

AHA SCIENTIFIC STATEMENT

Resistance Exercise Training in Individuals With and Without Cardiovascular Disease: 2023 Update: A Scientific Statement From the American Heart Association

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ABSTRACT: Resistance training not only can improve or maintain muscle mass and strength, but also has favorable physiological and clinical effects on cardiovascular disease and risk factors. This scientific statement is an update of the previous (2007) American Heart Association scientific statement regarding resistance training and cardiovascular disease. Since 2007, accumulating evidence suggests resistance training is a safe and effective approach for improving cardiovascular health in adults with and without cardiovascular disease. This scientific statement summarizes the benefits of resistance training alone or in combination with aerobic training for improving traditional and nontraditional cardiovascular disease risk factors. We also address the utility of resistance training for promoting cardiovascular health in varied healthy and clinical populations. Because less than one-third of US adults report participating in the recommended 2 days per week of resistance training activities, this scientific statement provides practical strategies for the promotion and prescription of resistance training.

Key Words: AHA Scientific Statements ■ cardiovascular diseases ■ exercise ■ resistance training ■ risk factors

Resistance training ([RT] exercise that evokes muscular contraction against an external force) improves or maintains muscle mass and strength, and has beneficial physiological and clinical effects on cardiovascular disease (CVD) and CVD risk factors.^{1,2} Epidemiological evidence suggests that RT is associated with a lower risk of all-cause mortality and CVD morbidity and mortality.² Adults who participate in RT have ≈15% lower risk of all-cause mortality and 17% lower risk of CVD, compared with adults who report no RT. Approximately 30 to 60 minutes per week of RT is associated with the maximum risk reduction for all-cause mortality and incident CVD.² Given the expanded evidence supporting the use of RT to combat CVD, we updated the previous American Heart Association (AHA) 2007 scientific statement on the topic.³ This updated scientific statement synthesizes newer evidence regarding the

effect of RT on both traditional (eg, blood pressure, lipids) and nontraditional (eg, arterial stiffness, physical functioning, depression) CVD risk factors. One of the 8 components in AHA Life's Essential 8 is a focus on physical activity and "moving more," through both aerobic and muscle-strengthening activities.⁴ The effects of RT in adults with and without CVD and the benefits associated with combination (aerobic+resistance) training are discussed. Despite the well-documented benefits, only 28% of US adults report participating in 2 days per week of RT as recommended by the 2018 Federal Physical Activity Guidelines.⁵ This scientific statement is intended to provide a summary of cardiovascular-related benefits of RT tailored to clinicians and public health promotion. In addition to reviewing the benefits for performing RT, this scientific statement addresses the promotion, prescription, and safety considerations for RT engagement.

HEALTH BENEFITS OF RT

Traditional CVD Risk Factors

Resistance training can improve traditional CVD risk factors, including blood pressure (BP), glycemia, lipids, and body composition. Included evidence is based largely on randomized controlled trials of medium length (2–6 months); few data were available for trials >6 months. Most trials implemented programs of moderate- to high-intensity (40%–80% of maximum effort) RT on 2 to 3 days per week.

RT and Resting BP

RT can reduce resting BP in healthy adults,^{6–8} in those with prehypertension, hypertension, and elevated cardiometabolic risk.^{6,7,9} Several proposed mechanisms responsible for these benefits include improvements in endothelial function, vasodilatory capacity, and vascular conductance.¹⁰ Among healthy young adults (≤ 40 years of age), RT can elicit small, but significant reductions in diastolic BP (–1 mmHg).⁶ For middle-aged and older healthy adults (> 40 years), RT results in larger reductions in systolic BP (–4 mmHg) and diastolic BP (–2 mmHg).⁷ Effects of RT are more pronounced for both systolic and diastolic BP in those with prehypertension⁹ (–3 mmHg systolic BP; –3 mmHg diastolic BP) and hypertension⁸ (–6 mmHg systolic BP; –5 mmHg diastolic BP) compared with normotensive individuals. The listed evidence suggests that the decreases in resting systolic BP are similar when comparing RT with antihypertensive medications.⁶

RT and Glycemia

RT is associated with improvements in glycemia and insulin resistance across varied populations.^{7,11–13} Several proposed beneficial mechanisms of RT include improved insulin sensitivity, increased GLUT4 translocation in skeletal muscle, and increased energy expenditure both during and after exercise.¹⁴ In observational studies, regular participation in RT is associated with a 17% lower incidence of diabetes compared with no participation in RT.² The dose-response association appears nonlinear with a progressively lower risk of diabetes associated with participation in up to 60 minutes per week of RT, followed by a continued, more gradual decrease beyond this threshold duration.²

RT interventions may reduce fasting glucose by 2 to 5 mg/dL among older adults,⁷ and among those with prediabetes¹² and type 2 diabetes, as well,^{13,15} but not in young and healthy participants.⁷ Among older patients with type 2 diabetes, RT was associated with a 0.34% decline in hemoglobin A1c.¹³ Patients with more recent documented type 2 diabetes (< 6 years) and those with higher hemoglobin A1c at baseline ($\geq 7.5\%$) demonstrated greater decreases in hemoglobin A1c after RT.¹⁵

