# Dose–effect relationship of resistance training in cardiac rehabilitation program for patients with coronary artery disease: a systematic review

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Resistant training is an essential and effective component of cardiac rehabilitation program (CRP) for patients with coronary artery disease (CAD). The aim of the study was to find out the dose–effect relationship of resistant training in CRP for patients with CAD for the purpose of determining the optimal dose prescription that balances between safety and effectiveness. The study design was a systematic review with searching the electronic database of PEDro guided by inclusion and exclusion criteria. The results showed that resistant training added value to the aerobic training in CRP of patients with CAD and that different elements were used regarding its dose description, including intensity, frequency, duration, volume, and type. Regardless of the intensity, resistant training showed improvement in different outcome measures even more than aerobic training alone. High-repetition low-intensity resistant training showed to be beneficial. Both the duration of resistant training and time of involvement of it in the cardiac rehabilitation have an influence on its effect. Both dynamic and isometric resistant training programs were effective, in favor of the isometric type, and both concentric and eccentric training programs were effective, in favor of the eccentric type. The dose–effect of the resistant training in cardiac rehabilitation of patients with coronary artery diseases is not dependent only on the 5 elements for dose prescription, but it is largely dependent on the interactions between these 5 elements.

**Keywords:**
cardiovascular and noncardiovascular outcome measures, resistant training, training duration and frequency, training intensity, training volume and type

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## Introduction

Cardiovascular disease, including coronary artery disease (CAD), is a common global health problem, one of the noncommunicable diseases, leading cause of death, and the main risk factor for worldwide morbidity [1,2]. In addition to medication and surgery, cardiac rehabilitation program (CRP) is a common alternative in the health care strategy for patients with CAD. The CRP is recommended by the American Heart Association and the American College of Cardiology for not only rehabilitation purpose but also prevention of CAD [3–9]. One crucial component of CRP is the exercise therapy, which is considered as a nonpharmacological intervention that is shown to be effective for patients with CAD and that is used to improve cardiovascular health, particularly the exercise capacity, and the overall health as well [3,4,10–13]. The aerobic training (AT) and resistance training (RT) were recommended by the American Heart Association as the main components of exercise therapy within the CRP [5]. The accumulated studies in the literature had developed evidence for AT as the gold standard training for exercise therapy of CRP and as effective training in maintaining and even improving the exercise capacity and cardiovascular health [14–17]. Reduced physical and functional capacities were health problems faced by the patients with CAD, which raised the need for RT to address this health problems. RT, also named as strengthen training, is defined as muscular fitness in which the energy fuel is the ATP [18], and it includes using free weights, machines with stacked weights or pneumatic resistance, and rubber bands [4]. Historically, RT was added to AT in combined training (CT) protocol in the early 1990s, and since that time, RT has been an integral part of international recommendations for prevention and rehabilitation in patients with CAD [19,20]. The RT is now considered by the medical community as an essential part of exercise therapy in CRP for patients with CAD [21,22]. Different types of muscle contraction can be used with RT, namely, concentric and eccentric muscle contraction. In a concentric contraction, the muscle tension rises to meet the resistance, so that the muscle force is greater than the resistance, then the force remains stable as the muscle shortens. An example includes biceps curl. Eccentric contraction occurs when the force generated by the muscle is less than the resistance, so the muscle actively lengthens. Eccentric actions are often used when muscles must slow down body parts, control movements, or oppose external resistances. The downward phase of a biceps curl, for example, requires eccentric action of the biceps muscle. The muscle exerts force to control the speed of the downward movement, but its length increases [23,24]. Type of muscle contraction also includes dynamic and isometric muscle contractions. Lifting weights is an example of dynamic muscle contraction in which the muscle force developed resulted in joint movement. Meanwhile, an isometric action is a static action that involves sustained contraction against an immovable load or resistance with no or minimal change in length of the involved muscle group, and muscle generates force but there is no joint movement. When a barbell is held at the midpoint of the bicep curl, the biceps exert force but do not change in length [23–25]. The added RT in the CT had proved to be safe and effective training for patients with CAD [26–29] both after myocardial infarction (MI) [30,31] and after coronary artery bypass graft (CABG) surgery [32], in the form of improvement of exercise capacity, functional capacity, psychosocial well-being, and metabolic risk factors, including hypertension, hyperglycemia, and dyslipidemia in patients with CAD [4,33,34]. Adding RT to the AT in CRP also showed benefits of improvement in functional capacity, health-related quality of life (HRQOL), level of independency, and skeletal muscle strength and endurance with reduction in disability [33–35]. Despite this proved safe and beneficial effect of RT, the optimal dose prescription remains in need to be determined [36–42]. This may be owing to the relatively recent recommendation to include RT to CRP, the complexity of the training prescription in CRP, and because RT has not been fully adopted as a core only component of CRP [43]. Adding to that, the effect of different protocols of RT as well as the different doses of RT are not well studies. In fact, RT protocols vary widely with respect to the relative amount of weight lifted per exercise as percent of one-repetition maximum (1 RM) (intensity), the number of sets and number of repetitions per set (volume), the number of sessions per week (frequency), target muscle groups, and time of involvement of RT in the CR program, which could be another factor that influences the effect of RT in CRP for patients with CAD [44,45]. From one side, varied combination between AT and RT are available [46], and from the other side, knowledge to reach conclusion regarding the optimal RT dose prescription for beneficial training effects is available with insufficiency [42]. Meanwhile there is a required need by the health care team for evidence to guide the dose prescription of RT for patients with CAD [44]. This systematic review (SR) study aimed to find out the dose–effect relationship of RT in CRP for patients with CAD for the purpose of optimal dose prescription balancing between safety and effectiveness.

