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Review

Implementing resistance training in the rehabilitation of coronary heart disease: A systematic review and meta-analysis

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ABSTRACT

Background: Resistance training has demonstrated efficacy in cardiac rehabilitation programs, but the optimal prescription of resistance training is unknown. This systematic review with meta-analysis compared the effectiveness of cardiac rehabilitation consisting of resistance training either alone (RT) or in combination with aerobic training (CT) with aerobic training only (AT) on outcomes of physical function. Further, resistance training intensity and intervention duration were examined to identify if these factors moderate efficacy.
Methods: Six electronic databases were searched to identify studies investigating RT, coronary heart disease and physical function. The overall quality of evidence was assessed using the GRADE approach. Meta-analyses were performed when possible and qualitative analysis was performed for the remaining data.
Results: Improvements in peak oxygen uptake (WMD: 0.61, 95% CI: 0.20–1.10), peak work capacity (SMD: 0.38, 95% CI: 0.11–0.64) and muscular strength (SMD: 0.65, 95% CI: 0.43–0.87) significantly favoured CT over AT with moderate quality evidence. There was no evidence of a difference in effect when comparing RT and AT. Shorter duration CT was superior to shorter duration AT for improving peak oxygen uptake and muscular strength (low quality evidence) while longer duration CT was only superior to longer duration AT in improving muscular strength (moderate quality evidence).
Conclusions: CT is more beneficial than AT alone for improving physical function. Although preliminary findings are promising, more high-quality evidence is required to determine the efficacy of high intensity resistance training. Shorter duration interventions that include resistance training might allow patients to return to their normal activities of daily living earlier.

1. Introduction

Coronary heart disease (CHD) is a major cause of death and disability. In 2012, CHD was responsible for approximately 7.4 million deaths worldwide [1]. Cardiac rehabilitation is accepted as an essential component in the management of individuals with CHD and attending cardiac rehabilitation reduces the risk of all-cause mortality, cardiac mortality and re-infarction [2]. In addition, enhancing an individual's ability to return to activities of daily living (ADL), including domestic, occupational and recreational activities, has been identified as an important goal of cardiac rehabilitation to allow successful integration back into society [3–5]. Enhanced physical function in CHD patients, via increases in cardiorespiratory fitness and muscular strength, is required to improve the performance of ADL [6–8]. Consequently, it is important that cardiac rehabilitation programs foster improvements in both cardiorespiratory fitness and muscular strength. Furthermore, diminished levels of cardiorespiratory fitness and muscular strength have been associated with an increased risk of mortality [9,10].

Cardiac rehabilitation programs have traditionally been based on aerobic exercises, with resistance exercises only playing a subsidiary role [11]. While purposeful resistance exercises were originally assumed to be dangerous due to rapid increases in heart rate (HR) and arterial blood pressure [12], it has since been shown that resistance exercises can be safely performed in cardiac rehabilitation up to 90% of 1 repetition maximum (1RM) [13–15]. A previous meta-analysis reported that combining resistance and aerobic training significantly enhanced peak work capacity and muscular strength when compared to aerobic training [16]. Another meta-analysis by Yamamoto et al. [17] compared resistance training interventions (either alone or combination with aerobic training) to usual care or aerobic training alone in patients with CHD. Although these authors reported that resistance training/combined training enhanced peak oxygen uptake and muscular strength [17], intensity and duration were identified as moderating

Abbreviations: 1RM, 1 repetition maximum; 95% CI, 95% confidence interval; ADL, activities of daily living; AT, aerobic training alone; CHD, coronary heart disease; CT, combined training; RT, resistance training alone; SMD, standardised mean difference; WMD, weighted mean difference.

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factors that require future research [17]. Therefore, the dose of resistance training in cardiac rehabilitation including intensity and duration of the resistance component has not been systematically investigated and remains unknown.

The continual progression of purposeful resistance training, through alterations in frequency, time and intensity, can induce substantial improvements in muscular strength [18], which can lead to improvements in ADL [19] and decreased mortality risk [10]. In cardiac rehabilitation, resistance training has been recommended at a low–moderate intensity with 10 to 15 repetitions per exercise [20]. However, a dose–response relationship exists for resistance training intensity, where gains in muscular strength improve with greater resistance training intensity, even in people aged >65 years [21]. As approximately two-thirds of patients attending cardiac rehabilitation are older than 65 years [22,23], investigation into resistance training intensity during cardiac rehabilitation is warranted. If high intensity resistance training is prescribed in cardiac rehabilitation, greater increases in muscular strength might be elicited compared to resistance training prescribed at low or moderate intensities, with greater functional improvements obtained [19,21] and further reductions of mortality risk [10].

In addition to personal benefits, returning patients to work following a cardiac event is important due to the detrimental effect of lost productivity and wage replacement on a community's economy [24]. The median time taken to return to work after a cardiac event can be as long as 13 weeks [25,26]. As such, strategies that facilitate a speedier return to work for cardiac rehabilitation patients are important and could decrease some of the indirect costs associated with CHD [24]. Poor physical function has been identified as an important factor that delays return to work [27]. However, attendance at cardiac rehabilitation, which can increase physical function [28], is relatively poor, with approximately one third of eligible patients attending cardiac rehabilitation throughout the developed world [29–31]. One reason that is often cited for non-attendance at cardiac rehabilitation is a perceived lack of time [32,33]. Although different models exist for the delivery of cardiac rehabilitation, outpatient cardiac rehabilitation programs are generally 6 to 12 weeks in duration [3,34]. Therefore, shorter duration cardiac rehabilitation programs with the inclusion of resistance training might be warranted if they can reduce the time-burden on patients, leading to increased cardiac rehabilitation attendance.

Given that CHD remains a major burden worldwide [1], optimising the treatment of CHD is of importance. This systematic review with meta-analysis aimed to compare resistance training, prescribed alone (RT) or in combination with aerobic training (CT), to aerobic training alone (AT) on physical capacity. A further aim was to investigate how alterations in resistance training intensity and intervention duration moderated physical capacity outcomes in a CHD population.

2. Methods

2.1. Search strategy

Six electronic databases (PubMed, Medline, CINAHL, Scopus, Embase and Cochrane) were searched from the earliest available date to November 2016. Search terms were grouped into three constructs: ‘cardiac disease’, ‘resistance training’ and ‘functional capacity’. These constructs were searched individually and in combination using the ‘AND’ operation. Search terms for ‘cardiac disease’ were: heart disease(s), cardiac disease(s), coronary heart disease(s), coronary artery disease(s), angina, myocardial infarction, ischemic heart disease(s), cardiac revascularisation, cardiac revascularisation, myocardial ischemia, coronary artery bypass (surgery), ischemic artery disease(s), coronary infarction and coronary disease(s). Search terms for ‘resistance training’ were: resistance training, weight training, strength training, weight lifting, muscle strengthening, progressive resistance training, circuit training, exercise training, muscle contraction(s) and exercise therapy. Search terms for ‘functional capacity’ were: functional capacity, physical function, aerobic capacity, muscle strength, power, muscle power, muscle torque, $\dot{V}O_{2max}$, $\dot{V}O_{2peak}$, oxygen uptake, exercise capacity and exercise tolerance. One investigator (PX) reviewed studies by title and excluded inappropriate studies by the following exclusion criteria: 1) non-human participants or study not written in English; 2) not an original investigation; 3) not an adult population; 4) population had not experienced angina, myocardial infarction or acute coronary heart disease; 5) no prescribed exercise training; 6) insufficient RT prescription (i.e. RT not completed at least twice a week, number and/or names/descriptions of RT exercises not reported, intensity of RT exercises not reported, number of sets of RT exercises not reported, number of repetitions per set of RT exercises not reported); and 7) no functional outcome measures of cardiorespiratory fitness, muscular strength or muscular power. One investigator (PX) reviewed all studies by abstract while two investigators (BG and MK) reviewed half of the abstracts each. A unanimous decision was required between PX and BG/MK to exclude a study by abstract. Split decisions resulted in that study being reviewed by the final investigator (either BG or MK), whereby the majority decision resulted in that study being excluded or included. Full-text review was undertaken in the same manner as abstract review.

2.2. Data extraction

Data describing population characteristics, intervention duration and exercise prescription, control duration and exercise prescription, follow-up times and outcomes were extracted from included studies. Descriptive statistics from individual studies relating to change in: 1) cardiorespiratory fitness, as measured by $\dot{V}O_{2peak}$, exercise time or power output, and 2) muscular strength, as measured by 1RM or as peak isokinetic torque, were entered directly into Review Manager (RevMan, Version 5.3; The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark) for analysis. Required data were not able to be extracted from 3 studies. Where the required data were not published and authors were unable to be contacted, the means, standard deviations and participant numbers were obtained from a previously published meta-analysis [16] for inclusion in this meta-analysis.

2.3. Assessment of study quality

Assessment of study and outcome quality for each meta-analysis was completed according to the GRADE approach for systematic reviews [35]. Quality of evidence was assessed on a four-point scale including ‘high’, ‘moderate’, ‘low’ and ‘very low’ [35]. Quality of evidence for meta-analyses began at the high level and was downgraded to lower levels of evidence when risk of bias, inconsistency, indirectness, imprecision or publication bias were present.

2.4. Data analysis

This systematic review with meta-analyses aimed to assess the effectiveness of resistance training in individuals with CHD compared to aerobic training (AT). Studies including resistance training as an intervention were grouped into: 1) interventions that included resistance training in combination with aerobic training (CT); or 2) resistance training alone (RT). Both CT and RT alone were compared to AT alone for change in cardiorespiratory fitness ($\dot{V}O_{2peak}$ and peak work capacity) and change in muscular strength. In studies with more than one appropriate intervention group, the sample sizes, means and standard deviations were condensed into a single sample size, mean and standard deviation according to Higgins and Deeks [36]. To assess the influence of resistance training intensity on change in cardiorespiratory fitness and muscular strength, CT studies were stratified into high (≥70% 1RM or <12 repetitions per set) and low–moderate intensities (<70% 1RM or ≥12 repetitions per set) according to a previously published systematic review with meta-analysis [37]. Combined training studies were stratified into shorter duration (<12 weeks) and longer duration (≥12 weeks) interventions to assess the efficacy of different intervention lengths. An insufficient number of RT studies were identified to assess the effectiveness of resistance training intensity or intervention duration.

The weighted mean difference (WMD) with 95% confidence intervals (95% CI) was used to calculate effect size for change in $\dot{V}O_{2peak}$, while standardised mean differences (SMD) with 95% CI were used to calculate effect sizes for change in peak work capacity and muscular strength to account for differences in the measurement of these outcomes. Random effects models were used to create meta-analyses for these outcomes. Meta-analyses were completed for outcomes where appropriate levels of heterogeneity were detected. A non-significant chi-squared value assumed no significant heterogeneity between studies. Data in text are presented as mean ± standard deviation unless otherwise specified.

3. Results

3.1. Study selection

The literature search identified 3597 unique studies (Fig. 1). A total of 3443 studies were excluded after review of titles and abstracts,

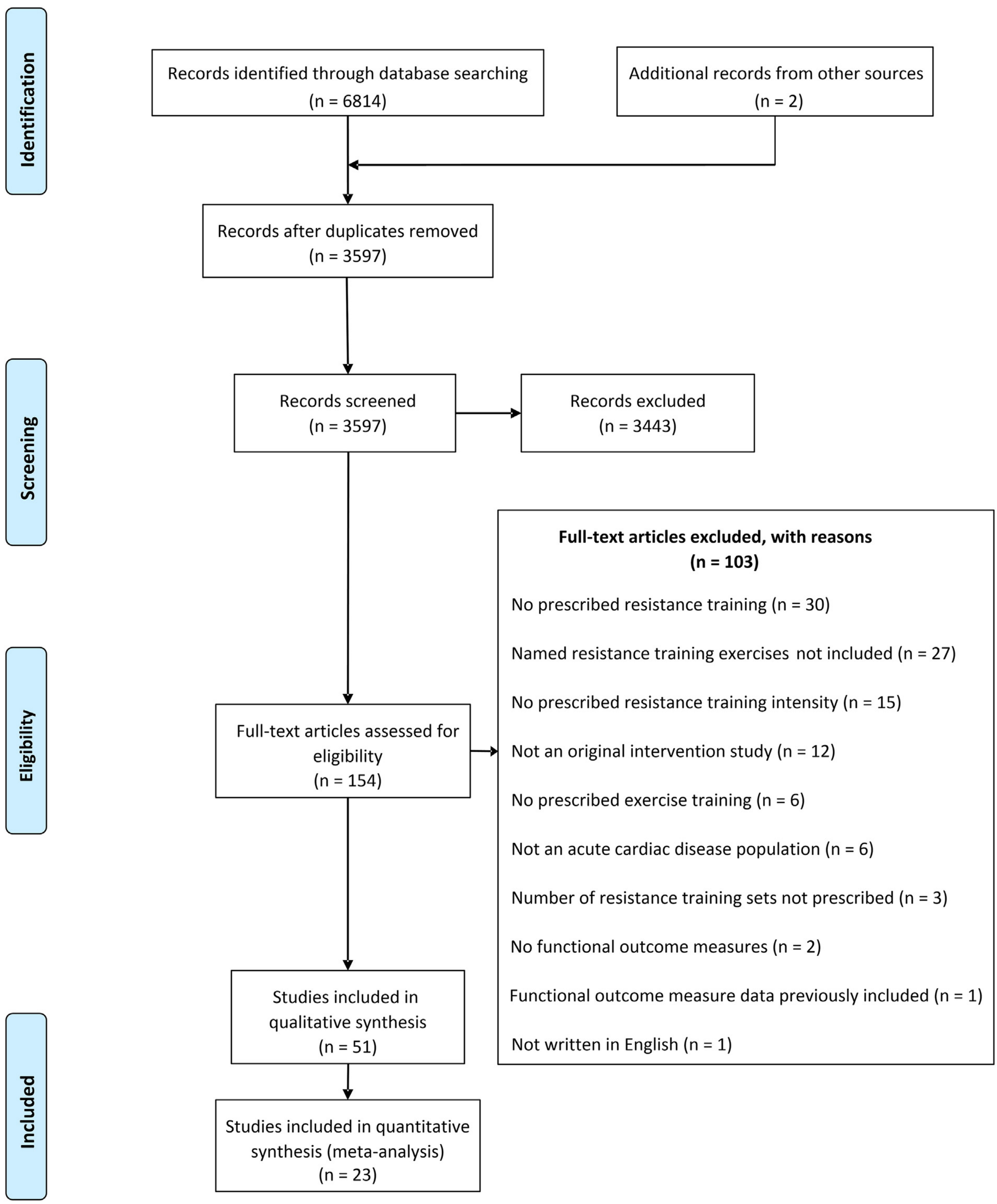

Fig. 1. Flow diagram of the systematic searches, record exclusions and included studies for qualitative and quantitative syntheses.

