Original Article
Efficiency of muscle strength training on motor function in patients with coronary artery disease: a meta-analysis

Yu-Jie Yang[1], Xiao-Hua He[2], Hai-Ying Guo[1], Xue-Qiang Wang[3], Yi Zhu[1,4]

[1]The Second Clinical Medical School, Nanjing University of Chinese Medicine, Road No. 138 Qixia District in Nanjing Xianlin, Nanjing 210000, Jiangsu, China; [2]Palmer College of Chiropractic Florida, 4777 City Centre Parkway Port Orange, FL 32129, USA; [3]Department of Sport Rehabilitation, Shanghai University of Sport, Shanghai 200438, China; [4]Rehabilitation Center, Hainan Provincial Nongken Ceneral Hospital, Hainan, China

Abstract: Background: Existing literature has shown that patients with coronary artery disease (CAD) can benefit greatly from the strength training; therefore, the strength training should play a more important role in cardiac rehabilitation. However, the medical community may still have conservation to apply the strength training owing to no comprehensive study so far to compare the effectiveness of the strength training to the other trainings, such as aerobic training. Objective: To evaluate the effect of strength training on motor function in patients with CAD. Methods: Published articles from the earliest date available to July 2015 were identified using electronic searches. Two reviewers selected independently relevant randomized controlled trials (RCTs) investigating exercise program with strength training versus control interventions (exercise without strength training, including aerobic training and no exercise group) for the treatment of CAD patients. We examined effects of exercise with strength training versus control interventions on peak oxygen uptake (VO_{2peak}), duration of exercise test and muscle strength. Two reviewers extracted data independently. Results: Twenty seven trials that represented 1151 participants passed the selection criteria and were evaluated for the effects of strength training in CAD patients. For improving VO_{2peak} [SMD (95%CI) = 0.58 (0.11, 1.06)] and muscle strength [upper limb, SMD (95% CI) =0.44 (0.34, 0.55); lower limb, SMD (95% CI) =0.33 (0.16, 0.50)], exercise program with strength training were significantly more effective than one without it. But there is no significantly difference on duration of exercise test [SMD (95%CI) = 0.17 (-0.04, 0.39)] in strength training group than in control group. Conclusions: We conclude strength training is effective in improving muscle strength and VO_{2peak}, in CAD patients, when compared to patients with control group. Furthermore, our evaluations suggest that strength training does not compromise clinical trial completion or safety.

Keywords: Coronary artery disease, muscle strength training, motor function, randomized controlled trials, meta-analysis

Introduction

Coronary artery disease (CAD) is the most common form of heart disease and the leading cause of mortality, with more than 7.2 million deaths worldwide each year [1]. The economic burden of CAD is substantial, including direct costs (primary care, inpatient care, outpatient care, medications care, cost of accident and emergency) and indirect costs (loss in productivity) [1, 2]. It is estimated that CAD cost more than €49 billion in the European Union in 2003 [2]. The largest component of total expenditures on cardiovascular disease is direct health

care cost (51%), followed by productivity losses (34%) and informal care (18%) [2]. CAD caused the loss of approximately 62.6 million DALYs (disability-adjusted life years) globally and was the second highest cause of burden of disease in highest and middle income countries [1].

Currently, cardiac rehabilitation has become one of the center pieces of comprehensive cardiovascular care programs. The efficacy of cardiac rehabilitation programs, particularly exercise-based cardiac rehabilitation for the secondary prevention of CAD, has been clearly demonstrated [3]. WHO's Prevention of Cardio-

vascular Disease guidelines also recommend "regular light to moderate intensity physical exercise" to all patients recovering from major CAD events (Ia A) [4]. Aerobic exercise prescription plays a dominant role in exercise-based cardiac rehabilitation program due to functional improvement-specific effectiveness and reduction of controllable risk factors of CAD [4-6]. Additionally, patients with CAD may also benefit from strength training which has not received adequate emphasis in some guidelines [4, 7]. Strength training has beneficial effects on muscular strength and endurance, cardiovascular function, metabolism, lowering CAD risk factors, psychosocial well-being and improving quality of life [8, 9]. However, the practice of strength training was constrained previously by concerns of resistance training-induced blood pressure elevation, an incident with potential increased risk of cardiovascular complications [9, 10]. Meanwhile, other studies suggest that it is unnecessary to worry about the induced blood pressure elevation in all cases when the training is appropriately prescribed and supervised [9, 10].

Several systematic reviews, including meta-analyses, have examined the efficacy of different exercise-based cardiac rehabilitation modalities for CAD [5, 10, 11]. Most of these reviews focused primarily on aerobic training modality. One meta-analysis published in 2012 (inclusion studies were published before October 2009) paid attention to a combination of aerobic and resistance training in individuals with CAD [6]. There was no review focused on resistance training modality for CAD. Since the publication of these reviews, more new trials have been conducted [12-15]. The purposes of this review were (1) to evaluate the effect of strength training on motor function in patients with CAD, (2) to observe whether using strength training in CAD patients is dangerous, (3) to make some improvements in the methodology by rating the quality of evidence according to the approach of the GRADE working group [16-20]. Compared with some published reviews [3, 5-7, 10, 11], we have paid more attention to strength training itself. And to our knowledge no review has yet used the approach of the GRADE working group to rate the quality of evidence in this field.

Methods

Search strategy

The electronic databases used for searching randomized controlled trials (RCTs) from the earliest date available until July 2015 included Cochrane Controlled Trials Register (CENTRAL), PubMed, MEDLINE, EMBASE, ISI Web of Science, China Biology Medicine disc, China National Knowledge Infrastructure, VIP Database for Chinese Technical Periodical and Wanfang Data. Relevant review articles and the reference lists of selected articles were examined for further studies.

Details of the search strategy used in the CENTRAL are presented in **Appendix I**. Briefly, search terms included coronary artery disease, coronary heart disease, coronary disease, coronary thrombosis, heart infarction, ischemia heart, myocardial infarction, myocardial ischemia, angina, coronary artery bypass graft, coronary angioplasty, coronary bypass, myocardial revascularization, strength training, power training, weight training, circuit training, resistance training. No language restrictions were applied.

Inclusion criteria

Types of studies: Only the RCTs that examined the effects of exercise programs with strength training versus control interventions on motor function in patients with CAD were included. Grouping situation include (1) Combined training group (CTG, strength training combined with aerobic training) versus Aerobic training group (ATG), (2) Strength training group (STG) versus No training group (NTG), and (3) Strength training group versus Aerobic training group. There was no date restrictions for publication searched. Only studies written in English and Chinese language were included in the analysis.

Types of participants: Both female and male subjects of all ages with CAD (MI, CABG, PTCA, PCI, or CAD defined by angiography) have been included. The papers that included participants with heart valve disease, heart failure, heart transplants or implant surgeries were excluded.

Types of interventions: We included the papers in which muscle strength training was compared with aerobic training or conventional therapies without exercise training. Strength trainings were usually performed using resistance machines, weights, dumbbells and rubber bands. Aerobic trainings usually included walking and/or jogging with/without treadmill; exercise using cycle ergometers, arm ergometers, dual-action cycles (both the arms and legs simultaneously), rowers, stair steppers, volleyball, or exercises according to a cardiac rehabilitation program. All groups received conventional therapies.

Types of outcome measures: The primary outcomes of interest were exercise capacity, including VO_{2peak}, duration of exercise testing and muscle strength. The secondary outcomes, were body composition, including body weight, body mass index (BMI) and safety measured by adverse events and withdrawals, were also paid attention.

Study selection

Two independent reviewers (Yang and Guo) used a pre-specified criteria to search titles, abstracts and full papers of clinical trials electronically. An article would be excluded if it was determined not to meet the inclusion criteria. Disputes on eligibility of inclusion were settled down first by discussion only if no further controversial, or second, if necessary, by a third reviewer (He) to arbitrate the final decision. Only studies that were considered eligible were included in the meta-analysis.

Data extraction

Data from included studies was extracted by two reviewers (Yang and Guo) separately, and then were compiled together into a standard table. In case of any discrepancies between the first two reviewers, the third reviewer (Wang) was used to serve as a verifier and arbitrator. The following information was extracted from the included articles, such as subject information, exercise prescription of intervention and control groups, as well as outcome measures.