## Patients and methods

To find out the dose–effect relationship of RT in CRP for patients with CAD, a systematic methodology was used to review the literature. The PEDro database was used for reviewing of the literature. The PEDro is a Physiotherapy Evidence Database known for high-quality studies of randomized trials, SRs, and clinical practice guidelines in physiotherapy. It is a free database [47]. Inclusion and exclusion criteria were developed to guide the searching strategy and selection process of the articles to be included in this SR. The included articles were with the following inclusion criteria: (a) articles included in the PEDro database; (b) articles with randomized control trials (RCTs), SR, and meta-analysis (MA); (c) publication date from 2010 to date; (d) publication with English language; (e) the CRP is applied on site-base; (f) articles with the objective of measuring the effect of RT; (g) adult patients (18–60 years) or adult and old patients (18 and above 60 years); (h) cardiac patients with CAD (e.g. MI and CABG surgery); (i) the CRP included RT or CT; (j) outcome measures used were cardiovascular and/or noncardiovascular; and (k) accessibility to full free article. The exclusion criteria included (a) CRP with home-based application; (b) patients with heart failure, heart transplants, or implantable defibrillators; (c) animal participants; and (d) patients with old age only. The author searched the PEDro for RT in CRP for patients with CAD and used the systematic selection process to filter the posted articles and to identify the articles to be included in the SR. The systematic selection process included three levels of checking the article relevancy to the study and matching to the inclusion and exclusion criteria: the first level is the relevancy of the article's title, the second level of relevancy was checked by reviewing the article's abstract, and reviewing the full free article was done to ensure the third and last level of article's relevancy. The relevant articles that passed the three levels of relevancy were included in the current SR study.