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leaving 154 studies for full-text review. A total of 103 studies were excluded during full-text review (Fig. 1). Two additional studies were included after inspection of reference lists from included studies. A total of 51 studies were included for review and analysis. Of the 51 included studies, only 23 included a CT or RT intervention with an AT control that investigated cardiorespiratory fitness or muscular strength. The remaining studies either included a no-exercise control group or did not include a control at all.

3.2. Combined training and resistance training alone versus aerobic training

The meta-analysis for CT versus AT for $\dot{V}O_{2peak}$ demonstrated a 'moderate' quality of evidence (Appendix A) with a significant effect in favour of CT (11 studies, 445 participants; WMD: 0.61, 95% CI: 0.20 to 1.01; Fig. 2). The meta-analysis for CT versus AT for peak work capacity demonstrated a 'moderate' quality of evidence (Appendix A) with a significant effect in favour of CT (11 studies, 422 participants; SMD: 0.31, 95% CI: 0.11 to 0.50; Fig. 3). For muscular strength, the meta-analysis for CT versus AT demonstrated a 'moderate' quality of evidence (Appendix A) with a significant effect in favour of CT (16 studies, 481 participants; SMD: 0.65, 95% CI: 0.43 to 0.87; Fig. 4).

The meta-analysis for RT versus AT for $\dot{V}O_{2peak}$ demonstrated a 'low' quality of evidence (Appendix B) with no evidence to suggest an effect in favour of either RT alone or AT (4 studies, 172 participants; WMD: −0.48, 95% CI: −2.33 to 1.38; Fig. 5). For muscular strength, the meta-analysis for RT versus AT demonstrated a 'very low' quality of evidence (Appendix B) with no evidence to suggest an effect in favour of either RT alone or AT (2 studies, 48 participants; SMD: 0.88, 95% CI: −0.86 to 2.62; Fig. 6).

One study compared CT vs RT [38]. $\dot{V}O_{2peak}$ increased by 4.5 ± 1.6 ml/kg/min in the CT group and increased by 3.5 ± 1.3 ml/kg/min in the RT group and significantly favoured CT (WMD: 1.00, 95% CI: 0.54 to 1.46). Peak work capacity, measured by exercise time, increased by 5.4 ± 2.6 min in the CT group and by 4.4 ± 2.3 min in the RT group and significantly favoured CT (WMD: 1.00, 95% CI: 0.07 to 1.93).

3.3. Influence of resistance training intensity

The meta-analysis for low–moderate intensity CT versus AT on $\dot{V}O_{2peak}$ demonstrated a 'moderate' quality of evidence (Appendix A) with a significant effect in favour of CT (10 studies, 373 participants; WMD: 0.79, 95% CI: 0.35 to 1.23; Fig. 2). A single study (72 participants) investigated high intensity CT versus AT for change in $\dot{V}O_{2peak}$, with no evidence to suggest an effect in favour of high intensity CT or AT (WMD: −0.50, 95% CI: −1.59 to 0.59; Fig. 2). The meta-analysis for low–moderate intensity CT versus AT on muscular strength demonstrated a 'moderate' quality of evidence (Appendix A) with a significant effect in favour of CT (15 studies, 447 participants; SMD: 0.58, 95% CI: 0.38 to 0.78; Fig. 4). A single study (34 participants) investigated high intensity CT versus AT for change in muscular strength, with a significant effect in favour of CT (SMD: 1.47, 95% CI: 0.70 to 2.24; Fig. 4).

There were four further high intensity CT studies [39–42] and seventeen low–moderate intensity CT studies [24,43–58] that investigated

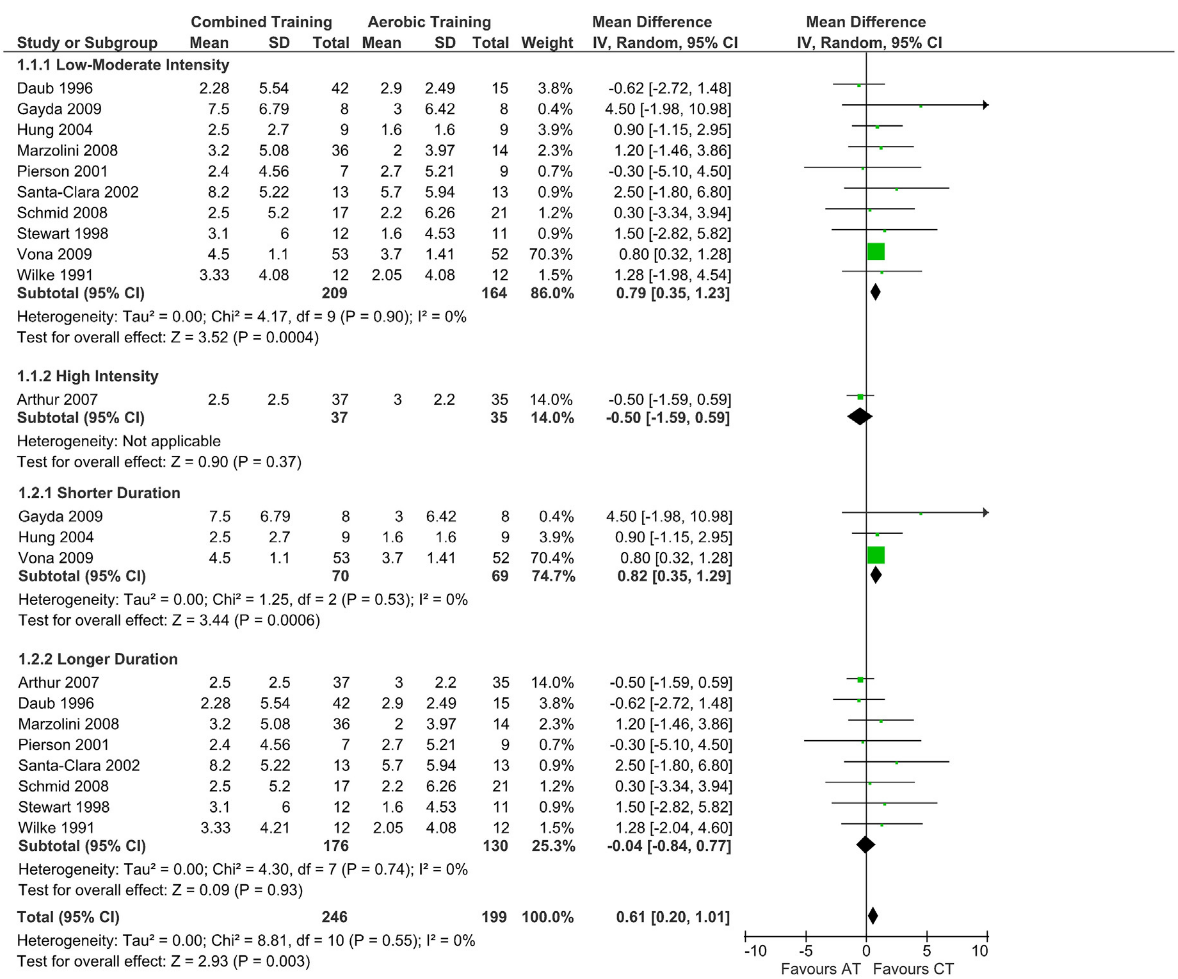

Fig. 2. Combined training versus aerobic training for change in $\dot{V}O_{2peak}$ stratified by: 1) low–moderate intensity CT and high intensity CT and 2) shorter duration intervention length and longer duration intervention length.

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Study or Subgroup	Combined Training Mean	SD	Total	Aerobic Training Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Beniamini 1999	2.3	3	18	1.2	2.8	16	8.4%	0.37 [-0.31, 1.05]
Butler 1992	101	85.83	9	114	91.24	10	4.7%	-0.14 [-1.04, 0.76]
Daub 1996	2.55	2.17	42	2.73	1.82	15	11.1%	-0.09 [-0.67, 0.50]
Ewart 1986	75	123.5	20	12	92.66	17	8.9%	0.56 [-0.10, 1.22]
Gayda 2009	54	38.92	8	26	32.06	8	3.7%	0.74 [-0.28, 1.77]
Hansen 2011	32	34.71	25	27	41.5	22	11.7%	0.13 [-0.44, 0.70]
Kelemen 1986	75	124	20	11	110.37	20	9.7%	0.53 [-0.10, 1.17]
McCartney 1991	150	118	10	25	46.3	8	3.6%	1.27 [0.23, 2.31]
Santa-Clara 2003	0.5	1.75	13	0.1	1.61	13	6.5%	0.23 [-0.54, 1.00]
Stewart 1998	74.8	118.63	12	53.9	104.44	11	5.7%	0.18 [-0.64, 1.00]
Vona 2009	5.4	2.6	53	4.6	2.8	52	26.1%	0.29 [-0.09, 0.68]
Total (95% CI)			**230**			**192**	**100.0%**	**0.31 [0.11, 0.50]**

Heterogeneity: Tau² = 0.00; Chi² = 8.22, df = 10 (P = 0.61); I² = 0%
Test for overall effect: Z = 3.05 (P = 0.002)

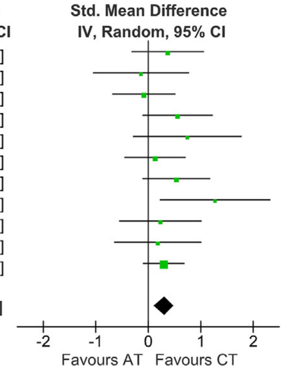

Fig. 3. Combined training versus aerobic training for change in peak work capacity.

the change in $\dot{V}O_{2peak}$ and/or muscular strength. The high intensity CT study that investigated the change in $\dot{V}O_{2peak}$ found a significant improvement [42], while another high intensity CT study reported a significant improvement in peak work capacity [41]. Similarly, nine low–moderate intensity CT studies that investigated $\dot{V}O_{2peak}$ found significant improvements [43,44,47,49–52,54,56], improvements in $\dot{V}O_{2peak}$ was approaching significance in one low–moderate CT study [24], another study found significant improvements in $\dot{V}O_{2peak}$ with CT combined with inspiratory muscle training but not with CT alone [58], while another three studies reported significant improvements in peak work capacity [45,46,53]. The mean improvement in $\dot{V}O_{2peak}$ for high intensity CT was 5.2 ± 6.4 ml/kg/min while the mean improvement for low–moderate intensity CT was 3.5 ± 5.1 ml/kg/min. All high intensity CT and low–moderate intensity CT studies that reported on muscular strength found significant improvements [39–41,43–45, 48,51,54–57].

Five further studies using high intensity RT [8,59–62] and two studies using low–moderate intensity RT [63,64] investigated the change in cardiorespiratory fitness and/or muscular strength. The four high intensity RT studies reported no significant change for $\dot{V}O_{2peak}$ with RT [8,59–61]; although, one of these studies was approaching significance ($p = 0.06$) for enhanced $\dot{V}O_{2peak}$ [8]. The low–moderate intensity RT study that reported $\dot{V}O_{2peak}$ found a significant decrease [63]. Two high intensity RT studies found significant increases in peak work capacity [8,62], while one low–moderate intensity RT study found no significant change in peak work capacity [63] and the other found a significant increase in peak work capacity [64]. All RT studies that investigated muscular strength reported significant increases [8,59–63].