Risk of bias assessment

Two reviewers (Yue and Guo) independently assessed the potential risk of bias for all included studies, which were categorized as "low",

"unclear", or "high" according to the Cochrane Collaboration recommendations [21]. The following information was evaluated, including random sequence generation, allocation concealment, blinding of participants, personnel and outcome assessment, incomplete outcome data and selective outcome reporting [21]. A third reviewer (Zhu) served as a verifier and arbiter if any disagreements occurred.

Rating the quality of evidence

All three reviewers who evaluated, verified and arbitrated the risk of bias also rated the quality of evidence according to the approach of the GRADE working group [16-20]. The quality of evidence and outcomes across studies were rated as (1) high: further research was very unlikely to change our confidence in estimation of the effect; (2) moderate: further research was likely to have an important impact on our confidence in estimation of the effect and might change the estimation; (3) low: further research was very likely to have an important impact on our confidence in estimation of the effect and was likely to change the estimation and (4) very low: any estimation of the effect was very uncertain [16, 17, 19, 20, 22]. Factors that might affect the quality of evidence included (1) limitations in study design or implementation; (2) incoherence of results; (3) indirectness of evidence; (4) imprecision and (5) publication bias [16-20].

Statistical analysis

Review Manager Software (RevMan5.2) was used for meta-analysis, while Grade profiler 3.6 software was used for the rating the quality of evidence.

Heterogeneity among the studies was evaluated by chi-square test and I square statistic. If significant heterogeneity (*P*-value > 0.10, I square < 50%) was associated with an effect estimate, a random effect model would be applied. Otherwise, a fixed effect model was applied. If heterogeneity existed among the studies, a sensitivity analysis was conducted. Since all of the variables in the studies included in this meta-analysis were continuous, therefore, the mean difference (MD) and 95% confidence interval (CI) were used to analyze the studies. *P* value < 0.05 was considered to be statistically significant.
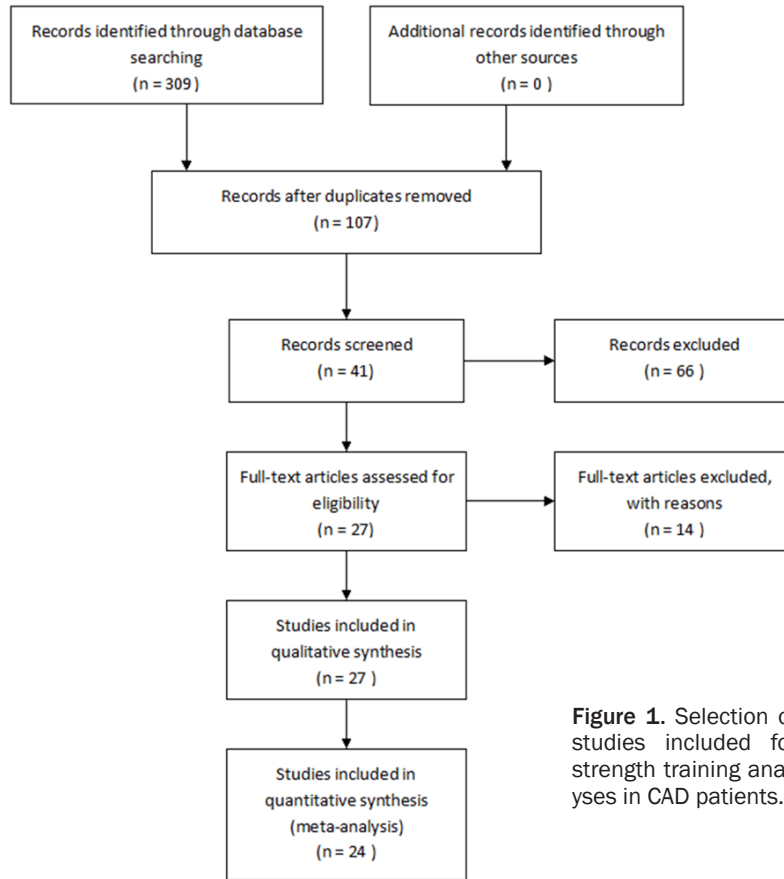
Figure 1. Selection of studies included for strength training analyses in CAD patients.

Systematic review registration: http://www.crd.york.ac.uk/PROSPERO. PROSPERO registration number: CRD42014012848.

Results

Study selection

Figure 1 shows the process of identifying and selecting eligible studies.Initial screening located 309 publications; from which, forty one were potentially eligible based on their titles and abstracts. After a careful full text assessment of these potentially eligible studies, 14 studies were removed due to inappropriate intervention, non-RCTs, and lack of original data from the authors. As a result, 27 RCTs [12-15, 23-45] were included for final analysis (**Table 1**).

Study characteristics

Methods and participants: The characteristics of the included studies and patients are presented in **Table 1**. This systematic review identified 27 studies with 1151 randomized patients. Exercise duration of patient interventions varied from 4 to 48 weeks. In twelve studies [12, 23-33], only males were recruited, while in

another six studies [25, 29-32, 35] only females were involved.

Interventions and outcomes: A strength training program was reported in all 27 recruited studies. Analyses of the studies based on chronological order revealed that resistance training involved in strength training programs were employed in the most current studies; furthermore, most of the strength training were designed on the basis of aerobic training. In addition, most of the resistance training programs were set up to be three sessions per week, incorporating six exercises and two sets per, Each set consisted of 10 to 12 repetitions corresponding to a load of 60 to 80% one RM. The aerobic training program was set up to be 20-120 minutes for each session, 2-6 times per week, at an intensity of 40-95% of peak heart rate. The duration of the exercise interventions ranged from 4 to 48 weeks. All patients received conventional therapy, including medication, education and advice about diet and exercise.

Risk of bias in included studies

The risk of bias for all included studies was assessed using the Cochrane Collaboration recommendations (**Figures 2** and **3**). The evidences of risk of bias involved in this meta-analysis had either a high overall risk or uncertain; only three studies [14, 34, 35] scored the greatest for higher quality compared to the others. All published studies claimed to employ the "randomization method" for trials; however, the exact methods for randomization were not clearly addressed. Among all 27 studies, only 4 studies [14, 29, 34, 35] described appropriate details of random sequence generation, and 2 studies 26, 29 revealed appropriate concealment of allocation. Due to difficulty of blindness for patients and clinicians to the chosen regimen, the rehabilitation trials were blinded to clinicians in 2 studies [34, 36]. The outcome