## Results

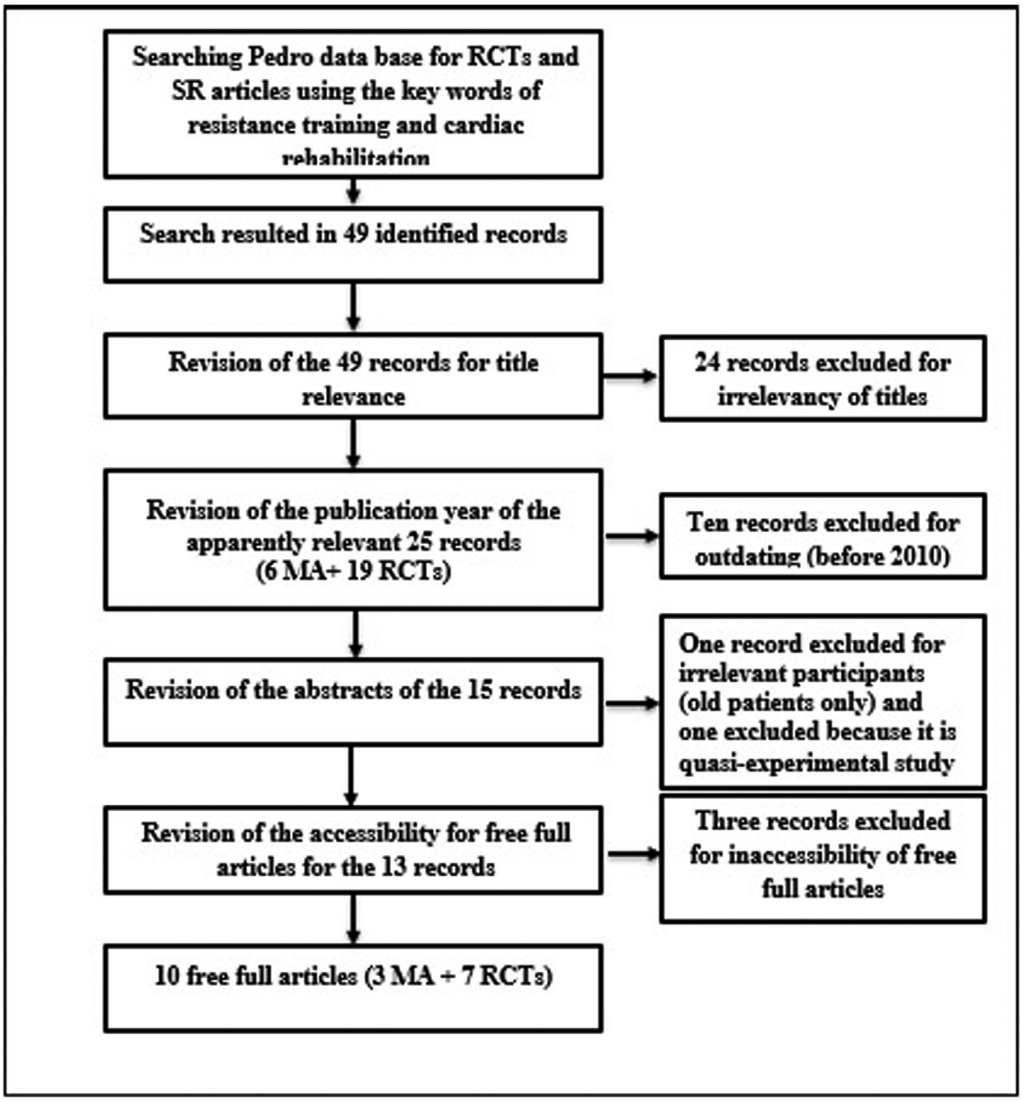
### Results of systematic selection process

Searching the PEDro for RT in CRP for patients with CAD resulted in 49 articles (Fig. 1). The first level relevancy (relevancy of article's title) showed 25 relevant articles. Regarding the 24 irrelevant articles, there were four causes for title irrelevancy: (a) irrelevant patients' diagnosis (*n*=15, comprising 10 heart failure, one Parkinson's disease, one spinal cord injury, one stroke, one metabolic disorders and one atrial fibrillation); (b) irrelevant patients' age (*n*=3, including two old age only and one pediatrics); (c) irrelevant intervention (*n*=4, including one exercise testing protocol, one weight loss protocol, one interval training, and one inspiratory muscle training); and (d) irrelevant language (*n*=2, one French language and one Icelandic language). The second level of relevancy (relevancy of the title's abstract) resulted in 13 included articles out of the 25 articles. The causes of excluding the 12 articles included the following: (a) outdating of the articles (*n*=10), (b) irrelevant patient's age (one old age only), and (c) irrelevant study design (one quasi-experimental design). The third level of relevancy excluded another three articles owing to inaccessibility to the free full text. The systematic selection process ended with 10 included articles (three MA of RCTs and seven RCTs) matched with the inclusion and exclusion criteria of this SR study. Within these 10 studies, nine studies investigated the effect of RT as part of CT, and only one study compared between two different protocols of RT.

