Journal of Multidisciplinary Healthcare

Dovepress
Taylor & Francis Group

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REVIEW

Resistance Exercise as a Safe Modality for Quality of Life Improvement in Patients with Coronary Artery Diseases: A Review

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Abstract: Individuals with cardiovascular diseases (CVD) tend to have decreasing cardiorespiratory fitness (CRF), muscle strength, and quality of life (QoL). Because of its multiple benefits, participation in an exercise-based cardiac rehabilitation (CR) program was highly recommended for CVD patients. Currently, there is a trend of increasing the use of resistance exercises (RE) in CR and treatment of CVD, including coronary artery disease (CAD), peripheral arterial disease, and stroke. The application of RE in CVD patients also raises concerns for physicians due to adverse events related to cardiovascular responses. Therefore, this review aimed to explore the effect of RE on cardiovascular responses, cardiovascular risk factors, muscle strength, CRF, and the QoL, including its safety in CAD patients. Articles published in the last ten years were searched using PubMed, Science Direct, Research Gate, and Google Scholar databases using relevant keywords. Studies found that the administration of RE in CAD patients was proven safe when prescribed properly. Some literature showed that RE affected CVD risk factors by improving blood pressure, blood sugar, lipid profile, and body composition. In addition, systemic vascular resistance change led to vasodilatation and reduced blood pressure. Fatal and non-fatal myocardial infarction and mortality also decreased after progressive RE. High-intensity RE was proven to be better at increasing muscle strength compared to low-intensity because it produced a greater increase in the number of myofibrils and neural adaptation. Subsequently, aerobic exercise (AE) combined with RE caused a better increase in CRF. An increase in muscle strength and CRF, as well as diminished symptoms and controlled risk factors obtained from RE administration, increased QoL. To conclude, RE was a safe modality for QoL improvement in CAD patients through controlling risk factors and improving muscle strength and CRF.

Keywords: cardiorespiratory fitness, muscle strength, quality of life, cardiac rehabilitation, resistance training

Introduction

Cardiovascular Diseases (CVD), including coronary artery disease (CAD), which is the leading cause of global burden and mortality, contribute to significant disabilities.[1] Furthermore, individuals with CVD tend to have sedentary behavior and low physical activity, which negatively impact physical fitness by decreasing cardiorespiratory fitness (CRF), specifically in individuals with many comorbid conditions. A decrease in CRF is associated with an increase in mortality and morbidity of CVD, which is believed to be the most important marker of cardiovascular health and functional ability.[2–5]

Received: 8 January 2025
Accepted: 10 March 2025
Published: 21 May 2025

CVD also causes a decrease in muscle mass and strength, specifically in the lower limbs, which results in reduced performance in carrying out daily activities.[3,5] This is influenced by the tendency of patients to limit and avoid physical activity because of recurrent heart attack risk.[6]

Physical activity that uses weights in some situations can cause disproportionate hemodynamic responses, including sudden increases in systolic blood pressure and heart rate, resulting in cardiac events. Meanwhile, supervised or monitored exercise can prevent patients from cardiac events and reduce such risks. Resistance exercises (RE) can increase muscle strength, which allows patients to conduct daily activities of lifting and carrying objects with a lower percentage of effort than their maximum ability.[7] Higher muscle strength or endurance was associated with an increased survival prognosis, performance of functional activities, independence, and the ability to return to work after a heart attack.[8]

Participation in an exercise-based cardiac rehabilitation (CR) program was highly recommended for CVD patients.[9] The benefits of CR included increased functional capacity and muscle strength, decreased submaximal heart rate and blood pressure, reduced inflammatory markers, alleviated angina symptoms, and improved lipid profile. Furthermore, these advantages extended to the reduction of body weight.[10] Currently, there is a trend of increasing the use of RE in CR and treatment of CVD, including CAD, peripheral arterial disease, and stroke.[9] Even though the benefits have been widely recognized, the application of this exercise in patients raised concerns for physicians about cardiovascular responses, causing adverse events.[11–14] This review explored the effect of RE on cardiovascular responses, CVD risk factors, muscle strength, CRF, functional activities, and quality of life (QoL) in patients with CAD. Safety aspects of RE and prevention of adverse events were also reviewed.

