stent placement/drug-eluting stent/percutaneous transluminal coronary angioplasty and high-intensity interval training/

high-intensity interval training/high interval training/high interval exercise/HIIT/high-intensity interval exercise/intensity aerobic exercise/aerobic exercise. The reference lists of all included papers or related systematic review and meta-analysis were checked to prevent the omissions.

2.2 | Eligibility criteria

Studies were included according to the following criteria operationalized by PICOD/S: (a) Patients: patients diagnosed with CAD who underwent PCI; (b) Intervention: patients in experimental group were mainly treated with HIIT; (c) Counter intervention: patients in control group received usual care or MICT respectively; (d) Outcomes: cardiopulmonary function, lipid profiles and in-stent restenosis; and (e) Study: randomized controlled trials (RCTs). Studies were excluded: (a) It was literature review, letters, or commentaries, case report, patent, meeting, editorial and animal trials; (b) the full text could not be accessed in public databases. (c) No efficient data can be extracted; and (d) publications were duplicated. All original studies have passed the ethical approval. Besides, the included studies were searched from public database and clearly marked the citation source.

2.3 | Study selection

EndNote X7, the Thomson research software was used screen out the duplicates. Then, titles, topics, abstracts and full text were checked orderly by 2 researchers (XY Z and DM X) according to the eligible criteria separately. Once any conflicts arose, they sought consultation with a superior researcher.

2.4 | Data extraction and quality assessment

A form was designed to extracting the basic information. If any data were missing, we would e-mail the corresponding author. The Cochrane handbook for Systematic Reviews of Intervention 5.1.0 was used to appraise the quality of eligible studies in terms of 7 items: randomization, concealment, blind of participation, researcher and data analyst, selective reporting, incomplete outcome data and other biases though judging as "high risk," "unclear risk" and "low risk."

2.5 | Statistical analysis

The authors conducted meta-analysis using Review Manager software (version5.3: the Nordic Cochrane Center, the Cochrane Collaboration, 2103). Considering the continuous outcome, standardized mean difference (SMD) effect size and 95% confidence intervals (CI) were selected for analysis. The heterogeneity of overall effect size was quantified with I^2 statistic. With $p > .1$, a fixed-effect model was adopted if $I^2 < 50\%$, which signify low heterogeneity (Higgins et al., 2003). Subgroup analysis was used if there exited significant differences between the groups.

3 | RESULTS

3.1 | Search results

Based on the eligibility criteria, 314 articles were retrieved though the literature search process. After the elaborative examination and discussion, 6 publications (Abdelhalem et al., 2018; Gao et al., 2015; Kim et al., 2015; Munk et al., 2009, 2010, 2011) were deemed applicable for meta-analysis. The following chart displays the search process and the reason for removing (Figure 1).

3.2 | Study characteristics

This meta-analysis encompassed 6 RCTs with 247 patients (114 in experimental group and 133 in control group). Patients after successful PCI were randomized into experimental group conducted with HIIT programme and control group underwent less intensive exercise. The common outcomes could consist of three aspects: cardiopulmonary function weighed by left ventricular ejection function (LVEF), peak oxygen take (VO_{2peak}) and heart rate (HR), lipid profiles such as high-density lipoprotein (HDL), low-density lipoprotein (LDL) and triglycerides (TGs) and late luminal loss (LLL). According to the template for intervention description and replication (TIDieR) framework (Hoffmann et al., 2014), the mean number of reported TIDieR checklist item was 8.2 ($SD = 1.46$) of a possible 12. No more than 9 checklist items were reported in the trials. All the trials provided a brief name, the rationale, the procedures, the locations, the duration and frequency of delivery of the intervention. The items least reported were the modes of delivery, tailoring and modifications of intervention (Table 1).

3.3 | Quality assessment

The results of quality assessment were listed in detail in Figure 2. Two trials involved the methods of randomization and concealed the way of allocation (Gao et al., 2015; Munk et al., 2009). The incomplete, selective report, as well as other bias were appraised in low risk. The amount of "low risk" accounted for 64% in all the checklists. Only 1 trial (Munk et al., 2009;) reported the blinding of participants and personnel. While no explicit literal statement indicated whether the participants and personnel known grouping situation or not, so it was considered as unclear risk. The unclear risk has a certain impact on the overall quality evaluation, but these studies all met the eligibility criteria and there were no high-risk factors. Therefore, these literatures were considered to be included. But more rigorous research design should be carried out in future intervention studies.

