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AHA SCIENTIFIC STATEMENT

Exercise Training in High-Risk Populations: A Scientific Statement From the American Heart Association

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ABSTRACT: There is broad consensus on the benefits of aerobic exercise training in patients with cardiovascular disease to improve cardiorespiratory fitness and lower the risk of adverse cardiovascular events. However, certain high-risk populations such as those with frailty, stroke, spinal cord injury, rheumatological conditions, or genetic cardiomyopathies and recipients of advanced heart failure therapies or cardiac implantable electronic devices warrant special considerations with regard to exercise training. This scientific statement summarizes the present state and future directions of exercise training for these high-risk populations, including functional deficits, responses to exercise training, modifications in training programs required to maximize safety and efficacy, and knowledge gaps in this field. Key findings common across most of these high-risk populations include (1) increased barriers to participation in exercise training at multiple levels; (2) low baseline cardiorespiratory fitness, creating heightened need for exercise interventions; (3) modifications to exercise prescription, frequently emphasizing strength, balance, and flexibility in addition to aerobic training, as well as accommodations with enhanced supervision and specialized equipment as needed; and (4) functional and quality-of-life gains in response to appropriately designed exercise programs that match or exceed those in more traditional populations. Future research is needed to further develop patient-centered training regimens designed to address the unique and heterogeneous needs of these populations, evaluate their impact on clinical and patient-centered outcomes, and advance scalable and equitable delivery of exercise therapies proven safe and effective.

Key Words: AHA Scientific Statements ■ arthritis ■ cardiomyopathies ■ cardiorespiratory fitness ■ cardiovascular diseases ■ frailty ■ spinal cord injuries

Prior studies have shown that higher cardiorespiratory fitness (CRF) is associated with greater longevity and lower risk of adverse cardiovascular outcomes, both in apparently healthy populations and those with chronic diseases.[1–5] For both populations, exercise training has been shown to be effective in improving CRF, mitigating cardiovascular risk factors, and improving quality of life.[1] Although there is a clear consensus on the benefits of regular aerobic exercise for patients with cardiovascular and other major disorders, individuals with complex, higher-risk chronic diseases have a generally low likelihood of participating in such activities. For example, patients with frailty, stroke, spinal cord injury (SCI), rheumatological conditions, or genetic cardiomyopathies and recipients of advanced heart failure (HF) therapies may be less likely to participate in or complete exercise training programs than individuals without those conditions.[1,6,7]

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Among patients with complex, higher-risk conditions, lack of participation in exercise training programs is likely multifactorial, due in part to failure of clinician referrals to cardiac rehabilitation (CR), patient reluctance or fear of exercise (ie, kinesiophobia), disease-related exercise limitations, and socioeconomic issues.[1] However, exercise training studies generally show substantial clinical benefits in these high-risk populations, with the greatest relative benefit in those with the lowest initial fitness levels.[2,8] The inclusion of strength, balance, and flexibility interventions often results in even larger benefits in performing daily activities, although most training programs do not devote significant time to these modalities.

The goals of this scientific statement are to highlight the prevalence and functional deficits of the aforementioned high-risk populations, their responses to exercise training, the modifications in training programs required to maximize safety and efficacy, and the knowledge gaps in this field, with future directions that address these gaps. This document is not intended to include all high-risk populations but rather was developed to assist clinicians in managing such patients and motivate future research, particularly for those conditions for which little guidance is available.

OLDER ADULTS WITH FRAILTY

Frailty is a syndrome of diminished intrinsic and allostatic reserve that manifests across physical, mental, and social domains. Although many different scales and criteria are available to assess frailty, the most commonly used approach to assess physical frailty requires at least 3 of the following: unintentional weight loss, weakness (measured by grip strength), slowness (measured by gait speed), low physical activity, and exhaustion.[9,10] Although frailty can occur throughout a lifetime, prevalence increases dramatically with age, particularly in older adults with cardiovascular disease (CVD), in whom the prevalence of frailty may reach 60%, depending on the definition used (Table 1).[9] A prime example of a CVD highly associated with frailty is HF with preserved ejection fraction. These patients are typically older, are more often women, and have multiple comorbid conditions, including hypertension, obesity, and diabetes.[6] Multimorbidity, sarcopenia, and cognitive impairment often coexist, worsening prognosis and undercutting capacities for physical performance and autonomous daily activity. Although a growing body of literature indicates benefits of exercise and physical activity to slow and even reverse frailty,[44] implementation requires a distinctive approach.

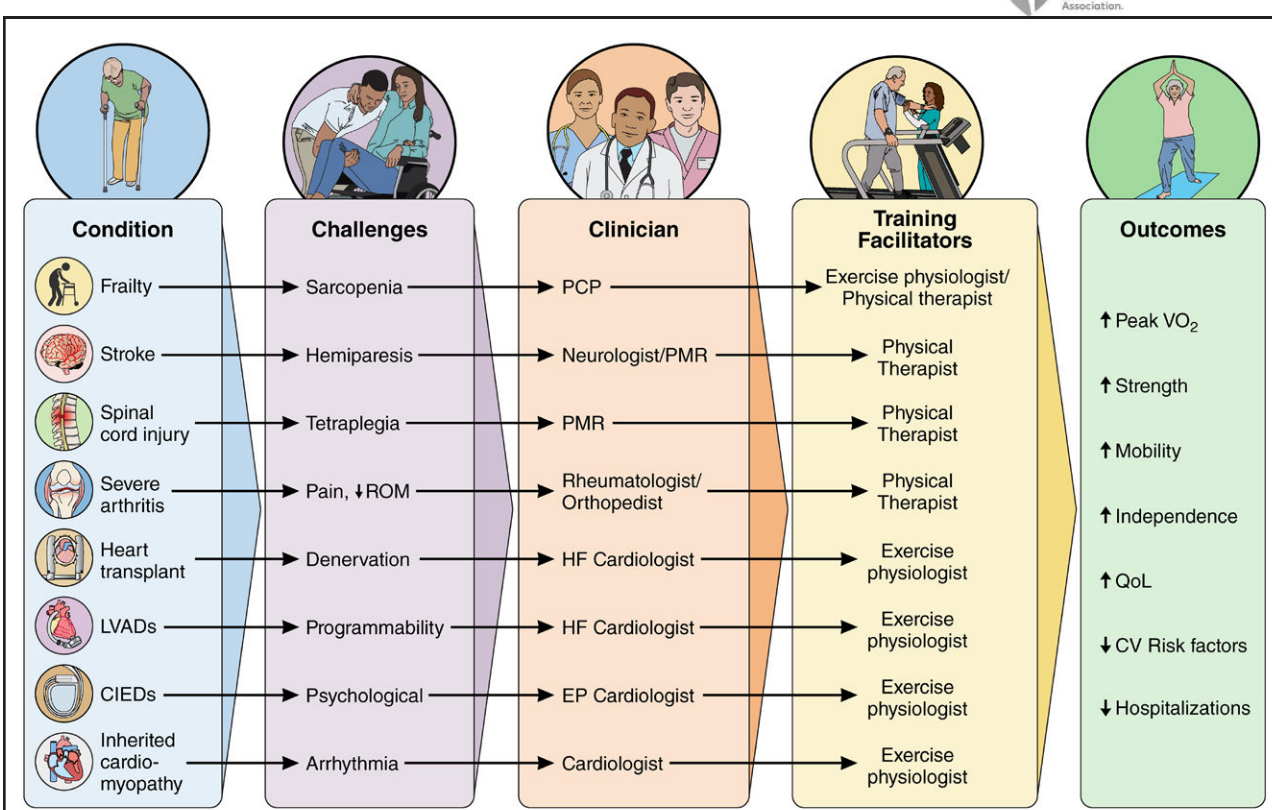

Figure. Supporting exercise among high-risk populations.
CEP indicates clinical exercise physiologist; CIED, cardiac implanted electrical device; CV, cardiovascular; EP, electrophysiologist; HF, heart failure; LVAD, left ventricular assist device; PCP, primary care provider; PMR, physical medicine and rehabilitation specialist; QoL, quality of life, ROM, range of motion; and $\dot{V}O_2$, oxygen consumption.