Methods

Original articles and systematic reviews and meta-analyses published in the last ten years were searched using PubMed, Science Direct, Research Gate, and Google Scholar databases. Keywords used were "resistance exercise and cardiovascular diseases", "resistance exercise and coronary artery disease", "resistance exercise and hemodynamic responses", "resistance exercise and cardiovascular responses", "resistance exercise and hypertension", "resistance exercise and diabetes mellitus", "resistance exercise and dyslipidemia", "resistance exercise and obesity" or "resistance exercise and overweight", "resistance exercise and blood pressure", "resistance exercise and blood glucose", "resistance exercise and blood sugar", "resistance exercise and lipid profile", "resistance exercise and cardiorespiratory fitness", "resistance exercise and functional capacity", "resistance exercise and muscle strength", "resistance exercise and functional ability", and "resistance exercise and quality of life". The article search was limited to articles published in English. Articles that were not available in full text were excluded. The outcomes to be explored were the effect of RE on cardiovascular or hemodynamic responses, CVD risk factors, cardiorespiratory fitness or functional capacity, muscle strength or muscular endurance, and quality of life. Data were presented in the form of tables or text.

Results

There were 23 articles found, consisting of five original articles and 18 reviews. Articles that explained cardiovascular responses, CVD risk factors, muscle strength, CRF, and QoL were seven, six, 12, 10, and five articles, respectively.

Discussion

Absolute and Relative Contraindication of RE in CVD Patients

RE is defined as any exercise that causes the contraction of skeletal muscles against external loads to increase fitness, including strength, endurance, tone, power, or mass.[14–16] In patients with CVD, RE can be administered in the form of a single exercise or in combination with aerobic exercise (AE).[16,17] Absolute contraindications to AE and RE are unstable CAD, uncontrolled arrhythmias, severe pulmonary hypertension, with mean pulmonary arterial pressure >55 mmHg, decompensated heart failure, severe symptomatic stenosis, endocarditis or acute pericarditis, myocarditis, and uncontrolled hypertension with blood pressure >180/110 mmHg, aortic dissection, and Marfan's syndrome. RE is also absolutely contraindicated when high-intensity RE with a load of 80–100% of 1-repetition maximum (RM) is given

 https://doi.org/10.2147/JMDH.S516441

to patients with active proliferative or moderate/severe non-proliferative diabetic retinopathy.[18] Relative contraindications that required consultation with a related physician before initiating RE included the presence of major risk factors for CAD, diabetes at all ages, uncontrolled hypertension with blood pressure >160/>100 mmHg, the low functional capacity of <4 metabolic equivalents (METs), presence of musculoskeletal limitations, and patients with defibrillator or pacemaker.[15] High-intensity aerobic interval and strength training were given to stable CAD with class I–III angina according to the Canadian Cardiovascular Society Classification, ischemia detected on the electrocardiogram during exercise, or CAD documented by angiography.[17]

Prescription of RE in CVD Patients

The American College of Sports Medicine (ACSM) recommended a prescription of RE in CR that included a frequency of 2–3 times per week on non-consecutive days. The intensity was advised to be set at a level which avoided significant fatigue, with a rating of perceived exertion (RPE) ranging from 11 to 13 on a scale of 6 to 20 or at 40–60% of 1-RM. It was suggested to perform 1–3 sets of 8–10 repetitions, focusing on large muscle groups using safe and comfortable equipment.[16] In patients with heart failure, RE was started at an intensity of 40% and 50% of 1-RM for the upper and lower body. The load increased gradually to 70% of 1-RM after several weeks to months. The exercise was conducted 1–2 times a week with non-consecutive days. In these patients, exercise using machines was better because it surpassed strength and balanced disorders.[16,19] In sternotomy patients, movement of the upper body was avoided until 8–12 weeks after surgery.[16,20] In those with peripheral arterial disease, the applied intensity given was relatively higher (60–80% of 1-RM).[16,21] In a time-limited setting, exercise was focused on large muscle groups by prioritizing the lower leg muscles.[16,22]

