Role of resistance training in heart disease

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ABSTRACT

Role of resistance training in heart disease. Med. Sci. Sports Exerc., Vol. 30, No. 10(Suppl.), pp. S396-S402, 1998. Since the mid-1980s resistance training has become an accepted part of the exercise rehabilitation process for patients eligible for traditional cardiac rehabilitation programs. A growing number of studies have demonstrated the safety of resistance training in Phase III/IV programs (Phase III-community based, beginning 6-12 wk posthospital discharge; a typical patient would be clinically stable with a functional capacity of ≥ 5 METs; Phase IV-long-term maintenance) and more recently in Phase II (beginning within 3 wk posthospital discharge and lasting up to 3 months). Evidence is consistent that this form of training provokes fewer signs and symptoms of myocardial ischemia than aerobic testing and training, perhaps because of a lower heart rate (HR) and higher diastolic pressure combining to produce improved coronary artery filling. The major role of resistance training in heart disease patients is to promote increased dynamic muscle strength. Increases in muscular strength have been associated with increased peak exercise performance, improved submaximal endurance, and reduced ratings of perceived leg effort. Two studies show that resistance training may result in improved self-efficacy for strength and exercise tasks and improved quality of life parameters such as total mood disturbance, depression/dejection, fatigue/inertia, and emotional health domain scores. The data on risk factor modification are somewhat equivocal. Studies on blood lipid profiles have mostly been contaminated by confounders, and the effects on blood pressure (BP) are inconsistent. There are encouraging reports that resistance training may increase glucose tolerance and insulin sensitivity, independent of changes in body fat or aerobic capacity. Future studies are needed in patients with congestive heart failure and orthotopic heart transplantation; muscle weakness is common in these groups and makes them excellent candidates to benefit from this form of exercise.

Supervised exercise occupies a central role in the rehabilitation of patients with coronary artery disease. Traditionally, the exercise prescription comprised only aerobic activities such as walking and cycling, which utilize large muscle groups in rhythmic contractions and improve exercise tolerance and functional capacity through a variety of circulatory and peripheral muscle adaptations. Resistance, or weightlifting training, was not recommended, most probably because of the acknowledged pressor response induced by sustained isometric contractions. An isometric contraction even of a small muscle group, such as the forearm muscles during handgrip dynamometry, is sufficient to invoke a "pressure load" on the heart (30). This is characterized by a modest rise in cardiac output (CO), mainly as a result of increased HR, little change in peripheral vascular resistance, but a significant increase in mean arterial pressure (MAP) (20). In patients with cardiac disease the responses to isometric exercise are variable but may include unfavorable
increases in left ventricular end-diastolic pressure and end-systolic volume, decreased left ventricular end-diastolic volume and ejection fraction (17), exacerbated wall motion abnormalities (20) and dysrhythmias (3). Nevertheless, many of these earlier studies were done on patients who exhibited active ischemia, and the advances in both medical and surgical management in the intervening time may make the results less applicable now.

In contrast, a growing number of studies in postmyocardial infarction patients have documented reduced ischemia during isometric exercise and weight-carrying (5,12,27), perhaps because of a lower HR and higher diastolic pressure combining to enhance coronary artery filling. Similarly, investigations of the acute circulatory responses to resistance exercise have noted a lower rate-pressure product and HR, a higher diastolic pressure, and reduced ischemia compared with the changes occurring during cycling exercise at the same relative intensities (22,29). In addition to research on the acute responses, the past decade has witnessed a proliferation of studies that have examined the potential benefits of resistance training in cardiac patients. As a result of these investigations there is now an acceptance of resistance training in the cardiac rehabilitation process, and it is endorsed by such notable agencies as the American College of Sports Medicine (2) and the American Association of Cardiovascular and Pulmonary Rehabilitation (1). The purpose of this review is to define the role of resistance training in patients with ischemic heart disease through an analysis of the literature relating to strength and functional capacity, psychological wellbeing and quality of life, and cardiac risk factors. Occasional anecdotal examples describing the experiences of patients in the McMaster Cardiac Exercise Rehabilitation Program will be used to supplement this information.

