Physical Activity Strategies

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Key Points

- The benefits of regular moderate-to-vigorous PA, and the associated improvements in CRF, far outweigh the risks for most individuals. Nevertheless, ostensibly healthy, inactive individuals starting to exercise should begin slowly, generally with a walking program, gradually increasing the intensity of exercise, provided they remain asymptomatic. Moderate- to high-risk individuals may particularly benefit from supervised exercise therapy.
- The US Preventive Services Task Force 2018 advised against routine screening with exercise testing to prevent cardiovascular events. On the other hand, asymptomatic patients who might benefit from exercise testing before beginning an exercise program include habitually sedentary individuals with multiple risk factors, an elevated coronary artery calcium score, or a family history of premature CHD who plan to start a vigorous exercise program or those whom the clinician suspects may be ignoring symptoms or not giving an accurate history.
- Vigorous exercise appears to be more effective than moderate-intensity exercise in reducing cardiovascular risk. Similarly, when comparing increased levels of PA versus CRF, the reductions in risk are more than twice as great for CRF.
- The optimal cardiovascular benefits of exercise are most likely to be achieved by the gradual progression of exercise training intensity, expressed

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as METs. Among patients with and without CHD, each 1-MET increase in exercise capacity confers an ~15% decrease in mortality up to about 10 METs, beyond which the additional survival benefits largely plateau.
- Unaccustomed vigorous PA, particularly when performed by inactive, unfit individuals with known or occult CVD, can acutely increase the risk of cardiac events, including sudden cardiac death and acute myocardial infarction.
- For deconditioned or inactive individuals, the minimum or threshold intensity for improving CRF approximates 30–45% VO_2R, which corresponds to ~60–70% of the highest heart rate achieved during peak- or symptom-limited exercise testing.
- As exertion-related acute cardiovascular events are often preceded by warning symptoms, patients should be strongly advised that symptoms require immediate cessation of endurance training/competition and medical review.
- Extreme endurance exercise training regimens are associated with potential cardiac maladaptations in some individuals, including accelerated coronary artery calcification, elevated cardiac biomarker release, myocardial fibrosis, and atrial fibrillation, as well as cardiovascular events, which may be described by a reverse J-shaped dose-response curve.
- The recent ACC/AHA Primary Prevention guidelines suggest at least 150 min of moderate-intensity exercise or 75 min of vigorous-intensity PA per week, or combinations thereof. Structured exercise should be complemented by upper body training, resistance training, and increased lifestyle PA. Using a pedometer can be helpful in tracking daily step totals.

1 Introduction

There is abundant evidence that the amount of habitual physical activity (PA) and the level of cardiorespiratory fitness (CRF) are inversely related to the risk of coronary heart disease (CHD). Nevertheless, regular exercise does not confer “immunity” to acute cardiac events. Moreover, high-volume, high-intensity exercise training regimens appear to induce maladaptive cardiac remodeling in some individuals. This chapter reviews PA strategies in individuals with and without CHD, with specific reference to the cardiovascular benefits of regular moderate-to-vigorous PA and improved CRF, the concept of oxygen consumption reserve, contemporary PA recommendations, value of progressing exercise training intensities, evolution of personalized activity intelligence, and complementary exercise interventions, including upper body training, resistance training, lifestyle PA, and high-intensity interval training. Additional topics include extreme exercise and cardiovascular health, using technology to promote PA, and strategies to enhance exercise adherence.

2 Epidemiologic Studies

In an early meta-analysis of 43 studies of the relation between physical activity (PA) and coronary heart disease (CHD) incidence, the relative risk of CHD in relation to physical inactivity ranged from 1.5 to 2.4, with a median value of 1.9 [1]. Moreover, the relative risk of a sedentary lifestyle appeared to be similar in magnitude to that associated with other major CHD risk factors. Another systematic review and meta-analysis of 33 PA studies, including 883,372 participants, reported risk reductions of 30–50% for cardiovascular mortality and 20–50% for all-cause mortality among the most physically active cohorts [2]. More recently, researchers analyzed data from two major ongoing cohort studies to evaluate the influence of five low-risk lifestyle factors on premature mortality and life expectancy in the US population [3]. The five low-risk lifestyle factors included not smoking; body mass index 18.5–24.9 kg/m^2; ≥30 min per day of moderate-to-vigorous PA; moderate alcohol intake; and a healthy diet score. During up to 34 years of follow-up, adherence to all five lifestyle-related factors significantly increased life expectancy at age 50 years for both men and women, 12.2 and 14 years, respectively, as compared with those who adopted "zero" low-risk factors. The most physically active cohorts of men and women demonstrated 7–8-year gains in life expectancy!