The Rationale of RE in CVD Patients

The rationale for supporting RE as an adjunct to aerobic exercise is that RE can improve CRF in addition to improving muscular fitness.[23] CRF has an independent protective effect against CAD and all-cause mortality, as shown in several studies with increased METs. Furthermore, each increase in METs was associated with a 10% reduction in mortality. One previous meta-analysis recommended that exercise programs for adult CAD patients should include a combination of AE and RE for optimal outcomes of CRF.[8]

Performing 2 to 3 days per week moderate- to high-intensity RE for 3 to 6 months increased muscular endurance and strength in both sexes of all ages by 25% to 100% based on training stimulus and initial muscle strength. Numerous recreational and occupational activities require dynamic or static efforts and often involve the upper extremities. Strength training also increased muscle endurance, with a slight increase in maximum oxygen consumption (VO2 max) as a measure of CRF. Submaximal walking time was also increased by 38% after 12 weeks of strength training. These findings suggested that improvement in CRF was caused by an increase in muscle strength through RE and aerobic exercise.[23]

Safety Issues of RE in CVD Patients

Several limitations in providing RE to patients with CVD included paying attention to excessive changes in heart rate and blood pressure, symptomatic blood pressure alteration, and loss of consciousness.[17,24] There were no proofs regarding excessive cardiovascular responses or safety issues, as shown by several studies. Administration of RE or simultaneous AE and progressive or high-intensity RE did not cause significant adverse effects.[8,14,24–26]

There were no signs of safety issues reported in one study because the variation of hemodynamic responses was within normal limits, and the patient did not experience any relevant symptoms during high- or low-intensity RE. This study also showed no major cardiovascular and musculoskeletal complications during light or high-intensity RE. There were 3 patients (7%) who reported lightheadedness for a few seconds and no other neurological complaints after each set of high-intensity RE, as well as second and third sets of low-intensity RE. Muscle fatigue and shortness of breath before starting the next set were reported by 3 (7%) and 4 (9.3%) patients, respectively.[24]

Research assessing the safety issues of RE in patients with CAD was limited. [24] Based on a previous systematic review and meta-analysis, the prevailing consensus indicated the absence of adverse effects in the group administered with a combination of AE and RE when compared to those undergoing only AE. In another study, 6 out of 19 patients reported discomfort during RE, which required modification. These discomforts included low back pain (4 patients), elbow tendonitis (1 patient), and shoulder pain (1 patient). Hypotension during RE due to dehydration was considered one of the causes.[25]

The risk of CVD is a major issue in RE for strengthening purposes. One systematic review reported no relationship between the intensity of dynamic strength training and cardiac events during exercise.[14] A meta-analysis of 34 studies found musculoskeletal complaints or complications in 8 with 23 cases and 20 of these cases occurred during exercise tests or progressive RE. In some cases, there were exacerbations of pre-existing diseases such as knee arthritis, which were relieved with lowered intensity and changes in body position. In addition, 5 musculoskeletal complaints resulted in exercise cessation.[8]

Adverse effects during RE can be prevented by thorough exercise preparation, avoidance of the Valsalva maneuver, adequate exercise supervision, and substantial consideration of the patient's functional capacity or muscle strength when prescribing exercises.[8,13,16,27,28] Before conducting the test or exercise, the patient was given instructions to abstain from consuming caffeinated or alcoholic beverages, as well as other stimulants. They were also advised not to engage in intense physical activity for 24 hours preceding the test or exercise. Furthermore, the patient obtained sufficient sleep the night before the test or exercise and had a light meal at least 2 hours before the commencement.[13] Intrathoracic pressure during the Valsalva maneuver also affected blood pressure. During the Valsalva maneuver with leg extension at an intensity of 100% of 1-RM, systolic blood pressure (SBP) and diastolic blood pressure (DBP) obtained were 311/284 mmHg. Meanwhile, when exercising with the same intensity performed during slow expiration, the increase in blood pressure was only up to 198/175 mmHg.[28]

To avoid the Valsalva maneuver, the subject is asked to exhale and inhale during the concentric and eccentric phases, perform slow movements, and warm up properly. [27,28] Subjects were then asked to rest for at least 10 minutes to achieve heart rate, blood pressure, and stroke volume levels as before measurement.[28]