### Results of patients' characteristics

Both sexes were represented in the 10 included studies, except in two studies, where only male patients were included. In the 10 included studies in this SR, patients

**Figure 1**




The three levels of articles' systematic selection process.

were either adult or adult and old. Of the 10 studies, four studies had patients' age ranged from 40 years to late 60th or early 70th. In one study, the patients' age was in a more limited range, from 55 to 60 years. However, in three studies, the mean patients' age was around 60 years. The most common inclusion criteria in the 10 studies were patients with CAD post-MI, CABG, or were after percutaneous coronary intervention. They were stable patients with ejection fraction less than 45 and with more than or equal to 50% or with more than or equal to 70% arterial diameter narrowing of at least one major coronary artery. Meanwhile, the most common exclusion criteria were severe or uncontrolled cardiac arrhythmia or unstable angina pectoris or uncontrolled hypertension, and musculoskeletal conditions limiting patient from participation in exercise training.

### Results of the used exercise therapy protocol and resistance training dose prescription

Different exercise therapy protocols were used in the 10 included studies (Table 1). The prescription of RT was based on duration (range, 1 to >7 months), frequency (two to five time/week), volume (range, 2–10 exercises/session, one to eight sets/session, and 10–20 repetition/exercise), type (concentric, eccentric, dynamic, and isometric), and intensity. The intensity of RT was prescribed with different ways, including (a) percentage from the 1 RM, (b) percentage from the maximum voluntary contraction, (c) heart rate (HR) reserve, and (d) ratings of perceived exertion of Borg scale and modified Borg scale. Table 2 summarizes the items of prescription of RT protocols. The variation in exercise therapy protocols also included the AT, where the duration was ranged from 8 to 60 min, and the intensity was ranged from 60 to 80% of peak oxygen consumption ($VO_2$ peak) in one study, 40–85% of peak HR in one study, and 60–70% of HR reserve in another study.

### Results of the used outcome measures

In Table 3, the used outcome measures in this SR were divided into two main categories: Cardiovascular outcome measures (COMs) and non-cardiovascular outcome measures (NCOMs).

**Table 1 Types of exercise therapy protocols used in the 10 included studies in the systematic review**

| Exercise therapy protocol | Number of studies |
|---|---|
| CT vs. AT alone | 4 |
| CT with RT of 2 sets×12 repetitions vs. CT with RT of 3 sets×15 repetitions | 1 |
| CT with concentric RT vs. CT with eccentric RT | 1 |
| 2 CT with different AT | 1 |
| AT, RT, and CT | 1 |
| CT in which RT is of one set, CT in which RT is of 3 sets, and AT alone | 1 |
| Isometric RT Vs. dynamic RT | 1 |
| Total | 10 |

AT, aerobic training; CT, combined training (AT+RT); RT, resistant training.

**Table 2 Elements of dose prescription of resistant training protocols used in the 10 included studies in the systematic review**

| Item of prescription of resistant training protocol | Description | Number of studies |
|---|---|---|
| Duration (per month) | Approximately 1 month (4–5 weeks) | 3 |
| | 2 months | 1 |
| | 3 months | 1 |
| | 6 months | 1 |
| | >7 months | 1 |
| | From 1 to 6 month | 1 |
| | From 1 to 7 months | 1 |
| | From 1 to >7 months | 1 |
| Frequency (times/week) | 2–5 times/week | 8 |
| Intensity | | |
| Percentage from 1 RM | From 30% to over 80% | 6 |
| From the MVC | 70% of isometric MVC | 1 |
| | 60% of dynamic MVC | 1 |
| Heart rate reserve | 75–85% | 1 |
| Rating of perceived exertion of Borg scale | The weight to elicit a score of 11–15 | 1 |
| Rating of perceived exertion of Modified Borg scale (1–7) | The weight to elicit a score of 4–6 | 1 |

MVC, maximum voluntary contraction; RM, repetition maximum.

