# Resistance Training for Chronic Diseases and Disabilities: Influence on Cardiovascular Risk Reduction

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**FRANKLIN:** ***Resistance Training for Chronic Diseases and Disabilities: Influence on Cardiovascular Risk Reduction.*** *Although exercise programs have traditionally emphasized dynamic lower-extremity exercise, research increasingly suggests that complementary resistance training has favorable effects on muscular strength, cardiovascular endurance, coronary risk factors, and psychosocial well-being. Resistance exercise has value in the prevention and treatment of orthopedic injuries, low back pain, osteoporosis, overweight and obesity, sarcopenia, and diabetes mellitus, and may be helpful in reducing older persons' susceptibility to falls. This form of exercise can also improve myocardial efficiency by reducing cardiac demands during daily activities such as carrying groceries or lifting moderate-to-heavy objects. Accordingly, most professional and government health associations or agencies now include resistance training as an integral component of a well-rounded physical conditioning program. Because long-term exercise compliance remains a challenge in persons with and without cardiovascular disease, resistance training can provide a means for enhancing the effectiveness and interchangeability of training benefits from one set of limbs to another, as well as for maintaining interest and increasing diversity. Nevertheless, it should serve as a complement to, rather than a replacement for, the aerobic exercise prescription. (J HK Coll Cardiol 2006;14(Suppl 2):B55-B63)*

*Prescriptive guidelines, rationale, resistance exercise, resistance training, safety*

**摘要**
雖然訓練計劃在傳統上強調低強度的運動方式，而研究卻不斷表明輔助的阻力訓練有助於增強肌肉力量和心血管的耐力，降低冠心病的危險因素，提高社會心理的良好適應力。阻力訓練在預防骨科損傷、腰部疼痛、骨質疏鬆、體重超標和肥胖、糖尿病中有著重要價值，此外它還有助於減少老年人的易跌倒。這種形式的訓練還能夠提高心肌的功效，它通過每日活動如手提雜物或中等至重的物品來減低心臟需求。因此，當前許多專業和政府的健康組織和機構將阻力訓練作爲整體身體訓練計劃的一個組成部分。由於長期訓練的依從性對有或沒有心血管疾病的人群仍然是一個挑戰，而阻力訓練可以提高訓練的有效性和可變性，從一組肢體到另一組肢體，並且能夠保持患者對訓練的興趣，提高訓練的多樣性。儘管如此，阻力訓練應當作爲一種輔助方法，而非替代有氧訓練。

關鍵詞：說明指導　基本原理　阻力運動　阻力訓練　安全性

Exercising to develop and maintain muscular strength, muscular endurance, and muscle mass is commonly referred to as resistance training. Weightlifting with barbells, or specially designed weight machines, is probably the most popular form of resistance training. Amateur and professional athletes have long recognized that the above-referenced benefits have a positive influence on athletic performance. Today, resistance training is practiced by individuals with and without chronic disease, because it is associated with favorable changes in cardiovascular function, metabolism, coronary risk factors, and psychosocial well-being. This article reviews the role of resistance

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training in persons with and without cardiovascular disease, with specific reference to health and fitness benefits, rationale, relevant physiologic and clinical considerations, safety, and training studies. Participation criteria/contraindications and prescriptive guidelines for varied patient populations are also provided.

## Health and Fitness Benefits

Resistance training has traditionally been viewed as a means for developing and maintaining muscular strength, endurance, power, and muscle mass. Evidence now suggests that it has favorable effects on selected health and fitness variables. Table 1 summarizes these benefits and attempts to weight them according to the recent literature.[1,2] The American College of Sports Medicine,[3,4] American Heart Association,[2,5] American Association of Cardiovascular and Pulmonary Rehabilitation,[6] and the Surgeon General's Report on Physical Activity and Health[7] all include resistance training as an integral component of a comprehensive physical conditioning program. It is also of potential value in the prevention and/or treatment of low back pain, obesity (via the maintenance or enhancement of lean body mass and basal metabolic rate), osteoporosis, sarcopenia (i.e., a loss of skeletal muscle mass that may accompany aging), diabetes mellitus, and orthopedic injuries, and may be helpful in reducing the susceptibility to falls in the elderly.[7] Moreover, regular progressive resistance training may have a favorable effect on resting blood pressure[8] and lipid and lipoprotein levels,[9] as well as on the other cardiovascular risk factors.[10]

## Rationale for Resistance Training

More than two decades ago, Blomqvist[11] summarized the exercise training literature, with specific

