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Resistance Exercise Training
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The metabolic effects of reduced muscle mass, engendered by normal aging or decreased physical activity, lead to a high prevalence of obesity, insulin resistance, type 2 diabetes, dyslipidemia, and hypertension.[1–4] These risk factors are associated with abnormalities in cardiovascular structure and function such as arterial stiffness and impaired endothelial function. Skeletal muscle is the primary metabolic "sink" for glucose and triglyceride disposal and is an important determinant of resting metabolic rate. Accordingly, it has been hypothesized that resistance exercise training (RT) and subsequent increases in muscle mass may reduce multiple cardiovascular (CV) disease risk factors.[5–8] The inclusion of RT as part of an exercise program for promoting health and preventing disease has been endorsed by the American Heart Association,[9] American College of Sports Medicine,[10] and the American Diabetes Association[11] as an integral part of an overall health and fitness program. Cross-sectional studies have shown that muscular strength is inversely associated with all-cause mortality[12] and the prevalence of metabolic syndrome,[13,14] independent of cardiorespiratory fitness levels. To date, however, the evidence that RT reduces CV risk factors remains equivocal.

This review will critically evaluate whether RT modifies CV risk factors and improves characteristics of CV structure and function. The topics will be limited to the effects of RT on major and independent risk factors for CV disease including diabetes mellitus, hypertension, dyslipidemia, and advancing age.[4] The quantitative relation between these risk factors and CV events has been elucidated by the Framingham Heart Study[4] and other studies. The topics will also include 2 predisposing risk factors—obesity and physical inactivity—that are designated as major risk factors by the American Heart Association.[1,2,4] To the extent possible, this review will examine the separate and independent effects of RT in studies that did not include a concomitant aerobic exercise component. However, in those instances where the data from RT studies are equivocal, studies that combined RT and aerobic exercise will be acknowledged to help the clinician formulate recommendations for their patients. Additionally, the review will focus mainly on primary prevention, for example, risk reduction in persons without established CV disease. Many low- to moderate-risk patients with established CV disease should be encouraged to incorporate RT into their physical conditioning program, especially those who rely on their upper extremities for work or recreational pursuits. However, the safety and effectiveness of RT in other populations of CV patients (eg, women, older patients with low aerobic fitness, patients with severe left ventricular dysfunction) have not been well studied. Accordingly, these patient subsets may require more careful evaluation and initial monitoring, and RT guidelines and recommendations must be modified accordingly. Moreover, there is only a limited body of literature assessing the independent benefits of RT on CV risk factors in patients with established CV disease. Studies conducted in cooperation with comprehensive cardiac rehabilitation programs typically include the confounding influences of aerobic activity, initiation of vasoactive and lipid-lowering drugs, and nutritional education with subsequent dietary modifications.

Rationale for Resistance Training

There is overwhelming research evidence that RT prevents decline in skeletal muscle mass and function when the mechanical stimuli provided by tasks of daily living are not sufficient to offset these declines with aging.[15–17] Adults who do not perform regular RT lose approximately 0.46 kg of muscle per annum from the fifth decade on.[18] Furthermore, adults who do not perform RT experience a 50% reduction in type 2 muscle fibers, the fibers responsible for high levels of strength, by age 80 years.[19] The profound beneficial effects of RT on the musculoskeletal system can contribute to the maintenance of functional abilities and prevent osteoporosis, sarcopenia, and accompanying falls, fractures, and disabilities.[15,17,18] A comprehensive comparison of the chronic effects of RT versus aerobic exercise training in multiple organ systems is presented in Table 1.

Long-term adaptation to RT lowers cortisol response to acute stress,[20] increases total energy expenditure and physical activity in healthy[18,21] and frail older adults,[22] and relieves anxiety, depression, and insomnia in clinical depression.[23] RT has beneficial effects on bone density,[18,24] osteoarthritic symptoms,[22,25] hypertension,[26,27] lipid profiles,[28] and exercise tolerance in coronary artery disease.[29] Conversely, the loss of skeletal muscle mass and contractile function that accompanies aging, for example, sarcopenia, is linked to peripheral insulin resistance, dyslipidemia, and increased adiposity.[30]

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TABLE 1. Comparison of the Effects of Aerobic Training to Resistance Training on Health and Fitness Variables