Another systematic review and meta-analysis found that 22 out of 34 studies discussed exercise supervision with supervisor qualifications, including sports specialists, physical therapists, cardiac nurses, and rehabilitation staff.[9] Supervised exercise occupied a central role in the rehabilitation of patients with CAD. The exercise prescription consisted of supervised AE and RE to determine the correct type of exercise, guiding the patient in exercises to gradually increase their tolerance without creating a safety risk. Supervision also guarantees the achievement of training objectives.[29]

There are no guidelines referring to a minimum level of CRF required to initiate RE. The ACSM guideline stated that a minimum aerobic capacity equivalent to 5 METs was required to initiate an RE program in CR.[27] Williams et al stated that CVD patients with stable symptoms participated in low- to moderate-intensity RE without medical diagnostic tests provided they have a functional capacity of ≥4 METs based on estimation using a questionnaire. [30] In patients who exercise regularly, it was important to consider the size of the muscles trained. Peak blood pressure is greater during exercise in larger muscle groups; hence, patients should avoid exercises recruiting large muscle groups, such as the double leg-press. Weights should also be selected carefully based on the size of the muscle trained.[27]

The Effect of RE on Cardiovascular Responses

Cardiovascular (hemodynamic) responses to RE were assessed by changes in blood pressure and heart rate measured within 10–30 seconds after the termination of exercise.[28] Other parameters measured were stroke volume and cardiac output.[24,28] Studies showed that hemodynamic responses to RE depended on dosage parameters such as intensity, repetitions, duration, length of rest intervals between sets, and the type of RE administered.[8,9,24,28]

One previous study was conducted to assess the hemodynamic responses of RE with lighter loads in CAD patients who started the CR program. This study found that RE with these two weights was safe, feasible, and well tolerated by patients. Hemodynamic parameters also increased during exercise and returned to initial values after the activity. The increase in hemodynamic parameters was similar in both groups. Low-intensity RE induced a greater (69%) increase in heart rate from 67 to 113 beats per minute compared to high-intensity RE (39%) from 64 to 89.[24] Similarly, a study reported that high-intensity progressive RE caused a lower hemodynamic response compared to low-intensity RE in patients with CAD (Table 1). [8]

Hemodynamic responses were related to muscle strength and exercise intensity. Lower muscle strength also caused an increase in neuromuscular activity as a response to training load. The responses were expressed by an increase in the firing rate of the lower limb motor units in response to higher metabolic and mechanical activities. They were then relayed to the central nervous system to increase sympathetic activity, which resulted in increased blood pressure during long-duration, low-intensity RE.[24]

 https://doi.org/10.2147/JMDH.S516441

Table 1 Studies Related to Effects of Resistance Exercise in Patients with Coronary Artery Disease

	Study (Year)/ Study Design	Objective	Participants	Outcome Measures	Result

1	Gjøvaag TF et al (2016)/
	A randomized, crossover study[8]
		To compare the effect of resistance exercise with the same intensity and different repetitions (4-RM and 15-RM) on cardiovascular and hemodynamic responses	Post-revascularization adult patients
			(n: 15) with left ventricular EF 42% ± 9%
				• Cardiovascular responses: SV, CO, left ventricular EDV, and EF
				• Hemodynamic responses: HR, SBP, DBP, MAP, and SVR
					• 4RM group
					  ○ Exercise SBP increased by approximately 18% compared to pre-exercise
					  ○ Exercise DBP increased by approximately 13% compared to pre-exercise
					  ○ Exercise SV increased by 20% and was not different from 15 RM
					  ○ SVR decreased by 15% compared to pre-exercise and was not different from 15 RM
					• 15RM group
					  ○ Exercise SBP increased by approximately 37% compared to pre-exercise and exercise at 4RM
					  ○ Exercise SBP for set 3 was significantly higher compared to set 2
					  ○ Exercise DBP increased by approximately 40% compared to pre-exercise and significantly higher than 4RM
					  ○ Exercise DBP for set 3 was significantly higher compared to set 2
					  ○ MAP after exercise was 21% higher than 4RM
					  ○ Exercise SV increased by 50%
					  ○ HR and CO increased significantly higher compared to 4RM
					  ○ SVR decreased by 50% compared to pre-exercise
					• Blood pressure recovery after exercise was 4 minutes
					• There were no differences between groups EF and EDV. These parameters increased moderately in both group