Table 1. Condition Prevalence and Physiological Deficits

		Deficits			
Condition	**Prevalence**	**Aerobic**	**Strength**	**Balance**	**Flexibility**
Frail older adults	≈10%–60% in community-dwelling older adults with CVD, depending on specific conditions and assessment tools[9]	30%–70% reduction in peak $\dot{V}O_2$, contributing to disability and reduced capacity for recovery[11]	11%–50% reduced strength, especially in lower limbs, due to sarcopenia and impaired neuromuscular function[12]	Reduced balance in up to 40%, often compounded with cognitive decline and visual and sensory deficits	Reduced flexibility common, particularly related to spine and joint mobility
Stroke	≈7 million adults in the United States with prior stroke ≈795 000 stroke incidence/y[13]	Decreased peak $\dot{V}O_2$ to 26%–87% that of healthy adults[14]	Muscle weakness due to hemiparesis or paresis in ≈65%[15]	Balance deficits in up to 83%[16]	Reduced flexibility with spasticity in ≈26%[17]
SCI	253 000–378 000 in the United States[18]: incomplete tetraplegia 48%, incomplete paraplegia 20%, complete tetraplegia 12%, complete paraplegia 20%	Peak $\dot{V}O_2$ averages 15–20 $mL \cdot kg^{-1} \cdot min^{-1}$, lowest in complete tetraplegia[3]	Proportional to level and completeness of injury[19]	Potential for balance deficits to affect exercise for those with incomplete injuries not wheelchair dependent	Not available
Severe arthritis	24% of US adults, including >50% of adults ≥65 y of age[20]	Not available	Not available	Not available	Fixed joint deformities occur with severe and late-stage disease
HTx	>5000 worldwide in 2023[21]	Peak $\dot{V}O_2$ (after HTx) 20–30 $mL \cdot kg^{-1} \cdot min^{-1}$ [22]	Reduced muscle mass, muscle strength, and muscle endurance, often related to degree of HF before HTx[23,24]	Not available	Not available
LVAD	≈2500 LVADs/y[25]	Peak $\dot{V}O_2$ 10–20 $mL \cdot kg^{-1} \cdot min^{-1}$ [26,27]	Not available	Not available	Not available
CIEDs	3 million Americans with pacemakers and ≈800 000 have ICDs[28]; 100 000–300 000 new implantations annually[13]	Peak $\dot{V}O_2$ 10–20 $mL \cdot kg^{-1} \cdot min^{-1}$ [29–37]	Not available	Not available	Not available
Inherited cardiomyopathies	HCM: ≈1:500 individuals[38]; ACM: ≈1:5000 individuals[39]; Channelopathy: ≈1:1000 individuals[40]	Preserved among patients with normal LV function Reduction in peak $\dot{V}O_2$ proportional to ventricular dysfunction[41]	Skeletal muscle atrophy, weakness, and reduced endurance proportional to severity of HF[42]	Lightheadedness or orthostatic intolerance from arrhythmias or reduced ventricular function[43]	Not available

ACM indicates arrhythmogenic cardiomyopathy; CIED, cardiac implantable electronic device; CVD, cardiovascular disease; HCM, hypertrophic cardiomyopathy; HF, heart failure; HTx, heart transplantation; ICD, implantable cardioverter defibrillator; LV, left ventricular; LVAD, left ventricular assist device; SCI, spinal cord injury; and $\dot{V}O_2$, oxygen consumption.

Hemodynamic improvement after revascularization, medical optimization, or valve interventions creates a window in which patients with frailty may be more capable of improving CRF. However, up to 40% of patients report fair or poor functional status after such interventions, regardless of their technical success,[45] suggesting that treating CVD alone is insufficient. Randomized trials in hospitalized older adults and community-dwelling older adults have proven that multicomponent exercise training can help prevent or mitigate functional decline (Supplemental Table).[7,46] TARGET-EFT (The Multicomponent Acute Intervention in Frail Geriatric Patients With CVD Using the Essential Frailty Toolset) and REHAB-HF (Physical Rehabilitation for Older Patients Hospitalized for Heart Failure) extended such benefits to patients with frailty with acute cardiovascular conditions, improving multiple domains of physical function (strength, balance, functional mobility, endurance), frailty measures ("defrailing"), and postdischarge quality of life using simple exercises for mobility and lower-extremity strength.[44,47] Restoring self-efficacy or the confidence and capacity for rudimentary physical function (strength, balance, endurance) is a key goal for patients with frailty, particularly because hospitalizations tends to exacerbate functional declines. Patients with frailty who achieve early, meaningful improvements in physical function and self-efficacy after a hospitalization are more likely to progress to restore mobility, daily activity, CRF, and independence.[2] The REHAB-HF trial showed that older patients hospitalized for HF derived significant functional improvement after a multicomponent exercise program that began in hospital.[6,44] Furthermore, the subset with HF with preserved ejection fraction had greater functional limitations at baseline than those with HF with reduced ejection fraction but experienced greater improvement in function as assessed by the Short Physical Performance Battery and 6-minute walk distance and nominally lower rates of subsequent hospitalization or mortality over the 3-month follow-up period.[48]

Exercise prescriptions for patients with frailty typically prioritize lower-extremity strength, balance, and rapid-force development (ie, brief, purposeful bursts to improve transfer ability), which may be essential to

Table 2. Training Modifications and Outcomes

Condition	Key training modifications	Outcomes	Delivery method	Evidence grade*
Older adults with frailty	Multicomponent interventions emphasizing strength, aerobic, flexibility, and balance exercises with structured progression[49] Strength and balance training often need to precede aerobic modalities to achieve sufficient capacity and for safety Emphasis on unsupported standing training, over-ground ambulation, and plyometric-type exercise for greater translational gain Individually tailored Nutritional supplementation (protein dense)[50] Aggregate, holistic care coordination	Improved: Strength Balance Walking distance and endurance Health-related QoL Self-efficacy Decreased: Frailty Disability Hospitalizations Mortality	Therapist supervised 1:1 multicomponent rehabilitation Home-based, function-stratified multicomponent exercise	Physical function, QoL: strong Clinical outcomes: moderate
Stroke	Aerobic exercise[8,51] 40%–70% of HR reserve; 55%–80% HR maximum; Borg RPE of 11–14 3–5 d/wk, 20- to 60-min sessions Cycle ergometer may need modifications; assisted treadmill walking Resistance training 1–3 sets of 10–15 repetitions of 8–10 exercises involving the major muscle groups at 50%–80% of 1RM 2–3 d/wk Machine vs free weights vs bands, seated vs standing Flexibility training 10- to 30-s hold for static stretching: 2–4 repetitions 2–3 d/wk (before or after aerobic or strength training)	Improved[52–55]: CRF METs Peak $\dot{V}O_2$ Physical function Ambulation Balance Upper- and lower-extremity muscle strength Cardiovascular risk factor profile Reduced systolic blood pressure Reduced fasting glucose Reduced fasting insulin Increased HDL cholesterol Cognitive function QoL	Supervised group or 1:1 sessions	Moderate
SCI	Injury defines training modalities available Complete paraplegia and tetraplegia: resistance arm exercise, aerobic arm exercise, and aerobic arm+lower-body electrical stimulation exercise Incomplete paraplegia and tetraplegia: body weight–supported exercise training may be used	Increased peak $\dot{V}O_2$ Potential increases in lean mass and insulin sensitivity No improvements in cardiovascular biomarkers, blood pressure, cardiac structure/function	Supervised home-based and rehabilitation-associated exercise programs Adaptive sports programs	Moderate
Severe arthritis	Occupational therapist, physical therapist, or exercise physiologist evaluation of exercise limitations, development of individualized modifications, and supervision of training initiation	RA: improved peak $\dot{V}O_2$,[56,57] strength,[56,57] pain,[56,58] physical function,[56,58] QoL,[59,60] inflammatory disease activity,[61–63] cardiovascular risk[64–66] Osteoarthritis: improved peak $\dot{V}O_2$,[67] strength,[68] pain,[58,69] function,[58,69] QoL[69]	Supervised 1:1 and group settings (both in person and virtual)	RA: moderate to strong Osteoarthritis: strong
HTx[2–24,70–75]	Moderate-intensity (Borg RPE 12–15) to high-intensity (Borg RPE 16–18) aerobic exercise Strength training Intensity should be individually tailored according to time from HTx Ensure sufficient time for warm-up and cooldown due to blunted HR response	Improved peak $\dot{V}O_2$ Improved muscle strength and vascular function Improved health-related QoL Facilitated partial reinnervation and improved HR exercise response	1:1 if needed for severely deconditioned patients Group-based CR sessions	Strong
LVAD	Familiarization of CR staff with device, device alarms (eg, low-flow alarms), and its peripheral equipment Stabilize external driveline during exercise Difficulty in measuring vital signs given pulseless circulation Requires electrocardiographic monitoring and Doppler to measure blood pressure[76] Maintain mean artery pressure 70–90 mm Hg	Improved peak $\dot{V}O_2$ Decreased LVAD hospitalizations Improved QoL[77]	Supervised group or 1:1 sessions	Limited