Table 1. Characteristics of included studies

Article	Subjects		Exercise protocol
Caruso 2015 [12]	CTG: 10 (61.3±5.2 yr) ATG: 10 (61.0±4.4 yr) All males, NYHA I-II	ST	Leg press maneuver (leg press) 8 wk, 2 times/wk, 1 h/time 30% 1-RM, 20 repetitions/set, 3 sets/time, 5 min between sets
		AT	Treadmill or cycle ergometer 8 wk, 2 times/wk, 1 h/time (70% HRmax for 20-30 min).
Ghroubi 2013 [13]	STG: 16 (59.25±1.70 yr) ATG: 16 (59.00±5.85 yr) 8-12 wk after CABG, LVEF > 40%, resting BP < 160/100 mmHg	ST	Isokinetic dynamometer (knee extension, knee flexion) 8 wk, 3 times/wk 20-30% MPT, 180°/s concentric mode, 10 repetitions/set, 10 sets for 2 legs/time, 1 min between sets
		AT	Cycle ergometer 8 wk, 3 times/wk, 1 h/time (70% HRR for 20 min)
Hansen 2011 [14]	CTG: 22 (60.5±8.9 yr) ATG: 25 (59.8±7.2 yr)	ST	Sitting leg extension, leg press 6 wk, 3 times/wk 65% 1-RM, 12-20 repetitions/set, 2 sets/time, 30 s between sets
		AT	Cycling, walking, arm cranking 6 wk, 3 times/wk, 40 mins/time (65% VO_{2peak})
Helgerud [15] 2011	CTG: 10 (60.5±8.9 yr) ATG: 8 (59.8±7.2 yr) Angina pectoris class I-III	ST	Horizontal dynamic leg press 8 wk, 3 times/wk 85-90% 1-RM, 4 repetitions/set, 4 sets/time, 2 min between sets
		AT	Treadmill interval walking 8 wk, 3-5 times/wk, 4×4 min interval training with 3 min active breaks (85-95% HRmax for 2 last minutes of intervals; 60-70% HRmax for active breaks)
Gayda 2009 [23]	CTG: 8; ATG: 8 All males, 55±8 yr, LVEF > 35%	ST	Resistance apparatus (quadriceps leg extension, lateral pull down) 7 wk, 3 times/wk 40% MVC, 10 repetitions/set, 3 sets/time
		AT	Cycle ergometer, callisthenics 7 wk, 3 times/wk, 1 h/time (individual VT power)
Vona 2009 [37]	ATG: 52 (56±6 yr) STG: 54 (57±8 yr) CTG: 53 (55±9 yr) NTG: 50 (58±7 yr) Symptom-free capacity≥ 75 W, LVEF ≥ 40%	ST	Weights and rubber bands 4 wk, 4 times/wk 60% MVC, 10-12 repetitions/exercise, 10 exercises/set, 3 sets/time
		AT	Cycle ergometer 4 wk, 4 times/wk, 1 h/time (75% HRmax)
Coke 2008 [40]	CTG: 16 (64±11 yr) ATG: 14 (65±10 yr) All females, exercise capacity > 5 METs	ST	Chest press, shoulder press, biceps curl, lateral row, and triceps extensio 12 wk, 2 times/wk 40-60% 1-RM, 12 repetitions/exercise, 10 exercises/set, 1 set/time
		AT	Based on individual exercise prescription 12 wk, 3 times/wk
Marzolini 2008 [35]	CTG-1: 18 (60.9±2.3 yr) CTG-2: 18 (62.7±2.7 yr) ATG: 14 (57.9±2.6 yr) Resting BP <160/110 mmHg	ST	Dumbbells and theraband (dumbbell row, half squat, bicep curl, heel raises, standing lateral raise, leg curl, supine lateral raise, curl up abdominal exercise, tricep extension, and four point alternate arm and leg lift.) 24 wk, 2 times/wk 60-75% 1-RM, 10-15 repetitions/exercise, 10 exercises/set, 1 or 3 sets/time
		AT	Walking and/or jogging 29 wk, 5 times/wk, 30-60 min/time (60-80% VO_{2peak})
Moghadam 2008 [41]	CTG-1: 18, CTG-2: 21 CTG-3: 18, ATG: 22 52.4±5.9 yr, LVEF ≥ 50%, exercise capacity > 5 METs, resting BP ≤160/105 mmHg	ST	Knee extension, knee flexions, arms crossing across chest, elbow extension, elbow flexion 8 wk, 3 times/wk 40%, 60%, or 80% 2-RM, 10-12 repetitions/exercise, 5 exercises/set, 2 sets/time, 30 s between sets
		AT	Treadmill walking, stationary cycle, arm ergometer 8 wk, 5 times/wk, 30-40 min/time (moderate intensity,according to the patients' heart rate, fatigue level and cardiac symptom)
Schmid 2008 [42]	CTG: 17 (54.7±9.4 yr) ATG: 21 (57.0±9.6 yr) LVEF ≥ 45%	ST	Leg press, leg curl, back extension, abdominal crunch, abdominal oblique crunch and latissimus pull 12 wk, 6 times/wk 40-60% 1-RM, 10-12 repetitions/exercise, 6 exercises/set, 2 sets/time, 60 s between sets
		AT	Upright, computer-controlled, rotational speed-independent bicycle 12 wk, 6 times/wk (70-85% HRmax)
Arthur 2007 [34]	CTG: 37, ATG: 35 All females, exercise capacity > 40% predicted METs, FEV1 or FVC ≥ 50% predicted	ST	Elbow flexion, bench press, leg press and knee flexion 6 mo, 2 times/wk 50-70% 1-RM, 8-12 repetitions/exercise, 4 exercises/set, 2 sets/time, 30-60 s between sets
		AT	Stationary cycles, treadmills, arm ergometers and stair climbers 6 mo, 2 times/wk, 1 h/time (40-70% functional capacity)

Study	Population		Intervention
Ades 2005 [43]	STG: 21 (72.9±6.1 yr) ATG: 21 (71.5±4.8 yr) All females, exercise capacity > 3 METs, resting BP ≤ 160/90 mmHg	ST	Weight lifting (leg extensions, leg press, leg curls, shoulder press, arm curls, lateral pulldown, bench press, triceps extension) 6 mo, 3 times/wk, 50-80% 1-RM, 10 repetitions/exercise, 8 exercises/set, 1-2 sets/time
		AT	Stretching, calisthenics, deep breathing-progressive relaxation exercises, and light yoga 6 mo, 3 times/wk
Hung 2004 [44]	CTG: 9 (71±7 yr) ATG: 9 (70±6 yr) All females	ST	Weight lifting (chest press, shoulder press, vertical row, triceps extension, biceps curl, latissimus dorsi pull down, leg extension, and leg curl) 8 wk, 3 times/wk 55% 1-RM (increased 2.5%/wk), 8-10 repetitions/exercise, 8 exercises/set, 1-2 sets/time
		AT	Treadmill or cycle ergometers. 8 wk, 3 times/wk, 30 min/time (70-85% HRmax)
Ades 2003 [45]	STG: 19, ATG: 14 All females, 72.3±5.6 yr, exercise capacity > 3 METs, resting BP ≤ 160/90 mmHg	ST	Weight lifting (leg extensions, leg press, leg curls, shoulder press, arm curls, lateral pull down, bench press, triceps extension) 6 mo, 3 times/wk 50-80% 1-RM, 10 repetitions/exercise, 8 exercises/set, 1-2 sets/time
		AT	Stretching, calisthenics, deep breathing-progressive relaxation exercises, and light yoga 6 mo, 3 times/wk
GU 2003 [39]	CTG: 20 (60±9 yr) ATG: 20 (60±8 yr) Angina pectoris class I-III, NYHA I-II	ST	Static contraction of gymnastics 6 wk, 5 times/wk 10-20 s/repetition, 4-8 repetitions/exercise, 15 exercises/set, 25 min/set, 1 set/time (70~85% HRpeak)
		AT	Stationary cycles 6 wk, 5 times/wk, consuming 1000 Kcal/week, RPE 11-13
Santa-Clara 2003 [24]	CTG: 13 (55±10 yr) ATG: 13 (57±11 yr) NTG: 10 (57±11 yr) All males	ST	Weight training machines (vertical traction, pectorals, chest press, deltoids, arm curl, triceps, leg extension, leg press), abdominal and low back exercises 12 mo, 3 times/wk 40-50% 1-RM, 8-12 repetitions/exercise, 10 exercises/set, 2 sets/time
		AT	Treadmill 12 mo, 3 times/wk 30-50 min, 60-70% HRR
Brochu 2002 [46]	STG: 13 (70.5±4.0 yr) ATG: 14 (70.7±5.3 yr) All females, exercise capacity > 3 METs, resting BP ≤ 160/90 mmHg	ST	Weight lifting (leg extensions, leg press, leg curls, shoulder press, arm curls, lateral pulldown, bench press, triceps extension) 6 mo, 3 times/wk 50-80% 1-RM, 10 repetitions/exercise, 8 exercises/set, 1-2 sets/time
		AT	Stretching, calisthenics, deep breathing-progressive relaxation exercises, and light yoga 6 mo, 3 times/wk, 30-40 min/time
Santa-Clara 2002 [25]	CTG: 13 (55±10 yr) ATG: 13 (57±11 yr) NTG: 10 (57±11 yr) All males, had completed phase II/III cardiac rehabilitation	ST	Variable resistance machines (vertical traction, pectorals, chest press, deltoids, arm curl, triceps, leg extension, leg press), abdominal and low back exercises 12 mo, 3 times/wk 40-50% 1-RM, 8-12 repetitions/exercise, 10 exercises/set, 2 sets/time
		AT	Walking, jogging, cycle ergometry, rowing, stepping, and other aerobic activities 12 mo, 3 times/wk, 30-40 min/time (60-70% HRR)
Pierson 2001 [36]	CTG: 10 (58.7±8.3 yr) ATG: 10 (61.0±8.0 yr) Exercise capacity > 5 METs	ST	Resistance machines (knee extension, hamstring curl, seated chest press, pullover, shoulder press, bicep curl, and tricep extension), dumbbells (forearm curls), spring-loaded grippers (hand-grip exercise) 6 mo, 3 times/wk 40% MMS, 12-15 repetitions/exercise, 9 exercises/set, 2 sets/time
		AT	Treadmills, cycle ergometers, recumbent cycle ergometers, rowers, and stair steppers 6 mo, 3 times/wk, 30 min/time (65-80% HRmax)
Stewart 1998 [26]	CTG: 12 (52.3±9.5 yr) ATG: 11 (57.2±9.9 yr) All males, LVEF ≥ 40%, resting BP ≤ 160/100 mmHg	ST	Resistance machines (lateral pulldown, leg extension, military press, bench press, leg curl, upright rowing) 10 wk, 3 times/wk 40% 1-RM, 10-15 repetitions/exercise, 6 exercises/set, 2 sets/time
		AT	Dual-action cycles 10 wk, 3 times/wk, 30-35 min/time (70-80% HRmax for 20-30 min)
Maiorana 1997 [28]	STG: 12 (61.2±8.4 yr) NTG: 14 (59.0±8.7 yr) All males, LVEF ≥ 50%, resting BP ≤ 160/100 mmHg	ST	Dumbbell and machine stack weights (bench press, lateral pull down, seated row, triceps extension, biceps curl, pectoral deck, pullover, hamstring curl, leg extension, calf extension, leg press, abdominal crunch) 10 wk, 3 times/wk 40-60% MVC, 10-15 repetitions/exercise, 12 exercises/set, 2-3 sets/time
Daub 1996 [27]	CTG-1: 14 (49.2±9.1 yr) CTG-2: 13 (47.2±7.3 yr) CTG-3: 15 (50.7±7.3 yr) ATG: 15 (49.9±6.8 yr) All males, LVEF ≥ 35 %	ST	Weight lifting machine (seated chest press, lateral pull downs, and rowing; and 4.5-9 kg for shoulder press, triceps extensions, and arm curls) 12 wk, 3 times/wk 20% 1-RM, 20 repetitions/exercise (CTG-1), 40% 1-RM, 10 repetitions/exercise (CTG-2), 60% 1-RM, 7 repetitions/exercise (CTG-3) 6 exercises/set, 2 sets/time
		AT	Walking and cycling 12 wk, 3 times/wk, 40 min/time (70-85% HRmax)