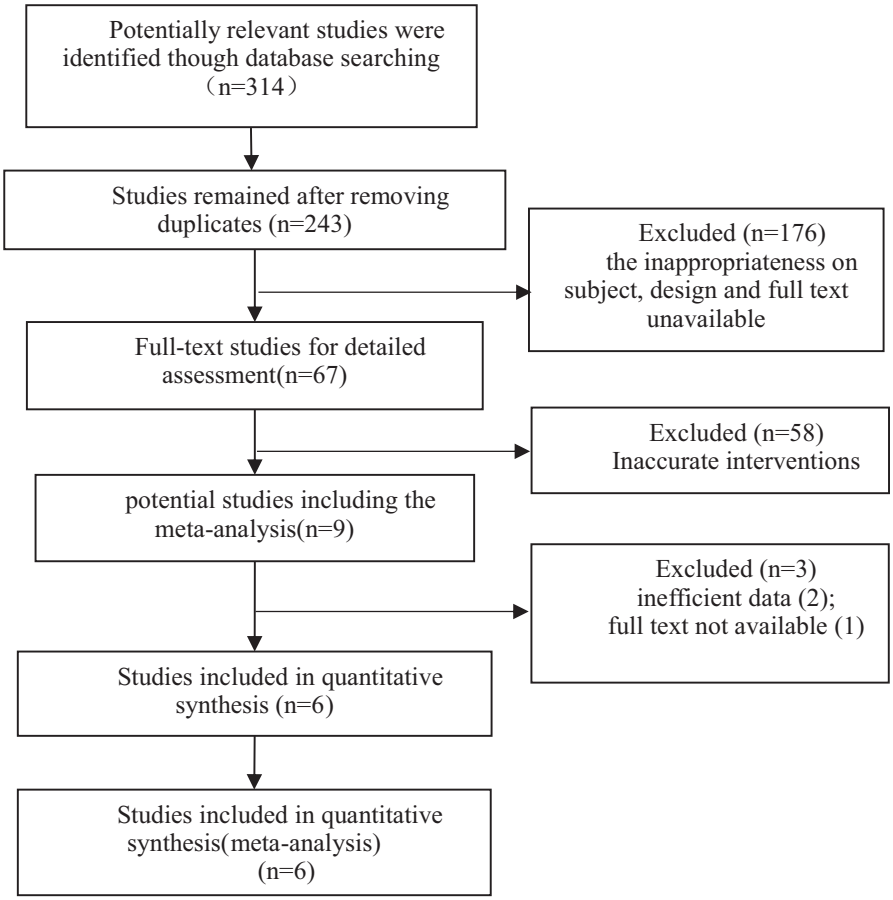

FIGURE 1 Flow chart of study selection process

3.4 | The results of meta-analysis

3.4.1 | Left ventricular ejection function (LVEF)

Left ventricular ejection function is an important reference index for evaluating left ventricular systolic function. The higher the EF value in the normal range, the better the patient's heart function. Two included RCTs (Abdelhalem et al., 2018; Gao et al., 2015) (N = 105 patients) reported the LVEF of post-PCI patients underwent HIIT and less intensive exercise. Considering the participants were randomizedly divided into three groups in the study of Gao (Gao et al., 2015), the included sample was formed into HIIT versus MICT (Gao 2009(1)) and HIIT versus usual care (Gao 2009(2)). According to the different measurements of control group, the effect of HIIT versus MICT and HIIT versus usual care was estimated in subgroup analysis. The meta-analysis showed the two groups had better homogeneity (I^2 = 3%, p = .36) in the fixed-effect model (Figure 3). HIIT had a statistically significant effect on elevating LVEF (SMD = 0.38, 95%CI [0.03, 0.73], p = .03).

3.4.2 | Peak oxygen uptake (VO2peak)

VO_{2peak} refers to the amount of oxygen that the human body takes in one minute when the cardiopulmonary function and the ability of the muscles to use oxygen reach their limits during long-term strenuous activities involving a large number of muscle groups. The higher VO_{2peak} value, the stronger the aerobic metabolism and the better the cardiopulmonary function. 3 RCTs (Gao et al., 2015; Kim et al., 2015; Munk et al., 2009; N = 133 patients) reported the VO_{2peak} of patients received HIIT and less intensive exercise after PCI. The meta-analysis demonstrated that there did not exist statistical heterogeneity between the two groups (I^2 = 0%, p = .52) in the fixed-effect model (Figure 4). HIIT had a statistically advantageous effect on increasing VO_{2peak} (SMD = 0.94, 95%CI [0.61, 1.28], p < .01).

3.4.3 | Heart rate (HR)

Three RCTs (Kim et al., 2015; Munk et al., 2009, 2010; N = 106 patients) explored patients' HR in different times. There was no statistical heterogeneity between the experimental and control groups (I^2 = 0%, p = .62) in the fixed-effect model (Figure 5). Compared with regular exercise, HIIT had no significant changing in peak or resting HR, day or night HR between two groups (SMD = −0.04, 95%CI [−0.29, 0.21], p = .73).

3.4.4 | Lipid profiles

The serum level of TGs, LDL and HDL is thought to be main indicators of lipid metabolism. The serum level of TGs and LDL is

TABLE 1 TIDieR checklist for included randomized controlled trials (evaluated by Xinyue Zhang & Dongmei Xu)