3 Cardiovascular Impact of Regular Physical Activity: Potential Underlying Mechanisms

Regular moderate-to-vigorous PA, structured exercise, or both can decrease the risk of initial and recurrent cardiovascular events, presumably from multiple mechanisms, including anti-atherosclerotic, anti-ischemic, anti-arrhythmic, anti-thrombotic, and psychologic effects (Fig. 1). In addition, ischemic and biochemical cardiac preconditioning offers a unique and undervalued nonpharmacological approach to prevent and attenuate acute coronary syndromes. Specifically, acute bouts of aerobic exercise impose an isolated stress on the myocardium such that cellular biochemistry is favorably altered and an ischemic resistant phenotype is conferred, at least temporarily [4]. Accordingly, it appears that regular increases in the rate-pressure product and somatic and cardiac metabolism evoked by moderate-to-vigorous PA can reduce subsequent infarct size and/or the potential for malignant ventricular arrhythmias triggered by acute myocardial ischemia [5].

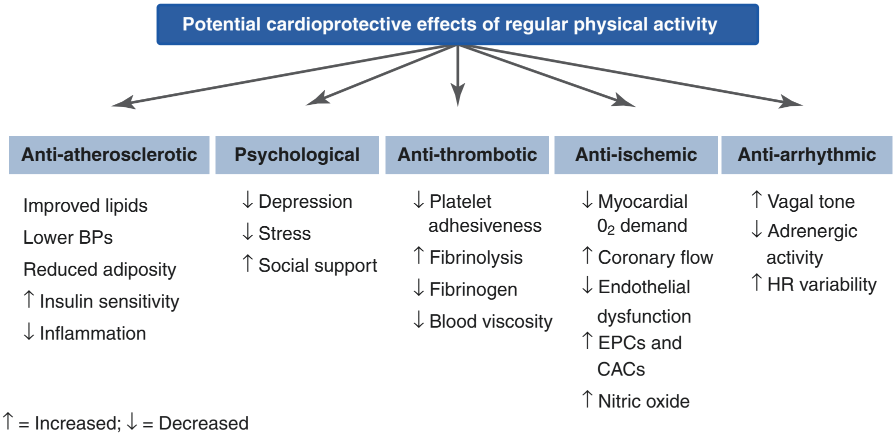

Fig. 1 A moderate- to vigorous-intensity endurance exercise program sufficient to maintain and enhance cardiorespiratory fitness may provide multiple mechanisms to reduce nonfatal and fatal cardiovascular events. BP blood pressure, CACs cultured angiogenic cells, EPCs endothelial progenitor cells, HR heart rate, ↑ increased, ↓ decreased, O_2 oxygen

3.1 Benefits of Vigorous Versus Moderate-Intensity Physical Activity

Emerging research strongly suggests that the gradual progression of exercise intensities, from moderate-to-vigorous to high-intensity training regimens (in selected individuals), may result in even greater cardioprotective benefits. Accordingly, vigorous PA (usually defined as ≥60% functional capacity or 70–89% of the measured maximal heart rate) appears to be superior to moderate-intensity exercise (40–59% of functional capacity or 55–69% of the maximal heart rate). Although some have defined vigorous- and moderate-intensity PA as ≥6 metabolic equivalents (METs; 1 MET = 3.5 mLO_2/kg/min) and 3.0–5.9 METs, respectively, these absolute values do not account for the fact that the cardiac demand of any PA is determined not by the specific metabolic level but by the metabolic demand relative to the individual's functional capacity [6].

Relative to the all-cause mortality reduction associated with exercise, intensity and duration appear to be inversely related. For example, the mortality reduction associated with a regular 5-min run approximates a 15-min walk, and a 25-min run is comparable with a 105-min walk [7]. In addition, at comparable levels of total energy expenditure, vigorous exercise seems to be more effective than moderate-intensity exercise in reducing cardiovascular risk [8]. Vigorous exercise intensities are also more effective than moderate intensities at increasing cardiorespiratory fitness (CRF), expressed as METs, especially for individuals with higher baseline CRF [9]. This has additional prognostic significance, since higher levels of CRF have been repeatedly shown to confer a lower risk of cardiovascular and all-cause mortality [10]. Other possible mechanisms associated with the incremental and

Table 1 Multiple mechanisms by which vigorous-intensity exercise training may be more effective than moderate-intensity exercise at reducing cardiovascular risk

↑	Parasympathetic tone
↑	Period of diastole and NO vasodilator function
↓	Shear stress on endothelial walls
↑	Artery compliance
↓	Plaque rupture
↓	Adverse ventricular remodeling
↓	Incident AF and/or HF
↓	Endothelial dysfunction and myocardial ischemia
↓	Arrhythmias
↑	Heart rate variability
↓	Sympathetic outflow
↓	Inflammation

Based on data from Ref. [11]
NO nitric oxide, *AF* atrial fibrillation, *HF* heart failure, ↑ increased, ↓ decreased

additive cardioprotective benefits of vigorous-intensity exercise training are shown in Table 1 [11].