2	Caruso FR et al (2017)/ A randomized controlled trial[13]	To compared the effect of resistance exercise with low-intensity and high-repetition and dynamic exercise on hemodynamic, ventilatory, autonomic, and metabolic responses in group of CAD patients given aerobic exercise (AEG) or combination of aerobic and resistance exercise (CEG)	Male CAD patients (n: 20)	• Hemodynamic response: HRV which indicates parasympathetic responses, changes in HR and CO at submaximal loads during both exercises • Autonomic response: parasympathetic tone • Metabolic response: lactate and VO2	Addition of resistance exercise in CEG resulted in: • HRV indices after training were higher compared to pre-training and AEG • HR mean reduction was 6.8 beats per minute during resistance exercise and 10.3 during aerobic • CO/load reduction was 10% during resistance exercise and 5% during aerobic • Blood lactate reduction was 15% • No improvement in VO2 after training

(*Continued*)

Table 1 (Continued).

	Study (Year)/ Study Design	Objective	Participants	Outcome Measures	Result
3	Helgerud J et al (2011)/ Randomized controlled trial[17]	• To investigate the effect of high-intensity AIT on peak SV and peak VO2 • To investigate the effect of MST on LPS and ME • To investigate the effect of AIT and MST on QoL	18 CAD patients (8 AIT and 10 MST)	• Peak SV • Peak VO2 • LPS • ME • QoL based on MacNew questioner	• AIT o Peak SV increased significantly by 23% o Peak VO2 increased significantly by 17% o No changes in LPS after exercise o ME increased from 19 ± 4% to 25 ± 5% o Improvement in total, physical, and social QoL scores (9%, 13%, and 10%, respectively) and no differences in the change of QoL score between groups • MST o There were no changes in peak SV or peak VO2 o LPS increased significantly from 138 ± 24 kg to 198 ± 24 kg o ME increased from 18 ± 4% to 25 ± 6% o Improvement in social QoL scores by 8%
4	Kambic T et al (2021)/ A Randomized, Crossover Clinical Trial[24]	To compared the hemodynamic response between LL-RE and HL-RE in CAD patients.	Stable CAD patients (n: 41) at ≥1 month after heart attack and/or revascularization	• HR • Blood pressure • Arterial oxygen saturation during exercise • RPE: using Borg's scale	• There were changes in HR, BP, patients reported symptoms during HL-RE or LL-RE. These changes were not clinically relevant. • During LL-RE vs baseline. o HR increased from 66 bpm to 86 bpm o SBP increased from 129 mmHg to 146 mmHg • During HL-RE vs baseline. o HR increased from 68 bpm to 86 bpm o SBP increased from 130 mmHg to 146 mmHg • During LL-RE vs HL-RE. o HR increase greater in LL-RE (32% vs 28%) o SBP and DBP: no significant differences o RPE was higher in HL-RE • HL-RE and LL-RE were proven safe and well tolerated.
5	Hussein N et al (2015)/ Randomized clinical trial[30]	To compare coronary risk factors, body composition, MET, and muscle strength between CEG and AEG in obese CAD patients.	CAD patients (n: 50) randomized equally to two groups.	• Lipid profile includes total cholesterol, TG, HDL, and LDL • BP, HR, RPP which is the product of SBP and RHR divided by one hundred • Body composition (body mass index, body density, percent body fat, and lean body mass) • MET • 1-RM	Lipid profile • Cholesterol, TG, and LDL decreased in CEG only • HDL significantly increased in both groups Blood pressure • Resting SBP, DBP, RPP significantly decreased in both CEG and AEG Body composition • Percent body fat reduce significantly in CEG compared to AEG • Lean mass increase greater in CEG MET increased significantly and was similar in both groups. Muscle strength increased in both groups, but it was not significant in AEG.