Included studies	Details
Item 1. Brief name: Provide the name or a phrase that describes the intervention	
Abdelhalem 2018	HIIT (high-intensity interval training)
Gao 2015	HIIT (high-intensity interval training)
Kim 2015	HIIT (high-intensity interval training)
Munk 2009	HIIT (high-intensity interval training)
Munk 2010	HIIT (high-intensity interval training)
Munk 2011	HIIT (high-intensity interval training)
Item 2. Why: Describe any rationale, theory or goal of the elements essential to the intervention	
Abdelhalem 2018	HIIT has been proved to improve long-term adherence in cardiac rehabilitation programmes (Bartlett et al., 2011)
Gao 2015	The safety and effectiveness of HIIT CAD patients have been preliminarily proved (American College of Sports Medicine, 2013)
Kim 2015	HIIT has been considered to be a safe and more effective method to improve exercise capacity (Guiraud et al., 2012)
Munk 2009	HIIT has been shown to be superior to MICT in improving exercise capacity and endothelial function in CAD patients (Rognmo et al., 2004)
Munk 2010	HIIT has been shown to be superior to MICT in improving exercise capacity and endothelial function in CAD patients and heart failure (Rognmo et al., 2004; Wisløff et al., 2007)
Munk 2011	Regular HIIT over 6 months is associated with a significant reduction of in-stent restenosis and reduction in CRP (Meyer et al., 2010)
Item 3. What (materials): Describe any physical or informational materials used in the intervention, including those provided to participants or used in intervention delivery or in training of intervention providers. Provide information on where the materials can be accessed (for example, online appendix, URL)	
Abdelhalem 2018	HIIT programme can be accessed at https://doi.org/10.2165/00007256-200131010-00002
Gao 2015	Not mention
Kim 2015	Not mention
Munk 2009	The programme can be accessed at http://circ.ahajournals.org/content/115/24/3086
Munk 2010	The programme can be accessed at http://circ.ahajournals.org/content/115/24/3086
Munk 2011	The programme can be accessed at http://circ.ahajournals.org/content/115/24/3086
Item 4. What (procedures): Describe each of the procedures, activities and/or processes used in the intervention, including any enabling or support activities	
Abdelhalem 2018	HIIT was prescribed as full 2 times weekly for 3 months (total of 24 sessions)
Gao 2015	With adaptive training be carried out with 60% of PP as exercise load for 1 week, the official training started 3 times weekly for 12 weeks after PCI
Kim 2015	The training started within 3 weeks after PCI, three times a week for 6 weeks
Munk 2009	The programme starting 11 ± 4 days after PCI, 3 times a week, 1 hr per session for 6 months
Munk 2010	This programme started 11 ± 4 days after PCI and lasted for 6 months
Munk 2011	This programme started 11 ± 4 days after PCI, 3 times a week, 1 hr per session for 6 months
Item 5. Who provided: For each category of intervention provider (for example, psychologist, nursing assistant), describe their expertise, background and any specific training given	
Abdelhalem 2018	All training session were under medical supervision
Gao 2015	Not mention
Kim 2015	All training sessions were supervised by medical staff
Munk 2009	The programme was provided by two experienced physical therapists specialized in cardiac rehabilitation
Munk 2010	The programme was provided by two experienced physical therapists specialized in cardiac rehabilitation
Munk 2011	Not mention
Item 6. How: Describe the modes of delivery (such as face to face or by some other mechanism, such as internet or telephone) of the intervention and whether it was provided individually or in a group	
Details: This included studies indicated that the intervention was delivered at hospital as item 7 shown without describing the modes of delivery by some information-based mechanism	

(Continues)

TABLE 1 (Continued)