Variable	Aerobic Exercise	Resistance Exercise
Bone mineral density	↑	↑ ↑ ↑
Body composition		
Fat mass	↓ ↓	↓
Muscle mass	↔	↑ ↑
Strength	↔	↑ ↑ ↑
Glucose metabolism		
Insulin response to glucose challenge	↓ ↓	↓ ↓
Basal insulin levels	↓	↓
Insulin sensitivity	↑ ↑	↑ ↑
Serum lipids		
High-density lipoprotein	↑ ↔	↑ ↔
Low-density lipoprotein	↓ ↔	↓ ↔
Resting heart rate	↓ ↓	↔
Blood pressure at rest		
Systolic	↓ ↓	↓
Diastolic	↓ ↓	↓
Physical endurance	↑ ↑ ↑	↑ ↑
Basal metabolism	↑	↑ ↑

↑ indicates increased; ↓, decreased; and ↔, negligible effect.

Sarcopenia is also accelerated in patients with chronic heart failure, a condition characterized by peripheral skeletal muscle abnormalities and muscle wasting. Several studies have shown beneficial effects of RT on muscle mass and strength in patients with chronic heart failure.[31,32] However, the relative mitigating effects of RT on primary and secondary CV risk factors remains controversial.

Resistance Training and Diabetes

Diabetes mellitus, glucose intolerance, and insulin resistance are central features of coronary artery disease risk, being strongly related to hypertension and dyslipidemia, proinflammatory markers, thrombogenic factors, and endothelial dysfunction. These abnormalities increase with age and represent the early stages of CV disease that precede the clinical manifestations of CV disease.[33] Maintaining good glycemic control hinges on enhancing insulin availability or secretion and overcoming insulin resistance. Unfortunately, central obesity and physical inactivity hinder medical management and may hasten development of chronic complications, particularly in elderly people with long-standing diabetes. Even when glycemic control is near optimal with medication, reducing insulin resistance by any other means must be explored in view of these adverse consequences.

Muscle contraction increases glucose uptake in skeletal muscle,[34] thereby forming the basis for recommending RT for individuals with abnormal glucose metabolism. Aerobic exercise uses large muscle groups for extended periods of time, but whole-body RT programs may provide equally high or higher recruitment of muscle mass over a comparable period of time. The American College of Sports Medicine has recommended the use of progressive RT as part of a well-rounded exercise program for individuals with type 2 diabetes.[35] Similarly, in the absence of contraindications, the American Diabetes Association also recommends RT for those with type 2 diabetes.[11] These recommendations are supported by evidence that RT is an integral component in the therapeutic management of glycemic control in both young and older type 2 diabetics,[28,36–38] particularly if the RT is performed in a supervised versus home-based program.[39]

Glucose Tolerance and Insulin Sensitivity

A frequent postulate is that RT and subsequent increases in skeletal muscle mass may improve glucose and insulin responses to a glucose load.[6,40] However, there are little data available showing that RT prevents type 2 diabetes. RT does not usually alter glucose tolerance or glycemic control regardless of age,[5–7,16,41,42] unless baseline glucose tolerance is abnormal.[36,38,40–44] Nevertheless, RT reduces acute insulin responses during an oral glucose tolerance test in healthy young, middle-aged, and older men in most studies.[5,6,45] RT also reduces acute insulin responses during glucose tolerance testing in diabetic men[36,38] and women[36,38,44] and improves insulin sensitivity during hyperglycemic and hyperinsulinemic-euglycemic clamps in diabetic and/or insulin-resistant middle-aged[6,46,47] and older men[42] and diabetic middle-aged[48] and older women.[42]

Glycemic Control

RT decreases glycosylated hemoglobin (HbA1c) levels in diabetic men[28,36,37,43] and women,[28,36,37] regardless of age. This effect is observed even in the absence of a lasting effect of RT on fasting glucose or insulin levels.[37] Improved glycemic control and decreased HbA1c levels are important for reducing the microvascular and macrovascular complications of diabetes. For example, the UK Prospective Diabetes Study[49] reported that each percentage point reduction in HbA1c was associated with a 35% reduction in microvascular complications, whereas the European Prospective Investigation of Cancer and Nutrition (EPIC)–Norfolk prospective population study showed that an increase of 1 percentage point in HbA1c was associated with a 28% increase in mortality risk, independent of other CV risk factors.[50] RT-induced improvements in glycemic control, however, appear to be intensity-dependent, with beneficial effects occurring when subjects train at 70% to 90% of the 1-repetition maximum strength (1-RM). One-repetition maximum is the maximal weight lifted in 1 attempt during strength testing. In studies where the RT intervention was less than 2 months and/or the exercise intensity was less than 50% of the 1-RM, improvements in HbA1c were modest or undetected.[47,51,52]

Resistance Training and Hypertension

Adopting a healthy lifestyle is critical for the prevention of high blood pressure (BP) and is an indispensable part of the treatment of hypertension.[53] The American Heart Association[9] and the American College of Sports Medicine[10] have each endorsed moderate-intensity RT as a complement to aerobic exercise programs in the prevention, treatment, and control of hypertension.