(*Continued*)

Table 2. Continued

Condition	Key training modifications	Outcomes	Delivery method	Evidence grade*
CIEDs[29–37]	ICD: Majority of exercise trials done in supervised CR Most training done at 60%–80% of peak $\dot{V}O_2$ Maintain exercise HR 20 bpm below lowest shock (ATP or shock) zone Maintain target HR threshold below ischemic threshold Pacemaker: Program on rate-response feature and adjust as needed to support exercise. Use higher upper rate limit (dual chamber) to retain biventricular pacing with CRT-D Both: Monitor HR using telemetry or HR monitor Perform exercise training test before starting to evaluate for arrhythmias; use 220–age to derive maximum HR if exercise test not available Ensure cooldown period for return to resting HR Caution for upper-body arm movements for the first 8 wk after initial implantation	ICD: Increased peak $\dot{V}O_2$ Increased 6MWD Mixed results for QoL Anxiety and depression may be reduced Death, hospitalizations not increased with exercise ICD shocks and ATP not increased Pacemaker: Increased peak $\dot{V}O_2$ Increased resting LVEF with CRT	Outpatient CR or home exercise	Strong
Inherited cardiomyopathies	HCM: Determine presence/absence of HF symptoms[78] Moderate-intensity exercise for patients with NYHA class I–III HF symptoms[78] Limited/no exercise training for patients with NYHA class IV HF symptoms[79] ACM: Avoid intense exercise[80] Avoid frequent exercise Long-QT syndrome: Ensure medical therapy is optimized (eg, use of β-blocker, ICD)[81]	HCM: Increased peak $\dot{V}O_2$[82] No signal of harm with moderate- or high-intensity exercise[82] ACM: Criteria for diagnosis increased with history of higher exercise duration and intensity[83] Rate of ventricular arrhythmias increase in proportion to exercise duration and intensity Long-QT syndrome: No signal of harm for medically optimized patients[81]	HCM: supervised group sessions ACM: intense and frequent exercise discouraged Long-QT syndrome: supervised group sessions	Moderate

Suggested training modifications and outcomes for the individual conditions reviewed and overall strength of evidence (limited, moderate, strong) for exercise interventions for each condition.

1RM indicates maximum resistance lifted; 6MWD, 6-minute walk distance; ACM, arrhythmogenic cardiomyopathy; ATP, antitachycardia pacing; CIED, cardiac implantable electronic device; CR, cardiac rehabilitation; CRF, cardiorespiratory fitness; CRT, cardiac resynchronization therapy; CRT-D, cardiac resynchronization therapy–defibrillation; HCM, hypertrophic cardiomyopathy; HDL, high-density lipoprotein; HF, heart failure; HR, heart rate; HTx, heart transplantation; ICD, implantable cardioverter defibrillator; LVAD, left ventricular assist device; LVEF, left ventricular ejection fraction; MET, metabolic equivalent; NYHA, New York Heart Association; QoL, quality of life; RA, rheumatoid arthritis; RPE, Rating of Perceived Exertion; SCI, spinal cord injury; and $\dot{V}O_2$, oxygen consumption.

*Evidence grade at time of publication.

minimize fall risk before aerobic modalities are feasible or safe (Table 2).[44] Prescriptions should be tailored to functional status with the use of performance measures such as the Short Physical Performance Battery to stratify patients and guide progression.[49] Exercise training workloads that would be considered low intensity for more fit individuals are often perceived and physiologically experienced as high intensity in patients with frailty. Initially, body weight resistance exercises and slow-movement aerobic exercises may be the most that can be tolerated, but they are still sufficient to achieve meaningful training gains that may exceed those of less frail individuals.[6,84] Aerobic training often must start with short bouts of exercise, with progressive increases in frequency and duration as tolerated before intensity or speed is increased. Notably, although many CR programs commonly default to recumbent devices for frail adults, with the rationale that they are safe and reassuring to patients (and staff), the CR core components emphasize the importance of resistance and balance training,[1] with corroborating studies highlighting the utility of unsupported standing training, over-ground ambulation, and plyometric-type exercises like step-ups for greater translational gain.[85,86]

Home training programs such as Vivifrail and supervised center-based programs such as REHAB-HF exemplify programs of progressive resistance, balance, and interval walking matched to baseline capacity that have successfully improved physical function and quality of life in older adults with frailty.[44,85] Adequate exercise supervision and care alignment with comorbid conditions and medications are also critical factors in ensuring safety, progression, and adherence. For older adults with frailty, exercise training is potentiated by protein-rich foods or supplements, targeting a daily intake of 1.5 g/kg body weight, to optimize muscle strengthening.[50]

Although CRF is usually regarded as the gold standard physiological assessment for patients with CVD, this benchmark becomes less practical and relevant for patients with frailty. Assessments of strength, balance, and submaximal endurance both are more feasible and provide greater utility for such functionally limited individuals. Sit-to-Stand repetitions, Timed Up and Go, and the Short Physical Performance Battery are among the tests that are useful to quantify lower-extremity strength and balance, particularly because these are more strongly linked to functional independence than cardiopulmonary exercise test. For those with greater CRF, endurance and mobility for everyday activities are more accurately measured with 6-minute walk distance or 400-m corridor walk than by cardiopulmonary exercise test. Serial testing with these instruments and patient-reported quality of life (eg, EQ-5D or Kansas City Cardiomyopathy Questionnaire) can be used to evaluate clinical changes. Given the role of sarcopenia and sarcopenic obesity as contributors to physical frailty and suboptimal responsiveness to training, assessments of muscle mass and body composition should be considered, assessed with upper-arm circumference, dual-energy x-ray absorptiometry, or computed tomography.[12] Moreover, assessments of basic and instrumental activities of daily living, together with cognition and mood, should be considered with brief screening tools to expose limiting factors beyond physical functional status.