4 Cardiorespiratory Fitness and Physical Activity as Separate Coronary Heart Disease Risk Factors: Comparative Benefits

Numerous studies now suggest that CRF is one of the strongest prognostic markers in persons with and without chronic disease, including CHD [10]. In fact, higher levels of CRF are associated with a reduced risk of developing hypertension, type II diabetes, atrial fibrillation, chronic kidney disease, and major cardiovascular events, including heart failure, myocardial infarction, stroke, and coronary artery bypass grafting [12]. Williams [13] reported that the risks of CHD and cardiovascular disease (CVD) decreased linearly in association with increasing percentiles of PA (Fig. 2). In contrast, there was a precipitous decrease in risk when the lowest is compared with the next-lowest percentile of CRF. Beyond this demarcation, the reductions in risk parallel those observed with increasing PA but was more than twice as great for CRF. Three important findings emerged from this report. First, being unfit warrants consideration as an independent risk factor. Second, a low level of CRF or aerobic capacity (VO_2 max) increases the risk of CVD to a greater extent than merely being physically inactive. Third, the primary beneficiaries of regular exercise appear to be those comprising the bottom 20% of the CRF/PA continuum. Although the cut points vary depending on age and gender, an exercise capacity <5–6 METs generally indicates a higher mortality group, whereas CRF levels of 9–12 METs or higher are associated with a marked survival advantage, including men and women with and without known CHD [14–18].

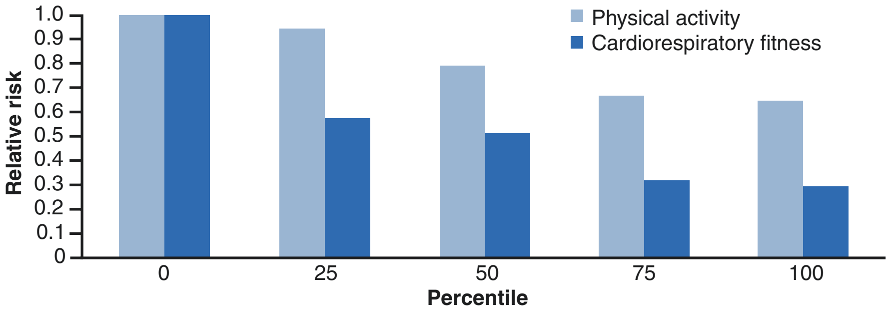

Fig. 2 The risks of coronary heart disease and cardiovascular disease decrease in association with increasing percentiles of physical activity and cardiorespiratory fitness, corresponding to 30% and 64% in the most active and fit individuals, respectively. Interestingly, little or no additional benefit occurs when moving from the 75th to the 100th percentile, that is, "good" to "excellent," suggesting a plateau in relative risk. (Based on data from Ref. [13])

4.1 Impact of CRF on Mortality and Other Health Outcomes

For the primary and secondary prevention of CHD, each 1-MET increase in CRF confers an ~15% decrease in mortality up to about 10 METs, beyond which the additional survival benefits largely plateau [19, 20]. This reduction in mortality compares favorably with the survival benefit conferred by commonly prescribed cardioprotective medications (i.e., low-dose aspirin, statins, ß-blockers, angiotensin-converting enzyme inhibitors) after acute myocardial infarction. In addition, individuals with low PA and/or CRF levels have higher annual healthcare costs [21], higher rates of incident heart failure [22], and increased cardiovascular events at any given coronary artery calcium score [23] and are 2–3 times more likely to die prematurely than their fitter counterparts when matched for coronary risk factor profiles [16, 24]. Increased levels of PA and/or CRF before hospitalization for acute coronary syndromes and elective or emergent surgical procedures also appear to confer more favorable short-term outcomes. A widely cited investigation of 2172 patients hospitalized for acute coronary syndromes (mean +/− SD age = 65.5 +/− 13 years; 76% men) evaluated the effect of prehospital and 1-month post-hospital discharge CVD health outcomes [25]. After adjusting for potential confounders, patients who were physically active demonstrated 0.56 lower odds of in-hospital mortality and 0.80 lower odds of recurrent cardiovascular events within the first 30 days of hospital discharge. Short-term complications after bariatric surgery [26] and coronary artery bypass grafting [27] have also been linked to reduced preoperative levels of PA or CRF (Fig. 3) [28].