Included studies	Details
Item 7. Where: Describe the type(s) of location(s) where the intervention occurred, including any necessary infrastructure or relevant features	
Abdelhalem 2018	The intervention was delivered at the cardiac rehabilitation clinic of the Cardiology department, Ain Shams University Hospital
Gao 2015	The training was delivered at cardiac rehabilitation centre of Jiangsu Province Official Hospital
Kim 2015	The training started three times a week for 6 weeks at Sanggye Paik Hospital
Munk 2009	The intervention was delivered at the Department of Cardiology, Stavanger University Hospital
Munk 2010	The intervention was delivered at the Department of Cardiology, Stavanger University Hospital
Munk 2011	The intervention was delivered at the Department of Cardiology, Stavanger University Hospital
Item 8. When and how much: Describe the number of times the intervention was delivered and over what period of time including the number of sessions, their schedule, and their duration, intensity or dose	
Abdelhalem 2018	Exercise consisted of 5 min of warm-up exercises followed by 30–35 min of continuous exercise [Alternating brief (2–5 min) higher intensity which aiming to reach 85%–95% of their initial heart rate reserve and similar time of moderate-intensity workloads throughout an exercise session], and end by 5 min of cool-down
Gao 2015	The programme was trained for 3 min and rested for 1 min. The interval training mode of rest was carried out, 10 groups of training each time, a total of 40 min
Kim 2015	The HIIT group exercised for a total of 45 min. Their programme consisted of a 10-min warm-up 50%–70% of heart rate reserve (HRR), followed by four times of 4-min intervals of walking on a treadmill at 85%–95% of HRR with three active pauses of 3-min walking at 50%–70% of HRR, and a 10-min cool-down at 50%–70% of HRR
Munk 2009	The training model included 10 minutes of warm-up at 60%–70% of maximal heart rate, followed by 4-min intervals at 80%–90% of maximal heart rate, when patients were riding an ergometric bicycle or were running. Intervals were interrupted by 3 min of active recovery at 60%–70% of maximal heart rate
Munk 2010	The group warmed up for 10 min at 60%–70% of maximal heart rate, before walking four 4-min intervals at 90%–95% of peak heart rate. Each interval was separated by 3-min active pauses, walking at 50%–70% of peak heart rate. The training session was terminated by a 3-min cool-down at 50%–70% of peak heart rate
Munk 2011	The programme consisted of a warm-up period, followed by four 4-min intervals at 80%–90% of maximal heart rate, when patients were riding an ergometric bicycle or running. Intervals were interrupted by 3 min of active recovery at 60%–70% of maximal heart rate
Item 9. Tailoring: If the intervention was planned to be personalized, titrated or adapted, then describe what, why, when and how	
Details: The intervention was adjusted to be more personalized in terms of the speed and inclination of the treadmill which were adjusted continuously to ensure that every training session was carried out at the assigned heart rate throughout the training period (Kim et al., 2015). Other studies did not describe the adjustment of intervention	
Item 10. Modifications: If the intervention was modified during the course of the study, describe the changes (what, why, when, and how)	
Details: No studies described the modifications of intervention	
Item 11. How well (planned): If intervention adherence or fidelity was assessed, describe how and by whom, and if any strategies were used to maintain or improve fidelity, describe them	
Abdelhalem 2018	All the patients were compliant to the programme. The exercise intensity was based on the HRR, and the target Heart rate (THR) calculated according to the Karvonen method
Gao 2015	Not mention
Kim 2015	The session training was monitored by electrocardiograph, heart rate, blood pressure using a telemetry monitoring system Written informed consent was obtained from all patients
Munk 2009	The sessions were monitored with individual pulse watches. The objectives have written informed consent
Munk 2010	All patients have written informed consent
Munk 2011	All patients have written informed consent
Item 12: How well (actual): If intervention adherence or fidelity was assessed, describe the extent to which the intervention was delivered as planned	
Abdelhalem 2018	All the patients completed the programme with no missing sessions or dropouts
Gao 2015	Not mention
Kim 2015	All patients successfully completed this training
Munk 2009	All patients except 1 randomized to training attended >90% of the training sessions, and no patient was lost to follow-up

(Continues)

TABLE 1 (Continued)

Included studies	Details
Munk 2010	There were no dropouts during the training period. Adherence to training was very good with 19 of 20 patients attending more than 90% of the training sessions
Munk 2011	No patients withdrew consent or were lost to follow-up except four patients with unstable angina excluded from analysis

risk factors for coronary artery disease, while HDL is a protective factor. 2 RCTs (Abdelhalem et al., 2018; Kim et al., 2015; 68 participants) reported the serum level of lipid profiles in the case of two interventions. The result of meta-analysis exhibited no heterogeneity in the level of HDL (I^2 = 0%, p = .87), but a little heterogeneity in LDL and TGs (I^2 = 29%, p = .24) in the fixed-effect model (Figures 6 and 7). Hence, HIIT had an weak impact on improving the serum level of HDL (SMD = 0.55, 95%CI [0.06, 1.03], p = .03) and has no effect on LDL and TGs (SMD = −0.05, 95%CI [−0.40, 0.30], p = .77).

3.4.5 | Late luminal loss (LLL)

Late luminal loss indicates the difference in the minimal lumen diameter of the target vessel before and after the intervention. The reduction of LLL implies that the degree of vascular restenosis is relatively small, which is a direct indicator to evaluate the recovery after intervention. Due to the employment of coronary angiography at 6 months after PCI, 2 RCTs (Munk et al., 2009, 2011; N = 76 patients) reported the LLL of stented coronary artery in patients received different types of exercise. With regard to bare metal stent (BMS) and drug-eluting stent (DES), Munk et al. (2009) separately discussed the LLL of patients implanted with two kinds of stents. The meta-analysis showed no statistical heterogeneity (I^2 = 0%, p = .57) in fixed-effect model (Figure 8). HIIT had a significant effect on shrinking LLL (SMD = −0.65, 95%CI [−1.07, −0.23], p < .01).

4 | DISCUSSION

According to the meta-analysis of 6 articles exploring the HIIT programme and less intensive exercise in patients diagnosed with CAD undergoing PCI, the results demonstrate that HIIT is an effective intervention to perfect cardiopulmonary function, especially for LVEF and peak oxygen uptake. Besides, late luminal loss is significantly smaller in patients with HIIT programme than that with less intensive exercise. However, synthesis of available data also shows that compared with less intensive exercise, HIIT has no significant effect on adjusting HR in patients after PCI whenever during exercise or rest, as well as on the day or night (Kim et al., 2015; Munk et al., 2010; Munk et al., 2009). In addition, the serum level of LDL and TGs has not obviously changed between two groups, while the serum level of HDL has slightly raised in HIIT group.