Abbreviations: AEG, aerobic exercise group; AIT, aerobic interval training; BP, blood pressure; CAD, coronary artery disease; CEG, combination exercise group; CO, cardiac output; DBP, diastolic blood pressure; EDV, end diastolic volume; EF, ejection fraction; HDL, high-density lipoprotein; HL-RE, high-load resistance exercise; HR, heart rate; HRV, heart rate variability; LDL, low-density lipoprotein; LL-RE, low-load resistance exercise; LPS, leg press strength; MAP, mean arterial pressure; ME, mechanical efficiency; MET, metabolic equivalent; MST, maximum strength training; QoL, quality of life; RHR, resting heart rate; RM, repetition maximum; RPE, perceived exertion rating; RPP, rate pressure product; SBP, systolic blood pressure; SV, stroke volume; SVR, systemic vascular resistance; TG, triglyceride; VO2, oxygen consumption.

https://doi.org/10.2147/JMDH.S516441

During isometric RE, there was an increase in heart rate and SBP or DBP, while stroke volume did not change. These changes caused a slight increase in cardiac output, and the vasoconstrictive effect prevented increased blood flow to non-contracting muscles. In addition, muscle contractions with low intensity allowed intramuscular pressure to reduce local blood flow in muscles, causing hypoxia. This situation triggered the heart to work harder to meet the oxygen needs of the contracting muscles. Furthermore, the cardiovascular load increased with continuous contractions.[31] High-intensity strength training (≥70% of 1-RM) was also more effective in increasing muscle strength, but the acute cardiovascular response was lower than low-intensity strength training.[14] During exercise with low to sub-maximal intensity, blood pressure increases with exercise duration. Therefore, the duration of RE was more important than the intensity in influencing blood pressure responses during RE.[9]

High-intensity strength training, specifically isometric exercises, can induce a stress effect leading to the Valsalva maneuver. The Valsalva maneuver is characterized by a significant increase in intrathoracic pressure, which causes an increase in systolic and diastolic blood pressure. This occurred when holding the breath during muscle contraction in strength training. Once breathing pressure was relieved, a significant increase in backflow could be triggered, leading to an increase in cardiac output. This resulted in a sharp rise in blood pressure and myocardial oxygen demand.[14,32]

A previous study investigated the relationship between RE with the same load but with different repetitions to clarify the effect of load and duration of exercise on cardiovascular and hemodynamic responses in patients with CAD. The result showed that the pressure response was higher after RE with a load of 15-RM compared to 4-RM. The increase in external loads was not a major determinant of blood pressure responses during RE. In addition, the 15-RM exercise was conducted to the point of fatigue (15 repetitions) with an exercise for 27 seconds and caused a significant increase in blood pressure compared to 4 repetitions with an exercise duration of 7.5 seconds (Table 1). [8]

One study found a greater increase in hemodynamic parameters with slower contraction repetition of 3 seconds for concentric and eccentric contractions or at a fast pace of 2 seconds compared to a very fast pace (1 second). Similarly, when the rest period between sets was more than 60 seconds, the duration of the exercise was 5–10 minutes. This study showed a greater increase in heart rate and blood pressure when the repetition speed was 1 second/1 second and the rest period between sets was 90 seconds. This dose was previously shown to induce an increase in heart rate and blood pressure as well as lower cardiac output compared to exercise with slower repetition rates and shorter rest periods (Table 1). [24]

The type of RE also influenced hemodynamic responses. One systematic review and meta-analysis found that responses during isometric RE caused a rapid increase in blood pressure. However, this increase was safe and caused a minimal hemodynamic response.[31] Studies that provided dynamic exercise obtained an increase in blood pressure and cardiac output. The increase in systolic blood pressure was more significant in low-intensity strength training.[14]

The Effect of RE on CVD Risk Factors

RE affected cardiovascular risk factors when given in the form of a single exercise or in combination with AE.[14,30] RE for strengthening purpose has been proven effective in controlling blood sugar, blood pressure, and lipid profile in elderly patients with high cardiovascular risk. These findings were considered as a basis for adding RE to AE.[14]