Systemic Blood Pressure

The rationale for RT as an adjunct to aerobic exercise for controlling BP stems from multiple studies. Two meta-analyses of RT and hypertension are noteworthy.[26,27] Inclusion criteria, consistent across both reviews, were (1) inclusion of a randomized nonexercise control group; (2) RT as the only intervention; (3) training for a minimum of 4 weeks; and (4) participants who were sedentary normotensive and/or hypertensive adults with no other concomitant disease. Kelley and Kelley[27] examined the effects of RT on resting BP in studies published between January 1966 and December 1998. A total of 11 studies met the inclusion criteria and represented initial and final BP assessments in 182 RT subjects and 138 control subjects. Decreases ($P \leq 0.05$) of approximately 3 mm Hg were found for both systolic and diastolic BP across all BP categories as the result of RT. These changes represented a 2% decrease for resting systolic BP and 4% for resting diastolic BP. No differences were found for changes in resting BP between studies that used conventional RT compared with a circuit RT protocol. A conventional RT protocol generally consists of lifting heavier weights with longer rest periods, whereas a circuit RT protocol consists of lifting lighter weights with shorter rest periods between exercises. By moving quickly between exercises and by using lighter weight with higher repetitions, circuit training introduces an aerobic component to the workout.[54]

In the more recent meta-analysis, Cornelissen and Fagard[26] pooled data from studies published between 1996 and 2003 that included 9 randomized controlled trials involving 341 participants. The overall effect of RT was a decrease of 3.2 mm Hg ($P=0.10$) in systolic BP and a decrease of 3.5 mm Hg ($P \leq 0.05$) in diastolic BP. Results from these meta-analyses are consistent with conclusions generated by narrative reviews.[17,55,56] Although these reductions seem modest, a systolic BP reduction of 3 mm Hg in average populations has been estimated to reduce cardiac morbidity by 5% to 9%, stroke by 8% to 14%, and all-cause mortality by 4%.[57] The lack of data on the effects of RT on ambulatory BP warrants further investigation because this may be more indicative of future CV disease morbidity and mortality.[58]

Control of BP is even more important in individuals who already have hypertension. Although there is general agreement that endurance training lowers resting BP in patients with mild to severe hypertension,[27,57] there is a paucity of data on the effects of RT alone on BP in individuals with hypertension. Only 20% of the outcomes in the 2 meta-analysis reviews were based on a mean initial resting systolic BP >140 mm Hg, whereas only 13% had a mean initial resting diastolic BP >90 mm Hg.[26,27] One study that used RT in combination with aerobic exercise in middle-aged hypertensive men for 10 weeks demonstrated reductions of 13 mm Hg for both systolic and diastolic BP.[59] Conversely, a similar program for 6 months in older adults with hypertension showed mean decreases in systolic and diastolic BP of 5.3 and 3.7 mm Hg, respectively.[60] The change in systolic BP, although significantly lower than study entry, was not different from values in the control group. Although any reduction in BP is desirable, the available studies do not answer the question regarding the independent benefit of RT in persons initially classified as being hypertensive or prehypertensive.