4.1 | Cardiopulmonary function

Compared with no extra exercise in patients, the regular-intensity rehabilitation is beneficial to improve ejection fraction and myocardial contractility in post-PCI patients (Zhang & Chang, 2019). In the light of present studies, we deeply investigated that less intensive exercise, even moderate-intensity exercise has not achieved a better effect than HIIT in terms of increasing the levels of LVEF and VO_{2peak} in patients after PCI, which indicates the intensity of exercise programme exerts different influence on cardiopulmonary function. Additionally, Munk et al. (2009) found that ventilatory threshold and maximal workload have greatly increased in post-PCI patients underwent HIIT project. While the results of this meta-analysis show no delectable changes in peak or resting heart rate between two groups, the functional capacity measured by metabolic equivalents had no statistically significant difference between the HIIT and MICT groups (Abdelhalem et al., 2018). It has been proved that prescription of HIIT should be given priority to recommend for patients with CAD or high cardiovascular risk who require cardiac rehabilitation in contrast with less intensive exercise (Guiraud et al., 2012).

4.2 | Lipid profiles

When it comes to lipid profiles, this research concludes serum levels of LDL and TGs have not markedly improved. Along with HDL, cholesterol has raised in HIIT programme. This finding has a bit discrepancy with the previous systematic review about healthy people or with physical health complications retrieved by Martland et al. (2020) that lipid and cholesterol profiles hardly vary with whether the HIIT prescription implemented or not. As the results found in Liou et al. (2016), no evident differences were surveyed in the levels of HDL and TGs for CAD patients comparing HIIT and MICT programmes. Perhaps this is the subtle secret that meta-analysis considers the integrated difference of confidence interval brought by the sample size, which gives more possibility to do high-quality original research to explore this controversy.

4.3 | Late luminal loss

Promisingly, the meta-analysis shows that late luminal loss in per stented artery for long-time follow-up is greater decreased in HIIT programme regardless of the stent types, which indicating the recovery of vessel diameter is satisfied. From an in-depth analysis,

the degree of LLL was actively correlated with inflammatory markers such as interleukin (IL)-6 (Munk et al., 2009, 2011). On the other hand, the reduction of LLL indicated the amelioration of endothelial function in accordance with previous study that the increased flow-mediated dilation, as well as the reduction in C-reactive protein were significantly synergistic with LLL following PCI (Munk et al., 2009). To some extent, restenosis caused by multiple factors is possibly related to LLL on account of the complicated mechanism of endothelial denudation and released inflammation factors (Ferns & Avades, 2000; Kipshidze et al., 2004). Therefore, the effect of HIIT programme is obviously favourable to decrease the levels of LLL, sequentially influencing the incidence of restenosis of stented arteries.

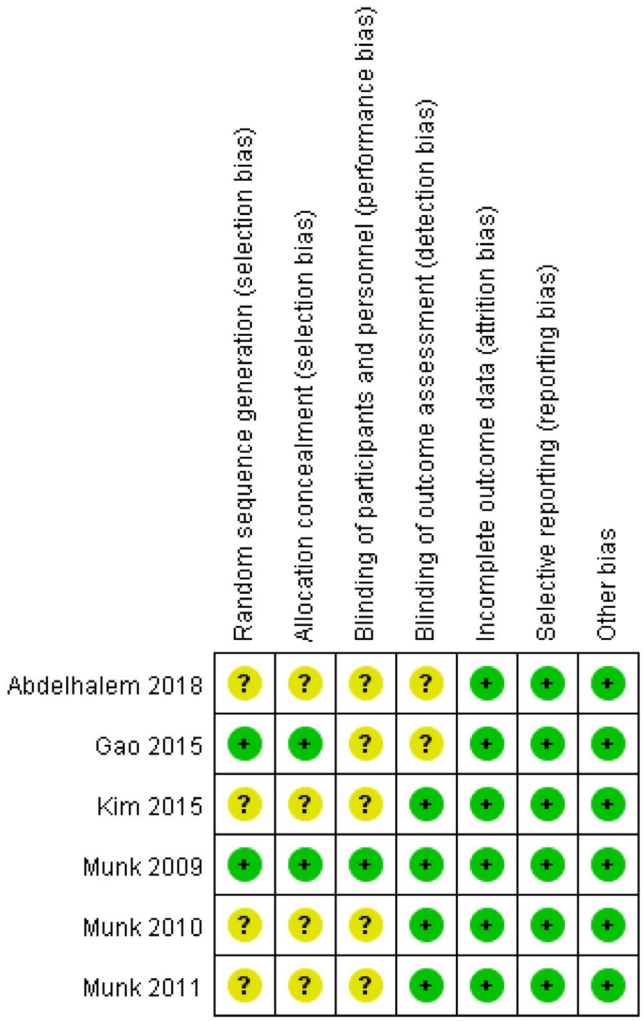

FIGURE 2 Quality assessment summary for each eligible study

4.4 | Effects of intervention characteristics based on previous research

After the PCI with bare metal stent or drug-eluting stent implanted, exercise rehabilitation becomes the fundamental prophylaxis for reducing the occurrence adverse cardiovascular events and improving cardiopulmonary function (Acar et al., 2015). The exercise programme usually consists of multiform aerobic exercise including treadmill, bicycle ergometer, running and other modes of exercise in different levels of intensity (Lee et al., 2013). Generally, HIIT programme conducts an interval protocol covering short-time activities at a minimal of 80% of VO_{2peak} or heart rate alternate with relatively less intensive recovery (Ahmadizad et al., 2016; Batacan et al., 2017; Milanovic et al., 2015; Munk et al., 2011). Recent studies have shown that HIIT is superior to MICT in enhancing peak VO_2 in patients with heart failure and reducing the total fat mass in patients with myocardial infarction (da Silveira et al., 2020; Dun et al., 2019). Excepting for the advantages HIIT programme brings, the safety should be considered before training. All training sessions in eligible studies were supervised by professional staff even monitored with technical medical devices. Besides, all the rehabilitation programme was started from half a month after PCI. On this basis, participants could be more secure in implementing the training to achieve lasting effect of this programme, which was proved by a meta-analysis that exercise would positively affect the cardiac function after this programme (Lavie et al., 2016).