In summary, exercise training for patients with frailty and CVD begins with a pragmatic, multidimensional assessment; progresses through individualized, multicomponent prescription; and targets outcomes that resonate with older adults, often enabling them to reclaim roles, routines, and self-efficacy.[87]

STROKE

Annually, >795 000 individuals in the United States experience a stroke, and ≈50% of stroke survivors have significant long-term disabilities (Table 1).[13] Patients with stroke demonstrate significant impairments in balance, mobility, strength, coordination, and cognitive function, as well as decreased CRF, exhibiting ≈60% of age- and sex-related normative values for sedentary healthy adults.[88] Consequently, they engage in less than half the recommended physical activity for their age group and spend ≈80% of their time sedentary.[8,89] Considering the substantial benefits that exercise training can provide, there is little reason to exclude it from rehabilitation strategies for most stroke patients once they are medically stable, regardless of stroke severity.[8,52,89] Engaging in physical activity after a stroke is associated with a significantly lower risk of subsequent myocardial infarction compared with a sedentary lifestyle.[90] In addition, participation in a moderate-intensity aerobic exercise program has been shown to decrease all-cause readmission rates and mortality.[53,54]

The American Heart Association and American Stroke Association endorse physical activity and exercise for stroke survivors throughout all phases of recovery to aid with the restoration of function, secondary stroke prevention, and reduction of cardiac events.[8] Current American Heart Association/American Stroke Association exercise guidelines for stroke patients recommend incorporating regular aerobic exercise (moderate intensity, lasting 20–60 minutes, 3–5 times a week), resistance training, flexibility exercises, and neuromuscular training into poststroke rehabilitation programs (Table 2).[8,51,91] However, stroke patients generally do not participate in these activities because of a lack of funding and program availability. Furthermore, current stroke rehabilitation programs provide only ≈3 minutes of low-intensity aerobic exercise per session.[8]

Many stroke survivors present with significant deficits, including hemiparesis, balance deficits, cognitive impairment, fatigue, speech impediments, attention deficits, and impulsivity, in addition to underlying CVD. The timing of initiation, rate of progression, and associated parameters of exercise training depend on neurobiological (ie, cerebral autoregulation, ischemic penumbra, hemorrhagic stroke parameters) and cardiovascular recovery and should be individualized to account for the unique deficits and comorbidities of each patient.[92]

Before an exercise program is initiated, obtaining medical clearance from a clinician is the essential first step to ensure that the program is safe and suitable for the patient's needs. A symptom-limited or submaximal exercise test should be considered before engaging in higher-intensity exercise. Accommodations for the physical impairments of stroke patients are essential for safe and effective participation. For hemiplegia or balance issues, seated equipment such as a recumbent cross-trainer or cycle ergometer should be used. Leg stabilizers, hand mitts, and torso belts may be needed for some patients to provide additional support. A harness apparatus, balance bars, or partial weight support systems can be incorporated for treadmill exercise to reduce the risk of injury. When strength training is incorporated, exercises should be selected to prevent excessive blood pressure increases and avoid the Valsalva maneuver. For stroke patients with speech or cognitive deficits, individualized methods to track pain and rate perceived exertion may be needed. Patients with dysphagia require close supervision for pulmonary status and oxygen saturation, and regular blood glucose checks are needed for patients with diabetes. In addition, immediate access to emergency medical response should be available during exercise for high-risk individuals. Research indicates that stroke patients can effectively engage in aerobic exercise programs in both group and individual settings.[91,93] However, patients with more severe impairments may benefit from a personalized approach based on their physical capabilities. The exercise format should be guided by the severity of the patient's neurological and cardiac issues, the timing of exercise initiation, and the intended mode and intensity of exercise.[94]

The acute poststroke phase is a critical and dynamic period for physiological recovery, requiring careful attention for cardiovascular and neurological stability, including resting blood pressure, cerebral autoregulation, blood-brain barrier function, the ischemic penumbra, and any hemorrhagic complications. Current evidence supports a phased approach to physical activity after stroke in which patients may begin light-intensity aerobic exercise within 30 days after stroke, progress to moderate-intensity exercise by 3 months, and advance to high-intensity exercise thereafter as appropriate, according to recovery and health status.[92] Research indicates that at least 8 weeks of exercise training is required for meaningful improvements, and ongoing physical activity is essential to maintain these benefits.[91] Exercise training, including aerobic and strength training and walking-based interventions, results in significant improvements in CRF, physical function (gait speed, walking distance, muscle strength, balance), cognitive function, and cardiometabolic profile (blood pressure, lipids, glycemic control) among stroke survivors (Supplemental Table).[52,89]

Aerobic exercise programs can be implemented in a range of settings such as outpatient clinics, community centers, and private residences. It is essential for high-risk individuals to have immediate access to emergency medical services. For patients at lower risk, home-based or virtual delivery programs can serve as a safe and effective alternative, depending on the mode and intensity of the exercise. In the United States, aerobic exercise programs are not currently funded for patients recovering from stroke despite evidence to support their benefit in this population.

SPINAL CORD INJURY

More than 18 000 SCI cases occur in the United States each year, and >300 000 individuals live with an SCI (Table 1).[18] Most often, SCI has no antecedent, occurring through accident or unrecognized pathology. It occurs across the life span without specificity, except that in young male individuals, it is more often due to traumatic injuries.

Without predisposing risk factors, the most important predictor of future health is the SCI lesion itself. Lesion level and severity determine functional impact: musculoskeletal paralysis, pulmonary insufficiency, cardiac limitations, and autonomic dysfunction, among others.[18] Hence, exercise interventions are critical to maximize function and maintain long-term health. The loss of muscle function and ensuing immobility typically result in a sedentary lifestyle that is difficult to overcome. Early access to appropriate forms of exercise is critical. However, individuals with SCI participate in exercise less than their able-bodied peers, and only 12% to 30% meet population-specific exercise guidelines.[19,95] As a result, individuals with SCI have high rates of cardiovascular and metabolic disease,[19] underscoring the need for regular exercise as a lifelong habit.

CRF decreases with higher and more complete SCIs (eg, cervical complete versus lumbar incomplete lesions). As a result, individuals with incomplete paraplegia may be able to achieve aerobic exercise recommendations designed for the able bodied but require greater focus on balance and strength. In contrast, those with higher-level SCI often require significant training modifications to achieve even population-specific aerobic exercise recommendations (Table 2).[18,19] Across all levels of injury, resistance training is recommended to improve strength and balance, with the broad consensus of 2 to 3 training sessions per week. Aerobic exercise training sessions range from 2 to 5 sessions per week at moderate to vigorous intensities for a total of 40 to 300 minutes of exercise (Table 2).[19] The optimal intensity can be difficult to ascertain because heart rate is an inadequate guide for exercise intensity in those individuals with injuries causing chronotropic incompetence. Therefore, perceptually based intensity has been suggested (eg, 10–11 on a 20-point scale or 2–3 on a 10-point scale). Meta-analyses suggest that across aerobic exercise training trials, typically lasting 6 to 12 weeks, the average improvement in peak $\dot{V}O_2$ is ≈3 $mL \cdot kg^{-1} \cdot min^{-1}$, a substantial improvement given the low pretraining peak $\dot{V}O_2$ in this population, with baseline values averaging 18 $mL \cdot kg^{-1} \cdot min^{-1}$ in otherwise young, healthy individuals.[3] However, aerobic exercise training over 6 to 24 weeks may not affect body composition or metabolic function and does not appear to alter CVD risk factors (Supplemental Table). Predicting the effects of aerobic exercise training in SCI is difficult in the context of nonstandardized exercise testing/intervention protocols, patient heterogeneity (eg, incomplete paraplegia versus complete tetraplegia, time since injury, age, sex), and sparse research on high-intensity interval training (HIIT).[96] Higher volumes and greater intensities of exercise than recommended,[19] perhaps through whole-body hybrid electrical stimulation and initiated subacutely after injury, are likely to result in the greatest improvements in exercise capacity and CVD risk factors.[3,96]

To initiate exercise without specialized equipment, individuals with SCI should perform low-intensity, short-duration seated or wheeling activities 2 to 3 times per week, with time and intensity increasing gradually with perceived exertion used as a guide. Proper seated positioning (if necessary); slow, controlled movements; and light resistance should be used, and exercise should be discontinued if significant symptoms (eg, dizziness, chest pain, or disproportionate shortness of breath) arise.