EFFECTS OF RESISTANCE TRAINING ON MUSCULAR STRENGTH AND FUNCTIONAL CAPACITY: PHASE III/IV

The majority of trials of resistance training in heart disease included patients with well-preserved left ventricular function who had already been taking part in Phase III (community-based) and IV (long-term maintenance, possibly unsupervised) programs, and usually included an aerobic training control group (Table 1). Most interventions were 12 wk or less and employed one to two sets of assorted upper- and lower-body exercises and 10-15 repetitions per set. Lifting was of moderate intensity, performed in addition to the usual aerobic exercise prescription, and done on three occasions each week.
The first investigation to demonstrate the positive effects of resistance training was by Kelemen et al. (24) in 1986, from the Johns Hopkins School of Medicine in Baltimore. The patients were 40 men who had already completed at least 3 months (average 30 months) of rehabilitation in a community college setting, allocated to either a usual care (aerobic exercise and recreational games) or to a circuit weight training (weight training to replace the recreational games) group. A traditional 3 d·wk⁻¹ aerobic prescription was common to both groups, but whereas the experimental group did circuit weight training comprising two sets of 10 exercises at a modest intensity of 40% of 1 RM (1 RM, the highest weight that can be lifted once with correct form throughout a complete range of motion), the control subjects engaged in recreational volleyball. Despite the modest training stimulus, after the 10-wk period there was an average increase in dynamic strength of 24% in the experimental group and little or no improvement in the controls. It was also noteworthy that the weight-trained patients increased their time to exhaustion on a standard Bruce treadmill test by 12%, but there was no change in the controls. The maximum oxygen uptake during the treadmill test was not measured, so it is uncertain whether the increased endurance resulted from improvements in oxygen transport and utilization or was mediated more by the increased leg strength. Whatever the mechanism, increases in dynamic leg strength and endurance capacity of these magnitudes in cardiac patients who had already been training for an average of 2.5 yr was an impressive finding.

Only one study has examined the effects of resistance training on peak oxygen uptake, stroke volume, and CO (19). The investigators compared the effects of hydraulic resistance training with cycle ergometry alone in 24 male patients who commenced an 8-wk training program 9-10 wk after aortocoronary bypass surgery. There were increases in peak oxygen uptake in both groups (11% in the resistance trained vs 20% in the cycle trained) as well as improvements in maximum stroke volume and CO, but only the resistance trained patients displayed any gains in dynamic strength and endurance. It is difficult to compare the results of a hydraulic resistance training program with programs involving either free weights or machine weight stacks because only concentric contractions are involved in the former. Perhaps this difference also explains why Maiorana et al. (24) found no increase in maximum oxygen uptake in their patients following 10 wk of free weight and machine stack training.

Since the first report by Kelemen et al. (24), subsequent investigations have noted similar increases in arm and leg dynamic strength after resistance training interventions lasting for up to 12 wk (see Table 1), but longer duration studies are scarce. In a 6-month period of supplemental circuit weight training done on three occasions each week using just one set of 12 repetitions at a low intensity of 30-40% of 1 RM, the average gain in dynamic strength was still an impressive 22% (33). The longest follow-up of patients doing resistance training compared the results of 17 patients who had attended at least 50% of available twice-weekly sessions during a 36-month period, with the performance of eight patients who had trained using traditional aerobic exercise (35); dynamic strength only increased in the resistance trained patients, the arms by 13% and the legs by 40%.

Only two investigations of resistance training in heart disease have used high training loads. In the study by Crozier Ghilarducci et al. (19), patients did one set of 8-12 repetitions of assorted lifting exercises at intensities up to 80% of maximum over a 10-wk period. The gains in dynamic strength were generally higher (up to 53%) than in previous studies using lighter loads, but the true effects are difficult to evaluate as there were only 10 highly selected patients and no control group. One of the 10 patients suffered a reinfarction during the intervention period, but it was outside of the exercise time and apparently unrelated to the resistance training.