3.4. Influence of intervention duration

The meta-analysis for shorter duration CT versus shorter duration AT for $\dot{V}O_{2peak}$ demonstrated a 'low' quality of evidence (Appendix A) with a significant effect in favour of shorter duration CT (3 studies, 139 participants; WMD: 0.82, 95% CI: 0.35 to 1.29; Fig. 2). The meta-analysis for longer duration CT versus longer duration AT for $\dot{V}O_{2peak}$ demonstrated a 'moderate' quality of evidence (Appendix A) with no evidence to suggest an effect in favour of either longer duration CT or longer duration AT (8 studies, 306 participants; WMD: −0.03, 95% CI: −0.84 to 0.77; Fig. 2). For muscular strength, the shorter duration CT versus shorter duration AT meta-analysis demonstrated a 'low' quality of evidence (Appendix A) with a significant effect in favour of shorter duration CT (7 studies, 196 participants; SMD: 0.76, 95% CI: 0.38 to 1.15; Fig. 4). The meta-analysis for longer duration CT versus longer duration AT for muscular strength demonstrated a 'moderate' quality of evidence (Appendix A) with a significant effect in favour of longer duration CT (9 studies, 285 participants; SMD: 0.56, 95% CI: 0.30 to 0.83; Fig. 4).

Five additional shorter duration CT studies [24,43,49–51] and eight further longer duration CT studies [42,44,47,48,52,54,56,58] investigated the change in $\dot{V}O_{2peak}$. When reported in ml/kg/min, $\dot{V}O_{2peak}$ was enhanced by 3.5 ± 4.5 ml/kg/min with shorter duration CT [43,49,50] and by 3.9 ± 5.6 ml/kg/min with longer duration CT [42,44,47,52,54, 56]. One other shorter duration CT study found an improvement in $\dot{V}O_{2peak}$ approaching significance ($p < 0.056$) [24] while the other found significant improvements of 146.0 ± 434.2 ml/min and 406.0 ± 456.9 ml/min respectively for low muscle volume and high muscle volume groups [51]. The other longer duration CT study reported improvements of 12% and 17% in $\dot{V}O_{2peak}$ respectively for older and younger groups [48]. Two further shorter duration CT studies [49,53] and six longer duration CT studies [42,45–47,52,56] investigated, and found significant improvements in, peak work capacity. Five further shorter duration CT studies [39,43,49–51] and nine longer duration CT studies [44–48,54–57] investigated the change in muscular strength, with all studies finding significant increases in muscular strength.

Two further shorter duration RT studies [61,63] and three longer duration RT studies [8,59,60] investigated the change in $\dot{V}O_{2peak}$. One shorter duration RT study found no change in $\dot{V}O_{2peak}$ [61] while the other found a significantly decreased $\dot{V}O_{2peak}$ [63]. The three longer duration RT studies found no change in $\dot{V}O_{2peak}$ [8,59,60]. A shorter duration RT study [62] and two longer duration RT studies [8,64] found significant increases in peak work capacity while another shorter duration RT study found no change [63]. Three further shorter duration RT [61–63] and longer duration RT [8,59,60] studies investigated and found significant increases in muscular strength.

3.5. Adverse and hemodynamic responses to exercises

Table 1 shows the reported cardiac and non-cardiac adverse responses or events to CT, RT, and AT for individual studies. 36 studies reported adverse events. 16 CT studies, four of which prescribed high intensity CT, reported no adverse responses or events to CT. One high intensity RT alone study reported no adverse responses or events with RT while one high intensity RT study reported no injury or muscle soreness with RT. Eight of the studies using AT reported no adverse responses or events with AT. Three studies reported adverse cardiac responses or events to CT and two studies reported non-cardiac adverse responses or events to CT. Three studies reported a cardiac adverse response or event to RT or muscular strength testing while six studies reported non-cardiac adverse responses or events to RT or muscular strength testing. Of the studies that utilised AT or cardiorespiratory fitness testing, six reported cardiac adverse responses or events while three reported non-cardiac adverse responses or events.

4. Discussion

The findings of these meta-analyses provide moderate quality of evidence to support the use of combined resistance training and aerobic training in cardiac rehabilitation programs to enhance improvements in $\dot{V}O_{2peak}$, peak work capacity and muscular strength. There was low and very low quality of evidence to demonstrate that resistance training

Study or Subgroup	Combined Training Mean	SD	Total	Aerobic Training Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
1.4.1 Low-Moderate Intensity								
Butler 1992	19.63	11.41	9	11.75	22.56	10	4.8%	0.41 [-0.50, 1.33]
Caruso 2015	44.3	56.19	10	-14.7	43.2	10	4.5%	1.13 [0.17, 2.09]
Daub 1996	5.04	12.24	42	-0.3	9.58	15	9.3%	0.45 [-0.14, 1.05]
Ewart 1986	20	11.7	20	8	9.51	17	7.4%	1.09 [0.39, 1.79]
Gayda 2009	29	49.16	8	6	50.8	8	4.2%	0.44 [-0.56, 1.43]
Hansen 2011	12	37	25	10	47	22	9.8%	0.05 [-0.53, 0.62]
Hung 2004	7	8.51	9	0	10	9	4.4%	0.72 [-0.24, 1.68]
Kelemen 1986	30.5	19.81	20	8	16.03	20	7.7%	1.22 [0.54, 1.90]
Marzolini 2008	16.15	30.53	36	6.1	27.18	14	8.8%	0.33 [-0.29, 0.95]
McCartney 1991	7.1	6.5	10	1.5	5.37	8	4.3%	0.88 [-0.10, 1.87]
Pierson 2001	64.5	44.93	7	26.6	49.35	8	3.7%	0.75 [-0.31, 1.81]
Schmid 2008	10.4	42.71	17	5.6	44.27	21	8.4%	0.11 [-0.53, 0.75]
Stewart 1988	16	12.17	17	6	9.06	8	5.2%	0.85 [-0.02, 1.73]
Stewart 1998	45.4	31.83	12	20.9	33.04	11	5.4%	0.73 [-0.12, 1.58]
Wilke 1991	26.4	30.1	12	14.2	26.2	12	5.9%	0.42 [-0.39, 1.23]
Subtotal (95% CI)			**254**			**193**	**93.6%**	**0.58 [0.38, 0.78]**
Heterogeneity: Tau² = 0.00; Chi² = 14.34, df = 14 (P = 0.42); I² = 2%								
Test for overall effect: Z = 5.63 (P < 0.00001)								
1.4.2 High Intensity								
Beniamini 1999	35	24.74	18	4	14.51	16	6.4%	1.47 [0.70, 2.24]
Subtotal (95% CI)			**18**			**16**	**6.4%**	**1.47 [0.70, 2.24]**
Heterogeneity: Not applicable								
Test for overall effect: Z = 3.75 (P = 0.0002)								
1.5.1 Shorter Duration								
Caruso 2015	44.3	56.19	10	-14.7	43.2	10	4.5%	1.13 [0.17, 2.09]
Ewart 1986	20	11.7	20	8	9.51	17	7.4%	1.09 [0.39, 1.79]
Gayda 2009	29	49.16	8	6	50.8	8	4.2%	0.44 [-0.56, 1.43]
Hansen 2011	12	37	25	10	47	22	9.8%	0.05 [-0.53, 0.62]
Hung 2004	7	8.51	9	0	10	9	4.4%	0.72 [-0.24, 1.68]
Kelemen 1986	30.5	19.81	20	8	16.03	20	7.7%	1.22 [0.54, 1.90]
McCartney 1991	7.1	6.5	10	1.5	5.37	8	4.3%	0.88 [-0.10, 1.87]
Subtotal (95% CI)			**102**			**94**	**42.2%**	**0.76 [0.38, 1.15]**
Heterogeneity: Tau² = 0.10; Chi² = 9.60, df = 6 (P = 0.14); I² = 38%								
Test for overall effect: Z = 3.90 (P < 0.0001)								
1.5.2 Longer Duration								
Beniamini 1999	35	24.74	18	4	14.51	16	6.4%	1.47 [0.70, 2.24]
Butler 1992	19.63	11.41	9	11.75	22.56	10	4.8%	0.41 [-0.50, 1.33]
Daub 1996	5.04	12.24	42	-0.3	9.58	15	9.3%	0.45 [-0.14, 1.05]
Marzolini 2008	16.15	30.53	36	6.1	27.18	14	8.8%	0.33 [-0.29, 0.95]
Pierson 2001	64.5	44.93	7	26.6	49.35	8	3.7%	0.75 [-0.31, 1.81]
Schmid 2008	10.4	42.71	17	5.6	44.27	21	8.4%	0.11 [-0.53, 0.75]
Stewart 1988	16	12.17	17	6	9.06	8	5.2%	0.85 [-0.02, 1.73]
Stewart 1998	45.4	31.83	12	20.9	33.04	11	5.4%	0.73 [-0.12, 1.58]
Wilke 1991	26.4	30.1	12	14.2	26.2	12	5.9%	0.42 [-0.39, 1.23]
Subtotal (95% CI)			**170**			**115**	**57.8%**	**0.56 [0.30, 0.83]**
Heterogeneity: Tau² = 0.02; Chi² = 8.86, df = 8 (P = 0.35); I² = 10%								
Test for overall effect: Z = 4.14 (P < 0.0001)								
Total (95% CI)			**272**			**209**	**100.0%**	**0.65 [0.43, 0.87]**
Heterogeneity: Tau² = 0.04; Chi² = 19.24, df = 15 (P = 0.20); I² = 22%								
Test for overall effect: Z = 5.77 (P < 0.00001)								
Test for subgroup differences: Chi² = 0.71, df = 1 (P = 0.40), I² = 0%								

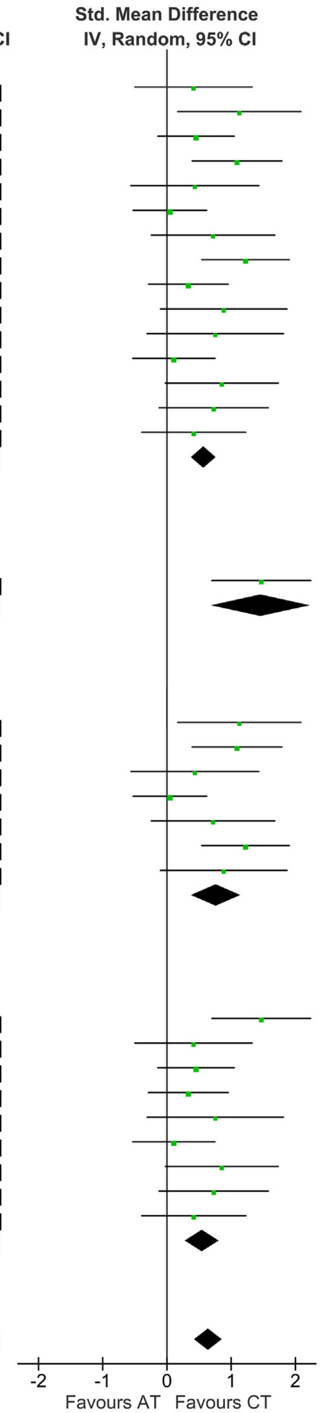

Fig. 4. Combined training versus aerobic training for change in muscular strength stratified by: 1) low–moderate intensity CT and high intensity CT and 2) shorter duration intervention length and longer duration length.

Study or Subgroup	Resistance Training alone Mean	SD	Total	Aerobic Training Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Ghroubi 2013	4	5.52	16	1.7	4	16	19.5%	2.30 [-1.04, 5.64]
Haennel 1991	2.4	3.26	8	4.3	4.53	8	16.1%	-1.90 [-5.77, 1.97]
Helgerud 2011	0.7	4.73	10	4.6	4.76	8	13.3%	-3.90 [-8.31, 0.51]
Vona 2009	3.5	1.3	54	3.7	1.41	52	51.2%	-0.20 [-0.72, 0.32]
Total (95% CI)			**88**			**84**	**100.0%**	**-0.48 [-2.33, 1.38]**
Heterogeneity: Tau² = 1.68; Chi² = 5.59, df = 3 (P = 0.13); I² = 46%								
Test for overall effect: Z = 0.50 (P = 0.62)								

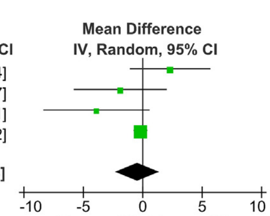

Fig. 5. Resistance training alone versus aerobic training for change in $\dot{V}O_{2peak}$.

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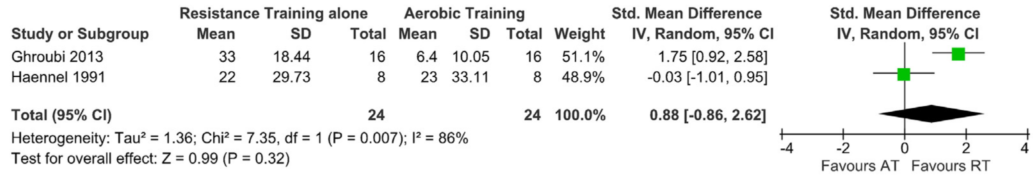

Fig. 6. Resistance training alone versus aerobic training for change in muscular strength.

alone was similar to aerobic training alone for improving $\dot{V}O_{2peak}$ and muscular strength. There was very low quality of evidence regarding high intensity combined training; however, qualitative synthesis of low–moderate and high intensity studies indicated that both low–moderate and high intensity resistance training enhance improvements in $\dot{V}O_{2peak}$, peak work capacity and muscular strength. Duration-stratified meta-analyses provide low quality of evidence, and qualitative synthesis suggests that shorter duration interventions involving resistance training can improve cardiorespiratory fitness and muscular strength.