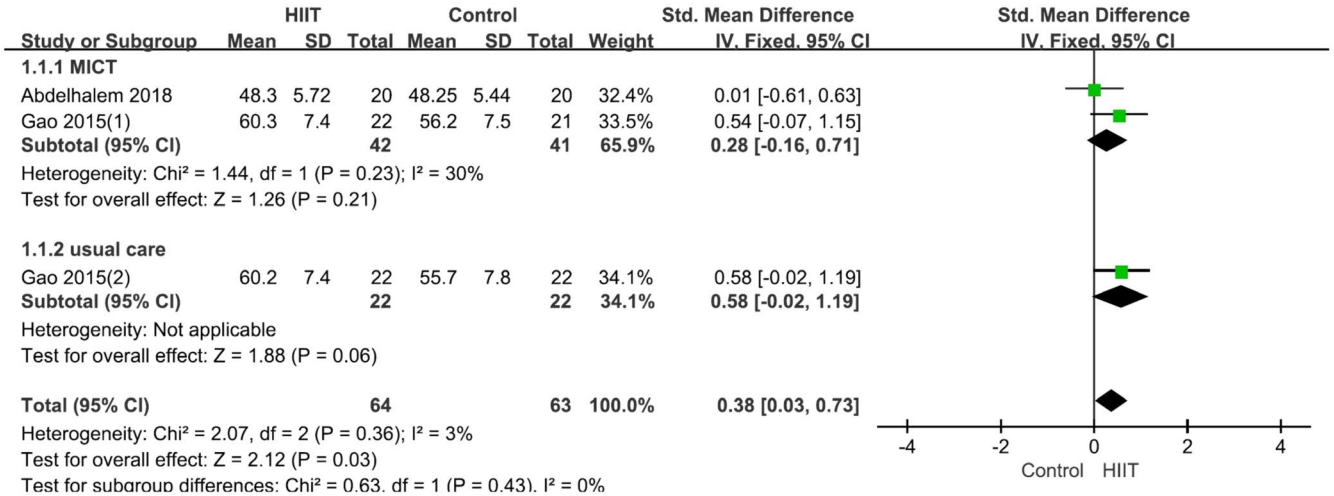

FIGURE 3 LVEF between two groups

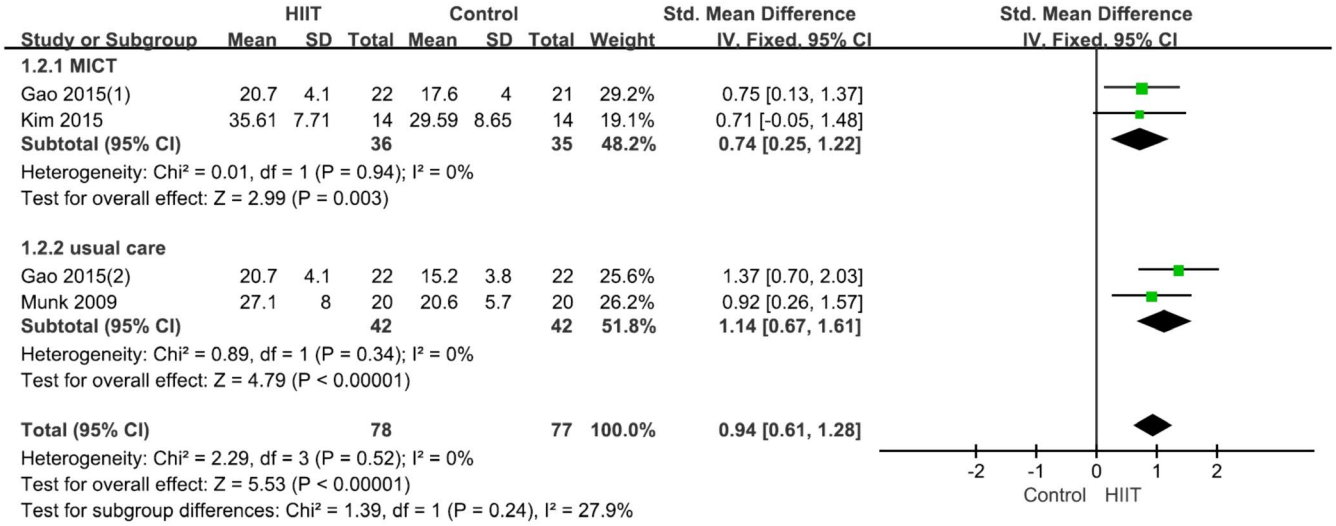

FIGURE 4 VO_{2peak} between two groups

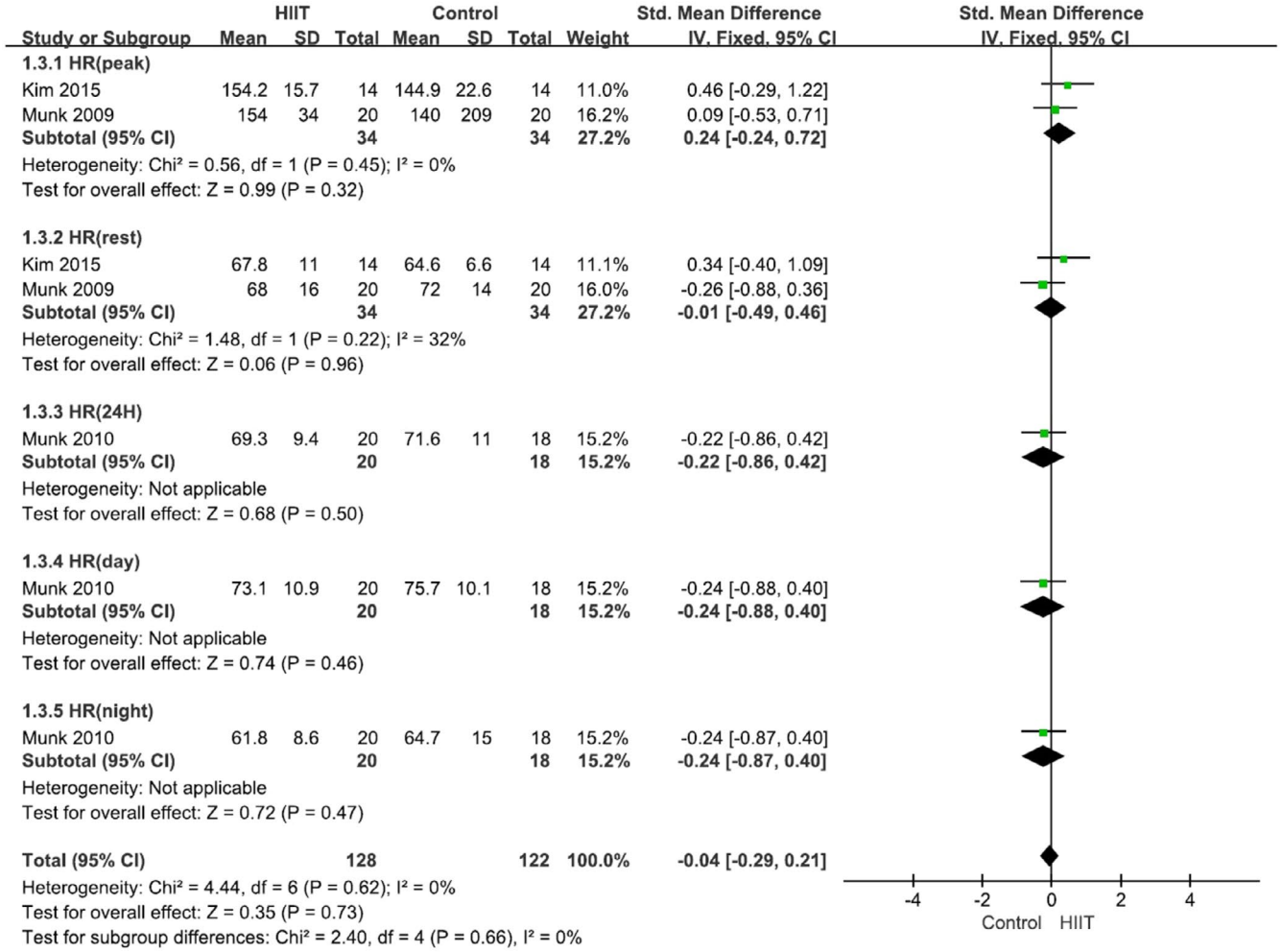

FIGURE 5 HR between two groups

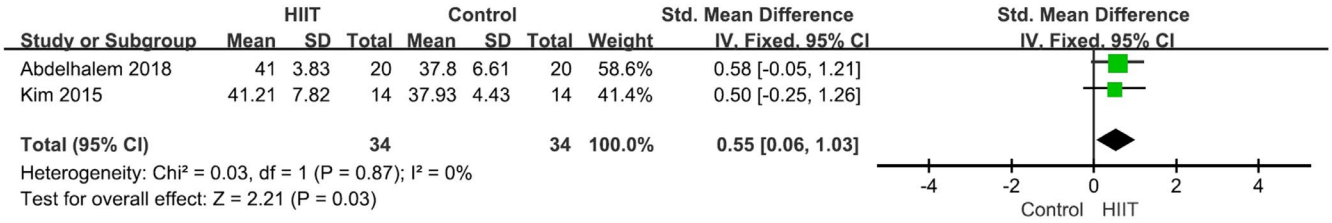

FIGURE 6 The serum level of HDL between two groups

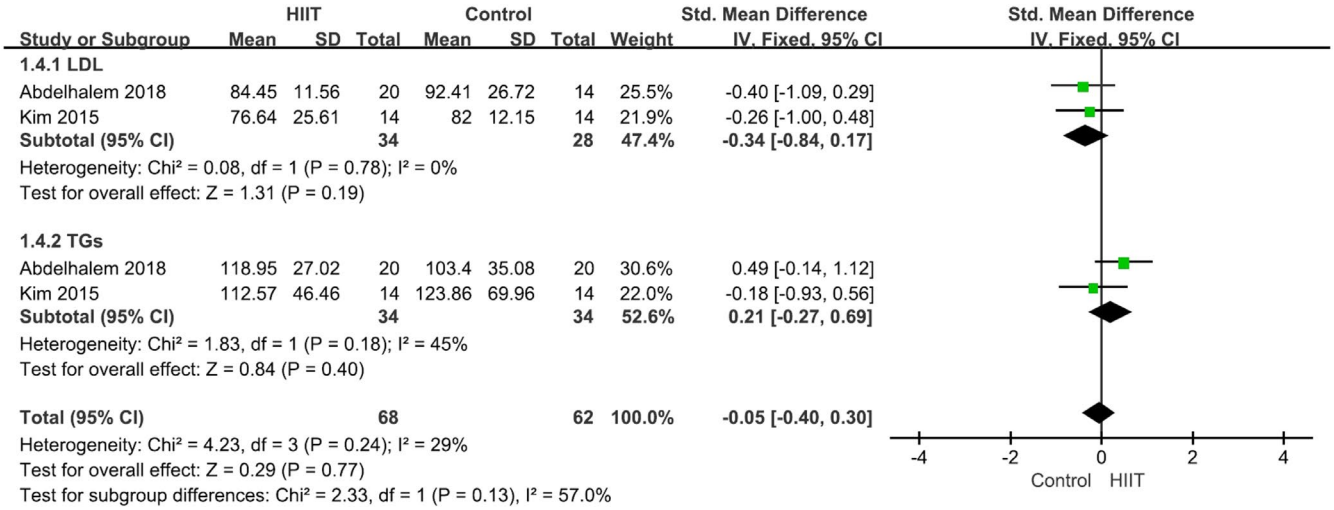

FIGURE 7 The serum level of LDL and TGs between two groups

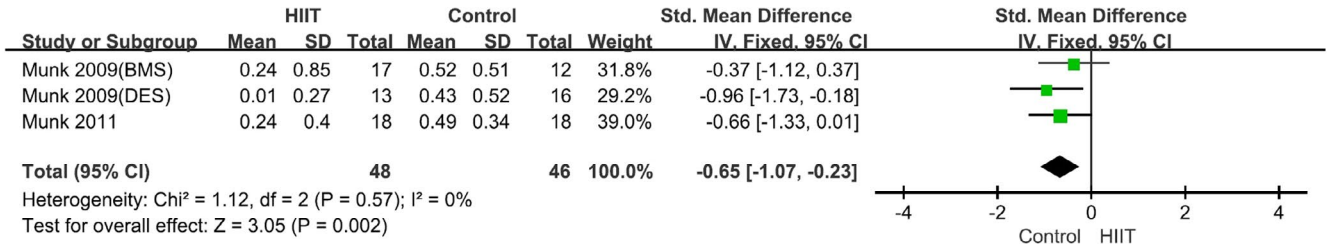

FIGURE 8 The LLL between two groups

4.5 | Limitations

There are some limitations to be noted in this analysis. Although the eligible trials are randomized and controlled, only few literatures are included in this analysis and the sample size is small leading to the lack of funnel plot. What's more, it also brings us to another limitation that the enrolled studies are heterogeneous in terms of the interventions in control group. Compared with