**Table 1. Effects of resistance exercise on selected health and fitness variables***

| Variable | Training adaptation |
|---|---|
| Bone Mineral Density | ↑↑ |
| Body Composition | |
| % fat | ↓ |
| Lean body mass | ↑↑ |
| Strength | ↑↑↑ |
| Glucose Metabolism | |
| Insulin response to glucose challenge | ↓↓ |
| Basal insulin levels | ↓ |
| Insulin sensitivity | ↑↑ |
| Serum Lipids | |
| HDL | ↑↔ |
| LDL | ↓↔ |
| Blood Pressure at Rest | |
| Systolic | ↓↔ |
| Diastolic | ↓↔ |
| $VO_2$max | ↑↔ |
| Endurance Time | ↑↑ |
| Physical Function | ↑↑↑ |
| Basal Metabolism | ↑↑ |

Legend: ↑ = increase; ↓ = decrease; ↔ = unchanged; ↑ or ↓ = small effect; ↑↑ or ↓↓ = moderate effect; ↑↑↑ or ↓↓↓ = large effect; HDL = high-density lipoprotein cholesterol; LDL = low-density lipoprotein cholesterol.

*Adapted from Pollock and Vincent.[1]

reference to strength training and training of the upper extremities, and concluded that: "...in a general sense the physiologic data support the concept that therapeutic exercise programs should not be limited to dynamic leg exercise but should include upper body activities. Exercise specifically designed to improve muscle strength may be beneficial, and the exclusion of all activities requiring predominately static efforts is not warranted."

The rationale to support resistance training as an adjunct to an aerobic exercise program stems from several lines of evidence. Moderate-to-high intensity resistance training regimens have been shown to improve muscular strength and endurance in men and women of all ages by 25% to 100% (or more),[12] depending on the training program and initial level of strength. Furthermore, many leisure and occupational activities require lifting, moving, or carrying a constant load, generally involving the upper extremities.[13] Because the magnitude of the pressor response to static exertion is proportionate to the percentage of the maximal voluntary contraction (MVC) used (Figure 1),[14] as well as the muscle mass involved,[15] any increase in strength should result in a lower rate-pressure product at any given load because the load now represents a lower percentage of the MVC. When heart rate and blood pressure responses to a standardized lifting or isometric test before and after a strength-training regimen have been compared, improvement has been reported.[16,17] Such findings strongly support the specificity of measurement and specificity of fitness concept. Thus, it appears that resistance training can decrease cardiac demands during daily activities like carrying groceries or lifting moderate-to-heavy objects.[2]

There are also intriguing data to suggest that strength training can increase endurance time to fatigue without an accompanying increase in maximal oxygen consumption ($VO_2$max) or aerobic capacity (Table 2). Hickson et al.[18] examined the effects of a lower extremity weight-training program (5 days a week for 10 weeks) on $VO_2$max and endurance time during cycle ergometer and treadmill exercise. Although $VO_2$max during progressive treadmill and cycle ergometer testing remained essentially unchanged, submaximal endurance time to exhaustion during cycling and treadmill exercise increased 46% and 12%, respectively. Similarly, Ades and associates[19] reported that 12 weeks of strength training improved submaximal walking time by 38%, whereas treadmill performance in a nonexercising control group remained unchanged. Collectively, these findings indicate that endurance is not a function of aerobic exercise alone, but can be significantly enhanced by weight training. This provides a further argument for the complementary use of progressive resistance training coupled with aerobic exercise.