Wosornu 1996 [33]	STG: 27 (59.2±6.4 yr) ATG: 27 (56.5±8.9 yr) NTG: 27 (56.6±7.0 yr) All males	ST	Bench press, military press, biceps curl, upright row, pull down, push down, pulley row, quadriceps curl, hamstrings curl and sit-up 6 mo, 3 times/wk Weights strated at 2-5 kg (increasing weight according to patients condition), 10 repetitions/exercise, 10 exercises/set, 3 sets/time
		AT	Based on the Canadian Airforce XBX physical fitness programme 6 mo, 3 times/wk, 12-40 min/time
Butler 1992 [29]	CTG: 9, ATG: 10 All males, 52.5±8.5 yr, resting BP ≤ 160/100 mmHg	ST	Resistance machines (triceps, upper back, lateral pull-down, chest press, arm curl, butterfly, shoulder raise, military press) 6 wk, 3 times/wk 40% 1-RM, 10 repetitions/exercise, 8 exercises/set, 2 sets/time
		AT	Treadmills, cycle ergometers 12 wk, 3 times/wk, 37 min/time (70-85% HRmax or 65-85% HRR for 30 min)
Haennel 1991 [30]	STG: 8 (51.1±2.3 yr) ATG: 8 (51.5±4.0 yr) NTG: 8 (56.9±1.4 yr) All males, NYHA I-II	ST	Resistance machines (knee extension, knee flexions, elbow extension, elbow flexions, shoulder extension, shoulder flexions) 8 wk, 3 times/wk 8-16 repetitions/exercise, 6 exercises/set, 3 sets/time
		AT	Cycle ergometers 8 wk, 3 times/wk, 34 min/time (70% HRR)
McCartney 1991 [32]	CTG: 10, ATG: 8 All males, 52±2 yr, resting BP ≤ 160/95 mmHg	ST	Arm curl, leg press, leg calf extension and knee extension 10 wk, 2 times/wk 40-80%1-RM, 10-15 repetitions/exercise, 4 exercises/set, 2-3 sets/time
		AT	Arm and leg cycle ergometry, walking and jogging 10 wk, 2 times/wk, 40 min/time (60-85% HRmax)
Kelemen 1986 [31]	CTG: 20, ATG: 20 All males, 55±8.5 yr	ST	Resistance machines (vertical fly, arm curl, shoulder press, high pulley, low pulley, bench press, double leg curl, double leg extension, bent leg sit-ups, hip flexor) 10 wk, 3 times/wk 40% 1-RM, 10-15 repetitions/exercise, 10 exercises/set, 2 set/time
		AT	Walking, jogging, volleyball 10 wk, 3 times/wk, 40 min/time (85% HRmax)

CTG: Combined Training Group; STG: Strength Training Group; ATG: Aerobic Training Group; NTG: No Training Group; ST: Strength Training; AT: Aerobic Training; LVEF: Left Ventricular Ejection Fraction; MET: Metabolic Equivalant; NYHA: New York Heart Association Classification; BP: blood pressure; FEV1: Forced Expiratory Volume in One Second; FVC: Forced Vital Capacity. 1-RM: One Repetition Maximum; 2-RM: Two Repetition Maximum; MVC: Maximum Volunteer Contraction; MMS: Maximal Muscle Strength; MPT: Maximum Peak Torque; HRR: Heart Rate Reverse.
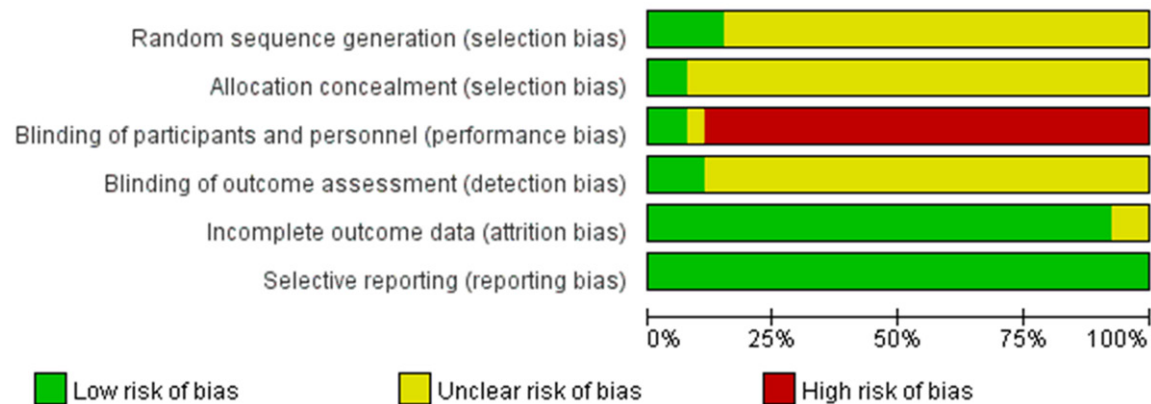

Figure 2. Overview of risk of bias in selected studies included to evaluate the effect of strength training in CAD patients.

assessors were blinded in 3 trials [14, 35, 37]. Two studies [27, 33] reported incomplete data, in which the selective outcome reporting were at a low risk of bias.

The quality of evidence

Overall level of evidence was classified as low (duration of exercise test, upper limb strength,

lower limb strength) or very low (VO_{2peak}) as a result assessed by the GRADE approach (**Table 2**).