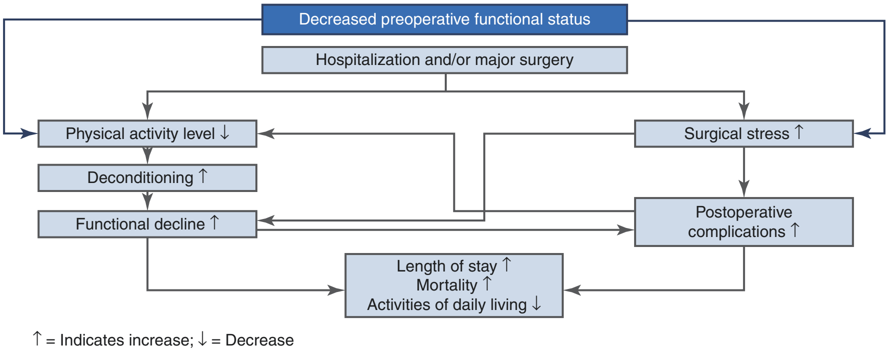

Fig. 3 Possible impact of decreased preoperative physical activity or cardiorespiratory fitness on hospitalized patients undergoing emergent or elective surgery with specific reference to short-term outcomes. (Adapted from Hoogeboom et al. [28], with permission from Wolters Kluwer Health)

5 Exercise Prescription/Programming

Selected health professionals, including exercise physiologists, physical therapists, and nurse clinicians, are generally responsible for writing exercise prescriptions, under the supervision of a physician (in clinical settings). Several professional associations, such as the American College of Sports Medicine and the American Council on Exercise, offer instruction and proficiency standards and competency certification. Structured exercise training sessions should include a preliminary aerobic warm-up (~10 min), a continuous or accumulated conditioning phase (≥30 min), and a cooldown (5–10 min) followed by stretching activities. These pre- and post-exercise components may not be necessary for conventional walking programs. The warm-up facilitates the transition from rest to the aerobic conditioning phase, reducing the potential for ischemic electrocardiographic responses, which can occur with sudden strenuous exertion [29]. The ideal warm-up for any endurance activity is the same activity but at a lower intensity. Hence, individuals who use brisk walking during the endurance phase should conclude the warm-up with a moderate walking pace. Similarly, cycle ergometry at 150–300 kilogram-meters per minute (kg-m/min) serves as an ideal warm-up for individuals who train at 450–600 kg-m/min. The cool-down provides a gradual recovery from the intensity of the endurance phase. A walking cool-down enhances venous return during recovery, decreasing the likelihood of hypotension and related sequelae (e.g., post-exercise light-headedness). It also facilitates the dissipation of body heat, promotes more rapid removal of lactic acid than stationary recovery, and ameliorates the potential deleterious effects of the post-exercise rise in plasma catecholamines [30].

5.1 The Concept of Oxygen Consumption Reserve (VO_2R)

One of the most commonly employed methods of establishing the target heart rate (THR) for training is the maximum heart rate (MHR) reserve method [31]:

$$\text{THR} = (\text{MHR} - \text{resting heart rate}[\text{RHR}]) \times (\text{exercise intensity}) + \text{RHR}$$

Although it was traditionally believed that a given percentage of the heart rate reserve corresponded to the same percentage of the VO_2 max [32], more recent studies have shown that it more closely approximates the same percentage of the oxygen uptake "reserve" (% VO_2R) [33]. This concept relates heart rate reserve to a level of metabolism that starts at a resting level (i.e., 1 MET) rather than from zero. An additional advantage is increased accuracy in establishing training workloads for low-fit patients. To calculate the target VO_2 (TVO_2) based on VO_2R, the following equation is used:

$$TVO_2 = (VO_2\,\text{max} - VO_2\,\text{rest})(\text{exercise intensity}) + VO_2\,\text{rest}$$

This equation has the same form as the Karvonen et al. [31] or heart rate reserve calculation of the THR. In the TVO_2 equation, VO_2 rest is 3.5 mL O_2/kg/min (1 MET), and the exercise intensity is as low as 30% (for extremely unfit or deconditioned individuals) to 80%. Intensity is expressed as a fraction in the equation. For example, what is the TVO_2 at 40% of VO_2R for a patient with a 4-MET exercise capacity (i.e., a VO_2 max of 14.0 mL/kg/min)?

$$TVO_2 = (14.0 - 3.5)(0.40) + 3.5 = (10.5)(0.40) + 3.5 = 4.2 + 3.5 = 7.7\,\text{mL/kg/min or } 2.2\,\text{METs}$$

Once an appropriate TVO_2 (MET) level is identified, the training METs may be estimated from the resting and exercise heart rate response, the rule of 2 and 3 miles per hour (mph; graded treadmill walking), or by selecting an activity with an appropriate MET requirement from published tables (Table 2) [34].