SEVERE ARTHRITIS

Severe arthritis is characterized by joint pain, stiffness, swelling, and joint deformities that substantially limit daily function. Approximately 24% of US adults and >50% of adults ≥65 years have arthritis, with 44% of those reporting activity limitations constituting severe arthritis.[20] Among the many types of arthritis, osteoarthritis and rheumatoid arthritis (RA) are most common. Adults with severe arthritis are more likely to have poor health, overweight/obesity, psychological distress, low education and income, and disabilities preventing employment.[20] Furthermore, compared with the general population, adults with RA are almost twice as likely to develop CVD.[97] Arthritis is associated with reduced CRF (peak $\dot{V}O_2$), endurance, strength, flexibility, and physical function. In a study of 404 older patients with knee osteoarthritis, 71% women (age, 68±10 years), mean peak $\dot{V}O_2$ was 17 mL·kg^{-1}·min^{-1}.[98] Among 67 patients with RA, 64% women (age, 53±10 years), lower-extremity strength was 65% to 75%, and estimated peak $\dot{V}O_2$ was 80% that of matched controls.[99] Fortunately, arthritis-related pain and physical function can be improved with exercise training.[58]

For RA, clinical guidelines strongly recommend regular exercise to improve CRF, strength, and physical function and reduce pain (Table 2).[56] Improvements in CRF and strength occur regardless of age and severity of functional deficits with minimal adverse events.[57,59,100] Multiple types of exercise programs improve physical functioning, including combined aerobic and resistance training (with and without flexibility and neuromuscular exercises) and aquatic exercise, with water providing movement resistance (Supplemental Table).[57,61,62] Aerobic exercise training, with and without resistance training, reduces fatigue.[101–103] Aquatic exercise, resistance training, and combined aerobic and resistance training reduce RA inflammatory disease activity (eg, Disease Activity Score for 28 Joints).[61–63] For example, meta-analyses show that resistance training improves the Disease Activity Score for 28 Joints (standardized mean difference, −0.69 [95% CI, −1.26 to −0.11]).[63] Furthermore, combined aerobic and resistance training with or without HIIT improves multiple measures of CVD risk, including peak $\dot{V}O_2$, blood pressure, triglycerides, high-density lipoprotein cholesterol, and endothelial function (Supplemental Table).[64–66] Although both aerobic training and resistance training reduce fat mass, resistance training may provide superior fat reduction, along with increases in lean mass.[60] Although HIIT interventions improve CRF, HIIT alone provides minimal improvements for inflammatory disease activity or traditional CVD risk factors (eg, lipid profiles and blood pressure) among patients with RA.[104]

For individuals with osteoarthritis of the hip or knee, meta-analyses support that multiple types of exercise training interventions improve osteoarthritis pain, function, physical performance, and quality of life with minimal adverse effects (Table 2).[69] Exercise effects for osteoarthritis pain reduction and functional improvement are similar in magnitude to those resulting from standard pharmacological therapy.[105] Strength training is a key part of knee osteoarthritis treatment, with lower-extremity strength increases underlying improvements in self-reported function and pain.[106] Although prior osteoarthritis recommendations focused on non–weight-bearing exercise, both non–weight-bearing and weight-bearing strength training improves pain and function, with weight-bearing exercise offering potentially greater benefits in quality of life with fewer adverse events.[107]

Guidelines for specific amounts and intensities of exercise for patients with arthritis are based on expert opinion and typically follow those for the general population and older adults; randomized controlled trials of specific modifications are lacking (Table 2). Patients with severe arthritis should be evaluated by a physical therapist or a clinical exercise physiologist to discern activity limitations, develop modifications as needed, and provide a period (eg, 3 months) of supervised exercise training. Regardless of arthritis type or severity, exercise training individualized according to functional limitations should be a key component of arthritis management. Individuals without access to specialized equipment or supervision are encouraged to perform enjoyable, pain-free activities such as walking, cycling, and aquatic exercises that promote CRF, balance, and mobility with low risk of injury.

CARDIAC IMPLANTABLE ELECTRONIC DEVICES

More than 3 million Americans live with pacemakers, and ≈800 000 have implantable cardioverter defibrillators (ICDs),[28] with 100 000 to 300 000 new implantations each year (Table 1).[13] Peak $\dot{V}O_2$ in this population is highly variable although low at 17.4 mL·kg^{-1}·min^{-1} on average.[29–37,108] Multiple studies have shown that aerobic exercise training after receipt of an ICD or cardiac resynchronization therapy pacemaker or defibrillator is effective at improving CRF with few ICD shocks or antitachycardia pacings, deaths, or hospitalizations (Supplemental Table).[109–114] However, many ICD recipients are reluctant to participate in vigorous physical activity for fear of activating arrhythmias and ICD shocks.

Pacemaker recipients require careful monitoring of their heart rate response to exercise and possible pacemaker adjustments to ensure appropriate response. Approximately 3000 individuals with cardiac implantable electronic devices (CIEDs) have participated in structured clinical trials of exercise interventions.[114,115] These trials have included mostly men with an average age of ≈60 years. Although the majority of programs were conducted within a supervised outpatient exercise center, 3 studies of home exercise have been completed,[32,35,36] with all reporting improvements in CRF similar to those of supervised programs.[109–115] The mode of exercise prescribed is typically cycling or walking for 30 to 60 minutes on 3 to 5 d/wk at 60% to 80% of maximal heart rate for a minimum of 6 weeks (Table 2). Peak $\dot{V}O_2$, as measured by cardiopulmonary exercise test, improved by 2 mL·kg^{-1}·min^{-1} (range, 0–2 mL·kg^{-1}·min^{-1}) on average among individuals with CIEDs following a structured exercise program.[109–116] Despite demonstrated improvements in CRF, the impact of exercise on quality of life, psychological adjustment, patient-centered outcomes, and other biomarkers is rarely reported for individuals with CIEDs. Little has been written about the techniques, protocols, costs, and expert knowledge needed to bring exercise training to larger populations with CIEDs.

For patients with ICDs initiating an exercise program, a symptom-limited exercise test is recommended before exercise to monitor for cardiac arrhythmias.[117–119] The ICD should be deactivated during the exercise test to prevent ICD shocks. Thereafter, exercise should be prescribed to achieve a peak heart rate at least 10 to 15 bpm below the ICD activation rate to avoid delivery of ICD therapies (shocks or antitachycardia pacing) during exercise. Heart rate should be tracked and recorded with each exercise session, noting the highest heart rate achieved during exercise and ensuring ongoing safety in performing the specific exercise type. For patients prescribed medications that act at the sinus or atrioventricular node (eg, β-blockers), it is recommended that these be taken 1 to 2 hours before exercise.

For patients with pacemakers, including those with an ICD, the following adaptations are recommended to maximize performance and comfort.[117–119] First, the rate-response feature should be turned on, and the upper tracking rate should be set to a heart rate that the patient can achieve while exercising. Second, heart rate and symptoms should be tracked and recorded with each exercise session, ensuring that the heart rate rises with increasing levels of exertion. Last, if the heart rate achieved during exercise is inappropriate (ie, too fast or too slow), the rate-response feature on the pacemaker should be adjusted accordingly.