**Table 3 Outcome measures used in the systematic review**

| Category | Type | Number of studies |
|---|---|---|
| Cardiovascular outcome measures | Exercise capacity in terms of $VO_2$ peak or $VO_2$ max | 4 |
| | Maximum metabolic equivalent | 1 |
| | Exercise time during symptom-limited cardiopulmonary exercise testing | 1 |
| | Left ventricle ejection fraction | 2 |
| | Cardiac output | 1 |
| | Adverse effects or side effects | 4 |
| Noncardiovascular outcome measures | Skeletal muscle strength (lower extremity muscle strength, upper extremity muscle strength, and trunk muscle strength) | 6 |
| | Skeletal muscle endurance | 1 |
| | Health-related quality of life | 5 |
| | Body composition | 2 |
| | Body weight and BMI | 1 |

### Results of effect of resistance training

Results showed that the RT was an added value to the AT and that the CT with addition of RT revealed better improvements than the AT alone for both cardiovascular outcome measures and NCOMs. Exercise capacity in terms of $VO_2$ peak, heart rate variability (HRV), and exercise time showed more significant improvement with the CT than the AT alone [4,12,43,44,48]. The NCOMs also showed better improvement with CT more than with AT alone, such as upper and lower extremities skeletal muscle strength [4,43,44,48], skeletal muscle endurance [48], body composition [4,21,43], and HRQOL [12,21,43,45,49]. Results also showed that a significant pre–post training effect was found in concentric and eccentric RT, with a tendency for a better improvement of symptom-limited $VO_2$ and ankle plantar flexor maximal isometric voluntary contraction with the eccentric RT protocol [50]. Pre–post significant increase also shown in peak power output, in favor of isometric RT protocol [21]. Like AT, RT showed pre–post training significant increase in maximal HR and systolic blood pressure (SBP), with no significant difference between the isometric and dynamic RT protocols, but the isometric RT protocol significantly decreased the maximal diastolic blood pressure (DBP), whereas the dynamic protocol significantly increased it [21]. In addition, the results indicated that there was no significant difference between the effects of two volumes of RT (two sets×12 repetitions vs. three sets×15 repetitions), and both volumes induced pre–post improvement in $VO_2$ peak and skeletal muscle strength [44]. In one study, the addition of RT for 3 months after a solo 3 months of AT did not produce any further improvement in $VO_2$ peak [45]. Meanwhile, the same study recorded no change in lipid profiles (high-density lipoprotein) and HRQOL (self-evaluated health) during the 3-month duration of AT; however, it showed increase during the further 3 months with the addition of RT [45]. Comparison between AT, RT, and CT indicated that aortic systolic pressure is significantly decreased with the AT and RT, whereas the aortic diastolic pressure significantly decreased with RT only [3]. The RT also had no effect on cardiac mechanical function [(Left ventricular ejection fraction (LVEF) and cardiac output (CO)], whereas both the AT and CT resulted in significant improvement [3]. Another comparison between three training protocols [49] showed that AT, CT (RT one set), and CT (RT three sets) significantly improved the HRQOL (self-efficacy of lower body physical activity tasks), and the RT of three-set group showed marked improvement than the RT of one set. For the HRQOL (self-efficacy for upper body physical activity tasks), AT had no effect, and both RT groups showed significant improvement, with favorable effect in the RT of three sets. Regarding the physical component of HRQOL, the three training protocols showed significant improvement. Although RT of one set and RT of three sets significantly decreased the depression score in the same way, the depression score was not improved with AT [49]. The RT revealed to be safe for patients with CAD with no observed adverse or side effects. This is true for different RT type (isometric and dynamic) and volume (two sets×12 repetitions vs. three sets×15 repetitions) [12,21,44,49,50].