Adverse events were reported during CT, RT and AT (Table 1). There was no evidence to suggest that resistance training or high intensity resistance training increased the number of reported adverse events when compared with aerobic exercise. Therefore, these findings suggest that resistance training or combined resistance and aerobic training pose a similar risk of adverse events as aerobic training alone.

Based on current meta-analyses, improvements in $\dot{V}O_{2peak}$, peak work capacity and muscular strength were significantly greater with CT when compared with AT. These findings extend a previous meta-analysis, which reported improvements in lower body strength, upper body strength and peak work capacity that significantly favoured CT compared to AT [16]. The current meta-analyses included an additional two studies for $\dot{V}O_{2peak}$ [65,66], eight studies for peak work capacity [13, 38,67–72] and seven studies for muscular strength [14,66,67,69–71,73], which were not included in the previous meta-analysis [16]. The current results also support previous findings from Yamamoto et al. [17] who reported that CT/RT significantly enhanced $\dot{V}O_{2peak}$, peak work capacity and muscular strength compared to AT/usual care controls [17]. However, findings from the current meta-analysis, which analysed CT and RT interventions separately, suggest that improvements in $\dot{V}O_{2peak}$ result from CT rather than RT interventions. In contrast, a meta-analysis of patients with heart failure showed no differences in $\dot{V}O_{2peak}$ improvements between CT and AT interventions [74]. It is possible that reduced ejection fraction and lower initial exercise capacity might diminish the supplementary benefits of RT when combined with AT in patients with heart failure. The downgrading of evidence from high to moderate in the current meta-analyses was primarily due to a lack of sufficient methodological detail around blinding participants and personnel involved in the studies, leading to an unclear risk of bias for most studies. Nevertheless, given the difficulty and practicality of blinding participants and personnel in exercise-based studies, the moderate level of evidence still provides robust data that support the efficacy of combined resistance training with aerobic training on cardiorespiratory fitness and muscular strength in patients with CHD.

The improvements in cardiorespiratory fitness identified in the current meta-analyses and qualitatively synthesised studies support including purposeful resistance training with aerobic training to enhance the response to aerobic conditioning. As well as improving ADL [6,7] and mortality risk [9], improvements in cardiorespiratory fitness are correlated with enhanced self-efficacy and associated with greater exercise participation following a structured exercise program in older adults [75,76]. As such, the inclusion of resistance training to aerobic training might promote healthy long-term exercise maintenance via improvements in cardiorespiratory fitness and self-efficacy more than aerobic training alone. The results also supported including purposeful resistance training with aerobic training to enhance muscular strength. Improvements in muscular strength from the addition of resistance training to aerobic training could decrease mortality risk [10], improve the capacity of these individuals to complete ADL [19] and thus lead to an increased quality of life [77].

It might be expected that AT would improve $\dot{V}O_{2peak}$ more than RT alone while RT alone might be expected to improve muscular strength more than AT. However, findings from the current meta-analyses provided low level evidence that there was no effect in favour of RT alone or AT alone for improvement in $\dot{V}O_{2peak}$ and very low level evidence that there was no effect in favour of RT alone or AT alone for improvement in muscular strength. Level of evidence was downgraded in these meta-analyses due to risk of bias, imprecision, and inconsistency. It is likely that the imprecision, due to an inadequate sample size, and inconsistency, due to significant heterogeneity, result from a lack of studies that investigate RT alone versus AT alone. Increased muscle mass and muscular strength via adaptations to resistance training can increase an individual's capacity to generate force and complete work [78]. Improvements in $\dot{V}O_{2peak}$ after RT might reflect a combination of peripheral and central adaptations to this mode of training, whereby RT can cause muscular adaptations that lessen the peripheral limitations to exercise performance and, consequently, increase $\dot{V}O_{2peak}$ recorded during progressive exercise testing. Additionally, resistance training can provide stress to the body's cardiovascular system [79]. However, whether the stress on the cardiovascular system during the RT interventions resulted in cardiorespiratory adaptations, thus leading to improvements in $\dot{V}O_{2peak}$ and the results of this meta-analysis, is unknown. More studies investigating RT versus AT alone are required to provide higher quality evidence to provide more robust evidence to the efficacy of RT alone versus AT for improvement in physical capacity.

A direct comparison between CT and RT was only available for a single study [38]. Although both interventions improved $\dot{V}O_{2peak}$ and peak work capacity, the improvements were significantly larger in CT when compared to RT [38]. More studies investigating RT alone versus CT are required to confirm that these findings are transferable to wider populations.

There is a dearth of studies that evaluate the effects of high intensity resistance training on physical function; therefore, it is difficult to determine the effects of resistance intensity within the meta-analyses. Consistent improvements in cardiorespiratory fitness were found among qualitatively synthesised studies using a low–moderate intensity CT intervention [43–47,49–54,56] or high intensity CT intervention [41,42]. High intensity RT studies found no change in $\dot{V}O_{2peak}$ [8,59–61] while the study using low–moderate intensity RT reported a significant decrease in $\dot{V}O_{2peak}$ [63]. Furthermore, high intensity RT studies found significantly improved peak work capacity [8,62], while no change in peak work capacity was found in one low–moderate RT study [63] and the other low–moderate intensity RT study found significantly improved peak work capacity [64]. Although the level of evidence is not strong, these data suggest that high intensity RT is more beneficial than low–moderate intensity RT to improve cardiorespiratory fitness. This might be due to the dose–response relationship between resistance training intensity and improvement in muscular strength [21] and the aforementioned discussion on how increased force generating capacity might improve performance during a graded exercise test. Alternatively, it is possible that higher intensity RT elicits enhanced peripheral and/or central training effects that result in improved cardiorespiratory responses to exercise.

The small number of studies in the intensity-stratified meta-analysis for muscular strength made it difficult to determine the effect of high

Table 1
Characteristics of the included studies.

Study	Participants	Interventions	Intervention duration	Outcome	Change (post–pre)	Adverse events
Adams [39]	MI; CABS; PCI; angina; cardiomyopathy $n = 61$ Mean age (low): 64 ± 10 years Mean age (medium): 57 ± 12 years Mean age (high): 61 ± 9 years	1) CT (high intensity) — low risk; $n = 24$ 2) CT (high intensity) — medium risk; $n = 19$ 3) CT (high intensity) — high risk; $n = 18$	8 weeks	Leg ext. 1RM	CT (low): +10.0 ± 19.7 kg CT (med): +8.0 ± 16.2 kg CT (high): +8.2 ± 21.6 kg	No adverse events
Ades [8]	CHD (MI; CABS; PCI; angina) $n = 33$ Mean age: 72 ± 6 years	1) RT (high intensity); $n = 19$ 2) Flexibility; $n = 14$	6 months	$\dot{V}O_{2peak}$ 6MWD Leg ext. 1RM	RT: +1.0 ± 3.5 ml/kg/min FLEX: not reported RT: +52.1 ± 116.1 m FLEX: not reported RT: +12.0 ± 22.6 kg FLEX: not reported	Not reported
Ades [59]	CHD (MI; CABS; PCI; angina) $n = 42$ Mean age (RT): 73 ± 6 years Mean age (FLEX): 72 ± 6 years	1) RT (high intensity); $n = 21$ 2) Flexibility; $n = 21$	6 months	$\dot{V}O_{2peak}$ Leg ext. 1RM	RT: +0.9 ± 3.6 ml/kg/min FLEX: +0.3 ± 3.0 ml/kg/min RT: +24.0 ± 10.3 kg FLEX: +3.5 ± 13.5 kg	Not reported
Arthur [85]	MI; CABS $n = 82$ Mean age: not reported	1) CT (high intensity); $n = 40$ 2) AT; $n = 42$	6 months	$\dot{V}O_{2peak}$	Required data not reported	Not reported
Back [41]	CHD (CA stenosis; angina) $n = 37$ Median age (CT): 62 years Median age (standard CR): 64 years	1) CT (high intensity); $n = 21$ before training, $n = 18$ after training 2) Standard CR; $n = 15$ before CR, $n = 16$ after CR	8 months	GXT peak power	CT: significant improvement CR: no change	No serious adverse events
Beniamini [80]	MI; CABS, PCI; angina $n = 34$ Mean age (CT): 58 ± 12 years Mean age (AT): 59 ± 12 years	1) CT (high intensity); $n = 18$ 2) AT; $n = 16$	12 weeks	GXT time Knee ext. 1RM	CT: +2.3 ± 3.0 min AT: +1.2 ± 2.8 min CT: +35.0 ± 24.7 kg AT: +4.0 ± 14.5 kg	Exacerbation of pre-existing arthritic knee pain (AT, $n = 1$) No signs or symptoms of cardiac ischemia or arrhythmia.
Brochu [60]	CHD (MI; CABS; angina) $n = 25$ Mean age: 71 ± 5 years Mean age (RT): 71 ± 4 years Mean age (FLEX): 71 ± 5 years	1) RT (high intensity); $n = 13$ 2) Flexibility; $n = 12$	6 months	$\dot{V}O_{2peak}$ 6MWD Leg ext. 1RM	RT: +1.3 ± 3.2 ml/kg/min FLEX: 0.0 ± 3.0 ml/kg/min RT: +58.0 ± 105.7 m FLEX: +28.0 ± 88.3 m RT: +6.7 ± 4.4 kg FLEX: +1.8 ± 6.3 kg	Anginal symptoms during GXT (RT, $n = 4$; FLEX, $n = 2$) Exacerbation of arthritic conditions (RT, $n = 2$) Dizziness in supine position (RT, $n = 1$)
Butler [67]	MI; CABS; PCI $n = 21$ Mean age (CT): 51 ± 7 years Mean age (AT): 53 ± 7 years	1) CT (low–mod intensity); $n = 9$ 2) AT; $n = 10$	12 weeks	GXT time Mean 8 UB 1RM	CT: +1.7 ± 1.4 min AT: +1.9 ± 1.5 min CT: +8.9 ± 5.2 kg AT: +5.3 ± 10.2 kg	Recurrent chest pain (CT, $n = 1$)
Caruso [86]	CHD $n = 20$ Mean age (CT): 61 ± 5 years Mean age (AT): 61 ± 4 years	1) CT (low–mod intensity); $n = 10$ 2) AT; $n = 10$	8 weeks	Leg press 1RM	CT: +44.3 ± 56.2 kg AT: −14.7 ± 43.2 kg	Joint pain during 1RM assessment ($n = 1$) Joint pain during exercise training (CT, $n = 1$; AT, $n = 1$) No other abnormalities
Chludilova [47]	CABS $n = 10$ Mean age: 64 ± 7 years	CT (low–mod intensity); $n = 10$	12 weeks	$\dot{V}O_{2peak}$ GXT peak power Leg ext. 1RM	CT: +3.8 ± 4.8 ml/kg/min CT: +34.0 ± 28.2 W CT: +6.0 ± 9.0 kg	Not reported
Coke [57]	MI; CABS; PCI; angina $n = 32$ Mean age (CT): 64 ± 11 years Mean age (UC): 65 ± 10 years	1) CT (low–mod intensity); $n = 16$ 2) Usual care; $n = 16$	12 weeks	Chest press 1RM	CT: +1.0 ± 1.9 kg UC: +0.4 ± 1.3 kg	Not reported
Crozier Ghilarducci [40]	CHD (MI; CABS; angina) $n = 10$ Mean age: 57 years	CT (high intensity); $n = 10$	10 weeks	Leg ext. 1RM	CT: +14.0 ± 7.0 kg	No ischemic ST-segment changes or arrhythmias during 1RM testing. No ischemia symptoms or abnormal HR or BP responses during exercise