ADVANCED HF

Left Ventricular Assist Devices

Although HF remains epidemic in the United States, only 2512 left ventricular assist devices (LVADs) were implanted in 2022, representing ≈3% of patients with stage D HF (Table 1).[25] With improvements in technology, continuous-flow LVADs have significantly increased survival, with current 1- and 5-year survival rates of 86% and 64%, respectively.[25] Most patients are supported with intravenous inotropic therapy, temporary mechanical circulatory support, or a combination of inotropic therapy and temporary mechanical circulatory support at the time of LVAD implantation. Thus, these patients are often immobile, frail, and malnourished in the immediate postoperative period. After device implantation, they require intensive in-hospital physical therapy and medical optimization before ambulatory CR or other exercise interventions can begin.[76]

CRF for patients supported with an LVAD is limited by right ventricular dysfunction, pulmonary hypertension, anemia, residual skeletal muscle abnormalities, chronotropic incompetence, inability of the LVAD to respond to increased workloads, and sensitivity of the LVAD to increased afterload during exercise.[26] Peak $\dot{V}O_2$ remains depressed in the range of 11 to 20 mL·kg^{-1}·min^{-1}, and native left ventricular contractility frequently provides a significant contribution to peak exercise performance.[26]

The general approach to CR in patients with an LVAD includes supervised aerobic (bicycle or treadmill) exercise at 50% to 70% of peak $\dot{V}O_2$, 60% to 80% of heart rate reserve, or Borg Rating of Perceived Exertion at 11 to 13 for those who are paced for 20 to 30 minutes, combined with strength training of limb muscles with 2 to 3 sets of 10 to 15 repetitions at 50% of maximum voluntary contraction.[120] There are also reports of HIIT with 3 to 4 minutes at 80% to 90% of peak $\dot{V}O_2$ followed by moderate-intensity exercise (50% peak $\dot{V}O_2$).[121] There is no formal LVAD guideline recommendation for CR, although guidance exists from the American Association of Cardiovascular and Pulmonary Rehabilitation and American College of Sports Medicine. Because all patients with LVAD have severe HF, however, insurance coverage for CR is provided on that basis. An analysis of 2014 Medicare beneficiaries who received an LVAD revealed that 30% of 1164 such patients underwent CR. These patients had 23% lower first-year hospitalizations and 47% lower mortality rate after multivariable adjustment than those not participating in CR.[122] Although there are few randomized CR trials of patients with LVAD,[77] most studies have shown a significant increase in peak $\dot{V}O_2$ of 10% to 40% with endurance exercise with or without strength training, although this increase has not been consistently greater than improvement in peak $\dot{V}O_2$ in the usual-care arm (Supplemental Table).[77,123–129] Furthermore, CR has been shown to be safe in these patients, with the most common adverse events being arrhythmias.[76]

Monitoring of patients with an LVAD during CR or structured exercise requires familiarity with the LVAD and its peripheral components (ie, external batteries, controller, driveline, device alarms, and power base units; Table 2). Exercise should not be performed in the setting of low-flow alarms for which the differential diagnosis includes hypertension, hypovolemia, right ventricular failure, bleeding, arrhythmias, pump failure, obstruction, or pulmonary embolus. The presence of these alarms should be reported to the clinical care team. Continuous-flow LVADs produce a pulseless circulation for which heart rate and blood pressure monitoring is challenging. Electrocardiographic monitoring is needed to detect arrhythmias, and Doppler measurement is required to ensure a resting mean arterial pressure of 70 to 90 mm Hg, with exercise contraindicated with a mean arterial pressure >90 mm Hg In summary, exercise training in patients with LVAD begins with early mobilization with physical therapy in hemodynamically stable, ambulatory patients who can easily manage device peripheral components.[130] Formal CR usually begins after wound healing 8 to 12 weeks after LVAD implantation. Exercise prescriptions should be individualized by the clinical exercise physiologist and physician, depending on the type of device, time since implantation, and patient age and comorbidities. Group or individual training can be performed. A baseline 6-minute walk test or cardiopulmonary exercise test may be helpful to guide the initial exercise prescription.

Heart Transplantation

There has been recent growth in heart transplantation (HTx) procedures, with >4000 adult HTx procedures performed in the United States and 5887 globally in 2023 (Table 1).[21] Median survival exceeds 13 years for recipients who survive the first year after HTx.[21] Exercise responses after an HTx are significantly altered because of physiological changes resulting from surgery and the long-term effects of immunosuppressive therapy. The transplanted heart is initially decentralized (often referred to as denervated), lacking autonomic nervous system input. This leads to elevated resting heart rate (typically 90–110 bpm), blunted heart rate response during exercise (chronotropic incompetence), and delayed peak heart rate, often occurring during recovery rather than at peak exertion.[23,70] Most HTx recipients experience some degree of reinnervation and improvement of chronotropic response in the months to years after HTx but to a variable extent.[23]

Despite improved quality of life after HTx, CRF among HTx recipients often remains reduced, with peak $\dot{V}O_2$ 20% to 50% below expected even after CR.[71] Causes include chronotropic incompetence, diastolic dysfunction (ie, impaired ventricular filling limiting stroke volume) resulting from ischemia at the time of HTx, and peripheral limitations such as muscle atrophy, endothelial dysfunction, and reduced capillary density. Long-term use of immunosuppressive therapy such as corticosteroids and calcineurin inhibitors can also contribute to muscle weakness and myopathy, as well as weight gain and metabolic syndrome, further reducing exercise tolerance.[23,71]

Exercise training receives a Class IB recommendation after HTx[72] and can improve many of these negative physiological effects and potentially support sympathetic reinnervation and improve exertional heart rate response over time (Table 2).[22] Moderate-intensity aerobic exercise and strength training have been shown to improve peak $\dot{V}O_2$ and other measures of CRF, enhance muscle strength and vascular function, and improve health-related quality of life.[70] In 2017, a pooled analysis of 9 studies showed an average gain of 2.5 mL·kg^{-1}·min^{-1} (95% CI, 1.6–3.4) in the exercise groups compared with controls.[70] A more recent meta-analysis from 2023 showed an average gain of 3.0 mL·kg^{-1}·min^{-1} (95% CI, 2.3–3.8) favoring the exercise groups.[73] Furthermore, subanalyses from 2 meta-analyses have shown that HIIT is superior to moderate-intensity continuous exercise in increasing peak $\dot{V}O_2$.[73,74] Over the past decade, HIIT has been shown to be safe and beneficial among HTx recipients, with improvements in peak $\dot{V}O_2$ exceeding those from moderate-intensity aerobic exercise (Supplemental Table).[22] Both aerobic exercise and strength training are recommended for all stable patients receiving HTx and should be adjusted according to risk stratification and time since HTx. No specific equipment is required. Core-strengthening exercises are an appropriate starting point. Brisk walking on flat ground or slightly uphill and climbing stairs are effective aerobic activities. Exercise intensity should always be individualized. A heart rate monitor may be useful in guiding optimal intensity based on the individual's peak heart rate, along with the Borg Rating of Perceived Exertion scale (Table 2). Sufficient warm-up is essential before any exercise sessions because of the delayed heart rate response. Individually tailored 1:1 sessions may initially be required for severely deconditioned patients or those with major gait, balance, or strength deficits. However, most patients receiving HTx can enter standard phase 2 CR programs when clinically stable. For the first 6 months after HTx, moderate-intensity continuous exercise is preferred over HIIT to ensure that most patients have regained some degree of reinnervation and have achieved optimal recovery before pursuing HIIT.[22,24]

INHERITED CARDIOMYOPATHIES

Although data exist on the safety of exercise among patients with heritable cardiomyopathies such as hypertrophic cardiomyopathy (HCM), arrhythmogenic cardiomyopathy (ACM), and channelopathies, data are limited on the safety of exercise in other heritable conditions. As

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a result of the paucity of data, caution is advised on the initiation of an exercise training program in these populations. Patients should undergo exercise testing before initiation of training to evaluate for any exercise-related abnormality (eg, arrhythmia, hypotension, ischemic ST-segment changes) that could increase the risk of exercise. Clinicians may also use ambulatory electrocardiographic monitors in selected patients to evaluate for arrhythmias in real-world settings. Together, these data allow the development of individualized exercise prescriptions through a process of shared decision-making.[131] For patients with an inherited cardiomyopathy, this process should involve formal clearance by a health care professional before initiation of a formal training program.[131]

Hypertrophic Cardiomyopathy

The prevalence of HCM has been historically reported to be ≈1:500 individuals, but the true prevalence varies depending on whether only clinically evident cases are considered (Table 1).[38] For example, the prevalence of unexplained asymptomatic HCM in young adults may be anywhere from 1:200 to 1:500 individuals in the United States, whereas the prevalence of symptomatic HCM is ±1:3000.[38]