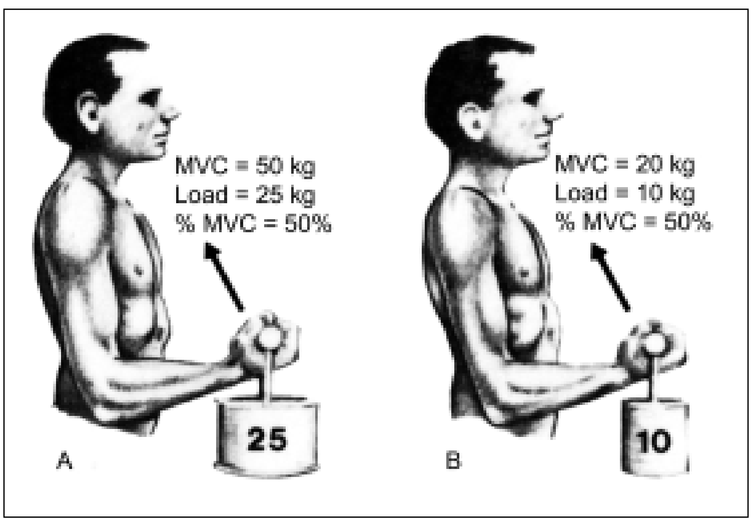


**Figure 1.** *The hemodynamic response to isometric exertion is directly proportional to the percentage of maximal voluntary contraction (%MVC) of the muscle group involved. The heart rate and blood pressure response depends on the tension exerted relative to the greatest tension possible in the muscle group (MVC), rather than the absolute magnitude of contraction (kg). For example, a person's pressure response to 50% MVC will be greater than for 25% MVC. Futhermore, a high degree of tension exerted by a stronger person (A) will produce approximately the same heart rate and blood pressure response as a low tension (but representing an equivalent relative tension, % MVC) developed by a weaker person (B), all other factors being equal.*

## Safety of Resistance Exercise

Although isometric or combined isometric and dynamic (isodynamic) exercise has traditionally been discouraged in patients with suspected or known coronary disease, it appears that resistance exercise is less hazardous than was once presumed, particularly in patients with moderate-to-high levels of cardiorespiratory fitness and normal or near-normal left ventricular function.[13] Moreover, signs or symptoms of myocardial ischemia, ventricular irritability, and abnormal hemodynamics occur less frequently during resistance testing than during treadmill testing to volitional fatigue. Increased subendocardial perfusion secondary to the elevated diastolic blood pressure that predictably accompanies resistance exercise may contribute to this response.[20,21]

Numerous investigations in healthy adults, persons with borderline hypertension,[22] and low risk cardiac patients have reported no cardiovascular events during strength testing and training. Gordon et al.[23] documented the safety of maximal strength testing (bench press, leg press, and knee extension) in 6,653 study participants (aged 20 to 69 years), including 5,460 men and 1,193 women who had undergone a preliminary comprehensive medical examination and maximal treadmill testing. All completed a series of progressive weight loads to determine the maximum weight that could be used to complete 1-repetition (i.e., 1-repetition maximum, 1 RM) on a variable resistance machine. There were no cardiovascular events during or immediately after the testing procedures.

More than a decade ago, an Expert Panel commissioned by the U.S. government reviewed 12 different studies to determine the safety and effectiveness of resistance testing or training in the rehabilitation of patients with coronary disease.[24] Circuit weight training was generally added to the physical conditioning regimens of men with coronary disease who had already been aerobically trained, generally for three months or more. The absence of signs or symptoms of myocardial ischemia, threatening ventricular arrhythmias, and cardiovascular events in these studies,[24] and in other recent reports including patients soon after acute myocardial infarction[25] and those with clinically stable congestive heart failure,[26] suggest that resistance testing and training is safe for selected coronary patients.

## Participation Criteria and Contraindications

Contraindications to resistance training are similar to or slightly more cautious than those used for the endurance training component of adult fitness or cardiac rehabilitation programs.[2,13] These include: unstable angina; stages 2 and 3 hypertension (≥160/≥100 mmHg); uncontrolled arrhythmias; a recent history of congestive heart failure that has not been evaluated and effectively treated; severe stenotic or regurgitant valvular disease; and hypertrophic cardiomyopathy. Regardless of the monitoring procedures employed, adverse signs and symptoms (e.g., dizziness, excessive dyspnea, chest pain/pressure, serious ventricular arrhythmias) are contraindicated, and resistance exercise should be stopped immediately.

**Table 2. Effects of lower extremity strength training on $VO_2$max and endurance time during cycle ergometer and treadmill exercise***

| | $VO_2$max (ml/kg/min) | | Length of time (sec) | |
|---|---|---|---|---|
| | Treadmill | Cycle Ergometer | Treadmill | Cycle Ergometer |
| Pre-training | 47.8 | 44.0 | 291 | 278 |
| Post-training | 48.8 | 44.6 | 325† | 407† |

†Pre-training vs post-training (P<0.01)

*Adapted from Hickson et al.[18]

## Training Studies

Numerous studies have reported on the benefits of resistance training in varied patient populations, including men and women with and without heart disease, as well as in patients with diabetes mellitus, physical disabilities, chronic obstructive pulmonary disease, and arthritis and related musculoskeletal disorders.[27] Others have documented favorable adaptations following a resistance training regimen in hypertension and stroke patients and organ transplant recipients.[27] Virtually all studies in coronary patients have reported significant improvements in weight-carrying tolerance (time) or increases in skeletal muscle strength, with comparable increases in overall strength for high (80% 1 RM) and moderate (30-40% 1 RM) training intensities.[24] However, some of the greatest improvements have been reported in older adults. Perhaps the most striking example was a training study of 10 elderly men and women who ranged in age from 87 to 96 years.[28] The subjects participated in an eight-week program of high-intensity strength training. Nine of the 10 subjects who completed the conditioning program demonstrated average increases in muscle strength, walking speed, and mid-thigh muscle girth of 174%, 48%, and 9%, respectively. The researchers concluded that resistance exercise enables dramatic strength gains, even in very old and frail persons.