Effects of strength training

Peak oxygen uptake (VO_{2peak}): Fourteen studies that included 731 randomized patients reported peak oxygen uptake (VO_{2peak}) measured by

Figure 3. Risk of bias for each selected study included to evaluate the effects of strength training in CAD patients.

cardiopulmonary exercise test. The data revealed a tendency that patients who received exercise with strength training had a more favorable effect on VO_{2peak} [SMD (95% CI) = 0.58 (0.11, 1.06)] when compared to controls (**Figure 4**). Compared with ATG, although it shows a trend that groups with strength training had a preferable effect on VO_{2peak}, there was no significant statistical difference in STG [5 studies, 223 patient, SMD (95% CI) = 0.01 (-0.39, 0.41)] and CTG [9 studies, 362 patient, SMD (95% CI) = 0.37 (-0.11, 0.86)]. While a significant improvement was revealed in STG compared to NTG [3 studies, 146 patient, SMD (95% CI) = 2.42 (1.27, 3.56)].

Duration of exercise test: Duration of cardiopulmonary exercise test was reported in ten studies, which included 682 randomized patients. The data revealed a trend that groups with strength training had a preferable effect on duration of exercise test, but no significantly difference on duration of exercise test in strength training group than in control group [SMD (95% CI) = 0.17 (-0.04, 0.39)] (**Figure 5**). Compared with ATG, there was no significant statistical difference in STG [2 studies, 159 patient, SMD (95% CI) = -0.13 (-0.40, 0.14)] and CTG [8 studies, 339 patient, SMD (95% CI) = 0.19 (-0.03, 0.41)]. And there was no significant statistical difference in STG compared to NTG [3 studies, 184 patient, SMD (95% CI) = 0.42 (-0.16, 1.01)].

Muscle strength

Upper limb strength: Twelve studies that included 455 randomized patients reported upper limb strength. The data showed more favorable

Table 2. The GRADE Working Group grades of evidence to determine effects of ST in CAD patients

No. of studies	Limita-tions	Inconsis-tency	Indirect-ness	Impreci-sion	Other con-siderations	No. of patients	SMD	95% CI	Quality	Impor-tance
Quality assessment						**Summary of findings**				
							Effect			
VO_{2peak}										
14	Serious	Serious	No serious	No serious	None	396	1.03	(0.43, 1.63)	Very low (+OOO)	Critical
Duration of exercise testing										
10	Serious	No serious	No serious	No serious	None	267	0.62	(0.32, 0.92)	Low (++OO)	Important
Upper limb muscle strength										
12	Serious	No serious	No serious	No serious	None	210	4.63	(3.11, 6.15)	Low (++OO)	Critical
Lower limb muscle strength										
12	Serious	No serious	No serious	No serious	None	210	4.63	(3.11, 6.15)	Low (++OO)	Critical

High quality: further research is very unlikely to change our confidence in the estimate of effect; Moderate quality: further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate; Low quality: further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate; Very low quality: Any estimate of effect is very uncertain.
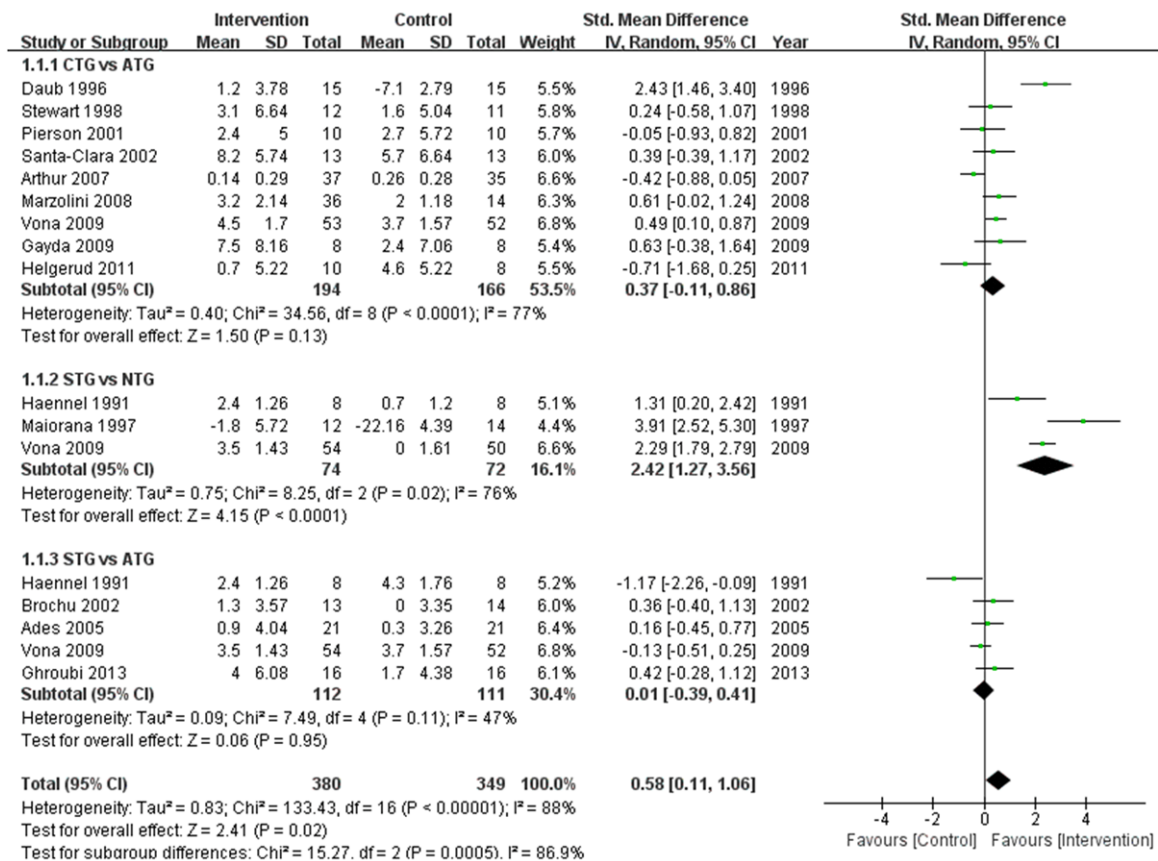
Figure 4. Meta-analyses of strength training versus control interventions effect on VO_{2peak}.

effects on muscle strength for individuals in the strength training group than those in the control group [SMD (95% CI) = 0.44 (0.34, 0.55)]. Compared with ATG, there was significant improvements in STG [3 studies, 91 patient, SMD (95% CI) = 0.90 (0.31, 1.48)] and CTG [8 studies, 322 patient, SMD (95% CI) = 0.39 (0.28, 0.51)]. And there was a preferable effect in STG compared to NTG [2 studies, 42 patient, SMD (95% CI) = 0.60 (0.24, 0.95)] (**Table 3**).

Lower limb strength: Twelve studies that included 454 randomized patients reported lower