## Discussion

Exercise therapy has been proved to be an effective integral part of CRP for patients with CAD. This exercise therapy includes the AT, which is considered the gold standard, as well as the RT. The RT started to be included in the CRP for patients with CAD since the 1990th to break the vicious cycle observed at that time. This vicious cycle includes reduction in exercise capacity for patients with CAD owing to the cardiac problem with consequent reduction in functional activity followed with reduction in skeletal muscle strength and endurance, which cause more limitation in functional activity and exercise capacity. This vicious cycle shows up as decrease in patients' HRQOL. When the RT was added to the AT in the exercise therapy in the form CT, it was aiming to improve the skeletal muscle strength and endurance to help improve the functional capacity with consequent improvement in exercise capacity and finally the HRQOL. Results of this SR proved that the RT was a perfect choice to be added to the AT to break the aforementioned vicious cycle. The RT was found to improve the exercise capacity (both the $VO_2$ peak and the exercise time), to have possible antihypertensive effect, to improve the upper and lower extremities skeletal muscles strength and endurance, and to improve the body composition as well as the sleep quality, depression and HRQOL. In addition, results of this SR also showed that the RT is safe, as well as the AT, as there was no observed side effects or adverse effects.

### Resistance training dose–effect relationship: resistance training protocol intensity and frequency

The problem with RT as with any other protocol within the exercise therapy is that the effects of certain RT prescribed dose cannot be generalized to other doses or other patient populations. For this reason, the current SR aimed to find out the dose–effect relationship of RT in CRP for patients with CAD for the purpose of determining the optimal dose prescription that balances between safety and effectiveness. The elements of dose prescription used for RT in the 10 studies included in the SR were five, comprising (a) intensity, (b) frequency, (c) volume, (d) duration, and (e) type.

It might be supposed that high intensity (>65% of 1 RM) of RT would have better effects than the low intensity (30–50% of 1 RM), but the results of this SR did not support this suppose. The results showed that regardless of the protocol intensity (identified as percentage of 1 RM) of the RT or CT, improvement of different CVOMs and NCVOMs was indicated even more than with the AT alone. The reason behind this may be that the intensity was not the solo element of dose description that varied within the 10 included studies. In the 10 included studies, dose prescription of RT was identified with different alternatives of the five elements. The interactions among these five elements would result in different or equal doses of RT and consequently with variant patterns of dose–effect relationship. In the current SR, the moderate intensity (50% of 1 RM) RT protocol [45] and the high intensity (80% of 1 RM) RT protocol [43] both significantly improved the upper and lower extremities skeletal muscle strength and the $VO_2$ peak, but the first moderate intensity protocol was performed for higher frequency (up to five times/week) than the second high intensity protocol (up to three times/week). The higher frequency in the first protocol may equalize the higher intensity in the second protocol and lead to an equal effect of both protocols. In other words, doing the RT protocol five times/week with lower intensity would end up with results like doing the RT protocol three times/week with higher intensity. Another example for this interaction is the RT protocol used in one of the included studies in this SR [48] in which high-repetition/low-intensity RT (HR/LL-RT) was applied for 8 weeks as part of CT. This HR/LL-RT protocol showed to be beneficial for patients with CAD in terms of producing significant improvement in skeletal muscle strength and endurance and different HR variability indices, which indicates an increase in parasympathetic modulation (a potential shift toward increased parasympathetic and decreased sympathetic nervous activity). It could be said that the high repetition of the RT augmented the effect of low intensity and produced positive effects. In addition, the achievement of skeletal muscle strength with only low-intensity RT with high repetition may point toward the concept of low-intensity RT protocols could allow the right balance of positive physiologic gains and safety in patients with CAD [48]. For this reason, the HR/LL-RT is recommended in patients with CAD to avoid harmful hemodynamic effects induced by higher resistance loads [51].