## Exercise Prescription

Although the traditional prescription has involved performing each exercise three times (e.g., 3 sets of ~10 repetitions per set), a single set of exercises to volitional fatigue, with weight loads corresponding to ~50 ± 10% of 1 RM, has been found to be as effective as multiple-set programs that are prescribed in the adult fitness setting. Consequently, for the average person beginning a strength training regimen, single set programs performed a minimum of two times per week are recommended over multiple set programs because they are highly effective and less time consuming.[29]

Because the effect of physical conditioning is specific to the area of the body being trained, resistance training regimens should include 8 to 10 different exercises involving the major muscle groups of the upper (Figure 2) and lower extremities, at a load that permits 8 to 12 repetitions/set for healthy, sedentary adults or 10 to 15 repetitions/set for elderly persons or cardiac patients (Figure 3; Table 3).[2-7,30,31] Periodized multiple-set regimens at a greater training frequency (>2 times per week) may provide greater benefits for healthy, younger individuals whose goals include maximum gains in strength, lean body mass and athletic performance.[32,33]

To approximate the appropriate weight loads for resistance training, one can determine the maximum weight load that could be used to complete a 1-RM during a given exercise (e.g., bench press, leg press, military [overhead] press), and then lift an arbitrary percentage of that amount during each set of the exercise. An initial intensity that corresponds to 30% to 40% of 1 RM for the upper body and 50% to 60% of 1 RM for the lower body is recommended;[2] however, even lower relative intensities (e.g., 20% of 1 RM) have been shown to improve strength soon after acute myocardial infarction.[25] When determination of the 1 RM is deemed unnecessary or potentially hazardous, the load-repetition relationship for resistance training may be estimated from the number of repetitions that can be completed (Table 4).[34]

Previous studies using electromyographic analysis of the involved muscle groups and the measurement of blood lactate during acute bouts of resistance exercise indicate that perceived exertion may be a valid method of gauging exercise intensity.[35] The finding that a gender-specific perceived exertion response does not exist, despite significantly higher strength values in men, suggests a similar stimulus-response relationship as a function of relative contraction intensity.[36] As a general guideline, individuals should work to a perceived exertion during resistance training that approximates 11 to 14 ("fairly light" to "somewhat hard") on the Borg[37] category scale, recognizing that the rating will increase over a set of 10 to 15 repetitions. Empiric experience suggests that if by the 5th repetition, an individual has a perceived exertion >15 or >7 on the category or category-ratio scales, respectively, he/she will probably not be able to complete 15 repetitions, which is the frequency per set commonly recommended for older persons and cardiac patients.