RT and Lipid Profiles

There is a favorable, although modest, effect of RT on total cholesterol, triglycerides, and high-density lipoprotein cholesterol.^{7,16} Resistance training interventions result in improvements in high-density lipoprotein cholesterol (+2 to +12 mg/dL), total cholesterol (–8 mg/dL), and triglycerides (–7 to –13 mg/dL).^{7,16} The effect of RT on lipids and lipoproteins may be less pronounced in younger adults (< 40 years of age), corresponding to significant, although small, improvements in high-density lipoprotein cholesterol only (+2 mg/dL).⁷ Evidence for an effect on low-density lipoprotein cholesterol is less consistent. A meta-analysis of 46 studies, including varied populations with and without elevated cardiometabolic risk, reported a significant decrease of approximately –10 mg/dL in low-density lipoprotein cholesterol.¹⁶ In contrast, another meta-analysis found no significant reductions in low-density lipoprotein cholesterol in older adults without elevated cardiometabolic risk, whereas older adults with elevated cardiometabolic risk showed significant decreases in low-density lipoprotein cholesterol (–13.4 mg/dL) after RT.⁷

RT, Body Composition, and Weight

RT appears to have a beneficial effect on lean body mass and fat mass.^{17,18} Among adults who are overweight or obese, RT alone is associated with increased lean body mass (0.8 kg), decreased body fat percentage (–1.6%), and decreased whole-body fat mass (–1.0 kg) compared with nontraining controls.¹⁷ RT alone is unlikely to produce clinically significant weight loss.¹⁹ RT improves body composition by reducing body fat stores, increasing or maintaining muscle mass, and increasing resting metabolic rate; it may attenuate weight gain over time.²⁰

In summary, more recent data suggest that RT has significant and favorable effects on traditional CVD risk factors, including resting BP, glycemia, lipids and lipoproteins, and body composition. Benefits tend to be greater in older adults and those with elevated cardiometabolic risk factors.

RT and Nontraditional CVD Risk Factors

Accumulating research since 2007 has identified potential mechanisms, beyond the favorable effect on conventional CVD risk factors by which RT may reduce CVD risk (Table 1). Resistance training appears to confer small to moderate beneficial increases in cardiorespiratory fitness through mechanisms such as increased leg strength, improvements in oxidative enzymes, and increased type II muscle fibers.²¹ Although RT often has modest benefits for cardiorespiratory fitness, this can still be clinically meaningful given the well-established benefits of even moderate levels of cardiorespiratory fitness for lower risk of cardiovascular

Table 1. Associations of Resistance Training With Nontraditional Cardiovascular Risk Factors

Nontraditional risk factor	Association	Summary
Cardiorespiratory fitness	↑ or ↔	Small or moderate improvements in fitness in adults with and without CVD (+1 to 3 mL·kg ⁻¹ ·min ⁻¹ in $\dot{V}O_{2\max}$). ^{6,17} For people with coronary heart disease, similar improvements in $\dot{V}O_{2\max}$ shown with RT (17%) as with aerobic training (21%) ¹⁸
Arterial stiffness	↔, ↑, or ↓	Low-intensity to moderate-intensity RT favorably associated with lower central (−0.7±1.4 m/s) and peripheral (−1.3±1.07 m/s) PWV. ²⁰ Effects of high-intensity RT are inconsistent, identifying studies with positive and negative associations with PWV. ²⁰
Inflammation (CRP)	↓ or ↔	RT lowers CRP by −0.26 to −0.37 mg/L in adults overall. ^{6,13} RT lowers CRP in adults with elevated cardiometabolic risk by −2.47 mg/L. ⁶ Among 3 studies of adults with overweight or obesity, associations for CRP coincided with fat mass reduction. ²¹
Fibrinolysis and coagulation	↑ fibrinolysis ↔ coagulation	Higher volume and intensity RT associated with a greater fibrinolytic response and platelet activity, although on the basis of limited evidence in only apparently healthy young adults. ²² Among patients with coronary artery disease, a single RT session was associated with improvements in the fibrinolytic response without elevating potential thrombotic markers. ²²
Endothelial function	↑	Improvements of ≈2%–3% (flow-mediated dilation) in adults with and without cardiometabolic conditions. ^{6,23}
Depression and anxiety	↓	Moderate-effect sizes in reduction in depressive symptoms (ES=0.66). ²⁴ Small-to-moderate effect in reductions in anxiety (ES=0.33). ²⁵
Quality of life	↑	Positive effect on mental health–related QoL measures, including total Mental Component (ES=0.54), Mental health (ES=0.64), and Vitality (ES=0.39). ²⁶ Positive effect on physical health–related QoL measures, including total Physical Component (ES=0.50), Bodily pain (ES=0.81), General health (ES=0.57), and Physical functioning (ES=0.40). ²⁶
Sleep	↑ sleep quality	Moderate-effect sizes in better sleep outcomes, with the strongest beneficial associations for sleep quality. Associations are less consistent for sleep duration. ²⁷

CRP indicates C-reactive protein; CVD, cardiovascular disease; ES, effect size; PWV, pulse wave velocity; QoL, quality of life; and RT, resistance training. ↑ represents direct association; ↓ represents inverse association; ↔ represents no association.

events and mortality in adults with and without cardiovascular disease.²² Higher volumes of RT are most beneficial to elicit changes in fitness.²¹ RT appears to favorably influence endothelial function,^{7,23} whereas the effects of RT on arterial stiffness and inflammatory makers are less consistent, ranging from null to beneficial associations.^{7,16,24,25} Limited evidence from studies with small sample sizes suggests there are beneficial effects of RT on fibrinolysis.²⁶ A 2022 AHA presidential advisory statement introduced the Essential 8, adding sleep health as a new component and emphasizing the foundational factor of psychological health and well-being for preserving and optimizing cardiovascular health.⁴ Recent evidence suggests that RT is associated with enhanced sleep quality,²⁷ and reduced symptoms of depression and anxiety and improved quality of life, as well.^{28–30}