Arterial Stiffness

With aging, hypertension, insulin resistance, and diabetes, there is increased arterial stiffness from degeneration of the arterial media, increased collagen and calcium content, and arterial dilation and hypertrophy. These factors lead to increased systolic BP and an increased risk of cardiac events.[61] Several studies have shown that aerobic exercise is associated with reduced arterial stiffness in healthy subjects of all ages,[62] competitive aerobic athletes,[63] patients with coronary artery disease,[64] and hemodialysis patients.[65] Moreover, when aerobic exercise is combined with RT, there is no evidence of increased arterial stiffness.[66] However, less is known about the independent effects or RT on arterial stiffness. Two cross-sectional studies have suggested that young and middle-aged men who participate in regular RT have greater arterial stiffness than age-matched sedentary control subjects.[67,68] However, only 3 interventional studies have examined the effect of RT on arterial function.[69–71] Miyachi et al[70] reported that RT 3 days per week for 4 months decreased carotid arterial compliance by 19% ($P<0.05$) in young, healthy men who were novice weight trainers. Interestingly, carotid arterial compliance returned to baseline values within 2 months after RT was discontinued. Cortez-Cooper et al[69] reported that high intensity RT for 4 days per week for 3 months in young, healthy women who were novice weight trainers (n=23; age 29±1 years, mean±SD) increased carotid augmentation index (a measure of arterial wave reflection and arterial stiffness) from −8±13% to 1±18% ($P<0.05$), and carotid-femoral pulse-wave velocity increased ($P \leq 0.05$) from 791±88 to 833±96 cm/s. Paradoxically, neither study reported increases in systolic or diastolic BP secondary to RT.

Contradictory results were recently reported by Rakobowchuk and coworkers.[71] By using similar vascular measurement techniques, they found that central arterial compliance was unaltered after 3 months of RT in young men (n=28; age 23±3.9 years, mean± SD). The discrepancy between studies may be explained by differences in the RT protocols. The 2 studies in which central arterial stiffness increased used RT protocols consisting of high-intensity super sets and an extremely high volume (up to 6 sets per exercise),[69,70] both of which are not commonly recommended for the majority of the population and are usually performed by competitive athletes.[9,10] Conversely, the study in which arterial stiffness was unchanged used a progressive training protocol that increased intensity but not the volume of exercise over 12 weeks.

Mechanisms for Change in Arterial Compliance

Studies reporting adverse effects of RT on the arterial system have only speculated about mechanisms responsible for the changes.[67–70] The elastic properties of the arterial wall are determined by both structural components (eg, relative composition of elastin and collagen) and functional components (eg, vasoconstrictor tone exerted by the vascular smooth muscle cells). Because 3 to 4 months of RT are unlikely to

cause marked structural changes in the arterial wall, changes in the functional components of the arterial wall need to be considered. One potential mechanism is endothelial dysfunction manifested as a reduction in the bioavailability of nitric oxide. Recent evidence, however, indicates that 4 months of RT in healthy young men does not impair endothelium-dependent vasodilation in the brachial artery.[72] Another mechanism for functional change in the arterial wall is increased sympathetic tone. There is evidence that RT increases resting humoral norepinephrine levels, a surrogate marker of sympathetic nervous system activity.[73] However, increased sympathetic nervous system vasoconstrictor tone is likely to be greater in peripheral muscular arteries than in central elastic arteries. Surprisingly, both studies reporting increases in stiffness of central conduit arteries after RT did not show changes in peripheral muscular arteries.[69,70] Results from narrative[15,17,55,56] and meta-analytical reviews[26,27] do not support the contention the RT increases vascular resistance. Moreover, those findings are compatible with the absence of hypertension observed among isometric and power athletes.[74,75]

Resistance Training and Obesity

Obesity is an important risk factor for CV disease, left ventricular dysfunction, congestive heart failure, stroke, and cardiac arrhythmias.[3] Weight loss in obese patients can improve or prevent many of the obesity-related CV risk factors (ie, insulin resistance and type 2 diabetes mellitus, dyslipidemia, hypertension, and inflammation) and can improve diastolic function.[3] Moreover, these benefits are often found after only modest weight loss (≈5% of initial weight) and continue to improve with increasing weight loss.[3]

Obesity Prevention

Epidemiological evidence supports the use of increased exercise in preventing age-associated weight and fat gains.[1] Exercise recommendations to treat or prevent obesity have focused mainly on aerobic activities.[1] However, RT is a behaviorally feasible and efficacious alternative to endurance exercise for weight control. For example, resting energy expenditure (REE) decreases with aging, and this decrease is closely correlated to losses in skeletal muscle mass.[76] RT increases muscle mass by a minimum of 1 to 2 kg in studies of sufficient duration.[77] Theoretically, a gain of 1 kg in muscle mass should result in an REE increase of approximately 21 kcal/kg of new muscle.[78] In practice, RT intervention studies report REE increases in the range of 28 to 218 kcal/kg of muscle.[79–82] RT, when sustained over years or decades, translates into clinically important differences in daily energy expenditure and age-associated fat gains. However, even without a change in REE, maintenance of muscle mass through midlife years may prevent age-associated fat gains by promoting an active lifestyle.[15,83,84]