### Resistance training dose–effect relationship: resistance training protocol duration

RT duration is related to the training effect on the cardiovascular health [3]. It is to be noted that in one of the included studies [4], the RT with moderate intensity was applied for only 4–8 weeks, whereas in another study [43], RT with high intensity was applied for 4–29 weeks. One could logically assume that higher intensity with longer duration RT would end with effect values higher than that with lower intensity and shorter duration. The results of the two studies [4,43] did not support this assumption, the $VO_2$ peak was increased by 0.92 ml/kg/min with the first RT protocol (moderate intensity and shorter duration), and it increased by only 0.41 ml/kg/min with the second RT protocol (high intensity and longer duration). It is to be noted that this even modest increase in $VO_2$ peak can obtain significant prognostic and functional benefits [52]. This result could be explained by younger upper limit of age range (60 years) of patients participated in the first protocol than the upper limit of age range of patients participated in the second protocol (71 years). This assumption is in line with the results of one of the studies, which found that different age is associated with the effect of training on the cardiovascular health [3]. It is important to mention that it is not only the duration of protocol that could influence the effect of RT but also the time of involvement of RT in the CR program. In the study that delayed the involvement of RT in the CR program to 3 months after the AT, the $VO_2$ peak showed no further improvement, but the lipid profiles (high-density lipoprotein) and HRQOL were improved. These results ensured that the time of involvement of RT in the CR program is an important element to be added to the dose prescription elements.

### Resistance training dose–effect relationship: resistance training protocol volume

One of the included studies [44] in the current SR compared between two RT protocols with different volumes (two sets×12 repetitions vs. three sets×15 repetitions), and the results showed that both volumes significantly improved the $VO_2$ peak, skeletal muscle strength, blood lipids, and hemodynamics (HR, SBP, and DBP) but with no significant difference between the two volume protocols. Although this study did not support the difference of RT effects with different protocol volume, another included study [49] indicated that higher RT volume produces more positive effects, as the three-set RT protocol improved the HRQOL (self-efficacy for lower and upper body physical activity tasks) more than the one-set RT protocol. The controversy between these two studies' results raised suspicion about the ability of volume element to influence dose–effect relationship of RT. The cause that RT protocol with different sets did not show difference in the measured outcomes in first study may be owing to the used short duration (4 weeks) and medium intensity (60% of 1 RM), whereas the different sets of RT protocol in the second study that produced different outcome measure may be owing to the used longer duration (29 weeks) and higher intensity (75% of 1 RM). The patients' age could not be one reason for the difference between the two studies' results because the mean age of patients in both studies was very close (62.7 and 60.6 years, respectively). Indeed, this result supports the aforementioned assumption that the interactions among the five elements of RT dose prescription would affect the dose–effect relationship.