Resistance Versus Aerobic Versus Combined Training and CVD Risk Factors

A common yet understudied question is “What type of exercise is most effective for preventing CVD?” Several large observational studies suggest that, although no statistically significant differences were found between RT versus aerobic training (AT) alone, combining RT and AT (combination training [CT]) resulted in slightly larger reductions in some CVD risk factors, including obesity,³¹ diabetes,³² and hypercholesterolemia.³³ CT appears to

have stronger associations than either AT or RT alone with all-cause and CVD mortality.^{2,34} Compared with adults reporting no activity, individuals participating in CT have a 40% to 46% lower risk of all-cause and CVD mortality.² In contrast, RT or AT alone is associated with an 18% to 29% lower risk of all-cause and CVD mortality compared with no activity.²

Several meta-analyses, based primarily on interventions ranging 2 to 6 months, summarized the comparative effectiveness of RT, AT, and CT on CVD risk factors (Table 2). Overall, despite variations in study design and populations, RT, AT, and CT appear to similarly improve BP and lipids.^{35–37} CT appears to be more effective for improving body composition and glycemic control especially in patients with type 2 diabetes.^{12,19,37–39} RT is potentially a viable alternative to AT and may provide independent and additive benefits to AT for improving CVD risk factors. However, additional well-designed large randomized controlled trials with long-term (≥6 months) interventions directly comparing RT, AT, and CT are needed.

Individuals who do not meet the aerobic physical activity guidelines are less likely to participate in RT than those who are aerobically active. For example, only 3.6% of adults who report no aerobic activity do RT, compared with 43.5% of adults who are aerobically active and participate in RT.⁵ Physical inactivity is an established CVD risk factor. RT may be a viable strategy to support cardiovascular health among those who are otherwise

Table 2. Associations of Resistance, Aerobic, and Combined Training With Traditional CVD Risk Factors

	Magnitude of benefit			Conclusion	Summary of evidence
					
Blood pressure	+	+	+	RT, AT, and CT have similar favorable, small to moderate effects on both systolic and diastolic BP	Systolic BP significantly reduced after RT (−1.8 mm Hg) and AT (−3.5 mm Hg), but insignificantly after CT (−1.4 mm Hg). Diastolic BP significantly reduced after RT (−3.2 mm Hg), AT (−2.5 mm Hg), and CT (−2.2 mm Hg). ³² No significant differences between training types.
Lipid profile	+	+	+	RT, AT, and CT have similar favorable small to moderate effects on lipids	RT, AT, and CT improve lipid profile (eg, triglyceride, HDL and LDL cholesterol) by 4%–5%. No significant differences between training types. ^{33,34}
Glycemic control	+	++	+++	All modes have benefits. CT may have the strongest associations followed by AT, then RT.	In patients with type 2 diabetes, CT lowered HbA1c by 0.17% more than AT, and AT lowered HbA1c by 0.20% more than RT. ³⁵ In patients with prediabetes, CT and AT are superior to RT in reducing HbA1c and CT is most effective in controlling fasting blood glucose levels. ¹⁰
Body weight: Weight loss	0	+	+	AT and CT have small to moderate effects on weight loss. CT may be most beneficial for weight maintenance.	Greater reductions in body weight in CT (−2.0 kg) and AT (−1.2 kg), compared with RT. ³⁴
Weight maintenance	0	+	++		When used in combination with AT, RT may help assist with weight loss or maintenance by increasing resting metabolic rate, fat oxidation, and lean mass. ³⁶
Body composition: Lean mass	++	+	+++	RT is more beneficial for lean mass gains than AT.	Lean body mass improves more in CT (+0.9 kg) and RT (+1.3 kg), compared with AT. ³⁴
Fat mass	0	++	+++	AT is more beneficial for fat mass loss than RT. CT provides the greatest benefits for both fat and lean mass.	Greater reductions in fat mass in CT (−1.9 kg) and AT (−1.2 kg), compared with RT. ³⁴ CT is also superior to AT or RT for reducing subcutaneous abdominal fat. ³⁷

+ small to moderate benefit; ++ moderate benefit; +++ moderate to large benefit; 0 no effect.  = resistance training;  = aerobic training; and  = combined training. AT indicates aerobic training; BP, blood pressure; CT, combination training; HbA1c, hemoglobin A1c; HDL, high-density lipoprotein; LDL, low-density lipoprotein; and RT, resistance training.

aerobically inactive. As demonstrated in this scientific statement on RT’s independent cardiovascular benefits, RT programs targeted toward populations with low levels of aerobic activity may improve cardiorespiratory fitness, physical function, and cardiovascular health through RT alone.

RT BENEFITS AND CONSIDERATIONS FOR SPECIFIC POPULATIONS

In addition to the aforementioned cardiovascular benefits of RT, there are additional benefits for specific populations with or at high risk of CVD. In some populations, RT can provide unique benefits, yet requires specific considerations. We updated the 2007 summary of evidence on women, patients with heart failure (HF), and older adults. In addition, we summarize the evidence for RT among pregnant and postpartum women, and examples of other chronic conditions including people living with peripheral artery disease (PAD), human immunodeficiency virus (HIV), Alzheimer disease and related dementias (ADRD), and chronic kidney disease (CKD).