Currie [42]	CHD (MI; CABS; PCI; angiographically documented stenosis >50% in at least 1 major CA; positive stress test with chest discomfort and >1 mm ST-segment depression) n = 19 Mean age (MICT): 66 ± 8 years Mean age (HIIT): 63 ± 8 years	1) CT (high intensity) – MICT; n = 10 2) CT (high intensity) – HIIT; n = 9	6 months	$\dot{V}O_{2peak}$ GXT peak power	MICT: +4.4 ± 7.6 ml/kg/min HIIT: +6.1 ± 4.8 ml/kg/min MICT: +30.0 ± 54.7 W HIIT: +49.0 ± 59.2 W	Not reported
Daub [68]	MI n = 57 Mean age (CT-20): 49 ± 9 years Mean age (CT-40): 47 ± 7 years Mean age (CT-60): 51 ± 7 years Mean age (AT): 50 ± 7 years	1) CT (low–mod intensity) – 20% 1RM; n = 14 2) CT (low–mod intensity) – 40% 1RM; n = 13 3) CT (low–mod intensity) – 60% 1RM; n = 15 4) AT; n = 15	12 weeks	$\dot{V}O_{2peak}$ GXT time Chest press 1RM	CT (20): +3.7 ± 7.3 ml/kg/min CT (40): +2.0 ± 5.1 ml/kg/min CT (60): +1.2 ± 3.5 ml/kg/min AT: +2.9 ± 2.5 ml/kg/min CT (20): +3.3 ± 2.4 min CT (40): +2.5 ± 2.2 min CT (60): +1.9 ± 1.7 min AT: +2.7 ± 1.8 min CT (20): +3.5 ± 11.8 kg CT (40): +6.4 ± 13.6 kg CT (60): +5.3 ± 11.7 kg AT: −0.3 ± 9.6 kg	Resistance exercise: Arrhythmias (n = 1) Aerobic exercise: ST depression (n = 25) Angina (n = 12) Arrhythmias (n = 3) Hypertension (n = 3) Hypotension (n = 2)
Ewart [69]	MI; CABS; angina n = 40 Mean age: 55 ± 9 years	1) CT (low–mod intensity); n = 20 2) AT; n = 20	10 weeks	Mean 2 LB 1RM	CT: +9.1 ± 5.3 kg AT: +3.6 ± 4.3 kg	No adverse events
Fragnoli-Munn [48]	MI; PTCA (PCI) n = 45 Mean age (older): 68 ± 3 years Mean age (younger): 48 ± 7 years	1) CT (low–mod intensity) – older; n = 19 2) CT (low–mod intensity) – younger; n = 26	12 weeks	$\dot{V}O_{2peak}$ Leg ext. 1RM	OLD: 12% increase YOU: 17% increase OLD: +10.0 ± 15.0 kg YOU: +17.0 ± 16.1 kg	Low-grade muscle soreness during strength training.
Gayda [70]	MI; PCI; CABS; myocardial ischemia n = 16 Mean age: 55 ± 8 years	1) CT (low–mod intensity); n = 8 2) AT; n = 8	7 weeks	$\dot{V}O_{2peak}$ GXT peak power Quadriceps MVC	CT: +7.5 ± 6.9 ml/kg/min AT: +3.0 ± 6.4 ml/kg/min CT: +54.0 ± 38.9 W AT: +26.0 ± 32.1 W CT: +29.0 ± 49.2 Nm AT: +6.0 ± 50.8 Nm	Not reported
Ghroubi [87]	CABS n = 32 Mean age (RT): 59 ± 2 years Mean age (AT): 59 ± 6 years	1) RT (low–mod intensity); n = 16 2) AT; n = 16	8 weeks	$\dot{V}O_{2peak}$ Quadriceps PT	RT: +4.0 ± 5.5 ml/kg/min AT: +1.7 ± 4.0 ml/kg/min RT: +42.0 ± 16.5 Nm AT: +6.8 ± 13.8 Nm	Knee pain (AT, n = 5; RT, n = 3) ST-segment depression (AT, n = 2)
Gremeaux [49]	PCI n = 14 Mean age (CON): 45 ± 5 years Mean age (ECC): 53 ± 1 years	1) CT (low–mod intensity) – CON cycling; n = 7 2) CT (low–mod intensity) – ECC cycling; n = 7	5 weeks	$\dot{V}O_{2peak}$ GXT peak power Knee ext. MVC	CON: +1.2 ± 5.5 ml/kg/min ECC: +3.5 ± 3.0 ml/kg/min CON: +40.0 ± 32.1 W ECC: +24.3 ± 7.1 W CON: +86.1 ± 156.5 N ECC: +52.6 ± 126.6 N	No adverse events
Haennel [88]	CABS n = 24 Mean age (RT): 51 ± 6 years Mean age (AT): 52 ± 11 years Mean age (NE): 57 ± 4 years	1) RT (low–mod intensity); n = 8 2) AT; n = 8 3) no exercise; n = 8	8 weeks	$\dot{V}O_{2peak}$ Knee ext. PT	RT: +2.4 ± 3.3 ml/kg/min AT: +4.3 ± 4.5 ml/kg/min NE: +0.7 ± 3.1 ml/kg/min RT: +22.0 ± 29.7 Nm AT: +23.0 ± 33.1 Nm NE: +2.0 ± 10.0 Nm	Not reported
Hansen [71]	MI; angina n = 47 Mean age (CT): 60 ± 9 years Mean age (AT): 59 ± 7 years	1) CT (low–mod intensity); n = 22 2) AT; n = 25	7 weeks	GXT peak power Knee ext. PT	CT: +32.0 ± 34.7 W AT: +27.0 ± 41.5 W CT: +12.0 ± 37.0 Nm AT: +10.0 ± 47.0 Nm	Not reported
Helgerud [15]	MI; CABS; PCI n = 18 Mean age (CT): 65.0 ± 5.5 years Mean age (AT): 61.4 ± 3.7 years	1) RT (high intensity); n = 10 2) AT; n = 8	8 weeks	$\dot{V}O_{2peak}$	RT: +0.7 ± 4.7 ml/kg/min AT: +4.6 ± 4.8 ml/kg/min	Not reported
Hermes [58]	CABS n = 24	1) CT + IMT (low–mod intensity); n = 12	12 weeks	$\dot{V}O_{2peak}$	CT + IMT: significant improvement CT: no change	No adverse events

(continued on next page)

Table 1 (*continued*)

Study	Participants	Interventions	Intervention duration	Outcome	Change (post–pre)	Adverse events
	Mean age (CT + IMT): 55 ± 8 years Mean age (CT): 60 ± 9 years	2) CT (low–mod intensity); *n* = 12				
Hung [89]	MI *n* = 18 Mean age (CT): 71 ± 7 years Mean age (AT): 70 ± 6 years	1) CT (low–mod intensity); *n* = 9 2) AT; *n* = 9	8 weeks	$\dot{V}O_{2peak}$ Chest press 1RM	Required data not reported CT: +7.0 ± 8.5 kg AT: 0.0 ± 10.0 kg	Not reported
Izawa [43]	MI *n* = 124 Mean age (CT): 62 ± 12 years Mean age (NE): 62 ± 10 years	1) CT (low–mod intensity); *n* = 82 2) no exercise; *n* = 42	8 weeks	$\dot{V}O_{2peak}$ Knee ext. PT	CT: +5.4 ± 4.0 ml/kg/min NE: +0.8 ± 3.9 ml/kg/min CT: +0.4 ± 0.4 Nm/kg NE: +0.1 ± 0.4 Nm/kg	No adverse events
Izawa [50]	MI; CABS; valve replacement *n* = 442 Mean age (YOU): 55 ± 7 years Mean age (OLD): 71 ± 4 years	1) CT (low–mod intensity) – younger; *n* = 242 2) CT (low–mod intensity) – older; *n* = 200	8 weeks	$\dot{V}O_{2peak}$ Knee ext. PT	YOU: +3.2 ± 5.2 ml/kg/min OLD: +1.9 ± 4.9 ml/kg/min YOU: +0.3 ± 0.4 Nm/kg OLD: +0.2 ± 0.4 Nm/kg	No adverse events
Karlsen [61]	CHD (MI; CABS; PCI) *n* = 17 Mean age (RT): 67 ± 6 years Mean age (NE): 62 ± 3 years	1) RT (high intensity); *n* = 10 2) no exercise; *n* = 7	8 weeks	$\dot{V}O_{2peak}$ Leg press 1RM	RT: +0.7 ± 4.7 ml/kg/min NE: +0.6 ± 1.9 ml/kg/min RT: +60.0 ± 24.0 kg NE: −1.0 ± 65.7 kg	No adverse events
Kelemen [90]	CHD (MI; CABS; angina) *n* = 40 Mean age: 55 ± 8.5 years	1) CT (low–mod intensity); *n* = 20 2) AT; *n* = 20	10 weeks	GXT time Leg ext. 1RM	CT: +1.3 ± 2.1 min AT: +0.2 ± 1.8 min CT: +30.5 ± 19.8 kg AT: +8.0 ± 16.0 kg	Ventricular bigeminy – resistance and aerobic exercise (CT, *n* = 4) Isolated PVC – resistance and aerobic exercise (CT, *n* = 4) Symptomatic hypotension due to dehydration (CT, *n* = 1) No sustained arrhythmias or other CV complications. No limitations due to angina.
Kida [51]	MI *n* = 70 Mean age: 60 ± 10 years Mean age (LMV): 60 ± 10 years Mean age (HMV): 61 ± 11 years	1) CT (low–mod intensity) – LMV; *n* = 37 2) CT (low–mod intensity) – HMV; *n* = 33	8 weeks	$\dot{V}O_{2peak}$ Knee ext. PT	LMV: +146 ± 434.2 ml/min HMV: +406 ± 456.9 ml/min LMV: +12.6 ± 36.0 Nm HMV: +8.2 ± 36.6 Nm	No adverse events
Maiorana [63]	CABS *n* = 26 Mean age (RT): 61 ± 8 years Mean age (NE): 59 ± 9 years	1) RT (low–mod intensity); *n* = 12 2) No exercise; *n* = 14	10 weeks	$\dot{V}O_{2peak}$ GXT time Leg press 1RM	RT: −1.8 ± 5.2 ml/kg/min NE: −1.4 ± 4.0 ml/kg/min RT: 0.0 ± 2.0 min NE: −0.1 ± 1.4 min RT: +18.5 ± 24.2 kg NE: −1.3 ± 26.0 kg	Vasovagal episode during RT (*n* = 1) No ischemic symptoms or significant ST-segment depression
Marzolini [91]	CHD (CABS; PCI) *n* = 52 Mean age: 61 ± 15 years Mean age (CT-3): 63 ± 12 years Mean age (CT-1): 61 ± 10 years Mean age (AT): 58 ± 10 years	1a) CT (low–mod intensity) – 3 sets; *n* = 18 1b) CT (low–mod intensity) – 1 set; *n* = 18 2) AT; *n* = 16	29 weeks	$\dot{V}O_{2peak}$ Knee ext. PT	CT-3: +3.3 ± 4.7 ml/kg/min CT-1: +3.1 ± 5.5 ml/kg/min AT: +2.0 ± 4.0 ml/kg/min CT-3: +13.0 ± 26.3 Nm CT-1: +19.3 ± 30.3 Nm AT: +6.1 ± 27.2 Nm	Ischemia during GXT (*n* = 2) No other adverse events
McCartney [81]	CHD (MI; CABS; angina) *n* = 18 Mean age: 52 ± 8 years	1) CT (low–mod intensity); *n* = 10 2) AT; *n* = 8	10 weeks	GXT peak power Knee ext. 1RM	Required data not reported CT: +7.1 ± 6.5 kg AT: +1.5 ± 5.4 kg	No adverse events
Mital [24]	CHD (Bypass or Angioplasty) *N* = 47 Mean age (JCT male): 46 ± 9 years Mean age (JCT female): 53 ± 1 years Mean age (UC male): 56 ± 9 years Mean age (UC female): 59 ± 9 years	1) Job-sim CR (low–mod intensity CT); *n* = 17 2) conventional CR (aerobic-based); *n* = 30	9 weeks	$\dot{V}O_{2peak}$	JCT: +613.4 ml/min CON: +586.8 ml/min	Not reported
Omiya [54]	MI *n* = 70 Mean age: 60 ± 11 years	1) CT (low–mod intensity) – IR; *n* = 23 2) CT (low–mod intensity) – normal; *n* = 23	3 months	$\dot{V}O_{2peak}$ Knee ext. PT	IR: +4.9 ± 4.7 ml/kg/min NOR: +3.3 ± 5.8 ml/kg/min β-CD: +2.5 ± 6.0 ml/kg/min	No adverse events