In a study from our laboratory, 24 male patients were randomly allocated either to a aerobic training group (controls) or to combined aerobic and resistance training (28). Training was done on two occasions each week for 10 weeks; aerobic training was balanced between groups, and the controls substituted recreational games for the resistance training period. In the initial resistance
training sessions, patients did two sets of 10 (arms) or 15 (legs) repetitions with weights corresponding to 40 to 50% of their 1 RM; this was gradually increased to three sets at approximately 80% of 1 RM by the end of the study. As with most other studies, the patients had already undergone cardiac exercise rehabilitation for an average of 5.6 months so at the outset they could be considered "trained." Despite this prior participation, there were significant increases in dynamic strength and exercise performance in the combined intervention group but no change in the aerobic training controls. Increases in dynamic 1 RM strength ranged from an average of 21% in leg exercises up to 43% in the single-arm curl movement. At the end of the study patients were also required to lift their pretraining 1 RM as many times as possible to provide a measure of lifting endurance. The initial 1 RM could now be lifted an average of 14 times before fatigue, suggesting that a strength-related activity of daily living that required almost maximum effort before training could be reduced to a submaximal, potentially safer, level after the intervention (Fig. 1). In support of Kelemen et al. (24), we noted a significant 15% increase in the maximum power output during incremental progressive cycle ergometry testing, but peak oxygen uptake was not measured. Furthermore, there was a significant reduction in Borg (1-10 scale) ratings of perceived exertion (7) for leg effort at power outputs above 50% of the pretraining maximum. Similarly, in the combined intervention group there was a 109% increase in the cycling time at 80% of the pretraining maximum power output until the patients perceived their leg effort to be very severe, at which time the test was terminated (Fig. 2). We may speculate that both the increased maximum power and the improved endurance may be attributed in large part to reduced perception of effort arising from stronger leg musculature.

Figure 1-The number of times after training that the initial one-repetition maximum could be successively lifted in single-arm curl, single-knee extension, and single-leg press exercise after 10 wk (20 sessions) of
either aerobic endurance training (open bars) or combined aerobic and resistance training (shaded bars). *$P < 0.05$ compared with pretraining; **$P < 0.01$ compared with pretraining; # significant group X time interaction. Modified with permission from reference 28. McCartney, N., R. S. McKelvie, D. R. S. Haslam, and N. L. Jones. Usefulness of weightlifting training in improving strength and maximal power output in coronary artery disease. Am. J. Cardiol. 67:939-945, 1991 [Medline Link] [CrossRef].

![Bar graph showing cycling time to a Borg RPE of 7](image)

Cycling Time to a Borg RPE of 7 (very severe) for Leg Effort

Figure 2-Cycle ergometry time at 80% of the pretraining maximal power output before attaining a Borg (1-10 scale) rating of perceived exertion for the legs of 7 (very severe). Open bars, aerobic endurance training group; shaded bars, combined aerobic and resistance training. *$P < 0.05$ compared with pretraining; # significant group X time interaction. Modified with permission from reference 28. McCartney, N., R. S. McKelvie, D. R. S. Haslam, and N. L. Jones. Usefulness of weightlifting training in improving strength and maximal power output in coronary artery disease. Am. J. Cardiol. 67:939-945, 1991 [Medline Link] [CrossRef].

Stronger muscles after training should also result in reduced circulatory responses during the lifting of fixed loads (18), so it is tempting to speculate that resistance training may afford several benefits to patients engaged in strenuous activities of daily living. Two case examples from the McMaster Cardiac Exercise Rehabilitation Program support this hypothesis.

Case 1: 50-yr-old male, exertional angina, no previous myocardial infarction. This patient suffered from exertional angina, especially with upper body exercise, and peripheral intermittent claudication. He had been doing regular aerobic exercise, including arm ergometry, for several months before resistance training was added to his exercise prescription. One of the patient's hobbies was to use his power boat during the summer months, but when required to tilt up the
outboard motor, he found it difficult and it usually provoked angina. After a few weeks of resistance training the patient reported that he could pull up the motor with ease, without angina.

**Case 2: 77-yr-old female in cardiac risk factor modification program.** After 6 wk of resistance training this patient reported that the intervention had "changed her whole life." Apparently the patient liked to bathe regularly but arm weakness made it extremely difficult for her to lift herself out of the bath afterward; she reported extreme fear of falling and of not being able to get out altogether. With just a few weeks of resistance training, the patient could use her arms to lift herself out of the bath with minimal effort, and she was delighted.

**SUMMARY**

A growing number of reports have demonstrated that resistance training can be used safely in Phase III and IV rehabilitation in the majority of patients who are candidates for conventional aerobic exercise. This form of training should be used in conjunction with aerobic exercise, not in place of it. Reported performance benefits include: increased dynamic strength, increased peak exercise capacity, improved submaximal endurance, reduced ratings of perceived exertion during heavy exercise, and anecdotal evidence of improved function in strenuous activities of daily living.