Table 2 Energy cost (METs) of common occupational and leisure-time physical activities

Light (<3.0 METs)	Moderate (3–<6 METs)	Vigorous (≥6 METs)
Cycling (stationary, light intensity)	Cycling (as transportation)	Cycling (race)
Fishing	Mowing lawn	Heavy farming (bailing hay)
Golf	Swimming (moderate)	Swimming (fast)
Sweeping	Table tennis	Tennis
Walking slowly or strolling	Walking briskly	Walking briskly uphill or jogging

METs metabolic equivalents. (Based on data from Ref. [34])

5.2 *Exercise Modalities/Training Intensities*

The most effective exercises for the endurance or conditioning phase include walking, graded walking, jogging, running, stationary cycle ergometry, outdoor cycling, swimming, skipping, rowing, arm ergometry, and combined arm-leg ergometry. To improve CRF, the "minimum" or threshold intensity for training approximates 30–45% of the VO_2R, which corresponds to ~60–70% of the highest heart rate achieved during peak- or symptom-limited exercise testing [9, 35, 36]. Over time, the exercise intensity should be increased to 50–80% of the VO_2R (or maximal heart rate reserve) to further increase CRF, provided one remains asymptomatic. The widely used Borg Rating of Perceived Exertion (RPE) scale [37] provides an adjunctive methodology to regulate the exercise intensity (Table 3). Exercise rated as 12–15 (6–20 scale), between "somewhat hard" and "hard," or 4–6 (0–10 scale), between "somewhat strong" and "very strong," is generally considered appropriate. However, during the first 4–6 weeks of training, ratings of 11–13 (category scale) and 3–4 (category-ratio scale) are strongly recommended.

5.3 *Contemporary PA Recommendations*

Moderate- to vigorous-intensity PA (MVPA), which corresponds to any activity ≥3 METs, has been consistently shown to reduce the health risks associated with numerous chronic diseases and the risk of developing them [38]. Because unaccustomed vigorous PA is associated with acute cardiac events [39], advocating

Table 3 Ratings of perceived exertion

Category scale		Category-ratio scale	
6		0	Nothing at all
7	Very, very light	0.5	Very, very weak (just noticeable)
8		1	Very weak
9	Very light	2	Weak (light)
10		3	Moderate
11	Fairly light	4	Somewhat strong
12		5	Strong (heavy)
13	Somewhat hard	6	
14		7	Very strong
15	Hard	8	
16		9	
17	Very hard	10	Very, very strong (almost max) maximal
18			
19	Very, very hard		
20			

Adapted from Borg [37], with permission from Wolters Kluwer Health regular brisk walking, before gradually advising the progression to graded walking or jogging, is strongly recommended for previously inactive middle-aged and older adults [40]. To promote and maintain health, moderate-intensity aerobic (endurance) PA for a minimum of 30 min for 5 days each week, or vigorous-intensity PA for a minimum of 20 min for 3 days each week, or combinations thereof, is recommended [38]. However, even lesser amounts of exercise appear to be beneficial. Wen et al. [7] found that subjects who walked just 15 min a day or 90 min a week had a 14% reduction in death rates over an average follow-up of 8.1 years compared to their inactive counterparts. Although traditional recommendations suggest that accumulated MVPA bouts should last 10 or more minutes to achieve the 30-min daily minimum, recent studies suggest that even shorter periods of MVPA, accrued over time, can evoke cardiovascular and metabolic health benefits [41, 42].

6 Progression of Exercise Training Intensities for Optimal Cardiovascular Benefits

Most middle-aged and older individuals, with and without CHD, initiate exercise programs at ~2–3 METs, corresponding to walking at ~2–3 mph, but fail to increase the intensity of their exercise over time as their CRF improves [43]. This failure prevents them from achieving the maximal reduction in their risk of CVD.

CRF levels are influenced by age and gender, and little additional survivor benefit occurs when levels increase from "good" to "excellent," suggesting there is a plateau in the reduced relative risk for CVD that can be achieved through exercise [13, 15, 16]. The following table (Table 4) provides "good" fitness levels and recommended aerobic training requirements (METs) to achieve them for men and women [11]. To delineate reference standards for CRF, we employed the Fitness Registry and the Importance of Exercise: A National Database (FRIEND) [44]. Age- and gender-adjusted "good" fitness levels were calculated at the 60th percentile.