Women

RT interventions can improve muscular strength and endurance, body composition, and CVD risk factors in women of all ages.^{20,40,41} CVD and osteoporosis have a bidirectional relationship and shared common risk factors.⁴² Significant deterioration in bone mineral density over time, a particular concern in postmenopausal women, may be partially prevented with RT.¹⁶ RT improves bone mineral density in the femoral neck and the lumbar spine in pre- and postmenopausal women.^{43,44} RT, when combined with other weight-bearing, high-impact, aerobic activities (eg, jumping rope, tennis), appears most beneficial for bone health in women.^{43,45}

Most women do not regularly engage in RT. According to 2018 data, only 24% of US women engaged in RT ≥2 days per week.⁵ To maximize adherence, RT programs should proactively address common barriers and motivations specific to women. In the limited research on this topic, some strategies, such as group-based training, social support, family-friendly, or home-based workout options requiring minimal or no equipment, have been used to increase RT participation in women.⁴⁶ However,

given the low RT participation rates and the minimal evidence, this highlights an area for future research on RT program adoption and maintenance among women.

Pregnant and Postpartum Women

Resistance training, in general, is safe and recommended during pregnancy and the postpartum period.⁴⁷ In pregnant women with no contraindications, RT can be an integral component of an exercise program and does not appear to have adverse effects on maternal or fetal health during pregnancy.⁴⁸ Maternal benefits are most favorable for CT versus RT or AT alone, with the strongest evidence pertaining to improvements in cardiorespiratory fitness and urinary incontinence.⁴⁹ Limited high-quality trials of RT-only have addressed maternal CVD risk factors. One report suggested that RT may reduce the need for insulin therapy in women with gestational diabetes and support healthy gestational weight gain.⁴⁸ Among postpartum women enrolled in an 18-week supervised RT intervention, there were small to moderate reductions in postnatal depression scores and favorable changes in body composition.⁵⁰

Pregnancy-related symptoms, safety concerns, lack of information, and inadequate social support are common barriers to exercise during pregnancy.⁵¹ Motivational counseling using the “5 A’s” (ask, advise, assess, assist, and arrange), has been proposed to promote exercise during pregnancy and the postpartum period.⁴⁷ Before recommending a RT routine, health care professionals should conduct an evaluation to rule out contraindications (eg, preterm labor, preeclampsia, severe anemia).⁴⁷ RT programs should follow pregnancy-specific guidelines, given the physiological alterations during pregnancy, including joint instability, postural changes, and increases in body temperature.⁴⁸

Older Adults

The number of adults meeting the muscle-strengthening Physical Activity Guidelines declines across the life course, with older adults ≥ 65 years of age having the lowest proportions participating in RT. For example, 34% of adults 25 to 34 years of age versus 19% of adults ≥ 65 years of age reported participating in RT ≥ 2 times per week.⁵ Resistance training can slow the rate of aging-related declines in muscle mass, power, strength, and function in healthy older adults and those with chronic conditions.²⁰ In healthy older adults, RT improves muscle strength and power and results in increased mobility, physical function, and cardiorespiratory fitness.^{1,20} In older adult populations with frailty, sarcopenia, or osteoarthritis, and in institutionalized older adults (mean age ≥ 80 years), gains in strength after RT meaningfully improved physical function.^{12,52–55} RT can benefit muscle mass during aging. Greater skeletal muscle mass in older adults is independently associated with clinical and functional end points such as better physical performance,

mobility, and the prevention of injurious falls.⁵⁶ A key component of the Physical Activity Guidelines for older adults is a focus on balance, to address the major health concern of falls.⁵⁷ Falls in older adults are a leading cause of chronic disability and loss of independence. RT can reduce the risk of falls and injury from falls (eg, fractures) in older adults. RT programs that incorporate balance-challenge exercises (eg, feet closer together, minimal hand support) may be the most effective in fall prevention.²⁰

RT interventions in older adults with known or suspected CVD demonstrated improvements in risk factors, including glucose tolerance, lipids and lipoproteins, insulin resistance, and resting BP.^{15,58,59} A dose-response association has been demonstrated; higher training volumes (2–3 sets per exercise) and intensity (55%–80% of 1 repetition maximum [RM]), compared with lower volume (1 set per exercise) and intensity ($<55\%$ of 1-RM) resulted in greater reductions in total body fat mass and waist circumference^{55,60} and enhanced muscle quality, mass, strength, and functional status.^{20,54,60,61} Modifications to RT exercises should be considered on the basis of the health status and the presence of chronic health conditions.²⁰ Older adults can benefit from participating in RT to attenuate age-related declines in physical capacity and prolong functional independence.^{20,62}

People With HF

Exercise training improves cardiovascular fitness or functional capacity in patients with HF.^{63–65} The underlying mechanisms for improvements may differ between HF with reduced ejection fraction and HF with preserved ejection fraction. Although there was initial reluctance in applying RT to patients with HF, due to disproportionate increases in the rate-pressure product and systemic vascular resistance and concomitant decreases in left ventricular ejection fraction, these perceptions have been refuted.⁶⁴

RT significantly improves lower and upper extremity strength and endurance, cardiorespiratory fitness ($\dot{V}O_2$ peak $+2.6$ mL $\cdot$ kg $^{-1}\cdot$ min $^{-1}$), 6-minute walk distance ($+49.9$ m), and quality of life.^{63,64} Clinicians may consider prescribing RT when AT is deemed inappropriate or unviable, because RT alone can elicit meaningful benefits.⁶⁴ RT can be considered an initial strategy in patients with HF who are deconditioned to a point where AT can be difficult to initiate.⁶⁶ Combining RT with AT in clinically stable patients with HF is safe and may provide independent and additive benefits, including improved capacity for occupational and leisure-time activities, muscle strength and endurance, cardiorespiratory fitness, and quality of life.