Visceral Adipose Tissue

RT can reduce total body fat mass in men[84,85] and women,[83,85–87] independent of dietary caloric restriction. However, regional distribution of fat may be more important to health than the total amount of body fat. Excessive central obesity and especially visceral adipose tissue have been linked with the development of hyperlipidemia, hypertension, insulin resistance and glucose intolerance, diabetes, and heart disease.[15,17,88,89] Fat distributed in the arms and legs, however, appears to impose little or no risk.[15,88,89] Although there may be a genetic predisposition for visceral adipose tissue, increasing age, high fat diets, and a sedentary lifestyle are also important determinants.

Several studies have demonstrated decreases in visceral adipose tissue after RT programs.[84,85,87,90,91] Treuth and coworkers[84,87] assessed body composition in older men by using dual-energy x-ray absorptiometry[84] and in older women by using computed tomography[87] and observed significant decreases in visceral fat after 16 weeks of RT. Ross et al[90,91] used magnetic resonance imaging to measure regional fat losses after exercise combined with diet interventions. In their first study,[90] both diet plus aerobic exercise and diet plus RT elicited similar losses of visceral fat that were greater than losses of whole-body subcutaneous fat. In a follow-up study,[91] they isolated the effects of endurance exercise training and RT by comparing the responses to diet alone and diet combined with each training modality in middle-aged obese men. All 3 groups lost significant amounts of total body fat, and all 3 groups experienced a significantly greater visceral fat loss compared with whole-body subcutaneous fat loss. The changes amounted to a 40% reduction in visceral fat in the RT and diet group, 39% in the endurance training and diet group, and a 32% reduction in the diet-only group.

One study has raised the possibility of gender specificity in visceral fat reduction in response to RT. Hunter et al[85] studied older women and men (age, 61 to 77 years) after 25 weeks of supervised RT. Both genders significantly increased muscle mass but men increased muscle more than women (2.8 versus 1.0 kg, respectively). Similar decreases in total body fat mass were found for the men (1.8 kg) and women (1.7 kg). However, women lost a significant amount of visceral adipose tissue (131 to 116 cm^2), whereas the men did not (143 to 152 cm^2). Similarly, women also lost a significant amount of subcutaneous adipose tissue (254 to 239 cm^2), but men did not (165 to 165 cm^2). Conversely, in a 6-month study of RT combined with aerobic exercise, men lost more visceral adipose tissue than women, but losses of total and subcutaneous adipose tissue were similar.[60] Although more research is needed to clarify these possible gender-specific responses, the overall available body of literature supports the use of RT, with or without aerobic exercise, and with or without diet modification, as an effective intervention that contributes to the reduction of abdominal obesity.

Obesity Reduction

Studies of the efficacy of RT in the context of total body weight loss have had mixed results. Studies that use more severe caloric intake restriction have not shown gains in muscle mass,[92,93] whereas RT studies with less severe caloric restriction have shown muscle mass gains with only modest losses in body weight.[87,90,91,94] RT studies that attempt to maintain caloric balance during the intervention typically do not observe major changes in body weight in either gender, despite significant reductions in fat mass and percent body

TABLE 2. Summary of Guidelines for Resistance Training for Disease Prevention

Exercise mode	Resistance exercise consists of weight lifting. Machines are preferred for safety and ease of use; hand-held weights, barbells, and elastic bands can also be used.
No. of exercises	8 to 10 exercises covering the major muscle groups; chest, shoulders, arms, back, abdomen, thigh, lower legs
Intensity	Resistance (weight) is set at 30% to 40% of 1 repetition maximum for upper body and 50% to 60% for lower-body exercises. One repetition maximum is the highest weight lifted 1 time. If testing is not available, use a weight that can be lifted for 8 to 10 repetitions; increase weight when 15 repetitions can be done easily.
Duration	Resistance training consisting of a single set of 8 to 10 exercises takes about 20 minutes
Frequency	Resistance exercise should be done at least twice per week.
Precautions	Risk/benefit ratio of resistance exercise is very favorable. Contraindications to resistance training are the same as those for aerobic exercise. Treatment for systolic BP>160 mm Hg or diastolic BP>100 mm Hg should be initiated before starting any type of exercise program. Avoid extended breath-holding to minimize exaggerated BP response.

fat.[15,84,85,87] In essence, body weight does not change much because loss of fat mass is generally offset by the gain in muscle mass. Conversely, endurance training–induced decreases in fat mass are more likely to be associated with reductions in body weight because there is no offsetting gain in muscle mass.