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	Mean age (IR): 62 ± 7 years Mean age (normal): 57 ± 13 years Mean age (β-CD): 61 ± 10 years	3) CT (low–mod intensity) – β-CD; $n = 24$			IR: +0.1 ± 0.4 Nm/kg NOR: +0.2 ± 0.5 Nm/kg B-CD: +0.2 ± 0.5 Nm/kg	
Pardaens [52]	AVS; MVS $n = 144$ Mean age: 64 ± 10 years Mean age (AVS): 65 ± 12 years Mean age (MVS): 64 ± 9 years	1) CT (low–mod intensity) – low/medium risk AVS; $n = 38$ 2) CT (low–mod intensity) – high risk AVS; $n = 33$ 3) CT (low–mod intensity) – low/medium risk MVS; $n = 46$ 4) CT (low–mod intensity) – high risk MVS; $n = 27$	3–5 months	$\dot{V}O_{2peak}$ GXT peak power	LM-AVS: +6.0 ± 6.0 ml/kg/min H-AVS: +4.0 ± 4.1 ml/kg/min LM-MVS: +5.0 ± 7.0 ml/kg/min H-MVS: +2.0 ± 4.5 ml/kg/min LM-AVS: +34.0 ± 50.6 W H-AVS: +28.0 ± 30.8 W LM_MVS: +35.0 ± 43.0 W H-MVS: +20.0 ± 26.3 W	Not reported
Pfob [53]	angina leading to MI, CABS or PCI $n = 24$ Mean age: 57 ± 10 years	CT (low–mod intensity); $n = 24$	5 weeks	GXT peak power	CT: +14.3 ± 31.5 W	Not reported
Pierson [92]	CHD $n = 20$ Mean age (CT): 59 ± 8 years Mean age (AT): 61 ± 8 years	1) CT (low–mod intensity); $n = 10$ 2) AT; $n = 10$	6 months	$\dot{V}O_{2peak}$ Knee ext. 2RM	CT: +2.4 ± 4.6 ml/kg/min AT: +2.7 ± 5.2 ml/kg/min CT: +29.3 ± 20.4 kg AT: +12.1 ± 22.4 kg	Discomfort during training (CT, $n = 6$) Low back pain during training (CT, $n = 4$) Elbow tendonitis (CT, $n = 1$) Shoulder pain (CT, $n = 1$) Anginal symptoms causing early test termination (CT, $n = 1$)
Santa-Clara [65]	CHD (MI; CABS; PCI; angina) $n = 36$ Mean age (CT): 55 ± 10 years Mean age (AT): 57 ± 11 years Mean age (NE): 57 ± 11 years	1) CT (low–mod intensity); $n = 13$ 2) AT; $n = 13$ 3) no exercise; $n = 10$	12 months	$\dot{V}O_{2peak}$	CT: +8.2 ± 5.2 ml/kg/min AT: +5.7 ± 5.9 ml/kg/min NE: −4.0 ± 5.4 ml/kg/min	No adverse events
Santa-Clara [72]	CHD (MI; CABS; PCI; angina) $n = 36$ Mean age (CT): 55 ± 10 years Mean age (AT): 57 ± 11 years Mean age (NE): 57 ± 11 years	1) CT (low–mod intensity); $n = 13$ 2) AT; $n = 13$ 3) no exercise; $n = 10$	12 months	GXT time	CT: +0.5 ± 1.8 min AT: +0.1 ± 1.6 min NE: −1.5 ± 1.9 min	Not reported
Schmid [14]	MI $n = 38$ Mean age (CT): 55 ± 9 years Mean age (AT): 57 ± 10 years	1) CT (low–mod intensity); $n = 17$ 2) AT; $n = 21$	3 months	$\dot{V}O_{2peak}$ Knee ext. PT	CT: +2.5 ± 5.2 ml/kg/min AT: +2.2 ± 6.3 ml/kg/min CT: +10.4 ± 42.7 Nm AT: +5.6 ± 44.2 Nm	No adverse events
Sparling [55]	CHD or high-risk from CR $n = 22$ Mean age (CT): 56 ± 7 years Mean Age (AT): 56 ± 8 years	1) CT (low–mod intensity); $n = 16$ 2) AT; $n = 6$	26 weeks	Leg ext. 90% 1RM	CT: +21.0 ± 32.5 kg AT: not measured	High initial BP during RT ($n = 2$)
Stewart [73]	MI; CABS, angina $n = 25$ Mean age: 58 ± 8 years	1) CT (low–mod intensity); $n = 17$ 2) AT; $n = 8$	3 years	Sum 2 LB 1RM	CT: +16.0 ± 12.2 kg AT: +6.0 ± 9.1 kg	Increased episodes of angina over study duration but no cardiac events (CT, $n = 4$; AT, $n = 1$). Recurrent MI over course of study (AT, $n = 1$). CABS over course of study (AT, $n = 1$) No patients limited by angina during testing or training.
Stewart [13]	MI $n = 23$ Mean age (CT): 52 ± 10 years Mean age (AT): 57 ± 10 years	1) CT (low–mod intensity); $n = 12$ 2) AT; $n = 11$	10 weeks	$\dot{V}O_{2peak}$ GXT time Sum 2 LB 1RM	CT: +3.1 ± 6.0 ml/kg/min AT: +1.6 ± 4.5 ml/kg/min CT: +1.2 ± 2.0 min AT: +0.9 ± 1.7 min CT: +20.6 ± 14.4 kg AT: +9.5 ± 15.0 kg	ST depression during baseline testing ($n = 1$) No adverse events during exercise training
Tokmakidis [44]	CHD (MI; CABS; PCI) $n = 27$ Mean age (CT): 56 ± 9 years Mean Age (NE): 57 ± 12 years	1) CT (low–mod intensity); $n = 14$ 2) No exercise; $n = 13$	8 months	$\dot{V}O_{2peak}$ leg ext. & ham curl 1RM	CT: +3.9 ± 6.0 ml/kg/min NE: +0.3 ± 6.6 ml/kg/min CT: significant improvement NE: not reported	No adverse events

(continued on next page)

Table 1 (*continued*)

Study	Participants	Interventions	Intervention duration	Outcome	Change (post–pre)	Adverse events
Tokmakidis [56]	CHD $n = 21$ Mean age (water CT): 52 ± 12 years Mean age (NE): 51 ± 9 years	1) water CT (low–mod intensity); $n = 11$ 2) No exercise; $n = 10$	4 months	$\dot{V}O_{2peak}$ GXT time Sum 6 1RM	W-CT: +2.2 ± 4.5 ml/kg/min NE: +0.2 ± 6.6 ml/kg/min W-CT: +1.3 ± 1.9 min NE: 0.0 ± 1.7 min W-CT: +34.7 ± 32.8 kg NE: not reported	No adverse events
Turban [62]	Heart disease in CR $n = 18$ Mean age: 56 ± 10 years Mean age (WM): 56 ± 11 years Mean age (EB): 55 ± 8 years	1) RT (high intensity) – WM; $n = 9$ 2) RT (high intensity) – EB. $N = 9$	5 weeks	Peak workload Knee ext. 1RM	WM: +40.00 W EB: +42.20 W WM: +8.2 kg EB: +8.7 kg	No adverse events
Volaklis [45]	CHD (MI; CABS; PCI) $n = 27$ Mean age (CT): 56 ± 9 years Mean age (NE): 57 ± 12 years	1) CT (low–mod intensity); $n = 14$ 2) No exercise; $n = 13$	8 months	$\dot{V}O_{2peak}$ Exercise time Leg ext. 1RM	CT: see [44] NE: see [44] CT: +1.5 ± 2.8 min NE: +0.1 ± 2.7 min CT: +11.10 ± 2.1 kg NE: not reported	No adverse events
Volaklis [46]	CHD (MI; CABS; PCI) $n = 34$ Mean age (CT): 58 ± 10 years Mean age (water CT): 53 ± 13 years Mean age (NE): 51 ± 10 years	1) CT (low–mod intensity); $n = 11$ 2) water CT (mod intensity); $n = 11$ 3) No exercise; $n = 10$	4 months	GXT time Sum of 6 ex 1RM	CT: +0.9 ± 10.5 min W-CT: +1.3 ± 6.1 min NE: +0.1 ± 5.1 min CT: +34.2 ± 42.6 kg W-CT: +34.7 ± 32.8 kg NE: +0.4 ± 30.4 kg	No adverse events
Vona [38]	MI $n = 209$ Mean age (CT): 55 ± 9 years Mean age (RT): 57 ± 8 years Mean age (AT): 56 ± 6 years Mean age (NE): 58 ± 7 years	1) CT (low–mod intensity); $n = 53$ 2) RT (low–mod intensity); $n = 54$ 3) AT; $n = 52$ 4) No exercise; $n = 50$	4 weeks	$\dot{V}O_{2peak}$	CT: +4.5 ± 1.6 ml/kg/min RT: +3.5 ± 1.3 ml/kg/min AT: +3.7 ± 1.4 ml/kg/min NE: +0.5 ± 1.5 ml/kg/min	No adverse events
Wilke [66]	CHD (MI; CABS; PTCA (PCI); angina; AVS) $n = 36$ Mean age: 61 ± 7 years	1) CT (low–mod intensity); $n = 12$ 2) AT; $n = 12$ 3) Weight-carrying; $n = 12$	12 weeks	$\dot{V}O_{2peak}$ Leg press 1RM	CT: +3.3 ± 4.2 ml/kg/min AT: +2.1 ± 4.1 ml/kg/min WC: +1.0 ± 5.2 ml/kg/min CT: +26.4 ± 30.1 kg AT: +14.2 ± 26.2 kg WC: +2.9 ± 24.9 kg	Re-injury of shoulder during 1RM testing (CT, $n = 2$) No cardiac adverse events
Wosornu [64]	CABS $n = 77$ Mean age: 57 ± 8 years Mean age (RT): 59 ± 6 years Mean age (AT): 57 ± 9 years Mean age (NE): 57 ± 7 years	1) RT (low–mod intensity); $n = 24$ 2) AT; $n = 27$ 3) No exercise; $n = 26$	6 months	GXT peak work	RT: +1.4 ± 3.4 METS AT: +2.0 ± 2.7 METS NE: +0.3 ± 3.2 METS	No serious adverse events. Dyspnoea, fatigue, leg ache, chest pain limiting exercise tests ($n = 5$)

Abbreviations: 1RM = 1 repetition maximum; 2RM = 2 repetition maximum; 6MWD = 6-minute walk test distance; AT = aerobic training; AVS = aortic valve surgery; β-CD = beta-cell dysfunction; BP = blood pressure; CA = coronary artery; CABS = coronary artery bypass surgery; CHD = coronary heart disease; CON = concentric; CR = cardiac rehabilitation; CT = combined training; CT + IMT = combined training and inspiratory muscle training; CV = cardiovascular; EB = elastic band; ECC = eccentric; ext. = extension; FLEX = flexibility; GXT = graded exercise test; H = high; HIIT = high intensity interval training; HMV = high muscle volume; IR = insulin resistance; JCT = job-simulated combined training; kg = kilograms; LB = lower body; LM = low/medium; LMV = low muscle volume; low–mod = low–moderate; m = metres; med = medium; METS = metabolic equivalents; MI = myocardial infarction; MICT = moderate intensity continuous training; min = minute; ml = millilitres; MVC = maximal voluntary contraction; MVS = mitral valve surgery; NE = no exercise; Nm = Newton metres; OLD = older; PCI = percutaneous coronary intervention; PT = peak torque; PVC = premature ventricular complexes; RT = resistance training; UB = upper body; UC = usual care; $\dot{V}O_{2peak}$ = peak rate of oxygen consumption, distribution, and utilisation; W = Watts; W-CT = water combined training; WC = weight carrying; WM = weight machines; YOU = younger.

and low–moderate intensity resistance training. Among qualitatively synthesised studies, muscular strength significantly improved regardless of resistance training intensity [8,39–41,43–45,48,51,54–56,59–63]. It has been suggested that the inclusion of high intensity resistance training in the treatment of individuals with CHD might promote faster improvements in muscular strength than lower intensity resistance training [80]. More rapid improvements in muscular strength could allow earlier return to suitable ADL and enhanced work capacity. As such, this would allow individuals to reach the goals of cardiac rehabilitation sooner. Importantly, high intensity resistance training has also been shown to be safe for individuals in cardiac rehabilitation [40,81]. While the results of this review suggest that resistance training at low–moderate or high intensities can improve muscular strength, the scope for high intensity resistance training to be more beneficial than low–moderate intensity resistance training warrants further high-quality randomised-controlled trials versus aerobic training in this population.

The meta-analyses for shorter duration CT versus shorter duration AT demonstrated low quality of evidence that shorter duration CT was superior to shorter duration AT for improvement in cardiorespiratory fitness and muscular strength. For longer duration CT versus longer duration AT, the meta-analyses demonstrated moderate quality of evidence that there was no evidence to suggest a difference between longer duration CT and longer duration AT for change in $\dot{V}O_{2peak}$ and that change in muscular strength significantly favoured longer duration CT. Consistent improvements were found in cardiorespiratory fitness and muscular strength in qualitatively synthesised CT studies regardless of intervention duration [39–56]. In qualitatively synthesised RT studies, longer duration interventions [8,59,60] appeared more favourable for improving cardiorespiratory fitness while muscular strength was significantly improved regardless of intervention duration [8,59–63]. The dissonance in effect for $\dot{V}O_{2peak}$ between shorter duration CT compared to shorter duration AT and longer duration CT compared to longer duration AT is interesting, due to the importance of cardiorespiratory fitness in this population [9]. It might be that improvements in cardiorespiratory fitness are enhanced with CT compared to AT over shorter duration interventions before plateauing across longer duration interventions. As such, it might be that shorter duration programs that improve cardiorespiratory fitness can provide a base for longer term health benefits.

The significant effect favouring shorter duration CT compared to shorter duration AT for $\dot{V}O_{2peak}$ is strongly influenced by a single study performed by Vona and colleagues [38], one of three studies in this meta-analysis. This study included a large number of participants (105 out of the 139 included in shorter duration interventions) relative to other included studies, and thus was heavily weighted to determine the effect [38]. Given the low level of evidence, more studies should investigate the efficacy of shorter duration CT for improving $\dot{V}O_{2peak}$. If shorter duration CT interventions are effective for improving $\dot{V}O_{2peak}$ and muscular strength, it might be prudent to offer shorter duration cardiac rehabilitation programs for individuals citing time as a reason for not maintaining cardiac rehabilitation [33]. It is plausible that the implementation of effective shorter duration cardiac rehabilitation might allow patients to resume their usual social and employment activities earlier, which could lead to greater improvement in health outcomes. Nevertheless, regardless of intervention duration, ongoing exercise at the conclusion of CR is required to continue to improve or maintain improvements achieved in $\dot{V}O_{2peak}$ and muscular strength [82,83], thereby continually reducing mortality risk [9,10] and potentially enhancing the capacity to complete ADL [19,84].

There are some limitations to this systematic review and meta-analysis. The publication date of included studies ranges from 1986 to 2015 and the medical treatment of CHD patients has changed over this time. It is possible, therefore, that the effects of exercise might be influenced by differences in medical background of participants across these studies. Additionally, only a small number of studies were included in this review that either investigated high intensity resistance training or provided comparisons between RT alone against AT alone or CT. These findings present future research opportunities, particularly as high intensity resistance training can be performed safely and might further improve physical function in this population.