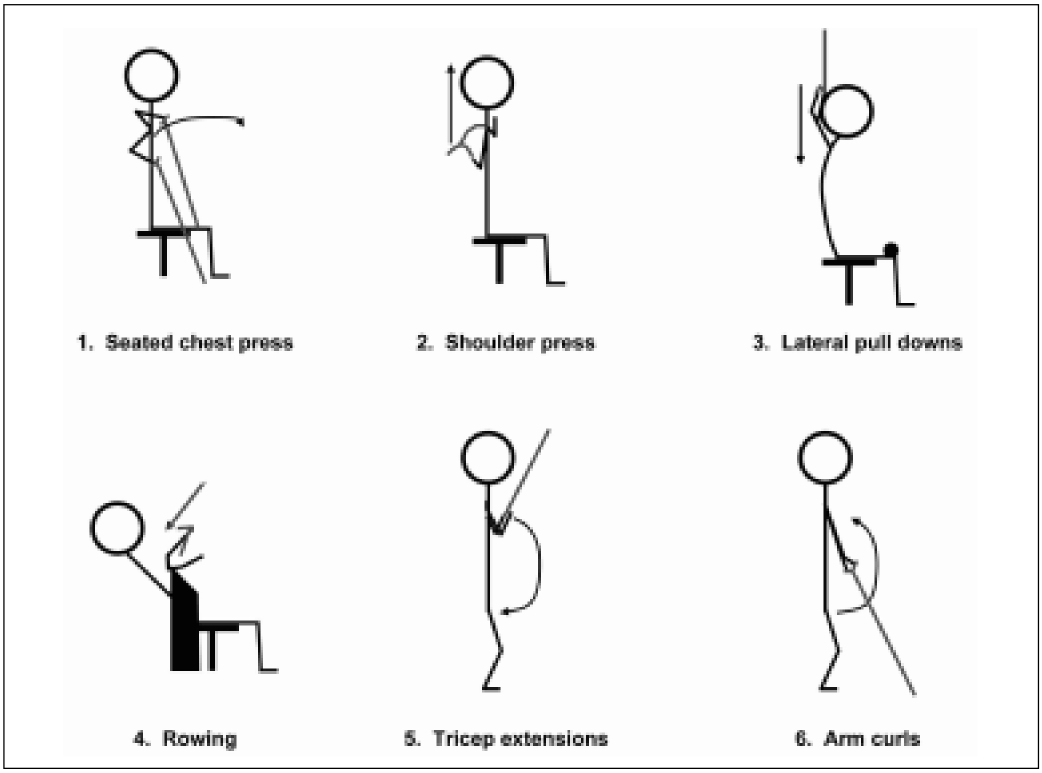


**Figure 2.** *Upper body exercises that are commonly used in a resistance training program. Ideally, such regimens should include 8 to 10 different exercises, and some that are targeted to lower-body muscle groups (e.g., quadriceps extension or leg press, leg curls [hamstrings], calf raise).*

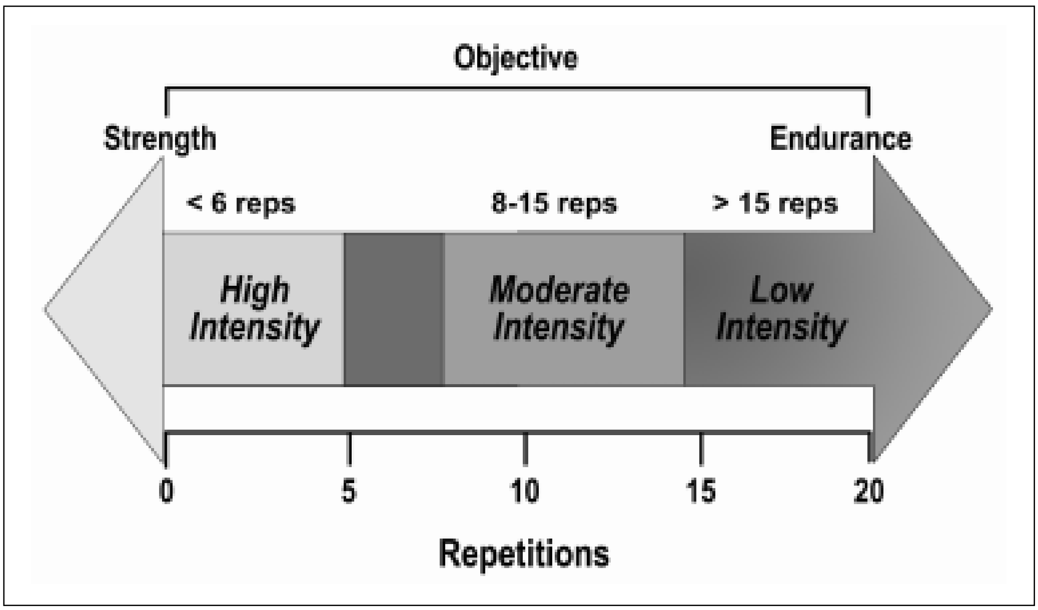


**Figure 3.** *Classification of weight training intensity (resistance). A lower repetition range, with a heavier weight, may better optimize strength and power, whereas a higher repetition range, with a lighter weight, may better enhance muscular endurance. Using weight loads that permit 8 to 15 repetitions (reps) will generally facilitate improvements in muscular strength and endurance.*