Resistance Training and Dyslipidemia

There is a dearth of well-controlled studies investigating the effect of RT intervention on lipid metabolism in individuals with normal lipoprotein-lipid profiles and those who are hypercholesterolemic. Cross-sectional evidence regarding the relation between muscle strength, RT, and plasma lipoprotein-lipid profiles is contradictory. Tucker and Silvester[95,96] studied 8499 male employees of more than 50 companies and observed a reduced risk of hypercholesterolemia among individuals participating in RT programs. However, only those individuals who participated in RT >4 hours per week maintained this reduced risk when confounding variables were controlled. In contrast, Kohl et al[97] studied 1193 women and 5460 men and reported no significant association between muscle strength and total or low-density lipoprotein cholesterol for either gender. However, there was a direct association between both upper and lower body strength and triglyceride levels in men.

Most interventional studies have failed to adequately control for normal variations in lipoproteins and lacked proper dietary controls and/or lacked statistical power. When these factors are controlled, most studies show no improvement in lipid profiles after RT in either middle-aged or older adults.[40,87,98,99] However, the lack of significant lipoprotein-lipid changes with RT may be due to the fact that total cholesterol values for most study groups has been ≤200 mg/dL at study entry. Individuals with normal lipoprotein-lipid profiles may require greater exercise stimulus and energy expenditure coupled with significant reductions in body weight to further improve lipid profiles. Alternatively, Shoup and Durstine[100] postulated that for changes in blood lipids to occur, lipoprotein lipase levels need to increase or remain elevated postexercise, or associated hepatic lipase must be suppressed to reduce conversion of high-density lipoprotein cholesterol (HDL-C) subfraction HDL_2-C to HDL_3-C. It is possible that the RT stimulus in most studies does not generate these cellular changes.

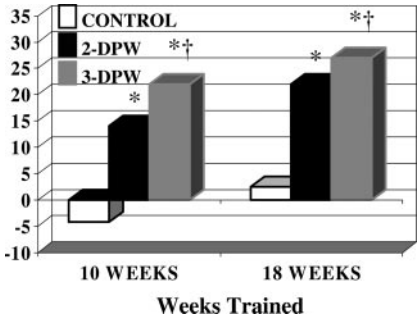
Screening and Precautions

The risk-to-benefit ratio of RT is highly favorable for most healthy individuals. The hemodynamic response to aerobic exercise is an increase in heart rate, with a progressive rise in systolic BP with little or no change in diastolic BP, and a widening of the pulse pressure.[9] These responses result primarily in a volume load on the heart. Conversely, RT causes a marked rise in both systolic and diastolic BP and consequently mean blood pressures, with less of a rise in heart rate compared with aerobic exercise.[101] Thus, RT imposes primarily a pressure load on the heart. Because of the considerably lower response of heart rate during RT, this mode of exercise generally results in a lower rate-pressure product compared with aerobic exercise. Among the many studies of RT in healthy adults, there have been no reported cardiovascular complications. The American College of Sports Medicine[95] and the American Heart Association[9] indicate that the contraindications to RT are similar to those for endurance exercise. Thus, the same screening criteria used for healthy adults before participation in endurance exercise would apply.

Selected individuals should consult their healthcare practitioners before beginning a vigorous exercise program. For those at moderate risk or higher, such as men age 45 years and over, women age 55 years and over, those with major risk factors for arteriosclerosis, and those with diabetes at any age, the American College of Sports Medicine recommends a medical history and physical examination including an exercise stress test before initiating a vigorous exercise program.[95] Because of the marked rise in BP with RT, those with uncontrolled hypertension (systolic BP ≥160 mm Hg and/or diastolic BP ≥100 mm Hg) should be controlled to lower levels before starting an exercise program.[102] High-intensity RT should also be avoided by individuals who have active proliferative retinopathy or moderate or worse nonproliferative diabetic retinopathy. To minimize excessive BP responses, individuals should be told to avoid extended breath-holding during their workouts.[35,80,103]