In our experience, if patients can progress to training intensities that are 60–80% of the VO_2R, without adverse signs/symptoms or excessive RPEs (i.e.,

Table 4 "Good" fitness levels for middle-aged and older men and women and the training aerobic requirements associated with these cardiorespiratory fitness levels

		Age groups (y)				
		30–39	**40–49**	**50–59**	**60–69**	**70–79**
Men	Good fitness	≥12.9	≥11.5	≥10.0	≥8.7	≥7.7
	Training METs	8.1–10.5	7.3–9.4	6.4–8.2	5.6–7.2	5.0–6.4
Women	Good fitness	≥9.2	≥8.2	≥7.2	≥6.1	≥5.5
	Training METs	5.9–7.6	5.3–6.8	4.7–6.0	4.1–5.1	3.7–4.6

Adapted from Franklin et al. [11], with permission from Elsevier

≥15 [hard work] on the 6–20 scale), it is likely that they can attain the corresponding age- and gender-adjusted cardioprotective fitness levels that are compatible with decreased mortality and increased survival. For example, "good" fitness for a 65-year-old man is ≥8.7 METs; accordingly, a training intensity of 5.6–7.2 METs, achieved after 6–12 months of slow progressive increases in exercise intensity, provided the patient remains asymptomatic, would serve as a worthwhile goal. This training intensity approximates single tennis or brisk walking (4.5–5.0-mph pace) (Table 2) [34] or graded treadmill walking (3.0 mph, 7.5% grade). Although not all patients will achieve "good" CRF levels for their age group, most will be able to increase CRF levels beyond the "bottom 20%," thus significantly improving survival and health outcomes. Those who attain the age-/gender-recommended training MET levels are likely to achieve "good" fitness and optimal cardiovascular benefits.

6.1 Energy Expenditure of Graded Treadmill Walking: Rule of 2 and 3 mph

As stated above, walking at 2 and 3 mph approximates 2 and 3 METs, respectively [45]. At a 2-mph speed, each 3.5% grade increment adds an additional MET to the energy expenditure. For individuals who can walk at the faster speed, that is, 3 mph, each 2.5% increase in treadmill grade adds an additional MET. Thus, walking at a 3 mph, 7.5% grade, would approximate 6 METs.

6.2 Using the Heart Rate Index Equation to Estimate METs During Exercise

A simple method for estimating oxygen uptake during PA, expressed as METs, in persons with and without heart disease, including those taking ß-blockers, employs the resting and exercise heart rates using the heart rate index equation [46]:

$$\text{METs} = \left(6 \times \text{Heart Rate Index}\right) - 5$$

where the heart rate index equals the activity heart rate divided by the resting heart rate.

Example: A tennis player's resting heart rate of 60 beats per minute (bpm) is increased to 120 bpm during a tennis match. His MET level is estimated as follows: 120 bpm/60 bpm = 2.0 heart rate index which is multiplied by 6, yielding 12, from which we subtract 5, yielding an estimated 7 METs (120/60 × 6) − 5 = (2 × 6) − 5 = 7 METs.

6.3 Evolution of Personalized Activity Intelligence

Recently, researchers developed a new fitness metric termed the personalized activity intelligence or PAI score, which is derived from the cumulative fluctuations in heart rate over the most recent 7 days, to provide an approximation of the relative intensity of PA and associated energy expenditure. It was based on changes in heart rate obtained from the HUNT Fitness Study database involving >60,000 participants over 2 decades, which monitors the intensity of PA as it relates to the development of CVD [47]. PAI is calculated based on the individual user's age, gender, resting heart rate, and maximum heart rate and gives more credit for vigorous as opposed to mild- to moderate-intensity PA. For example, a 30-min intense bike ride earns eight times the PAI score that an hour-long 3-mile walk earns for the same individual, 56 versus 7 PAI points, respectively [48]. According to the above-referenced HUNT study analysis, including >1 million person-years of observations during an average follow-up of 26.2 years, men and women achieving a weekly PAI level ≥ 100 had a 20 +/− 3% reduced risk of CVD mortality compared with an inactive control cohort [47]. Collectively, these data, and another relevant report [49], suggest that large daily fluctuations in heart rate and associated energy expenditure, expressed as METs, appear to confer not only increased survival benefits but decreased healthcare costs as well.

7 Complementary Training Modalities/Techniques

7.1 Upper Body Training

Lower extremity training does not necessarily confer training benefit to the upper extremities and vice versa. Moreover, many activities of daily living require arm work to a greater extent than leg work. Consequently, patients who rely on their upper extremities for occupational or recreational activities should be advised to train the arms as well as the legs, with the expectation of improved cardiorespiratory and hemodynamic responses to both forms of effort. Recommendations for dynamic arm exercise are shown in Table 5 and include three variables: the appropriate exercise heart rate, the workload or power output that will elicit a safe and effective load for training, and the proper training equipment or modalities [50].