There was a 23% reduction in the risk of fatal and nonfatal myocardial infarction in male respondents who did progressive RE for 30 minutes or more per week and an 18% reduction in men who conducted walking exercises 3.5 hours per week. Mechanisms for reducing mortality due to the administration of these two types of exercises were not identified. The same increase in CRF between progressive RE and AE was associated with a reduced risk of death.[8]

A previous systematic review and meta-analysis that assessed the effect of isometric exercise on SBP, DBP, and mean arterial pressure (MAP) in subclinical patients showed that isometric RE lowered blood pressure. Reduction in blood pressure was similar and greater than other modalities. Meanwhile, SBP decreased by almost 7 mmHg after isometric exercise.[31] Another study found that a combination of AE and RE caused a decrease in SBP in the intervention group. A reduction in mean SBP of 2 mmHg might not be clinically significant.[33]

The mechanism of blood pressure reduction due to RE was still unclear through changes in the systemic resistance of blood vessels. The isometric exercise was reported to increase vascular nitric oxide-mediated vasodilation in response to reactive hyperemia in patients receiving antihypertensive medication. This effect was only seen in the exercised limb with normal blood pressure. Isometric exercise also improved endothelial function and increased the diameter of limb arteries, increasing blood flow and reducing vascular resistance. In addition, there was limited evidence that isometric RE was associated with decreased sympathetic modulation of blood vessels, and larger studies reported potential adaptations to blood vessel function after isometric exercise.[34] The intensity of less than 40% maximum force increased catecholamine, adrenaline, and nor-adrenaline levels. In isometric exercises, which were carried out until fatigued, the increase in adrenaline was more dominant than noradrenaline, increasing cardiovascular responses.[33]

A previous study compared the effect of AE and RE combination on coronary risk factors in patients with CAD and obesity. The combination caused significant reductions in cholesterol, triglyceride, and low-density lipoprotein (LDL) and increased high-density lipoprotein (HDL) levels. The result showed that obese patients with CAD who performed a combination of AE and RE indicated a decrease in body fat percentage. The increase in fat-free muscle mass was not significantly higher in the group receiving a combination of AE and RE compared to AE alone. Patients with heart disease who performed a combination of AE and RE for 12 weeks lost body fat and gained lean mass (Table 1). [30]

Controlled CVD risk factors also increased motivation and self-confidence in carrying out physical activities and exercise, as well as other healthy lifestyles, such as controlling diet and weight management. [35] The reason was due to reduced anxiety and fear of disease worsening triggered by physical activity or exercise. Furthermore, improving healthy lifestyles was related to improving the QoL.[35–37]

The Effect of RE on Muscle Strength

To increase muscle strength in CVD patients, RE was given in a single exercise or in combination with AE. It was administered from the beginning of the CR program along with AE or after regular AE for 4–6 weeks.[13,16] Data from several studies showed that administering a combination of AE and RE caused an increase in muscle mass and strength.[8,13,14,30] A significant increase in muscle strength was found in patients who conducted a combination of AE and RE varied between 42% −54%. One study found an increase in muscle strength from 45% to 95% in male CVD patients trained for 12 weeks with high-intensity RE.[30] One systematic review and meta-analysis reported that the provision of high-intensity RE in the management of patients with CAD led to a faster increase in muscle strength compared to RE having a lower intensity.[26]

The strength gained in the first few weeks of an RE program was largely caused by neuromuscular adaptation. The nervous system recruits larger motor units with a higher frequency of stimulation to provide the strength needed to overcome the load placed on muscles. The increase occurred due to increased muscle tension due to a more efficient nerve recruitment process.[38–43]

Muscle hypertrophy is an increase in total muscle mass and cross-sectional area. It is more common in fast-twitch muscles than in slow-twitch.[42,44,45] Type 2A fibers show the greatest growth, more than types 2B and 1 fibers. Muscle hypertrophy is experienced after 6 to 7 weeks of endurance training.[42,44–46] Furthermore, it occurred through the remodeling of proteins in cells and an increase in the size and number of myofibrils. An increase in the number of actin and myosin filaments with the addition of sarcomeres contributes to the size of the fiber.[43,47,48]