Historically, exercise was discouraged among patients with HCM because of concerns about the risk of sudden cardiac arrest. However, recent data suggest that the risk is likely lower than previously hypothesized.[132] In 1 prospective observational analysis, 166 patients with HCM were stratified according to self-reported categories of physical activity.[133] Overall, the risk of cardiac events was not increased among patients with HCM participating in vigorous exercise (defined as at least 1 activity at a metabolic level of activity of ≥6.0 metabolic equivalents for ≥60 h/y) compared with nonvigorous exercise over ≈3 years of follow-up.[133] In a second study, 15 patients with HCM were randomized to 5 months of moderate-intensity aerobic exercise or HIIT (Supplemental Table).[82] Peak $\dot{V}O_2$ improved similarly in both groups by 1.3 mL·kg^{-1}·min^{-1}, and, it is important to note, there were no serious arrhythmias or adverse cardiac events.[82] In comparison, HIIT may improve peak $\dot{V}O_2$ by up to ≈5 mL·kg^{-1}·min^{-1} in healthy individuals, although the actual magnitude of the response to training depends on several factors, including baseline CRF, age, and duration of training.[134] In another study, 136 patients with HCM were randomized to 16 weeks of moderate-intensity exercise training or to usual activity.[135] Moderate-intensity exercise increased peak $\dot{V}O_2$ by 1.35 mL·kg^{-1}·min^{-1}. The American Heart Association and American College of Cardiology recommend mild- to moderate-intensity exercise for most patients with HCM and that participation in high-intensity physical activity or competitive sports may be considered after a comprehensive evaluation and shared decision-making process (Table 2).[38,132] Exercise training among patients with HCM may be completed in either an individualized or group setting. However, formal CR is typically not reimbursed unless the individual has concomitant HF with reduced ejection fraction.

Arrhythmogenic Cardiomyopathy

ACM is a rare inherited cardiomyopathy with a prevalence of ≈1:5000 (Table 1).[39] Vigorous exercise among patients with ACM is discouraged because of the risk of phenotypic conversion of patients with genetic variants in the *PKP2* (plakophilin-2) gene, which affects ≈50% of patients diagnosed with ACM.[136] In a study of 87 carriers of desmosomal mutations, there was a strong association between higher self-reported exercise frequency and meeting the diagnostic criteria for ACM (Supplemental Table).[136] Furthermore, endurance athletes (self-reported) developed symptoms at a younger age, were more likely to meet the diagnostic criteria for ACM, and had a lower lifetime survival free of ventricular arrhythmias or HF.[136] For these reasons, individuals with ACM who participate in vigorous exercise should undergo close imaging surveillance to monitor for signs of phenotypic disease progression.[132] In addition, participation in vigorous physical activities by individuals with genotype *PKP2*-mediated ACM increases their risk of ventricular arrhythmias, ICD shocks, and disease progression; therefore, participation in higher-intensity exercise is generally discouraged.[132] For patients with non-*PKP2* ACM or genotype-negative ACM, the impact of exercise on adverse outcomes is less clear, and participation in higher-intensity exercise should be individualized through a shared decision-making process.[132]

Channelopathies

Channelopathies refer to heritable conditions such as long QT syndrome, catecholaminergic polymorphic ventricular tachycardia, and Brugada syndrome that have been associated with sudden cardiac arrest. Historically, exercise was discouraged among patients with channelopathies. However, in light of emerging data supporting the safety of exercise for individuals with these conditions, contemporary trends are moving away from binary decisions on clearance to a model involving shared decision-making that incorporates a patient-centered risk assessment and development of an emergency action plan.[137] In 1 prospective observational analysis of individuals with long QT syndrome (N=1,413), which has a prevalence of ≈1:2000,[138] rates of self-reported adverse cardiac events (ie, sudden death, sudden cardiac arrest, ventricular arrhythmias treated by an ICD, and arrhythmic syncope) were similar between those who reported participation in vigorous and those who participated in nonvigorous exercise (Supplemental Table).[81] Notably, in this study, >90% of participants were on a β-blocker, had undergone sympathetic denervation, had an ICD, or had received a combination of these therapies.[81] For individuals on appropriate medical therapy, exercise may be conducted on an individual basis. For individuals in whom there is increased concern for exercise-associated arrhythmias, exercise training may be conducted in formalized rehabilitation programs that support continuous telemetry monitoring. However, current reimbursement models do not include coverage for formal CR among patients with long QT syndrome or other channelopathies.

Among all patients with cardiac channelopathies, several general principles should be considered before exercise training programs are started.[139] Patients should be closely managed by cardiologists with expertise in channelopathies,[139] and disease-specific medical therapies should be optimized. Fluid and electrolyte balance should be maintained, particularly for individuals with long QT syndrome,[139] and disease-specific triggers should be avoided (eg, overheating during exercise among patients with Brugada syndrome; Table 2).[139] Decisions on participation in exercise programs should also incorporate symptom severity.[139] For example, asymptomatic patients with catecholaminergic polymorphic ventricular tachycardia and a negative exercise test can exercise when treated optimally.[139] However, those with abnormal exercise tests or disease-related symptoms should undergo medical optimization to reduce test abnormalities and resolve symptoms before initiating exercise programs.[139]

PATIENT-REPORTED OUTCOMES MEASURES ACROSS CONDITIONS

Patient-reported outcome measures offer essential insights into how exercise training affects what patients value most: daily functioning, independence, symptom burden, and quality of life. Although the high-risk populations reviewed in this scientific statement may differ substantially in etiology and physiology, the patient-reported outcome measure domains that matter most to patients are likely similar. Core areas consistently include physical functioning (eg, mobility, transfers, stair climbing), fatigue, pain interference, emotional well-being, cognitive function, social participation, and overall health-related quality of life. Validated tools such as PROMIS Global Health, PROMIS Physical Function and Fatigue, the Stroke Impact Scale, the Short Form 36, and the Kansas City Cardiomyopathy Questionnaire can sensitively track these outcomes across diverse conditions. Integrating patient-reported outcome measures with physiological measures (eg, peak $\dot{V}O_2$-, 6-minute walk distance) provides a more complete assessment of exercise benefits and helps align training programs with patient-centered goals. Systematic use of patient-reported outcome measures in both clinical practice and research will support individualized care and better capture meaningful changes in patients' lived experiences.

GAPS AND FUTURE DIRECTIONS

Although some gaps are unique to the individual conditions reviewed, many are shared across populations as discussed herein (Table 3). Although the benefits of exercise training in these populations of increasing CRF and physical functioning are well documented, evidence remains limited for some subgroups, and overall participation in exercise programs remains low as a result of a combination of patient, clinician, and system-level factors.[1] Patient factors include cost, geographic inaccessibility, transportation, sociodemographic factors, and competing priorities. Although traditional CR is reimbursed by Medicare, noncardiac conditions are generally not covered, creating a major financial hurdle for individuals with lower income. Community-based and home-based programs may overcome or mitigate these issues but require further development and, in most higher-risk conditions, should be initiated only after a period of close supervision. The major clinician factor limiting exercise program participation is the failure to refer patients, an issue well described for traditional CR programs.[1] Automatic referrals and electronic health record prompts have been shown to increase referrals to CR programs but are not widely implemented. During routine office visits, patients should be queried about their exercise habits and encouraged to increase their physical activity as tolerated. Walking should be emphasized in this regard given its broad applicability without need for specialized equipment.

Development of a structured approach to risk assessment and identification of individuals' unique deficits is needed to guide training modifications. For the majority of conditions discussed, clinical studies have focused predominantly on the efficacy and safety of moderate-intensity aerobic exercise, with lesser emphasis on nontraditional training modalities with the potential for additional clinical benefit (eg, strength, balance, and flexibility). Thus, additional research is needed, including both feasibility and head-to-head trials, to determine the relative benefits of different and innovative training modalities, intensities, durations, and frequencies to guide the development of individualized, patient-centered training regimens that account for the unique and heterogeneous needs of these populations. Furthermore, the majority of training studies have focused on the impact of exercise on traditional markers of CRF (eg, peak $\dot{V}O_2$ or 6-minute walk distance). Future research is needed that evaluates the impact of exercise training both on clinical outcomes and on end points meaningful to patients such as performing daily activities, quality of life, and psychological well-being.