### Resistance training dose–effect relationship: resistance training protocol type

Both dynamic and isometric RT appeared to be beneficial for patients with CAD. In the current SR, one RCT study [21] used only RT for the patients with CAD and applied two protocols with different RT types: dynamic and isometric. Results showed that the two protocols were safe with no adverse effects. Both protocols improved the upper and lower extremities skeletal muscle strength as well as sleep quality and HRQOL but with no significant difference between both types [21]. Both protocols produced significant improvement in peak power output as measured with the cardiopulmonary exercise test, and the between-group comparison favors isometric RT. The favoring of isometric RT protocol may be explained by the claim that many patients with CAD experience degenerative joint changes owing to either aging or inactivity accompanying the decrease of exercise capacity and consequent shortage of functional capacity. Isometric RT protocol could be more convenient for such patients with CAD, as there is no joint movement as in the case with the dynamic RT protocol. Regarding the blood pressure (BP), dynamic RT resulted in increase in both SBP and DBP, whereas the isometric RT showed partial antihypertensive effect. Isometric RT increased the SBP, but it reduced the DBP. Another SR and subsequent MA done confirmed this antihypertensive effect of isometric RT in terms of SBP, DBP, and mean BP [25]. The study added that reduction in BP appeared to be larger in hypertensive males and those over 45 years of age, and training involved unilateral arm for more than 8 weeks duration. It was also reported that BP reductions were observed independent of weight loss. The difference regarding the SBP between these two studies [21,25] may be related to the longer duration RT protocol (>8 weeks) in the MA study [25] compared with the shorter duration RT protocol (4 weeks) in the RCT study [21]. Moreover, in the RCT study, the whole-body isometric RT training was used, whereas the antihypertensive effect favors the unilateral arm training. The arm training is favored in other study in which the arm isometric RT appears to be superior to leg isometric RT, and this may be explained by the fact that the active muscle mass is smaller in the arm, so the threshold at which the arteries become occluded may also be lower, and repeated exposure to arterial occlusion leads to repeated bouts of hypoxia in the forearm, which results in stimulus for changes in arterial stiffness [53]. The partial antihypertensive effect of isometric RT can also be explained by the improvement of microvascular perfusion, as with isometric contraction, microvessels are compressed for longer time than the dynamic contraction, enhancing better perfusion [3]. Other studies also supported isometric RT as antihypertensive nonpharmacological agent and stated that isometric RT may elicit BP reductions greater than those seen with dynamic aerobic and dynamic RT [54–56]. This result highlighted the importance of muscle group (s) involved in the RT protocol as a dose description element that influence the dose–effect relationship of RT. Moreover, it is to be noted that some activities of daily living and occupational tasks require isometric muscle contraction, so it is beneficial to consider the isometric training for patients with CAD during CRP especially for patients who wish to return to their jobs [57]. Another comparison took place between the concentric and eccentric types of RT in one of the 10 included studies [50], and the comparison is in favor of eccentric type. Both concentric and eccentric types of RT improved the CVOMs (symptom-limited $VO_2$ peak, peak workload, and walked distance on 6-min walk test) and NCVOMs (lower extremity skeletal muscle strength), with better improvement with the eccentric RT [50]. During muscle contraction including RT, there are two phases of skeletal muscle contraction, concentric, and eccentric. The force generated during muscle contractions is higher in the eccentric phase [58]. This physiological effect of eccentric muscle contraction may explain the more skeletal muscle strength in the plantar flexors with eccentric RT than with concentric RT [50]. There is also a claim that eccentric RT produces less cardiopulmonary demands as compared with concentric RT [58] and that eccentric RT may be better suited for persons with low exercise tolerance and who are at risk of adverse cardiopulmonary events as well as for improving or maintaining cardiovascular fitness [58]. This claim may be considered as the reason for more improvement of symptom-limited $VO_2$ with eccentric RT than with concentric RT in patients with CAD observed in the aforementioned study [50]. It is important to also note that eccentric muscle contractions are essential in performing normal daily activities and physical activities such as stair climb and descent, body transfers, and balance tasks [59]. So, the eccentric RT produces more skeletal muscle strength, more improvement to exercise capacity, and the eccentric contractions are important for activity of daily living. These three factors make the eccentric RT a perfect RT protocol for patients with CAD. It can be said that none of the five elements used in the current SR for dose prescription were able as a solo element to identify dose–effect relationship, and the assumption of interaction among the five elements is theoretically valid.

## Conclusion

The RT is a beneficial and safe exercise therapy like the AT in the CRP of patients with CAD. It has positive effects on CVONs and NCVOMs even more than the AT alone. The beneficial effects of RT are highly dependent on the training dose prescription, which include the following five elements: training intensity, frequency, volume, duration, and type. These dose prescription elements are interacting together in different ways to produce different dose–effect relationships. It is the interaction rather than the elements themselves which shape the RT effects. Eccentric and isometric RT protocols are more beneficial than concentric and dynamic RT protocols. The HR/LL-RT appeared to be recommended because of its ability to balance between the outcomes of gains and safety.

### Clinical implication

The current SR raises the importance of isometric RT protocol, especially for patients who wish to return to their jobs and patients with degenerative joint diseases, with the implementation of eccentric RT especially when improvement of skeletal muscle strength is desirable, and the application of HR/LL-RT protocol especially when safety is more considered.

### Further study recommendation

The current SR highlighted the need for further study to establish well identified dose–effect relationship. Experimental study design and preferable randomized controlled studies are required to investigate the solo effect of each of the elements used in RT dose prescription with control of the rest of elements. In addition, other elements, rather than the five studied elements in the current SR, need to be investigated, such as the time of involvement of RT in the CRP and target muscle group.

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### Conflicts of interest

There are no conflicts of interest.

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