5. Conclusions

Combining resistance training with aerobic training in cardiac rehabilitation is more effective at increasing physical function than aerobic training alone. Low–moderate intensity combined training is effective in enhancing aerobic capacity compared to aerobic training alone while improvements in aerobic capacity were enhanced across shorter durations when resistance training is combined with aerobic training. Qualitative analysis suggests that high intensity resistance training is safe to perform and should be considered when implementing cardiac rehabilitation.

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Conflicts of interest

The authors report no relationships that could be construed as a conflict of interest.

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Appendix A. Summary of findings table for combined training versus aerobic training meta-analyses

Combined training versus aerobic training				
Patient or population: patients with coronary heart disease Settings: post-cardiac event Intervention: combined training Comparison: aerobic training alone				
Outcomes	Effect size: WMD/SMD (95% CI)	No. of participants (studies)	Quality of the evidence (GRADE)	Comments
$\dot{V}O_{2peak}$	WMD: 0.61 (0.20 to 1.01)	445 (11 studies)	⊕⊕⊕⊖ moderate[a]	Effect size — this represents a small effect
$\dot{V}O_{2peak}$ low–moderate intensity	WMD: 0.79 (0.35 to 1.23)	373 (10 studies)	⊕⊕⊕⊖ moderate[a]	Effect size — this represents a small effect
$\dot{V}O_{2peak}$ high intensity	WMD: −0.50 (−1.59 to 0.59)	72 (1 study)	⊕⊖⊖⊖ very low[b,c]	Effect size — this might represent no significant effect
$\dot{V}O_{2peak}$ shorter duration	WMD: 0.82 (0.35 to 1.29)	139 (3 studies)	⊕⊕⊖⊖ low[a,b]	Effect size — this represents a small effect

(continued on next page)

Appendix A (*continued*)

Combined training versus aerobic training

Patient or population: patients with coronary heart disease
Settings: post-cardiac event
Intervention: combined training
Comparison: aerobic training alone

Outcomes	Effect size: WMD/SMD (95% CI)	No. of participants (studies)	Quality of the evidence (GRADE)	Comments
$\dot{V}O_{2peak}$ longer duration	WMD: −0.04 (−0.84 to 0.77)	306 (8 studies)	⊕⊕⊕⊝ moderate[a]	Effect size — this might represent no significant effect
Peak work capacity	SMD: 0.31 (0.11 to 0.50)	422 (11 studies)	⊕⊕⊕⊝ moderate[a]	Effect size — this represents a small effect
Muscular strength	SMD: 0.65 (0.43 to 0.87)	481 (16 studies)	⊕⊕⊕⊝ moderate[a]	Effect size — this represents a medium effect
Muscular strength low–moderate intensity	SMD: 0.58 (0.38 to 0.78)	447 (15 studies)	⊕⊕⊕⊝ moderate[a]	Effect size — this represents a medium effect
Muscular strength high intensity	SMD: 1.47 (0.70 to 2.24)	34 (1 study)	⊕⊝⊝⊝ very low[a,b]	Effect size — this represents a large effect
Muscular strength shorter duration	SMD: 0.76 (0.38 to 1.15)	196 (7 studies)	⊕⊕⊝⊝ low[a,b]	Effect size — this represents a medium effect
Muscular strength longer duration	SMD: 0.56 (0.30 to 0.83)	285 (9 studies)	⊕⊕⊕⊝ moderate[a]	Effect size — this represents a medium effect

CI: confidence interval; SMD: standardised mean difference; WMD: weighted mean difference.
GRADE working group grades of evidence.
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: We are very uncertain about the estimate.
[a] Downgraded for risk of bias.
[b] Downgraded for imprecision (inadequate sample size).
[c] Downgraded for indirectness (female participants only).

Appendix B. Summary of findings table for resistance training versus aerobic training meta-analyses

Resistance training alone versus aerobic training

Patients or population: patients with coronary heart disease
Setting: post-cardiac event
Intervention: resistance training alone
Comparison: aerobic training

Outcomes	Effect size: WMD/SMD (95% CI)	No. of participants (studies)	Quality of the evidence (GRADE)	Comments
$\dot{V}O_{2peak}$	WMD: −0.48 (−2.33 to 1.38)	172 (4 studies)	⊕⊕⊝⊝ low[a,b]	Effect size — this might represent no significant effect
Muscular strength	SMD: 0.88 (−0.86 to 2.62)	48 (2 studies)	⊕⊝⊝⊝ very low[a,b,c]	Effect size — this might represent no significant effect

CI: confidence interval; SMD: standardised mean difference; WMD: weighted mean difference.
GRADE working group grades of evidence.
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: We are very uncertain about the estimate.
[a] Downgraded for risk of bias.
[b] Downgraded for imprecision (inadequate sample size).
[c] Downgraded for inconsistency (significant heterogeneity).

References

[1] World Health Organisation, Cardiovascular diseases (CVDs), WHO Media Centre 2016. Fact sheet no. 317, http://www.who.int/mediacentre/factsheets/fs317/en/ 2016 [accessed 29.06.2016].
[2] N. Oldridge, Exercise-based cardiac rehabilitation in patients with coronary heart disease: meta-analysis outcomes revisited, Futur. Cardiol. 8 (5) (2012) 729–751.
[3] National Heart Foundation of Australia and Australian Cardiac Rehabilitation Association, Recommended Framework for Cardiac Rehabilitation '04, 2006.
[4] M.F. Piepoli, U. Corra, W. Benzer, et al., Secondary prevention through cardiac rehabilitation: from knowledge to implementation. A position paper from the Cardiac Rehabilitation Section of the European Association of Cardiovascular Prevention and Rehabilitation, Eur. J. Cardiovasc. Prev. Rehabil. 17 (1) (2010) 1–17.
[5] G.J. Balady, P.A. Ades, V.A. Bittner, et al., Referral, enrollment, and delivery of cardiac rehabilitation/secondary prevention programs at clinical centers and beyond: a presidential advisory from the American Heart Association, Circulation 124 (25) (2011) 2951–2960.
[6] E.M. Nieuwenburg-van Tilborg, A.M. Horstman, B. Zwarts, S. de Groot, Physical strain during activities of daily living of patients with coronary artery disease, Clin. Physiol. Funct. Imaging 34 (2) (2014) 83–89.
[7] N. ter Hoeve, M.E. van Geffen, M.W. Post, et al., Participation in society in patients with coronary artery disease before and after cardiac rehabilitation, Arch. Phys. Med. Rehabil. 96 (6) (2015) 1110–1116.
[8] P.A. Ades, P. Savage, M.E. Cress, M. Brochu, N.M. Lee, E.T. Poehlman, Resistance training on physical performance in disabled older female cardiac patients, Med. Sci. Sports Exerc. 35 (8) (2003) 1265–1270.
[9] J. Myers, M. Prakash, V. Froelicher, D. Do, S. Partington, J.E. Atwood, Exercise capacity and mortality among men referred for exercise testing, N. Engl. J. Med. 346 (11) (2002) 793–801.
[10] T. Rantanen, Muscle strength, disability and mortality, Scand. J. Med. Sci. Sports 13 (1) (2003) 3–8.
[11] C.J. Lavie, R.V. Milani, Cardiac rehabilitation and exercise training in secondary coronary heart disease prevention, Prog. Cardiovasc. Dis. 53 (6) (2011) 397–403.
[12] J.H. Mitchell, K. Wildenthal, Static (isometric) exercise and the heart: physiological and clinical considerations, Annu. Rev. Med. 25 (1) (1974) 369–381.
[13] K.J. Stewart, L.D. McFarland, J.J. Weinhofer, E. Cottrell, C.S. Brown, E.P. Shapiro, Safety and efficacy of weight training soon after acute myocardial infarction.[Erratum appears in J Cardiopulm Rehabil 1998 May–Jun; 18(3):243], J. Cardiopulm. Rehabil. 18 (1) (1998) 37–44.
[14] J.P. Schmid, M. Anderegg, M. Romanens, et al., Combined endurance/resistance training early on, after a first myocardial infarction, does not induce negative left ventricular remodelling, Eur. J. Cardiovasc. Prev. Rehabil. 15 (3) (2008) 341–346.
[15] J. Helgerud, T. Karlsen, W.Y. Kim, et al., Interval and strength training in CAD patients, Int. J. Sports Med. 32 (1) (2011) 54–59.
[16] S. Marzolini, O. PI, D. Brooks, Effect of combined aerobic and resistance training versus aerobic training alone in individuals with coronary artery disease: a meta-analysis, Eur. J. Prev. Cardiol. 19 (1) (2012) 81–94.
[17] S. Yamamoto, K. Hotta, E. Ota, R. Mori, A. Matsunaga, Effects of resistance training on muscle strength, exercise capacity, and mobility in middle-aged and elderly patients with coronary artery disease: a meta-analysis, J. Cardiol. 68 (2) (2016) 125–134.
[18] R.W. Braith, K.J. Stewart, Resistance exercise training: its role in the prevention of cardiovascular disease, Circulation 113 (22) (2006) 2642–2650.