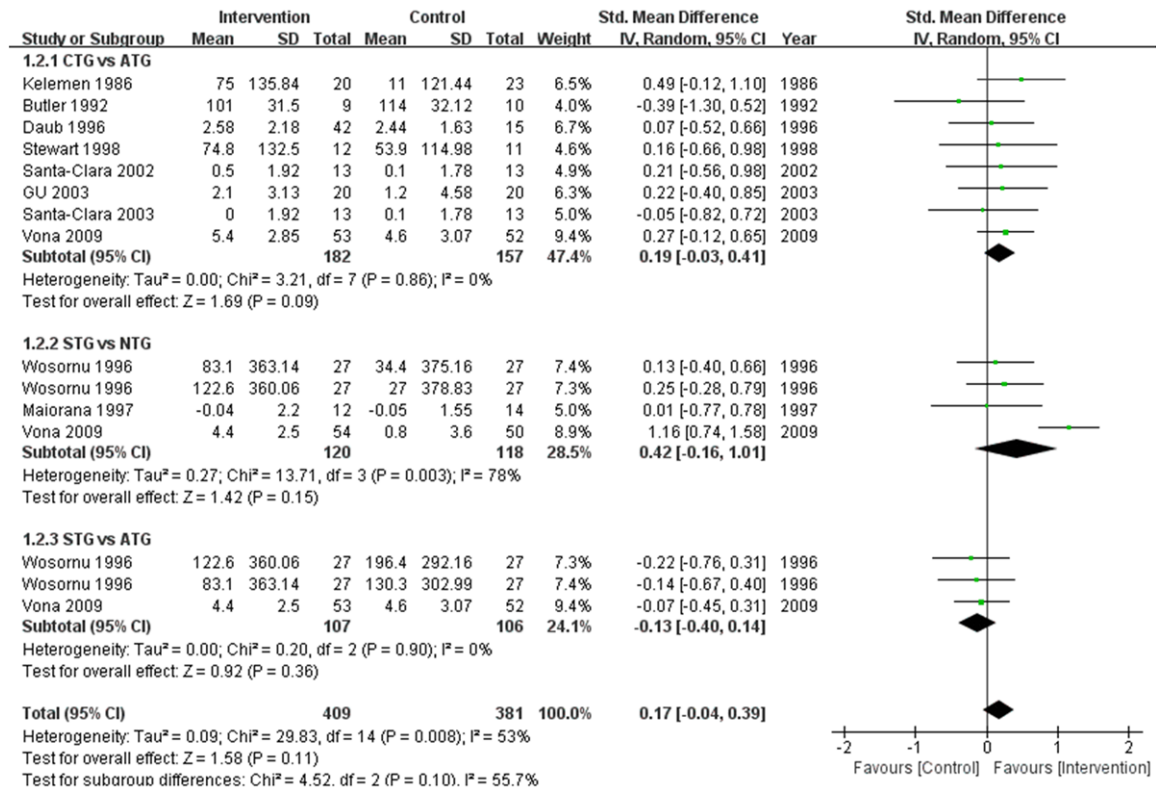| Study or Subgroup	Intervention			Control			Weight	Std. Mean Difference IV, Random, 95% CI	Year
	Mean	SD	Total	Mean	SD	Total			
1.2.1 CTG vs ATG									
Kelemen 1986	75	135.84	20	11	121.44	23	6.5%	0.49 [-0.12, 1.10]	1986
Butler 1992	101	31.5	9	114	32.12	10	4.0%	-0.39 [-1.30, 0.52]	1992
Daub 1996	2.58	2.18	42	2.44	1.63	15	6.7%	0.07 [-0.52, 0.66]	1996
Stewart 1998	74.8	132.5	12	53.9	114.98	11	4.6%	0.16 [-0.66, 0.98]	1998
Santa-Clara 2002	0.5	1.92	13	0.1	1.78	13	4.9%	0.21 [-0.56, 0.98]	2002
GU 2003	2.1	3.13	20	1.2	4.58	20	6.3%	0.22 [-0.40, 0.85]	2003
Santa-Clara 2003	0	1.92	13	0.1	1.78	13	5.0%	-0.05 [-0.82, 0.72]	2003
Vona 2009	5.4	2.85	53	4.6	3.07	52	9.4%	0.27 [-0.12, 0.65]	2009
Subtotal (95% CI)			182			157	47.4%	0.19 [-0.03, 0.41]	
Heterogeneity: Tau² = 0.00; Chi² = 3.21, df = 7 (P = 0.86); I² = 0%									
Test for overall effect: Z = 1.69 (P = 0.09)									
1.2.2 STG vs NTG									
Wosornu 1996	83.1	363.14	27	34.4	375.16	27	7.4%	0.13 [-0.40, 0.66]	1996
Wosornu 1996	122.6	360.06	27	27	378.83	27	7.3%	0.25 [-0.28, 0.79]	1996
Maiorana 1997	-0.04	2.2	12	-0.05	1.55	14	5.0%	0.01 [-0.77, 0.78]	1997
Vona 2009	4.4	2.5	54	0.8	3.6	50	8.9%	1.16 [0.74, 1.58]	2009
Subtotal (95% CI)			120			118	28.5%	0.42 [-0.16, 1.01]	
Heterogeneity: Tau² = 0.27; Chi² = 13.71, df = 3 (P = 0.003); I² = 78%									
Test for overall effect: Z = 1.42 (P = 0.15)									
1.2.3 STG vs ATG									
Wosornu 1996	122.6	360.06	27	196.4	292.16	27	7.3%	-0.22 [-0.76, 0.31]	1996
Wosornu 1996	83.1	363.14	27	130.3	302.99	27	7.4%	-0.14 [-0.67, 0.40]	1996
Vona 2009	4.4	2.5	53	4.6	3.07	52	9.4%	-0.07 [-0.45, 0.31]	2009
Subtotal (95% CI)			107			106	24.1%	-0.13 [-0.40, 0.14]	
Heterogeneity: Tau² = 0.00; Chi² = 0.20, df = 2 (P = 0.90); I² = 0%									
Test for overall effect: Z = 0.92 (P = 0.36)									
Total (95% CI)			409			381	100.0%	0.17 [-0.04, 0.39]	
Heterogeneity: Tau² = 0.09; Chi² = 29.83, df = 14 (P = 0.008); I² = 53%									
Test for overall effect: Z = 1.58 (P = 0.11)									
Test for subgroup differences: Chi² = 4.52, df = 2 (P = 0.10), I² = 55.7%									

Figure 5. Meta-analyses of strength training versus control interventions effect on duration of exercise testing.

Table 3. Comparative statistical analysis of effect of muscle strength exercise regimens on participants within included studies

Action	Studies	Participants	Statistical method	Effect estimates
Upper limb muscle strength				
CTG vs ATG	8 [26, 27, 29, 31, 36, 39, 40, 44]	322	Standardized mean difference, 95% CI	0.39 (0.28, 0.51)
STG vs NTG	2 [27, 28]	42		0.60 (0.24, 0.95)
STG vs ATG	3 [30, 43, 45]	91		0.90 (0.31, 1.48)
Total	12 [26-31, 36, 39, 40, 43-45]	455		0.44 (0.34, 0.55)
Lower limb muscle strength				
CTG vs ATG	7 [14, 26, 31, 34-36, 42]	289	Standardized mean difference, 95% CI	0.14 (0.01, 0.28)
STG vs NTG	2 [28, 30]	42		1.08 (0.54, 1.62)
STG vs ATG	4 [13, 31, 43, 45]	123		0.60 (0.07, 1.14)
Total	12 [13, 14, 26, 28, 30, 31, 34-36, 43, 45]	454		0.33 (0.16, 0.50)

CTG: Combined Training Group; STG: Strength Training Group; ATG: Aerobic Training Group; NTG: No Training Group; ST: Strength Training; AT: Aerobic Training.

limb strength. The data showed more favorable effects on muscle strength for individuals in the strength training group than those in the control group [SMD (95% CI) = 0.44 (0.34, 0.55)]. Compared with ATG, there was significant improvements in STG [2 studies, 42 patient, SMD (95% CI) = 1.08 (0.54, 1.62)] and CTG [7 studies, 289 patient, SMD (95% CI) = 0.14 (0.01, 0.28)]. And there was a preferable effect in STG compared to NTG [4 studies, 123 patient, SMD (95% CI) = 0.60 (0.07, 1.14)] (**Table 3**).

Adverse events and withdrawals (safety)

We found that only few studies (n = 6) reported the cardiovascular adverse events which occurred more frequently during aerobic train-

ing than during strength training. Reported cardiovascular adverse events associated with training were observed in 52 cases amongst 1151 participants. Four out of 52 cases (arrhythmia, n = 1; recurrence of coronary heart disease, n = 2; precordial pain, n = 1) occurred in the strength raining group, while all others happened in the aerobic training group. Except for these 52 cases, some other withdrawals occurred due to patients' personal reasons or health issues but not related to cardiovascular problems.

Discussion

The primary findings of this review indicate that the strength training can improve motor function among individuals with CAD. Collectively, the evidences suggest that strength training groups have a more effective improvement on motor function (upper and lower limb strength and aerobic performance capacity) than that in control groups. There is also a tendency that the strength training groups have a greater favorable change in VO_{2peak} and endurance as measured by duration of exercise testing then the control groups have. In addition, it is suggested that well implemented and careful monitored strength training is safe for patients with CAD in receiving cardiac rehabilitation. In this review, we found that cardiovascular adverse events occurred more frequently during aerobic training than during strength training.