high-intensity exercise, participants in control group underwent less-intensity exercise covering the moderate-intensity training or usual care which has been amended by the subgroup analysis. Therefore, it is necessary to develop more original studies about the performance of HIIT programme in CAD patients following PCI. More importantly, the intensity in experimental and control group should be precise and regulatory. The research design should be more rigorous.

5 | CONCLUSION

This meta-analysis demonstrates that HIIT programme might be favourable for CAD patients after PCI by improving cardiopulmonary function, such as LVEF and VO_{2peak}, as well as reducing late luminal loss in per stented arteries. Owing to the limited number of sample size and included studies, the effect of different intensity training, especially for HIIT programme, remains to be reevaluated meticulously and comprehensively though conducting higher-quality trials in future research.

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AUTHOR CONTRIBUTIONS

Xinyue Zhang and Dongmei Xu jointly identified the research problem, information retrieval and data analysis. Besides, this article was written by Xinyue Zhang. Guozhen Sun played a part in determining this topic. Zhixin Jiang helped to polish this article. Jinping Tian and Qijun Shan were both undertake the design of this project and supervise the process of research to guarantee the authenticity of paper.

DATA AVAILABILITY STATEMENT

The data used to support the findings of this study are available from the reference list (Abdelhalem et al., 2018; Gao et al., 2015; Kim et al., 2015; Munk et al., 2009, 2010, 2011). The corresponding journal name and doi have been also listed in References.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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