In addition to research focused on risk assessment and development of optimized training regimens, future

Table 3. Gaps and Future Directions

	Gaps	Future directions
Older adults with frailty	Differing approaches to optimal assessment of frailty Lack of prioritization for resistance and balance training (with associated nutritional enrichments) as a foundation to aerobic training No structured approach to tailor exercise intensity as a function of baseline frailty Overreliance on recumbent exercise modalities that fail to provide sufficient training stimulus	Develop biomarkers (biological and imaging) to better diagnose frailty and guide management Refine diet and use nutritional and pharmaceutical supplements to preserve skeletal muscle mass and function Refine and implement exercise training regimens to better accommodate multimorbidity and polypharmacy, including cognitive impairment, fear, and fall prevention imbalance Refine and implement exercise training regimens to optimize efficacy and impact for those thought to be exercise intolerant
Stroke	Absence of aerobic exercise in traditional neurorehabilitation for stroke patients; current programs provide ≈3 min/session Low adherence to recommended exercise and physical activity guidelines Limited knowledge about timing and dose of exercise in stroke patients Lack of funding for aerobic exercise programs in stroke patients	Integrate aerobic exercise into neurorehabilitation programs Develop novel approaches to facilitate adherence to recommended exercise programs Enhance knowledge about the timing and dose of exercise interventions for stroke patients Explore home- and other low-cost exercise programs
SCI	Lack of standardized exercise testing/intervention protocols-Subject heterogeneity may mask/reduce apparent training effects (eg, incomplete paraplegia vs complete tetraplegia, time since injury, age, sex) Insufficient studies using high-intensity training Low accessibility to exercise programs soon after injury, especially in mobility-restricted individuals	Develop standardized exercise testing/intervention protocols Use exercise modes that engage the highest possible muscle mass and intensity Increase accessibility to improve use soon after injury, especially among mobility-restricted population Address patient heterogeneity in developing training protocols
Severe arthritis	Lack of studies comparing varying exercise amounts, intensities, and frequencies across multiple outcomes Lack of studies of exercise interventions among individuals with significant mobility limitations (often an exclusion criterion) Lack of data on effect of arthritis drug therapy on exercise responses	Determine optimal exercise for desired outcomes (eg, pain, physical function, cardiovascular risk) Identify disease- and joint-specific modifications and strategies that permit persons with severe arthritis to engage in, maintain, and benefit from exercise Evaluate the impact of different drugs on exercise response
HTx	Uncertainty about optimal timing, intensity, frequency, and duration of exercise training Limited understanding of physiological mechanisms of improvements for different exercise modalities Long-term adherence to exercise training is suboptimal Lack of studies on long-term effects of exercise training Unclear effect of age on training response	Develop and test diverse exercise protocols, including HIIT, for different patient profiles Explore biological markers and personalized exercise prescriptions Explore shorter interval bouts to enhance adherence Design studies of long-term training effects Collect more data on training responses by age among transplant recipients
LVADs	Few randomized trials of exercise training in patients with LVAD generally and specifically those with newer-generation LVADs (Heartmate 3) Low use of CR early after implantation Lack of LVADs programmed to automatically adjust to changes in preload and afterload No standardization of exercise training protocols	Use CR to investigate the impact of new LVADs on CRF and clinical outcomes Initiate CR early after device implantation Develop LVADs programmed to respond to increased demands of exercise Develop standardized training protocols, including those suitable for home-based exercise training
CIEDs	Outcomes beyond peak $\dot{V}O_2$ and 6MWD rarely reported in exercise trials after CIED implantation (eg, biomarkers, QoL, costs) Lack of training studies using digital technologies Resistance exercise, with or without aerobic exercise, rarely included in CIED interventions Few studies evaluating home-based exercise training regimens ICD use and pacemaker use are not qualifying diagnoses for supervised outpatient CR Lack of sex-tailored exercise programs	Develop and implement research designs that include other important outcomes Digital technology–enhanced interventions to support uptake, monitoring, and maintenance of exercise Incorporate resistance exercise into exercise training prescriptions and maintenance Develop studies of home-based exercise training in patients with CIEDs Initiate efforts to extend CMS coverage for CR to patients with an ICD or pacemaker Develop sex-tailored exercise programs for patients with CIEDs

(*Continued*)

Table 3. Continued

	Gaps	Future directions
Inherited cardiomyopathies	Limited understanding of risk factors for sudden cardiac arrest with exercise in patients HCM and channelopathies Unclear optimal "dose" of exercise for patients with ACM Limited data on long-term effects of exercise restriction in patients with ACM and channelopathies	Enhance risk stratification for sudden cardiac arrest during exercise in patients with HCM and channelopathies Develop tailored exercise programs to preserve CRF without disease progression for patients with ACM Determine long-term effects of exercise restriction in patients with channelopathies at risk of sudden cardiac arrest during physical activity

6MWD indicates 6-minute walk distance; ACM, arrhythmogenic cardiomyopathy; CIED, cardiac implantable electronic device; CMS, Centers for Medicare & Medicaid Services; CR, cardiac rehabilitation; CRF, cardiorespiratory fitness; HCM, hypertrophic cardiomyopathy; HIIT, high-intensity interval training; HTx, heart transplantation; ICD, implantable cardioverter defibrillator; LVAD, Left ventricular assist device; QoL, quality of life; SCI, spinal cord injury; and $\dot{V}O_2$, oxygen consumption.

research should focus on the dissemination and implementation (using evidence-based implementation science frameworks) of exercise training strategies with proven benefit to equitably improve access to and participation in exercise programs such as home-based programs or community settings. Home-based CR has emerged as a reasonable option for patients unable to participate in center-based CR, particular for clinically stable low- to moderate-risk patients, for whom there is the most evidence to support efficacy and safety. Emerging evidence suggests the safety of home-based rehabilitation programs for higher-risk, frail populations.[140,141] Digital technologies are another promising tool for augmenting and extending the benefits of exercise training. However, additional research in this area is warranted to understand how to most effectively use these devices and their long-term behavioral and psychological consequences. There is the potential for wearable devices to provide novel insights into patients' daily lives for a range of lifestyle behaviors, capture novel digital biomarkers in patients' lived environments, and enhance risk stratification.[142] Ensuring that the digital devices track exercise accurately (ie, lower accuracy in individuals with slower gait speeds[143]) and in a manner that is clinically meaningful to this population (ie, step count may not be appropriate for all people) will be essential for these tools to maximize their impact. Implementation efforts should continuously evaluate process measures for ensuring the sustainability and scalability of the interventions and should ensure that the technology equitably improves access to exercise training without exacerbating the exclusion of sociodemographic subgroups or individuals with disabilities. Furthermore, future research is needed to determine how to effectively sustain physical activity levels long term, particularly in the face of changing circumstances and priorities when conflicting activities and motivations arise (eg, return to work after CR). Although digital technologies and motivational interviewing have shown promise in this regard, research is needed to determine how to use these tools efficiently and cost-effectively in clinical practice.

CONCLUSIONS

Exercise training has demonstrated clinical benefit in diverse populations, including patients with frailty, stroke, SCI, rheumatologic conditions, CIEDs, and some inherited cardiomyopathies and recipients of advanced HF therapies. Despite evidence to support the efficacy and safety of exercise training in the majority of conditions reviewed, these programs remain vastly underused. Additional research is urgently needed to identify a patient-centered approach to exercise training that accounts for patients' unique needs, with a focus on implementation to equitably increase access to such programs for all individuals with the potential for benefit.

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.

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*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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