People With PAD

Lower extremity PAD, characterized by atherosclerotic blockages of lower extremity arteries, is associated with

reduced lower extremity muscle mass and strength, and greater walking impairment secondary to intermittent claudication, compared with people without PAD.⁶⁷ A recent AHA scientific statement on optimal exercise programs concluded that, although consistent walking is first-line therapy for improving walking impairment in PAD, lower extremity RT provides an alternative therapeutic intervention in people with PAD.⁶⁸ RT alone can obviate the ischemic leg symptoms associated with walking exercise for PAD, and therefore may be more acceptable and less difficult than walking.^{69–71} RT with and without AT has favorable effects on selected walking measures and lower extremity strength.⁷⁰ RT programs are associated with a 49.4-m improvement in 6-minute walk performance and a 0.67 standardized mean difference improvement in peak walking distance compared with control nonexercise groups.⁷⁰ Yet, RT was less effective for 6-minute walk or treadmill walking distance compared with supervised walking programs.⁷⁰ Moderate- to high-intensity RT is associated with more pronounced improvement in walking performance compared with light-intensity RT.⁷¹ The effects of RT on vascular outcomes, such as blood flow, blood pressure, and functional capacity, have been investigated in only a few studies with mixed results, suggesting areas for future research.^{70,71} In summary, although less potent than supervised walking, RT may provide an alternative with substantial benefits in prolonging walking performance in patients with PAD.

People Living With HIV

People living with HIV experience comorbidities (eg, CVD, sarcopenia, frailty) earlier and more frequently than those without HIV and common treatment regimens for HIV may further exacerbate cardiovascular risk.^{72–74} People living with HIV face unique challenges to engaging in, and responding to RT, including mitochondrial dysfunction, altered proteostasis, muscle wasting, lipodystrophy, and cardiopulmonary deconditioning.⁷⁵ In general, RT is deemed safe and recommended for this population.⁷⁵ RT alone or combined with aerobic exercise improves strength, physical function, cardiorespiratory fitness, and cardiovascular health.^{76–78} People living with HIV initiating RT may get additional benefits doing so under the supervision of a trained exercise professional.⁷⁵

People Living With ADRD

ADRD affects millions of Americans and is a leading cause of morbidity and mortality in older adults. ADRD shares many of the same risk factors as CVD, including hypertension, diabetes, and physical inactivity.⁷⁹ RT can evoke functional brain changes, reduce white matter atrophy, and is associated with smaller white matter lesions.^{80,81} Although RT can improve cognitive function in

those with ADRD, the baseline level of cognitive impairment may influence responses to RT and bring about additional safety considerations. Those with moderate-to-severe symptoms of cognitive impairment may not derive the same benefits as those with mild symptoms.⁸² Degree of impairment, in general, should not prevent individuals with ADRD from engaging in RT. To maximize safety, it is necessary to tailor the prescribed RT regimen, setting, supervision, and equipment to the individual's cognitive function.

People Living With CKD

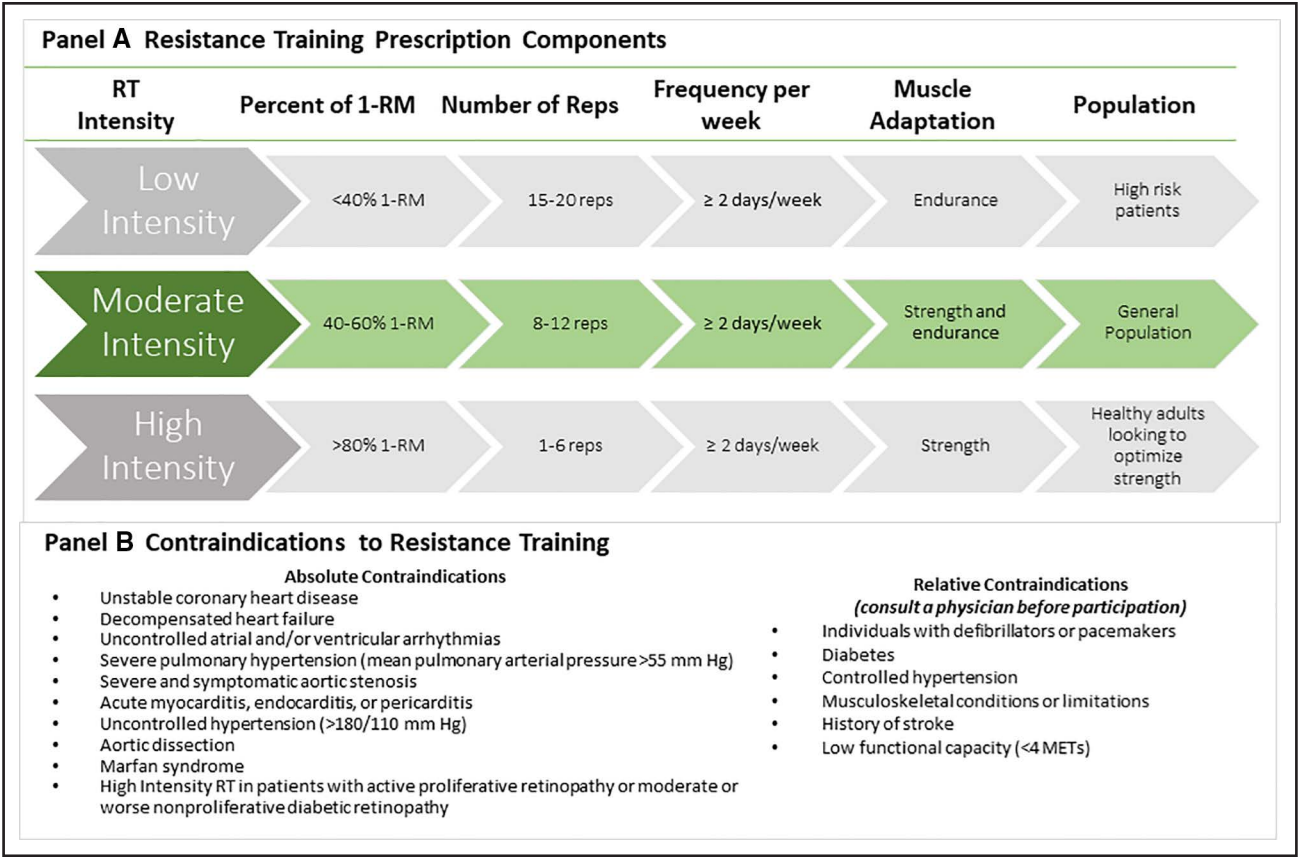
CKD is a risk factor for CVD morbidity and mortality. People with CKD experience significant reductions in functional capacity, muscle wasting, and muscular dysfunction.⁸³ RT for patients with CKD at all stages, including those undergoing dialysis, can be effective in increasing muscle mass, reducing intramuscular fat, improving muscle metabolism, increasing strength and functional capacity, and improving quality of life.^{83,84} RT is safe and well tolerated in this patient population.^{83–85} Individuals with CKD have an increased risk of bone fractures and tendon ruptures and a higher prevalence of diabetes, and these risks should be considered when developing a RT program.⁸³