Table 5 Recommendations for dynamic arm exercise training

Variable	Comment
Target heart rate	~10–15 bpm lower than for leg training
Work rate	~50 ± 10% of the power output (kg-m/min) used for leg training
Equipment	Arm ergometer, combined arm-leg ergometer, rowing machine, wall pulleys, simulated cross-country skiing devices

Based on data from Ref. [50]

7.2 Resistance Training

Resistance training can provide an effective method for increasing muscle strength and endurance, preventing and managing a variety of chronic medical conditions, favorably modifying selected coronary risk factors, and enhancing psychosocial well-being. In fact, studies suggest it is superior to aerobic or endurance exercise training in enhancing bone mineral density, muscle mass and strength, insulin sensitivity, and basal metabolism [51]. Resistance training has been shown to attenuate the rate-pressure product when any given load is lifted, which may reduce cardiac demands during daily activities such as carrying packages or lifting moderate-to-heavy objects [52, 53]. There are also intriguing data to suggest that strength training can increase muscular endurance capacity without an accompanying increase in CRF [54]. Other studies have shown that muscular strength is inversely associated with all-cause mortality [55] and the presence of metabolic syndrome [56] independent of CRF.

Although the traditional weight-training prescription has involved performing each exercise three times (e.g., 3 sets of 10–15 repetitions per set), it appears that 1 set provides similar improvements in muscular strength and endurance, at least for the novice exerciser. Consequently, single-set programs performed at least two times a week are recommended rather than multiset programs, because they are highly effective, less time-consuming, and less likely to cause musculoskeletal injury or soreness. Such regimens should include 8–10 different exercises at a load that permits 8–15 repetitions per set [51].

7.3 Lifestyle or Incidental Physical Activity

Randomized clinical trials have shown that an alternative approach to structured exercise, that is, increased lifestyle PA, has similar effects on CRF, body composition, and coronary risk factors as a conventional exercise program [57, 58]. These findings have important implications for public health, suggesting a viable alternative to habitually sedentary individuals who are not ready to comply with a formal exercise regimen. Accordingly, preventive medicine specialists should counsel patients to integrate increased PA into their daily lives. A 30-min documentary on the health benefits of walking, called Walking Revolution (http://vimeo.com/65986201), which is accessible on line, is highly motivational. A dog is a terrific walking partner, as are friends, neighbors, and family members. A phone app (http://everybodywalk.org/appl) to track walking, as well as programs that use pedometers (e.g., America on the Move) [59], to enhance awareness of PA by progressively increasing daily step totals, can be helpful in this regard. According to one systematic review, pedometer users in varied exercise interventions significantly increased their PA by an average of 2491 steps per day more than their control counterparts [60].

7.4 High-Intensity Interval Training (HIIT)

HIIT involves intermittent, usually regularly timed, 1–3-min bouts of high-intensity activity alternating with brief periods of MVPA. Numerous studies have compared the effectiveness of moderate-intensity continuous training (MICT) with HIIT for improving CRF and other measures of cardiovascular function in patients with and without CHD. In studies of healthy adults, HIIT regimens have been shown to induce greater increases than CRF than MICT, especially when the total work performed during training is comparable [61]. Among patients with CVD, including heart failure, HIIT was superior to MICT in improving CRF, physical work capacity, left ventricular remodeling (i.e., ejection fraction), and brachial artery flow-mediated dilation (endothelial function) [62]. On the other hand, a meta-analysis of 10 studies ($n = 472$ CHD patients) revealed that MICT was associated with a more marked decline in patients' average resting heart rate and body weight when compared with HIIT [63]. Moreover, a small study in CHD patients found a nearly six-fold higher risk for exercise-related acute cardiovascular events during HITT versus MICT [64]. In summary, although most studies suggest that HIIT elicits slightly greater increases in CRF (by ~0.5 MET) than MICT, while simultaneously providing a more time-efficient training alternative, concerns regarding the safety of repeated near-maximal exercise bouts in patients with known or suspected CHD suggest that it should not be recommended or prescribed, especially in unsupervised, nonmedical settings [65].

8 High-Volume, High-Intensity Endurance Training and Potential Adverse Cardiovascular Outcomes: Too Much of a Good Thing?