**Effects of resistance training on muscular strength and functional capacity: Phase II.** The resistance training studies mentioned thus far used predominantly low-risk patients who had already done 3 months or more of traditional exercise rehabilitation, so the relevance of the results to other groups of cardiac patients may be questioned. Nevertheless, four studies of resistance training that began in the early Phase II period of rehabilitation demonstrated similar positive effects.

The first published study examined the responses associated with 6 wk of circuit resistance training in 13 men who were 7-8 wk postmyocardial infarction or aortocoronary bypass surgery (34). At no time was the 1 RM strength measured, but by the end of the study patients were training comfortably with loads that were up to 82% greater than those that they started with. As with the Phase III and IV studies, the circuit training did not provoke any untoward signs or symptoms of ischemia.

Butler et al. (9) assessed the effects of 6 wk of supplementary circuit resistance training at an intensity of 40% of 1 RM in 12 patients undergoing Phase II rehabilitation. The resistance-trained patients exhibited a 22% increase in 1 RM dynamic strength, but there was no change in the control group. In contrast, the peak exercise performance in a standard Bruce treadmill test improved slightly more (30%) in the controls than in the resistance-trained patients (23%). Once again, the training failed to provoke any signs or symptoms of myocardial ischemia.

In a recent study, Stewart et al. (36) evaluated the effects of 10 wk of supplementary circuit resistance training in 12 patients who began the training regime within 6 wk of acute myocardial infarction. The 1 RM strength increased by an average of 31% for the legs and 20% for the arms; 11 control patients who had trained on a cycle ergometer showed smaller gains in dynamic leg (16%) and arm (10%) strength. An additional finding that was very similar to some studies of Phase III and IV patients (24,28) was a 14.0% increase in peak oxygen uptake during cycle ergometer testing and a nonsignificant (8%) change in the controls despite the fact that they had trained using this mode of exercise. Telemetry ECG recording did not identify any potentially malignant dysrhythmias or ischemic episodes during the resistance training, and there were no adverse events. This study suggests that resistance training in the early period postmyocardial infarction may result in greater improvements in dynamic strength and functional capacity than traditional aerobic exercise alone.
The final study of resistance training in Phase II rehabilitation was conducted at the Northern Alberta Cardiac Rehabilitation Program by Daub et al. (11). The study cohort comprised 57 low-risk patients who were within 6-16 wk postinfarction. Patients were randomized to a control group or one of three treatment groups. All patients trained aerobically, three times per week for 12 wk, but the treatment groups did two additional circuits of resistance training at intensities corresponding to either 20% (20 repetitions), 40% (10 repetitions), or 60% (7 repetitions) of 1 RM (total weight lifted was equivalent among groups). The 1 RM strength was unchanged in the control group but increased significantly and similarly in the three treatment groups (10.5 to 13.5%). In contrast to the findings of Stewart et al. (36), all four groups increased their peak oxygen uptake (from 4.4 to 13.4%; no difference among groups) and treadmill endurance time (from 19.2 to 34.6%; no difference among groups) in a comparable fashion. An observation lending further support to the safety of resistance testing and training was that only one patient had an uncomplicated dysrhythmia during this exercise compared with a total of 45 episodes of either angina (12), ST depression (25), dysrhythmias (3), hypertension (3) or hypotension (2) which occurred during aerobic testing or training.

**SUMMARY**

The evidence suggests that resistance training in Phase II rehabilitation is safe, provokes fewer signs and symptoms of myocardial ischemia than aerobic testing and training, and results in notable increases in dynamic strength, peak exercise capacity, and submaximal endurance. An important observation in one study was that even very low intensities of resistance training (20% of 1 RM) promoted notable increases in lifting capacity (11), which should make this form of exercise appealing to practitioners and patients alike. As many patients with an uncomplicated course return to work within 4 wk of their infarction (13), resistance training in Phase II rehabilitation is likely to assume greater importance in the future.

**Effects of resistance training on psychological well-being and quality of life.** Although difficult to demonstrate consistently, one of the most important contributions of cardiac rehabilitation may be an improved sense of well-being and self-efficacy (14), which should translate into enhanced quality of life. Only two studies have investigated the effects of resistance training on self-efficacy, which may be defined as the level of certainty of an individual that he or she can successfully complete a given task or assume a given behavior (14).