PRESCRIPTION OF RT

Figure 1 shows the general guidelines for RT in apparently healthy adults and clinical populations. RT can include free weights (ie, dumbbells), body weight (ie, push-ups, squats), machine weights, and resistance bands. For healthy adults, regimens of 8 to 10 different exercises involving major muscle groups (Figure 2), each exercise performed in 1 to 3 sets of moderate-intensity loads that permits 8 to 12 repetitions per set to volitional fatigue, ≥ 2 times per week, is effective for achieving muscular and cardiovascular benefits.^{1,20,57,86} Planned rest days between sessions can allow for appropriate neuromuscular adaptations.^{87,88} For clinical populations, modifications to lower intensity loads with higher repetitions can minimize risk while still providing health benefits. Body weight training can be as effective as training with weight machines or free weights.

RT Program Progression

When beginning a new RT program, an initial intensity should correspond to 40% to 60% of 1-RM, then gradually increasing the resistance, number of sets, or frequency of training over time.^{86–88} This progressive overload is key to maintenance or continued improvements in muscle adaptation and strength over time.^{1,20,89} The “2 for 2” rule can be applied: when an individual can achieve 2 more repetitions of a given exercise in 2



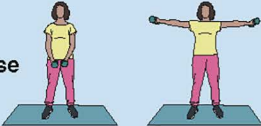
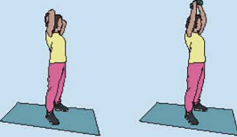
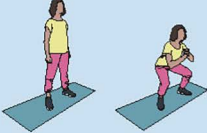
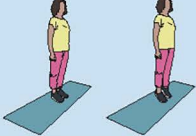
Major Muscle Group, accessory muscle group	Example Exercises	
Pectoralis, anterior deltoids, triceps	Chest press 	Push-up 
Deltoids	Shoulder press 	Shoulder raise 
Rhomboids, latissimus dorsi, rear deltoids, biceps	Seated row 	Bent-over row 
Triceps brachii	Triceps extension 	
Biceps brachii	Biceps curl 	
Quadriceps, Hamstrings, and Gluteals	Squat 	Lunge 
Gastrocnemius, soleus	Calf raise 	
Abdominals, obliques	Abdominal crunch 	
Quadratus lumborum	Back extension 	

Figure 2. Major muscle groups and example exercises. The name of the major muscle group involved in each exercise is in standard font. Accessory muscle groups involved in exercises are shown in italics. It is not necessary to perform all exercises in each resistance training session. Some compound exercises target >1 major muscle group. Eight to 10 exercises can be selected so that each major muscle group is exercised. Exercises can be completed using machines, free weights, elastic bands, or body weight.

have been shown to be safe and effective.⁹⁰ A meta-analysis of 7 trials demonstrated RT alone or with AT can improve physical and functional recovery, such as cardiorespiratory fitness.⁹⁰ However, future research is needed to determine optimal timing and progression of RT after a median sternotomy.

Initial Evaluation for Contraindications

Practitioners can initially evaluate the safety of RT participation using the same contraindications as the endurance component of adult fitness or exercise-based cardiac rehabilitation programs (Figure 1). Current statements and guidelines also recommend avoidance of intense exercise in selected patients with inherited cardiomyopathies.³ Although patients with hypertrophic cardiomyopathy are advised to avoid RT, an AHA statement regarding physical activity participation for young patients with genetic cardiovascular diseases suggested that low-intensity RT with machines might be permissible.⁹¹ RT programs of even lower relative intensities (eg, 20% of 1-RM) can safely improve strength after an acute coronary event.³ Therefore, some programs have adopted a more flexible approach for high-risk patients or those with absolute contraindications to traditional RT. Patients can safely perform modified approaches such as weight-bearing calisthenics, rubber band or spring devices, pulley weights, or light dumbbells or wrist weights. As with AT, adverse signs and symptoms (eg, dizziness, excessive dyspnea, chest pain and pressure, palpitations) require immediate medical evaluation, and patients should discontinue participating in RT until obtaining further medical clearance.⁸⁶