**Table 3. Standards, guidelines, and position statements regarding resistance training**

| Population (Reference) | Sets; Reps | Prescriptive Components†† Stations/Devices* | Frequency |
|---|---|---|---|
| **Healthy/Sedentary Adults** | | | |
| 1996 Surgeon General's Report[7] | 1-2 sets; 8-12 reps | 8-10 exercises | 2 d/wk† |
| 1998 ACSM Position Stand[3] | 1 set; 8-12 reps (persons under 50-60 yrs) 10-15 reps (persons 50-60 yrs and older) | 8-10 exercises | 2-3 d/wk |
| 2000 AHA Advisory[2] | 1 set; 8-12 reps (persons < 50-60 yrs) 10-15 reps (persons 50-60 yrs and older) | 8-10 exercises | 2-3 d/wk |
| 2006 ACSM Guidelines[4] | 1 set; 8-12 reps (range 3-20 reps) that can be performed at a moderate rep duration (~ 3 sec concentric, ~ 3 sec eccentric) | 8-10 exercises | 2-3 non-consecutive d/wk |
| **Elderly Persons** | | | |
| Pollock et al.[30] | 1 set; 10-15 reps | 8-10 exercises | 2 d/wk† |
| 2001 American Geriatrics Society[31] | Low: 40% 1 RM; 10-15 reps Moderate: 40%-60% 1 RM; 8-10 reps High: >60% 1 RM; 6-8 reps | Not specified | 2-3 d/wk |
| **Cardiac Patients** | | | |
| 2001 AHA Exercise Standards[5] | 1 set; 10-15 reps | 8-10 exercises | 2-3 d/wk |
| 2004 AACVPR Guidelines[6] | 1 set; 12-15 reps | 8-10 exercises | 2-3 d/wk |
| 2006 ACSM Guidelines[4] | 1 set; 12-15 reps | 8-10 exercises | 2-3 d/wk |

ACSM, American College of Sports Medicine; AHA, American Heart Association, AACVPR, American Association of Cardiovascular and Pulmonary Rehabilitation; reps, repetitions; 1 RM, one repetition maximum (measurement of isotonic or dynamic strength); d, days; wk, week.

*Minimum 1 exercise per major muscle group: e.g., chest press, shoulder press, triceps extension, biceps curl, pull-down (upper back), lower-back extension, abdominal crunch/curl up, quadriceps extension or leg press, leg curls (hamstrings), calf raise. †Minimum; ††As the individual progresses, overload can be achieved by increasing the resistance or weight, increasing the repetitions per set, increasing the number of sets per exercise, and/or decreasing the rest period between sets or exercises. An initial increase in the number of repetitions per set is recommended before an increase in resistance or weight load.

**Table 4. Approximate load repetition relationship for resistance training***

| % 1 RM | Number of repetitions possible |
|---|---|
| 60% | 17 |
| 70% | 12 |
| 80% | 8 |
| 90% | 5 |
| 100% | 1 |

*Adapted from Dingwall et al.[34]

The type of resistance exercise equipment may vary considerably in cost, complexity, operational skill, load settings, and time efficiency. The key is to select equipment that is safe, effective, and accessible. In recent years, the use of low-cost approaches that allow for a gradual progression in resistance or intensity has grown in popularity (e.g., calisthenics, pulley weights, spring pulleys). For higher level training or cardiac rehabilitation, weight machines are commonly recommended, because they reduce the isometric component associated with free weights, allow the patient to easily titrate training loads, and eliminate the need for a 'spotter.' Conventional guidelines, however, often impose conservative weight limits (0.5 to 2.0 kg) for the first 3 months after a cardiac event/intervention. Alternatively, new recommendations have been proposed that stratify the risk associated with common resistance exercises for selected cardiac patients that, if used in conjunction with perceived exertion and hemodynamic measurements, may accelerate patients' return to their desired levels of daily activity.[38]

## Conclusions

Many older patients lack the physical strength and/or muscular endurance to perform common activities of daily living. Indeed, the Framingham Study found that about half of all women over age 65 years cannot lift a 5 kilogram load in a specific manner. Resistance training can provide an effective method for improving muscular strength and endurance, preventing and managing a variety of chronic medical conditions (e.g., overweight/obesity, diabetes), modifying coronary risk factors, enhancing selected health and fitness variables, and aiding in the prevention of disability and falls. Weight training has also been shown to reduce the rate-pressure product when any given load is lifted.[17] Moreover, cross-sectional studies have now shown that muscular strength is inversely associated with the prevalence of metabolic syndrome[39] and all-cause mortality,[40] independent of aerobic fitness levels. Although the safety and effectiveness of resistance exercise in healthy persons and men with low-risk cardiovascular disease is well established, recommended participation criteria, absolute contraindications, and appropriate prescriptive guidelines should be followed.

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