We assessed the potential risk of bias for each study using the Cochrane Collaboration recommendations and rated the quality of evidence using the approach of the GRADE working group. To our knowledge no review has yet used the approach of the GRADE working group to rate the quality of evidence in this field. However, most of the included studies had a high risk of bias, and all three measured outcomes were assessed as a low or very low level of evidence. The main reason for a low quality outcome was that the generation of the random sequence and allocation concealment description was not clear. It was our understanding that it was difficult to blind patients and clinicians to the chosen regimen. The confidence interval of included studies was found to be different, which could be due to the results of included studies being heterogeneous, or that included studies may be limited by publication bias. Only fewer cardiovascular

adverse events were reported by included studies.

Previous studies have revealed that strength training could reverse multiple risk factors for CAD, lead to improvements in patient survival and play a more important role in secondary prevention of heart disease [6, 9, 10, 38]. Although the efficiency of improving aerobic ability and decreasing risk factors may not be as favorable as those during aerobic training, strength training can still enhance muscle strength and endurance of CAD patients, which is extremely important in day-to-day activities and safety [9, 10].

This review has several strengths. First, in order to ensure the quantity and quality of the included articles, we performed a comprehensive search from multiple databases to identify and select eligible trials; secondly, for the purpose of maximal reducing potential bias in this review, two independent reviewers were recruited to examine the obtained records and extracted data, assess the methodological quality of each trial and rate the quality of evidences; thirdly, a third reviewer was also included to play a role as a verifier and arbiter if any discrepancies occurred.

This meta-analysis has several practical implications; for example, the results suggest that strength training alone, can be effective in improving exercise capacity, such as VO_{2peak}, duration of exercise testing and muscle strength for patients with CAD. Combined strength training with aerobic training is more effective than aerobic training alone in enhancing aerobic capacity and muscle strength in patients with CAD. Meanwhile, the findings of this review also demonstrate that strength training would not have more risk of cardiovascular complications than aerobic training alone would if strength training is implemented and monitored appropriately. Therefore, combined strength training could be recommended to therapists when training patients, rather than aerobic training only. However, it should be noted that due to low quality data, further studies with rigorous design methodology and larger sample size are warranted to elucidate these results.

There were different strength training programs from different studies in this review. Those

strength training programs varied in the quantity and mode of training movements, muscles involved in the movements and details of exercise prescription (such as training intensity, sets, frequency, manner, subsequence, rest period, speed of muscle contraction and training volume, etc.). Five of the most commonly-used strength training actions are chest press, elbow extension, elbow flexion, leg extension, leg flexion. However, further research is required to standardize the strength training program, so that it may achieve the most optimized and maximized therapeutic effect.

Limitation of the study

There were also several limitations in this meta-analysis that is worthy to be addressed. First of all, just like the other systematic reviews, the findings of this meta-analysis were based on relatively low quality data mainly that might yield high risk of bias. Although several articles [13-17, 19, 39] included in this meta-analysis were published within the last five years, articles with rigorous methodological design were still deficient. Secondly, the overall level of evidence was classified as low or very low assessed by the GRADE approach for the reason we mentioned above. Thirdly, although there was no language restriction for searching articles, only English and Chinese literatures were included owing to the limitation of authors' language capacity.

In conclusion, the strength training is effective in improving muscle strength and VO_{2peak} in patients with CAD in comparison to the patients in control group. Further more, our evaluations suggest that strength training does not compromise clinical trial completion or safety.

Acknowledgements

Disclosure of conflict of interest

None.

Address correspondence to: Dr. Yi Zhu, The second Clinical Medical School, Nanjing University of Chinese Medicine Road No. 138 Qixia District in Nanjing Xianlin Nanjing 210000, Jiangsu, China. Tel: 008615365132012; Fax: 008615365132012; E-mail: zhuyi1010@163.com

References

[1] Mathers C FDM, Boerma JT. The global burden of disease: 2004 update. World Health Organization, 2008.

[2] Allender S SP, Peto V, et al. European cardiovascular disease statistics. European Heart Network 2008; 3: 11-35.

[3] Heran BS, Chen JM, Ebrahim S, Moxham T, Oldridge N, Rees K, Thompson DR and Taylor RS. Exercise-based cardiac rehabilitation for coronary heart disease. Cochrane Database Syst Rev 2011; CD001800.

[4] World Health Organization U. Prevention of cardiovascular disease. World Health Organization 2007.

[5] Cornish AK, Broadbent S and Cheema BS. Interval training for patients with coronary artery disease: a systematic review. Eur J Appl Physiol 2011; 111: 579-589.

[6] Marzolini S, Oh PI and Brooks D. Effect of combined aerobic and resistance training versus aerobic training alone in individuals with coronary artery disease: a meta-analysis. Eur J Prev Cardiol 2012; 19: 81-94.

[7] Leon AS, Franklin BA, Costa F, Balady GJ, Berra KA, Stewart KJ, Thompson PD, Williams MA, Lauer MS; American Heart Association; Council on ClinicalCardiology (Subcommittee on Exercise, Cardiac Rehabilitation, and Prevention); Council on Nutrition, Physical Activity, and Metabolism (Subcommittee on Physical Activity); American association of Cardiovascular and Pulmonary Rehabilitation. Cardiac rehabilitation and secondary prevention of coronary heart disease: an American Heart Association scientific statement from the Council on Clinical Cardiology (Subcommittee on Exercise, Cardiac Rehabilitation, and Prevention) and the Council on Nutrition, Physical Activity, and Metabolism (Subcommittee on Physical Activity), in collaboration with the American association of Cardiovascular and Pulmonary Rehabilitation. Circulation 2005; 111: 369-376.

[8] Fletcher GF, Balady GJ, Amsterdam EA, Chaitman B, Eckel R, Fleg J, Froelicher VF, Leon AS, Pina IL, Rodney R, Simons-Morton DA, Williams MA and Bazzarre T. Exercise standards for testing and training: a statement for healthcare professionals from the American Heart Association. Circulation 2001; 104: 1694-1740.

[9] Pollock ML, Franklin BA, Balady GJ, Chaitman BL, Fleg JL, Fletcher B, Limacher M, Pina IL, Stein RA, Williams M and Bazzarre T. AHA Science Advisory. Resistance exercise in indi-

viduals with and without cardiovascular disease: benefits, rationale, safety, and prescription: An advisory from the Committee on Exercise, Rehabilitation, and Prevention, Council on Clinical Cardiology, American Heart Association; Position paper endorsed by the American College of Sports Medicine. Circulation 2000; 101: 828-833.

[10] Bjarnason-Wehrens B, Mayer-Berger W, Meister ER, Baum K, Hambrecht R, Gielen S, German Federation for Cardiovascular P and Rehabilitation. Recommendations for resistance exercise in cardiac rehabilitation. Recommendations of the German Federation for Cardiovascular Prevention and Rehabilitation. Eur J Cardiovasc Prev Rehabil 2004; 11: 352-361.

[11] Taylor RS, Brown A, Ebrahim S, Jolliffe J, Noorani H, Rees K, Skidmore B, Stone JA, Thompson DR and Oldridge N. Exercise-based rehabilitation for patients with coronary heart disease: systematic review and meta-analysis of randomized controlled trials. Am J Med 2004; 116: 682-692.

[12] Caruso FR, Arena R, Phillips SA, Bonjorno JC Jr, Mendes RG, Arakelian VM, Bassi D, Nogi C and Borghi-Silva A. Resistance exercise training improves heart rate variability and muscle performance: a randomized controlled trial in coronary artery disease patients. Eur J Phys Rehabil Med 2015; 51: 281-289.

[13] Ghroubi S, Elleuch W, Abid L, Abdenadher M, Kammoun S and Elleuch MH. Effects of a low-intensity dynamic-resistance training protocol using an isokinetic dynamometer on muscular strength and aerobic capacity after coronary artery bypass grafting. Ann Phys Rehabil Med 2013; 56: 85-101.

[14] Hansen D, Eijnde BO, Roelants M, Broekmans T, Rummens JL, Hensen K, Daniels A, Van Erum M, Bonne K, Reyckers I, Alders T, Berger J and Dendale P. Clinical benefits of the addition of lower extremity low-intensity resistance muscle training to early aerobic endurance training intervention in patients with coronary artery disease: a randomized controlled trial. J Rehabil Med 2011; 43: 800-807.