The mechanism and biochemical changes that mediate the net changes in muscle strength and size are partly due to hormonal changes caused by RE.[49,50] In strength training, skeletal muscle ribosome biogenesis is induced, causing hypertrophy. Meanwhile, strengthening exercises also induce changes in muscle fiber type.[14,43,51,52] Contractile proteins can also accumulate in muscle fibers by increased synthesis, decreased breakdown rates, or a combination of both.[43,44,47] During muscle hypertrophy, the synthesis rate of contractile proteins is greater than the degradation, leading to a greater number of actin and myosin filaments in the myofibrils.[42,47]

High-intensity strength training increases myofibrils, which results in a greater increase in muscle mass.[14,41,53] This training produces greater neural adaptation, as evidenced by the percentage of voluntary contraction activation and increased amplitude on electromyographic examination during maximum force production.[14]

The Effect of RE on CRF

The addition of RE to AE causes an increase in CRF as measured by peak work capacity, peak oxygen consumption (VO2 peak), VO2 max, and 6-minute walking test distance (6MWD).[8,13,25,26,34] Furthermore, the combination of AE and RE results in a higher increase in peak work capacity in patients with CAD.[8,25,26]

The combination also increased VO2 peak with a greater increase in the group that received AE and RE.[26] A review of the literature and meta-analysis found that the combination showed an increase in 6MWD compared to the group given AE alone.[33]

There was a decrease in resting heart rate of 5 beats per minute in the group given a combination of AE and RE. Changes in peak heart rate were lesser when given AE and RE with 4–5 beats per minute. An increase in peak heart rate facilitated a slight increase in peak cardiac output and VO2. In addition, increased cardiac output facilitated the contractile reserve of the heart muscle.[33]

VO2 max values are usually not significantly affected by heavy RE.[43,54,55] Circuit weight training consisting of a series of exercises of 12 to 15 repetitions at 40% to 60% of 1-RM with brief rest periods of 15 to 30 seconds also produces a slight increase in VO2 max.[23,43,56] Meanwhile, the RE program designed to increase VO2 max should consist of higher training volume and shorter rest periods between sets. The maximum increase was substantially less than the results obtained from an AE program at 15% to 20%.[43,55,57] Based on these findings, when the primary goal of an exercise program is to increase VO2 max, some form of AE should be included in the activity.[43,54]

The Effect of RE on QoL

A previous review found that in the group given a combination of AE and RE, the QoL score increased. The average score on QoL in the RE group was 8.31% compared to the control.[34] Similarly, one previous study reported that some scores for QoL increased significantly after exercise in each group given high-intensity AE and muscle strength training. In the strength training group, the social scores detected by the MacNew questionnaire increased by 8%. In the group given AE, the total QoL score increased by 9%, while physical and social aspects increased by 13% and 10%, respectively (Table 1). [17]

An increase in the QoL score was obtained due to high muscle strength and CRF, as well as diminished symptoms and controlled CVD risk factors.[17,26,33,35–37] Similarly, an increase in muscle strength with the addition of RE to AE reduced the risk of death and increased the capacity to conduct daily activities to improve QoL. This increase resulted in a quicker return of the patient to daily activities and an increase in work capacity. Improved CRF was also associated with high self-satisfaction, leading to greater exercise participation after a structured exercise program.[26]

Conclusion

In conclusion, RE is safe for CAD patients because an exaggerated cardiovascular response has not been proven in properly prescribed exercise. It also improves QoL by controlling risk factors and improving muscle strength and CRF. This review found that previous studies used various prescriptions and outcome measures to know the effect of RE on CAD patients. This review also found that previous studies that assessed RE's effect specifically on muscle strength, CRF, and the QoL were limited. Based on our conclusion so far, future studies could be addressed to further observe the effect on muscle strength, cardiorespiratory fitness, and QoL due to limited research in the past and the disparity between prescription and outcome of resistance exercise in most cases.

Acknowledgments

The authors sincerely appreciate Universitas Padjadjaran for the invaluable opportunity to conduct this review and for the support in providing access to the necessary database facilities.

Disclosure

The authors declare that there is no conflicts of interest associated with this study.

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