Following 10 wk of circuit resistance training that resulted in an average gain in dynamic strength of 24% and a 12% increase in treadmill endurance time (24), there was increased self-efficacy for tasks demanding significant arm or leg strength. Self-efficacy for strength tasks in an aerobically trained control group were unchanged (15). This confirms a specificity of self-efficacy associated with exercise training; an aerobic training program is unlikely to improve a patient's perception that he can undertake heavy arm work, and the opposite is also true (14).

Beniamini et al. (4) recently investigated the effects of high-intensity resistance training on quality of life parameters in cardiac rehabilitation patients. A group of 38 patients added either high-intensity (up to 80% of 1 RM) resistance training or flexibility training to their usual exercise prescription. In agreement with the previous study by Ewart et al. (15), the resistance-trained patients improved their self-efficacy scores for strength-related tasks and also for jogging when compared with the flexibility-trained controls (Fig. 3). An added finding was that the resistance-trained patients also improved in quality of life parameters such as total mood disturbance, depression/dejection, fatigue/inertia, and emotional health domain scores.
Many patients who have suffered a myocardial infarction are often limited more by an inappropriate perception that they cannot do an activity rather than by any real physical limitation. Because of this, improvements in self-efficacy resulting from resistance training may allow patients to resume a more normal lifestyle and thus improve the quality of their lives. It seems strange that at a time when the benefits of resistance training in heart disease are becoming widely recognized, some physicians still tell their patients never to lift more than 20 pounds!

**SUMMARY TOP**

Limited research data suggest that resistance training for patients with coronary artery disease may have important implications for improving self-efficacy in strength-related tasks and for improving quality of life. More research in this area seems warranted.

**Effects of resistance training on coronary risk factors.** There are an increasing number of reports outlining the effects of resistance training on certain coronary risk factors, especially lipoprotein-lipid profiles, BP, and glucose metabolism. Because the findings are largely equivocal, only an overview will be presented here.

**Lipoprotein-lipid profiles.** There are reports that short periods of resistance training may result in decreases in low-density lipoprotein cholesterol and favorable increases in the high-density lipoprotein fraction. This work has been reviewed by Hurley (23) who has also highlighted the various confounders, including the lack of a control group, conclusions based on a single blood sample taken before and after the intervention, lack of account of changes in diet, body mass, and body composition, and subjects with a fairly normal lipid profile to begin with. Because of these methodological flaws it would appear that few conclusions can be reached about the effects of resistance training on blood lipids. The one study which did control for most potential confounders...
showed no change in lipoprotein-lipid profiles after 20 wk of resistance training in 16 men at high risk of coronary artery disease (25).

BP. Once again BP is an area of conjecture. Studies of borderline or defined hypertensives have demonstrated either decreases (21) or no change (6). More studies are needed before any meaningful conclusions can be reached.

Glucose metabolism. Glucose metabolism seems to be a more promising line of inquiry. It is well known that muscle mass decreases with advancing age, and it is theoretically possible that this may be a contributor to impaired glucose tolerance. With the potential of resistance training to increase muscle mass, even in extreme old age (16), it seems likely that it could result in improved glucose metabolism. There are encouraging reports that resistance training may increase glucose tolerance and insulin sensitivity (32) independent of changes in body fat or aerobic capacity (31), but more evidence must be provided.

CONCLUSIONS

Mounting evidence suggests that resistance training is a safe and effective mode of exercise in both Phase II and Phase III/IV cardiac rehabilitation programs. It is popular with patients and provokes fewer, and less serious, signs and symptoms of ischemia than does traditional aerobic exercise testing and training. The major role of resistance training in patients with heart disease is to increase dynamic strength, which can even be achieved using low intensities of lifting. Increased dynamic strength is often associated with increases in peak aerobic exercise capacity, greater submaximal endurance, and reduced ratings of perceived exertion. This form of training appears to improve psychological well-being, self-efficacy for tasks requiring significant arm or leg strength, and measures of quality of life. There is as yet no defined role for resistance training in the management of coronary risk factors, but the work on glucose metabolism seems promising. Future studies are needed on the effects of resistance training in other populations of heart disease patients, such as those with congestive heart failure and orthotopic heart transplantation (see review (8)). Pronounced generalized muscle weakness in these patients makes them excellent candidates for this form of exercise.

REFERENCES


**Keywords:**

WEIGHTLIFTING; CORONARY DISEASE; STRENGTH; EXERCISE CAPACITY; REHABILITATION