[15] Helgerud J, Karlsen T, Kim WY, Hoydal KL, Stoylen A, Pedersen H, Brix L, Ringgaard S, Kvaerness J and Hoff J. Interval and strength training in CAD patients. Int J Sports Med 2011; 32: 54-59.

[16] Guyatt GH, Oxman AD, Kunz R, Falck-Ytter Y, Vist GE, Liberati A and Schünemann HJ. Rating quality of evidence and strength of recommendations: Going from evidence to recommendations. BMJ 2008; 336: 1049.

[17] Guyatt GH, Oxman AD, Kunz R, Jaeschke R, Helfand M, Liberati A, Vist GE and Schüne-

mann HJ. Rating quality of evidence and strength of recommendations: Incorporating considerations of resources use into grading recommendations. BMJ 2008; 336: 1170.

[18] Guyatt GH, Oxman AD, Kunz R, Vist GE, Falck-Ytter Y and Schünemann HJ. What is "quality of evidence" and why is it important to clinicians? BMJ 2008; 336: 995-998.

[19] Jaeschke R, Guyatt GH, Dellinger P, Schünemann H, Levy MM, Kunz R, Norris S, Bion J; GRADE Working Group. Use of GRADE grid to reach decisions on clinical practice guidelines when consensus is elusive. BMJ 2008; 337: a744.

[20] Schünemann HJ, Oxman AD, Brozek J, Glasziou P, Jaeschke R, Vist GE, Williams JW, Kunz R, Craig J and Montori VM. Grading quality of evidence and strength of recommendations for diagnostic tests and strategies. BMJ 2008; 336: 1106-1110.

[21] Higgins JP and Green S. Cochrane handbook for systematic reviews of interventions. Wiley Online Library, 2008.

[22] Guyatt GH, Oxman AD, Vist GE, Kunz R, Falck-Ytter Y, Alonso-Coello P and Schünemann HJ. GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. BMJ 2008; 336: 924-926.

[23] Gayda M, Choquet D and Ahmaidi S. Effects of exercise training modality on skeletal muscle fatigue in men with coronary heart disease. J Electromyogr Kinesiol 2009; 19: e32-39.

[24] Santa-Clara H, Fernhall B, Baptista F, Mendes M and Bettencourt Sardinha L. Effect of a one-year combined exercise training program on body composition in men with coronary artery disease. Metabolism 2003; 52: 1413-1417.

[25] Santa-Clara H, Fernhall B, Mendes M and Sardinha LB. Effect of a 1 year combined aerobic- and weight-training exercise programme on aerobic capacity and ventilatory threshold in patients suffering from coronary artery disease. Eur J Appl Physiol 2002; 87: 568-575.

[26] Stewart KJ, McFarland LD, Weinhofer JJ, Cottrell E, Brown CS and Shapiro EP. Safety and efficacy of weight training soon after acute myocardial infarction. J Cardiopulm Rehabil 1998; 18: 37-44.

[27] Daub WD, Knapik GP and Black WR. Strength training early after myocardial infarction. J Cardiopulm Rehabil 1996; 16: 100-108.

[28] Maiorana AJ, Briffa TG, Goodman C and Hung J. A controlled trial of circuit weight training on aerobic capacity and myocardial oxygen demand in men after coronary artery bypass surgery. J Cardiopulm Rehabil 1997; 17: 239-247.

[29] Butler RM, Palmer G and Rogers FJ. Circuit weight training in early cardiac rehabilitation. J Am Osteopath Assoc 1992; 92: 77-89.

[30] Haennel RG, Quinney HA and Kappagoda CT. Effects of hydraulic circuit training following coronary artery bypass surgery. Med Sci Sports Exerc 1991; 23: 158-165.

[31] Kelemen MH, Stewart KJ, Gillilan RE, Ewart CK, Valenti SA, Manley JD and Kelemen MD. Circuit weight training in cardiac patients. J Am Coll Cardiol 1986; 7: 38-42.

[32] McCartney N, McKelvie RS, Haslam DR and Jones NL. Usefulness of weightlifting training in improving strength and maximal power output in coronary artery disease. Am J Cardiol 1991; 67: 939-945.

[33] Wosornu D, Bedford D and Ballantyne D. A comparison of the effects of strength and aerobic exercise training on exercise capacity and lipids after coronary artery bypass surgery. Eur Heart J 1996; 17: 854-863.

[34] Arthur HM, Gunn E, Thorpe KE, Ginis KM, Mataseje L, McCartney N and McKelvie RS. Effect of aerobic vs combined aerobic-strength training on 1-year, post-cardiac rehabilitation outcomes in women after a cardiac event. J Rehabil Med 2007; 39: 730-735.

[35] Marzolini S, Oh PI, Thomas SG and Goodman JM. Aerobic and resistance training in coronary disease: single versus multiple sets. Med Sci Sports Exerc 2008; 40: 1557-1564.

[36] Pierson LM, Herbert WG, Norton HJ, Kiebzak GM, Griffith P, Fedor JM, Ramp WK and Cook JW. Effects of combined aerobic and resistance training versus aerobic training alone in cardiac rehabilitation. J Cardiopulm Rehabil 2001; 21: 101-110.

[37] Vona M, Codeluppi GM, Iannino T, Ferrari E, Bogousslavsky J and von Segesser LK. Effects of different types of exercise training followed by detraining on endothelium-dependent dilation in patients with recent myocardial infarction. Circulation 2009; 119: 1601-1608.

[38] Wise FM and Patrick JM. Resistance exercise in cardiac rehabilitation. Clin Rehabil 2011; 25: 1059-1065.

[39] Gu XY, Li JA and Zhang Q. Effects and mechanism of isometric exercise training in patients with coronary artery disease. Chin J Rehabil Med 2003; 269-273.

[40] Coke LA, Staffileno BA, Braun LT and Gulanick M. Upper-body progressive resistance training improves strength and household physical activity performance in women attending cardiac rehabilitation. J Cardiopulm Rehabil Prev 2008; 28: 238-245; quiz 246-237.

[41] Moghadam BA, Bagheri H and Hadian MR. Effect of Strengthening Exercises on serum C-Reactive Protein after Coronary Artery Bypass Grafts. Iran J Public Health 2008; 93-100.

[42] Schmid JP, Anderegg M, Romanens M, Morger C, Noveanu M, Hellige G and Saner H. Combined endurance/resistance training early on, after a first myocardial infarction, does not induce negative left ventricular remodelling. Eur J Cardiovasc Prev Rehabil 2008; 15: 341-346.

[43] Ades PA, Savage PD, Brochu M, Tischler MD, Lee NM and Poehlman ET. Resistance training increases total daily energy expenditure in disabled older women with coronary heart disease. J Appl Physiol (1985) 2005; 98: 1280-1285.

[44] Hung C, Daub B, Black B, Welsh R, Quinney A and Haykowsky M. Exercise training improves overall physical fitness and quality of life in older women with coronary artery disease. Chest 2004; 126: 1026-1031.

[45] Ades PA, Savage P, Cress ME, Brochu M, Lee NM and Poehlman ET. Resistance training on physical performance in disabled older female cardiac patients. Med Sci Sports Exerc 2003; 35: 1265-1270.

[46] Brochu M, Savage P, Lee M, Dee J, Cress ME, Poehlman ET, Tischler M and Ades PA. Effects of resistance training on physical function in older disabled women with coronary heart disease. J Appl Physiol (1985) 2002; 92: 672-678.

Appendix I. Search strategies

Examples of search terms used in the CENTRAL databases:

1. coronary artery disease or coronary heart disease or coronary disease or coronary thrombosis or heart infarction or ischemia heart or myocardial infarction or myocardial ischemia or angina
2. coronary artery bypass graft or coronary angioplasty or coronary bypass or myocardial revascularization
3. CAD or CHD or MI or AMI or CABG or PTCA or PCI
4. (strength or power or weight or muscle strength or muscular or isometric strength or isotonic strength or isokinetic strength or resistance or resistant or progressive resistance or circuit or circuit weight) and (exercise or training or treatment or therapy)
5. randomized controlled trial or controlled clinical trial or randomized or clinical trials
6. (#1 or #2 or #3) and #4 and #5