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[19] D.M. Buchner, E.B. Larson, E.H. Wagner, T.D. Koepsell, B.J. De Lateur, Evidence for a non-linear relationship between leg strength and gait speed, Age Ageing 25 (5) (1996) 386–391.
[20] M.L. Pollock, B.A. Franklin, G.J. Balady, et al., AHA Science Advisory. Resistance exercise in individuals 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 101 (7) (2000) 828–833.
[21] N.J. de Vos, N.A. Singh, D.A. Ross, T.M. Stavrinos, R. Orr, M.A. Fiatarone Singh, Optimal load for increasing muscle power during explosive resistance training in older adults, J. Gerontol. A Biol. Sci. Med. Sci. 60 (5) (2005) 638–647.
[22] M.C. Audelin, P.D. Savage, P.A. Ades, Changing clinical profile of patients entering cardiac rehabilitation/secondary prevention programs: 1996 to 2006, J. Cardiopulm. Rehabil. 28 (5) (2008) 299–306.
[23] J. Evans, H. Bethell, S. Turner, G. Yadegarfar, Characteristics of patients entering cardiac rehabilitation in the United Kingdom 1993–2006: implications for the future, J. Cardiopulm. Rehabil. Prev. 31 (3) (2011) 181–187.
[24] A. Mital, D.E. Shrey, M. Govindaraju, T.M. Broderick, K. Colon-Brown, B.W. Gustin, Accelerating the return to work (RTW) chances of coronary heart disease (CHD) patients: part 1 — development and validation of a training programme, Disabil. Rehabil. 22 (13–14) (2000) 604–620.
[25] A.M. Maznyczka, J.P. Howard, A.S. Banning, A.H. Gershlick, A propensity matched comparison of return to work and quality of life after stenting or coronary artery bypass surgery, Open Heart 3 (1) (2016) 1–9.
[26] M.A. Hlatky, D. Boothroyd, S. Horine, et al., Employment after coronary angioplasty or coronary bypass surgery in patients employed at the time of revascularization, Ann. Intern. Med. 129 (7) (1998) 543–547.
[27] F.G. Slebus, H.T. Jorstad, R.J.G. Peters, et al., Return to work after an acute coronary syndrome: patients' perspective, Saf Health Work. 3 (2) (2012) 117–122.
[28] G. Sandercock, V. Hurtado, F. Cardoso, Changes in cardiorespiratory fitness in cardiac rehabilitation patients: a meta-analysis, Int. J. Cardiol. 167 (3) (2013) 894–902.
[29] K. Kotseva, D. Wood, G. De Backer, D. De Bacquer, Use and effects of cardiac rehabilitation in patients with coronary heart disease: results from the EUROASPIRE III survey, Eur. J. Prev. Cardiol. 20 (5) (2013) 817–826.
[30] V. Sundararajan, S.J. Bunker, S. Begg, R. Marshall, H. McBurney, Attendance rates and outcomes of cardiac rehabilitation in Victoria, 1998, Med. J. Aust. 180 (6) (2004) 268–271.
[31] R.J. Thomas, M. King, K. Lui, et al., AACVPR/ACC/AHA 2007 performance measures on cardiac rehabilitation for referral to and delivery of cardiac rehabilitation/secondary prevention services: endorsed by The American College of Chest Physicians, American College of Sports Medicine, American Physical Therapy Association, Canadian Association of Cardiac Rehabilitation, European Association for Cardiovascular Prevention and Rehabilitation, Inter-American Heart Foundation, National Association of Clinical Nurse Specialists, Preventive Cardiovascular Nurses Association, and the Society of Thoracic Surgeons, J. Am. Coll. Cardiol. 50 (14) (2007) 1400–1433.
[32] G. McKee, M. Biddle, S. O'Donnell, M. Mooney, F. O'Brien, D.K. Moser, Cardiac rehabilitation after myocardial infarction: what influences patients' intentions to attend? Eur. J. Cardiovasc. Nurs. 13 (4) (2014) 329–337.
[33] K.R. Evenson, J. Fleury, Barriers to outpatient cardiac rehabilitation participation and adherence, J. Cardiopulm. Rehabil. Prev. 20 (4) (2000) 241–246.
[34] R. Humphrey, M. Guazzi, J. Niebauer, Cardiac rehabilitation in Europe, Prog. Cardiovasc. Dis. 56 (5) (2014) 551–556.
[35] H. Balshem, M. Helfand, H.J. Schünemann, et al., GRADE guidelines: 3. Rating the quality of evidence, J. Clin. Epidemiol. 64 (4) (2011) 401–406.
[36] J. Higgins, J. Deeks, Cochrane handbook for systematic reviews of interventions, handbook.cochrane.org (2011) [accessed 08.07.2016].
[37] A. Zacharias, R.A. Green, A.I. Semciw, M.I.C. Kingsley, T. Pizzari, Efficacy of rehabilitation programs for improving muscle strength in people with hip or knee osteoarthritis: a systematic review with meta-analysis, Osteoarthr. Cartil. 22 (11) (2014) 1752–1773.
[38] M. Vona, G.M. Codeluppi, T. Iannino, E. Ferrari, J. Bogousslavsky, L.K. von Segesser, Effects of different types of exercise training followed by detraining on endothelium-dependent dilation in patients with recent myocardial infarction, Circulation 119 (12) (2009) 1601–1608.
[39] K.J. Adams, K.L. Barnard, A.M. Swank, E. Mann, M.R. Kushnick, D.M. Denny, Combined high-intensity strength and aerobic training in diverse phase II cardiac rehabilitation patients, J. Cardpulm. Rehabil. 19 (4) (1999) 209–215.
[40] L.E. Crozier Ghilarducci, R.G. Holly, E.A. Amsterdam, Effects of high resistance training in coronary artery disease, Am. J. Cardiol. 64 (14) (1989) 866–870.
[41] M. Back, B. Wennerblom, S. Wittboldt, A. Cider, Effects of high frequency exercise in patients before and after elective percutaneous coronary intervention, Eur. J. Cardiovasc. Nurs. 7 (4) (2008) 307–313.
[42] K.D. Currie, K.J. Bailey, M.E. Jung, R.S. McKelvie, M.J. MacDonald, Effects of resistance training combined with moderate-intensity endurance or low-volume high-intensity interval exercise on cardiovascular risk factors in patients with coronary artery disease, J. Sci. Med. Sport 18 (6) (2015) 637–642.
[43] K. Izawa, Y. Hirano, S. Yamada, K. Oka, K. Omiya, S. Iijima, Improvement in physiological outcomes and health-related quality of life following cardiac rehabilitation in patients with acute myocardial infarction, Circ. J. 68 (4) (2004) 315–320.
[44] S.P. Tokmakidis, K.A. Volaklis, Training and detraining effects of a combined-strength and aerobic exercise program on blood lipids in patients with coronary artery disease, J. Cardpulm. Rehabil. 23 (3) (2003) 193–200.
[45] K.A. Volaklis, H.T. Douda, P.F. Kokkinos, S.P. Tokmakidis, Physiological alterations to detraining following prolonged combined strength and aerobic training in cardiac patients, Eur. J. Cardiovasc. Prev. Rehabil. 13 (3) (2006) 375–380.
[46] K.A. Volaklis, A.T. Spassis, S.P. Tokmakidis, Land versus water exercise in patients with coronary artery disease: effects on body composition, blood lipids, and physical fitness, Am. Heart J. 154 (3) (2007) 560.e1–560.e6.
[47] V. Chludilova, L. Mifkova, J. Pochmonova, et al., Functional capacity in men after coronary artery bypass surgery influenced by physical training, Scr. Med. (Brno.) 80 (5) (2007) 203–210.
[48] K. Fragnoli-Munn, P.D. Savage, P.A. Ades, Combined resistive-aerobic training in older patients with coronary artery disease early after myocardial infarction, J. Cardpulm. Rehabil. 18 (6) (1998) 416–420.
[49] V. Gremeaux, J. Duclay, G. Deley, et al., Does eccentric endurance training improve walking capacity in patients with coronary artery disease? A randomized controlled pilot study, Clin. Rehabil. 24 (7) (2010) 590–599.
[50] K.P. Izawa, S. Watanabe, K. Oka, et al., Age-related differences in physiologic and psychosocial outcomes after cardiac rehabilitation, Am. J. Phys. Med. Rehabil. 89 (1) (2010) 24–33.
[51] K. Kida, N. Osada, Y.J. Akashi, H. Sekizuka, K. Omiya, F. Miyake, The exercise training effects of skeletal muscle strength and muscle volume to improve functional capacity in patients with myocardial infarction, Int. J. Cardiol. 129 (2) (2008) 180–186.
[52] S. Pardaens, V. Moerman, A.M. Willems, et al., Impact of the preoperative risk and the type of surgery on exercise capacity and training after valvular surgery, Am. J. Cardiol. 113 (8) (2014) 1383–1389.
[53] M. Pfob, N. Murzl, B. Eber, B. Muller, T. Weber, Ambulatory cardiac rehabilitation improves pulsatile arterial hemodynamics — a pilot trial, J. Kardiol. 19 (11–12) (2014) 336–337.
[54] K. Omiya, K. Minami, Y. Sato, et al., Impaired β-cell function attenuates training effects by reducing the increase in heart rate reserve in patients with myocardial infarction, J. Cardiol. 65 (2) (2015) 128–133.
[55] P.B. Sparling, J.D. Cantwell, C.M. Dolan, R.K. Niederman, Strength training in a cardiac rehabilitation program: a six-month follow-up, Arch. Phys. Med. Rehabil. 71 (2) (1990) 148–152.
[56] S.P. Tokmakidis, A.T. Spassis, K.A. Volaklis, Training, detraining and retraining effects after a water-based exercise program in patients with coronary artery disease, Cardiology 111 (4) (2008) 257–264.
[57] L.A. Coke, B.A. Staffileno, L.T. Braun, M. Gulanick, Upper-body progressive resistance training improves strength and household physical activity performance in women attending cardiac rehabilitation, J. Cardiopulm. Rehabil. Prev. 28 (4) (2008) 238–245.
[58] B.M. Hermes, D.M. Cardoso, T.J. Gomes, et al., Short-term inspiratory muscle training potentiates the benefits of aerobic and resistance training in patients undergoing CABG in phase II cardiac rehabilitation program, Rev. Bras. Cir. Cardiovasc. 30 (4) (2015) 474–481.
[59] P.A. Ades, P.D. Savage, M. Brochu, M.D. Tischler, N.M. Lee, E.T. Poehlman, Resistance training increases total daily energy expenditure in disabled older women with coronary heart disease, J. Appl. Physiol. 98 (4) (2005) 1280–1285.
[60] M. Brochu, P. Savage, M. Lee, et al., Effects of resistance training on physical function in older disabled women with coronary heart disease, J. Appl. Physiol. 92 (2) (2002) 672–678.
[61] T. Karlsen, J. Helgerud, A. Stoylen, N. Lauritsen, J. Hoff, Maximal strength training restores walking mechanical efficiency in heart patients, Int. J. Sports Med. 30 (5) (2009) 337–342.
[62] C. Turban, C. Culas, G. Deley, Effects of a short-term resistance program using elastic bands or weight machines in cardiac rehabilitation, Sci. Sports 29 (3) (2014) 143–149.
[63] A.J. Maiorana, T.G. Briffa, C. Goodman, J. Hung, A controlled trial of circuit weight training on aerobic capacity and myocardial oxygen demand in men after coronary artery bypass surgery, J. Cardpulm. Rehabil. 17 (4) (1997) 239–247.
[64] D. Wosornu, D. Bedford, D. Ballantyne, A comparison of the effects of strength and aerobic exercise training on exercise capacity and lipids after coronary artery bypass surgery, Eur. Heart J. 17 (6) (1996) 854–863.
[65] H. Santa-Clara, B. Fernhall, M. Mendes, L.B. Sardinha, 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. 87 (6) (2002) 568–575.
[66] N.A. Wilke, L.M. Sheldahl, S.G. Levandoski, M.D. Hoffman, S.M. Dougherty, F.E. Tristani, Transfer effect of upper extremity training to weight carrying in men with ischemic heart disease, J. Cardpulm. Rehabil. 11 (6) (1991) 365–372.
[67] R.M. Butler, G. Palmer, F.J. Rogers, Circuit weight training in early cardiac rehabilitation, J. Am. Osteopath. Assoc. 92 (1) (1992) 77–89.
[68] W.D. Daub, G.P. Knapik, W.R. Black, Strength training early after myocardial infarction, J. Cardpulm. Rehabil. 16 (2) (1996) 100–108.
[69] C.K. Ewart, K.J. Stewart, R.E. Gillilan, M.H. Kelemen, Self-efficacy mediates strength gains during circuit weight training in men with coronary artery disease, Med. Sci. Sports Exerc. 18 (5) (1986) 531–540.
[70] M. Gayda, D. Choquet, S. Ahmaidi, Effects of exercise training modality on skeletal muscle fatigue in men with coronary heart disease, J. Electromyogr. Kinesiol. 19 (2) (2009) e32–e39.
[71] D. Hansen, B.O. Eijnde, M. Roelants, et al., 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. 43 (9) (2011) 800–807.
[72] H. Santa-Clara, B. Fernhall, F. Baptista, M. Mendes, L.B. Sardinha, Effect of a one-year combined exercise training program on body composition in men with coronary artery disease, Metabolism 52 (11) (2003) 1413–1417.
[73] K.J. Stewart, M. Mason, M.H. Kelemen, Three-year participation in circuit weight training improves muscular strength and self-efficacy in cardiac patients, J. Cardpulm. Rehabil. 8 (8) (1988) 292–296.

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[74] D. Jewiss, C. Ostman, N.A. Smart, The effect of resistance training on clinical outcomes in heart failure: a systematic review and meta-analysis, Int. J. Cardiol. 221 (2016) 674–681.
[75] E. McAuley, S.L. Mihalko, S.M. Bane, Exercise and self-esteem in middle-aged adults: multidimensional relationships and physical fitness and self-efficacy influences, J. Behav. Med. 20 (1) (1997) 67–83.
[76] E. McAuley, C. Lox, T.E. Duncan, Long-term maintenance of exercise, self-efficacy, and physiological change in older adults, J. Gerontol. 48 (4) (1993) P218–P224.
[77] D.E.R. Warburton, N. Gledhill, A. Quinney, Musculoskeletal fitness and health, Can. J. Appl. Physiol. 26 (2) (2001) 217–237.
[78] American College of Sports Medicine, Progression models in resistance training for healthy adults, Med. Sci. Sports Exerc. 41 (3) (2009) 687–708.
[79] S.J. Fleck, Cardiovascular adaptations to resistance training, Med. Sci. Sports Exerc. 20 (5) (1988).
[80] Y. Beniamini, J.J. Rubenstein, A.D. Faigenbaum, A.H. Lichtenstein, M.C. Crim, High-intensity strength training of patients enrolled in an outpatient cardiac rehabilitation program, J. Cardpulm. Rehabil. 19 (1) (1999) 8–17.
[81] N. McCartney, R.S. McKelvie, D.R. Haslam, N.L. Jones, Usefulness of weightlifting training in improving strength and maximal power output in coronary artery disease, Am. J. Cardiol. 67 (11) (1991) 939–945.
[82] National Strength and Conditioning Association, Essentials of Strength Training and Conditioning, third ed. Human Kinetics, Champaign, Illinois, USA, 2008.
[83] American College of Sports Medicine, ACSM's Guidelines for Exercise Testing and Prescription, Eight ed. Lippincott Williams & Wilkins, Philadelphia, USA, 2010.
[84] T. Hortobágyi, C. Mizelle, S. Beam, P. DeVita, Old adults perform activities of daily living near their maximal capabilities, J. Gerontol. A Biol. Sci. Med. Sci. 58 (5) (2003) M453–M460.
[85] H.M. Arthur, E. Gunn, K.E. Thorpe, et al., Effect of aerobic vs combined aerobic-strength training on 1-year, post-cardiac rehabilitation outcomes in women after a cardiac event, J. Rehabil. Med. 39 (9) (2007) 730–735.
[86] F.R. Caruso, R. Arena, S.A. Phillips, et al., Resistance exercise training improves heart rate variability and muscle performance: a randomized controlled trial in coronary artery disease patients, Eur. J. Phys. Rehabil. Med. 51 (3) (2015) 281–289.
[87] S. Ghroubi, W. Elleuch, L. Abid, M. Abdenadher, S. Kammoun, M.H. Elleuch, 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. 56 (2) (2013) 85–101.
[88] R.G. Haennel, H.A. Quinney, C.T. Kappagoda, Effects of hydraulic circuit training following coronary artery bypass surgery, Med. Sci. Sports Exerc. 23 (2) (1991) 158–165.
[89] C. Hung, B. Daub, B. Black, R. Welsh, A. Quinney, M. Haykowsky, Exercise training improves overall physical fitness and quality of life in older women with coronary artery disease, Chest 126 (4) (2004) 1026–1031.
[90] M.H. Kelemen, K.J. Stewart, R.E. Gillilan, et al., Circuit weight training in cardiac patients, J. Am. Coll. Cardiol. 7 (1) (1986) 38–42.
[91] S. Marzolini, O. PI, S.G. Thomas, J.M. Goodman, Aerobic and resistance training in coronary disease: single versus multiple sets, Med. Sci. Sports Exerc. 40 (9) (2008) 1557–1564.
[92] L.M. Pierson, W.G. Herbert, H.J. Norton, et al., Effects of combined aerobic and resistance training versus aerobic training alone in cardiac rehabilitation, J. Cardpulm. Rehabil. 21 (2) (2001) 101–110.

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