Relative contraindications may apply to clinical subpopulations in which they should seek physician consultation and medical clearance before starting an RT program (Figure 1). Individuals with implanted pacemakers or defibrillators should consult with their physicians before engaging in upper-body RT.²⁰ Repetitive-motion activities such as RT can result in pacing lead fractures and dislodgment. In the absence of absolute contraindications (Figure 1), patients with type 2 diabetes can participate in RT.^{11,20,92} Patients should monitor glucose levels before and after RT sessions to prevent exercise-induced hypoglycemia.²⁰ Caution is advised for individuals with diabetic neuropathy because of greater susceptibility to orthostatic hypotension and musculoskeletal injury due to impaired sensory awareness and attenuated pain perception.³ High-intensity RT is contraindicated in patients with active proliferative retinopathy or moderate to severe nonproliferative diabetic retinopathy because it may trigger vitreous hemorrhage and retinal detachment.⁹² Individuals with musculoskeletal limitations, advanced arthritic conditions, severe osteoporosis and neuropathies, or previous stroke may benefit from low- to moderate-intensity RT.²⁰ Machines are likely safer than free weights for these patients, and the guidance of an exercise professional may provide enhanced benefit. Patients with controlled hypertension can safely participate in low- to moderate-intensity RT with proper breathing techniques.²⁰ Medications can affect hemodynamics, ECG changes, and exercise capacity, and therefore, should be considered when designing RT prescriptions.⁸⁶ For example, patients taking antihypertensive medica-

tions should incorporate extended cooldowns to prevent hypotension.

DISCUSSION

RT benefits cardiovascular health through avenues such as lowering BP, improving cholesterol, and improving insulin sensitivity. Controlling traditional and nontraditional risk factors decreases the risk of CVD and overall mortality. In observational studies, the dose-response association of RT with mortality and CVD is curvilinear. The greatest reduction in risk occurs between those performing no RT versus modest amounts of RT, the maximal benefit occurs at 30 to 60 minutes per week, and a lower risk compared with no RT remained until 130 to 140 minutes per day.² The evidence on higher levels is sparse and limits conclusions on the benefits or risks of high volumes of RT. Clinical trials also support similar benefits with modest training regimens of 2 sessions per week as enough to elicit benefits.

RT supports musculoskeletal and cardiovascular health for individuals across the adult life span. RT can benefit a wide range of populations living with chronic conditions who are at elevated CVD risk. This scientific statement focuses on RT in adult populations; however, RT can be initiated earlier than adulthood. The Physical Activity Guidelines recommend that children and adolescents 6 to 17 years of age participate in muscle-strengthening activities on at least 3 days as part of the recommended 1 hour per day of moderate to vigorous physical activity.⁵⁷ Youth athletes and nonathletes can experience positive outcomes from a well-supervised RT program, emphasizing proper technique.⁹³ Benefits range from lowering risks of injury, improved fitness, to better physical literacy, which may support continuing RT when entering adulthood.⁹³

Adequate intake of protein is necessary to fully realize the benefits of RT. Protein ingestion before or after a bout of RT stimulates muscle protein synthesis for building or maintaining muscle mass.⁹⁴ These benefits are important to support preserving muscle mass or delaying muscle loss during aging of all adults. A balanced diet through the consumption of whole foods with overall protein intake on the basis of the Acceptable Macronutrient Distribution Range is adequate to support muscle health benefits.⁹⁴

Population participation rates are lower for RT than AT.⁵ To promote RT, it is important to proactively address the unique barriers of this training modality, such as equipment availability, perceived complexity, and how to safely and effectively perform RT.⁸² Most RT programs are delivered face-to-face by exercise professionals, to demonstrate and supervise techniques for individuals new to RT.⁹⁵ However, the growth of mobile applications, online videos, and video conferencing may expand reach and reduce cost for RT interventions, particularly among adults