The favorable risk factor profiles and superb cardiac performance of long-distance runners, coupled with the finding that regular endurance exercise prevents cellular senescence in animals and humans, have led an increasing number of middle-aged and older adults to the conclusion that "more exercise is better." However, an increasing number of reports now suggest that potentially adverse cardiovascular manifestations may occur following high-volume and/or high-intensity long-term exercise training/competition. Accelerated coronary artery calcification, exercise-induced cardiac biomarker release, myocardial fibrosis, atrial fibrillation, and even sudden cardiac death have been reported in endurance athletes [6]. Other studies, in men and women with and without CHD, have reported a heightened mortality risk or poorer cardiovascular outcomes in those cohorts performing excessive exercises [66–68]. This relationship had been increasingly described by a U- or reverse J-shaped dose-response curve, with a plateau in benefit or even adverse health effects in some individuals at more extreme levels [69]. Because of the therapeutic effects of exercise, as well as the increased aerobic requirements and cardiac demands, underdosing and overdoing are possible. Accordingly, these reports should be considered when recommending extreme exercise regimens. Despite these concerns, the benefits associated with regular MVPA far outweigh the risks for the majority of the population [6].

9 Using Technology to Promote Physical Activity

Digital tools such as social media, mobile games on smart phones and tablets, varied apps that promote PA, and activity trackers may assist in reducing barriers to regular PA by helping patients with planning, increasing access to fitness programs, and providing daily goal reminders [70]. Self-monitoring techniques or devices (e.g., pedometers, accelerometers, personalized activity intelligence, heart rate monitors) can be helpful in this regard. Active-play video gaming can also be used to promote healthy weight and PA in children and adolescents, middle-aged and older adults, and patients with chronic disease [71]. One study in healthy adults, using an open-circuit indirect metabolic chamber, reported a wide range of aerobic requirements (1.3–5.6 METs) during Wii Sports and Wii Fit Plus game activities [72]. These levels of energy expenditure correspond to very slow (<1 mph) to extremely fast (~4.5 mph) walking speeds. Accordingly, using active-play video gaming to meet daily or weekly PA requirements may serve as a gateway to structured exercise regimens. In aggregate, these data suggest that using technology, a contributor to the physical inactivity epidemic, can also be part of the solution.

10 Strategies to Enhance Adherence to Physical Activity

Although many patients can be motivated to initiate an exercise program, maintaining the commitment can be challenging. Unfortunately, negative variables often outweigh the positive variables contributing to sustained interest and enthusiasm, leading to a decline in exercise adherence and program effectiveness. Common impediments to regular exercise include inadequate supervision/coaching, time inconvenience, musculoskeletal problems, exercise boredom, cost issues, lack of program awareness, intercurrent illness or injury, work- or family-related conflicts, and neutral or negative spousal support. Physicians and allied health professionals have an ethical obligation to inform patients of the dangers of physical inactivity, to assess our patient's barriers to being more active, and to counsel them regarding safe and effective exercise practices. Additionally, we can improve exercise compliance by referring our patients to quality physical conditioning programs that offer professional supervision and have proven efficacy. Several research-based counseling and motivational strategies may enhance patient interest and facilitate initiation of and compliance with a structured exercise program, increased lifestyle PA, or both (Table 6). Clearly, the built environment, including community parks and

Table 6 Strategies to enhance exercise compliance

Assess exercise habits and counsel patients to be physically active
Evaluate the patient's "readiness to change," and target interventions accordingly
Establish short-term, attainable goals; evaluate progress at subsequent office visits
Minimize injury with a moderate exercise prescription; emphasize gradual progression
Advocate exercising with others (i.e., social support)
Avoid overemphasis of regimented calisthenics
Consider gender differences in activity programming
Provide positive reinforcement through periodic testing and feedback of results
Recruit spouse support of the exercise program
Use progress charts or a computerized data system to record individual exercise achievements
Encourage patients to use certified, enthusiastic exercise professionals
Stress participation in activities that are enjoyable
Include an optional recreational game to the conditioning program format

walking and bike paths, should be supported by local governments to increase the accessibility to lifestyle PA.

11 Conclusions

We must conclude as William C. Roberts MD, Editor-in-Chief, *The American Journal of Cardiology*, summarized in 1984: "Exercise training? An agent with lipid-lowering, anti-hypertensive, positive inotropic, negative chronotropic, vasodilating, diuretic, anorexigenic, weight-reducing, cathartic, hypoglycemic, tranquilizing, hypnotic and anti-depressive qualities" [73]. The challenge for physicians and other healthcare providers is to refer increasing numbers of patients to home, club, or medically supervised exercise programs so that many more individuals may realize the cardioprotective and general health benefits that regular PA can provide. Exercise is medicine, and for the vast majority of patients who are not regularly active, the prescription remains unfilled.

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