Resistance Training Exercise Prescription

A summary of RT guidelines is presented in Table 2. RT of all major muscle groups can be accomplished through the use of expedient programs. Indeed, adherence rates in RT interventional studies are high and due, in part, to the minimal



Relative changes (%) in peak isometric strength during knee extension after 10 and 18 weeks of variable resistance training. Group 2 trained 2 days per week (DPW) (n=50); group 3 trained 3 DPW (n=41); control did not train. Data represent mean±SEM. *2-DPW and 3-DPW > control ($P \leq 0.01$); †3-DPW > 2-DPW ($P \leq 0.05$).

time requirement for full participation. Most studies report that RT 3 days per week elicits superior strength gains when compared with training regimens of lower frequency.[77,104] However, if training intensity remains high (7 to 10 repetitions performed to momentary muscular failure), RT only 2 days per week produces approximately 80% of the strength benefits reported by studies using traditional 3 days-per-week routines (Figure).[104] Using scientific evidence and expert opinion, the American Heart Association, with endorsement of the American College of Sports Medicine, has promulgated RT guidelines for individuals with and without CV disease.[9,95] The guidelines for those without CV disease are summarized briefly herein. RT is recommended a minimum of 2 days per week, with progression to 3 days per week. A typical workout should consist of 8 to 10 exercises to cover the major muscle groups, which includes the chest, shoulders, arms, back, abdomen, thighs, and lower legs. The resistance or weight lifted should be moderate, which is defined as 30% to 40% of 1 RM for upper body exercises and 50% to 60% of 1 RM for lower body exercises. If maximal strength testing is not available, the individual can, through trial and error, use a weight that can be lifted for a minimum of 8 to 10 repetitions. When 12 to 15 repetitions can be accomplished with little difficulty, the weight is increased. This progressive resistance strategy meets the requirements of the overload principle, which is the basis for improvement in strength. Furthermore, by using moderate weight and gradually increasing the workload in stages, there is less risk of musculoskeletal injury while maintaining effectiveness of the workout.

Summary

Although randomized controlled trials among diverse populations are needed to further examine the role of RT in reducing CV risk factors, the following conclusions can be made regarding the mitigating effects of RT on the risk of cardiovascular disease:

(1) RT does not appear to alter glucose tolerance or glycemic control regardless of age, unless baseline glucose tolerance is abnormal. Nonetheless, most studies show that RT improves insulin action either through reductions in acute insulin responses during an oral glucose tolerance test or increased glucose uptake during glycemic clamp procedures. Moreover, RT significantly decreases HbA1c in diabetic men and women regardless of age, and this effect is observed even in the absence of a lasting effect of RT on fasting glucose.

(2) In healthy, normotensive persons, RT elicits reductions of approximately 3 mm Hg for both systolic and diastolic BP. Future studies are needed in individuals initially classified as hypertensive or prehypertensive to determine the extent to which RT lowers BP when it is elevated at baseline. Until these studies are performed, an RT program combined with aerobic exercise should be recommended for lowering BP in hypertensive adults.

(3) There is some evidence that RT can increase central arterial stiffness during high-intensity and high-volume training regimens, but an explanation for this effect has not been determined. No studies have found increased BP or peripheral vascular resistance secondary to RT.

(4) There is good evidence that RT reduces total body fat mass in men and women, independent of dietary caloric restriction. There is also good evidence that RT reduces visceral adipose tissue in older men and women.

(5) There is little evidence that RT improves lipoprotein-lipid profiles. However, total cholesterol values for most study groups have been ≤200 mg/dL at study entry. Individuals with normal lipoprotein-lipid profiles may require greater exercise stimulus and energy expenditure coupled with significant reductions in body weight in order to further improve lipid profiles.

(6) Although RT by itself may have limited beneficial effects on CV disease risk factors, this mode of exercise is beneficial in the prevention and management of musculoskeletal injuries and disorders, osteoporosis, and sarcopenia. RT also reduces susceptibility to falls and prevents or delays impaired physical function in frail and elderly persons.

(7) Although performing RT by itself rather than in combination with aerobic exercise appears to contribute to some aspects of CV disease reduction, the available data do not permit accurate estimation of the magnitude of the risk reduction. Thus, for the individual without existing cardiac disease whose goal is to improve their CV health and prevent disease, there is little evidence herein to challenge existing exercise guidelines that call for moderate-intensity RT to be performed in combination with aerobic exercise.

Disclosures

None.

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