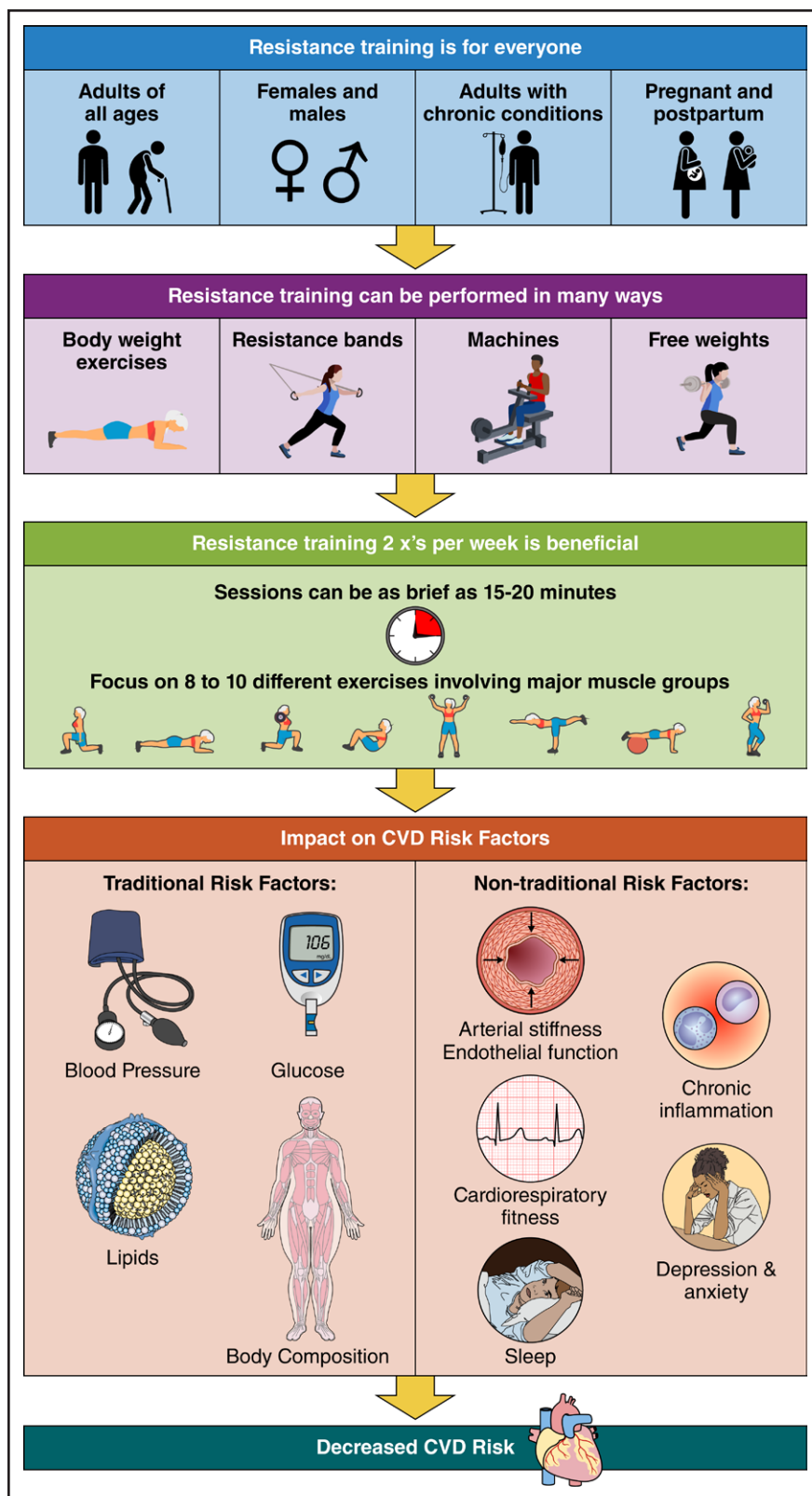


Figure 3. Summary of resistance exercise training.

CVD indicates cardiovascular disease.

with no contraindications who require minimal supervision. Exercises requiring minimal equipment (eg, elastic bands) to no equipment (eg, body weight exercises) can reduce complexity when developing home-based and digital RT programs. Research regarding strategies that minimize

complexity and equipment to address RT adoption and maintenance while providing sustained health benefits remain limited. Additional trials are needed to clarify the optimal RT prescriptions and behavioral change strategies in heterogeneous populations.⁹⁵

There are disparities in RT participation across demographic groups. Populations of older age, female sex, non-White race and ethnicity, and lower socioeconomic status are significantly less likely to participate in RT.^{5,96} RT promotion should be appropriately tailored to specific populations and consider a wide range of factors influencing RT participation. In comparison with research on determinants of aerobic activity participation, there is considerably less research on RT participation from a socioecologic approach. To address the low rates of RT and disparities in RT participation, it is vital to pursue implementation science, identify the intrapersonal (eg, intentions, self-efficacy), interpersonal (eg, social norms, social support), and environmental factors (eg, recreational facilities and access, neighborhood design), and to create feasible programs that can support the adoption and maintenance of RT.

CONCLUSION

Evidence describing the benefits of RT on traditional and nontraditional CVD risk factors has grown substantially since the 2007 AHA scientific statement. RT programs need not be time-consuming to be efficacious, requiring only 30 to 60 minutes per week (Figure 3). In general, a single set of 8 to 12 repetitions to volitional fatigue, using moderate weight loads of 40% to 60% of 1-RM, for 8 to 10 different exercises involving major muscle groups, performed twice per week are highly effective. Well-designed randomized controlled trials with long-term (≥6 months) interventions incorporating evidence-based behavior change and maintenance techniques are warranted and likely to reveal strategies for improved

implementation of RT in clinical and nonclinical settings. Recent evidence clearly demonstrates that RT is a safe, effective, and essential component of the overall physical activity regimen for CVD risk reduction.

ARTICLE INFORMATION

The American Heart Association makes every effort to avoid any actual or potential conflicts of interest that may arise as a result of an outside relationship or a personal, professional, or business interest of a member of the writing panel. Specifically, all members of the writing group are required to complete and submit a Disclosure Questionnaire showing all such relationships that might be perceived as real or potential conflicts of interest.

This statement was approved by the American Heart Association Science Advisory and Coordinating Committee on September 6, 2023, and the American Heart Association Executive Committee on September 18, 2023. A copy of the document is available at <https://professional.heart.org/statements> by using either “Search for Guidelines & Statements” or the “Browse by Topic” area. To purchase additional reprints, call 215-356-2721 or email Meredith.Edelman@wolterskluwer.com

The American Heart Association requests that this document be cited as follows: Paluch AE, Boyer WR, Franklin BA, Laddu D, Lobelo F, Lee D, McDermott MM, Swift DL, Webel AR, Lane A; on behalf the American Heart Association Council on Lifestyle and Cardiometabolic Health; Council on Arteriosclerosis, Thrombosis and Vascular Biology; Council on Clinical Cardiology; Council on Cardiovascular and Stroke Nursing; Council on Epidemiology and Prevention; and Council on Peripheral Vascular Disease. Resistance exercise training in individuals with and without cardiovascular disease: 2023 update: a scientific statement from the American Heart Association. *Circulation*. 2024;149:e217–e231. doi: 10.1161/CIR.0000000000001189

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Disclosures

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(Continued)

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This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be "significant" if (a) the person receives \$5000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns \$5000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition.

*Modest.
†Significant.

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This table represents the relationships of reviewers that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all reviewers are required to complete and submit. A relationship is considered to be "significant" if (a) the person receives \$5000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns \$5000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition.

*Modest.
†Significant.

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