REVIEW / SYNTHÈSE

Evidence-based risk assessment and recommendations for physical activity clearance: established cardiovascular disease[1]

Scott G. Thomas, Jack M. Goodman, and Jamie F. Burr

Abstract: Physical activity is an effective lifestyle therapy for patients at risk for, or with, documented cardiovascular disease (CVD). Current screening tools — the Physical Activity Readiness Questionnaire (PAR-Q) and the Physical Activity Readiness Medical Evaluation (PARmed-X) — require updating to align with risk/benefit evidence. We provide evidence-based recommendations to identify individuals with CVD at lower risk, intermediate risk, or higher risk of adverse events when participating in physical activity. Forms of exercise and the settings that will appropriately manage the risks are identified. A computer-assisted search of electronic databases, using search terms for CVD and physical activity risks and benefits, was employed. The Appraisal of Guidelines for Research and Evaluation were applied to assess the evidence and assign a strength of evidence rating. A strength rating for the physical activity participation clearance recommendation was assigned on the basis of the evidence. Recommendations for physical activity clearance were made for specific CVD groups. Evidence indicates that those who are medically stable, who are involved with physical activity, and who have adequate physical ability can participate in physical activity of lower to moderate risk. Patients at higher risk can exercise in medically supervised programs. Systematic evaluation of evidence indicates that clinically stable individuals with CVD may participate in physical activity with little risk of adverse events. Therefore, changes in the PAR-Q should be undertaken and a process of assessment and consultation to replace the PARmed-X should be developed. Patients at lower risk may exercise at low to moderate intensities with minimal supervision. Those at intermediate risk should exercise with guidance from a qualified exercise professional. Patients at higher risk should exercise in medically supervised programs.

Key words: adverse events, arrhythmia, cardiac rehabilitation, chronic heart failure, coronary arterial disease, hypertension, myocardial infarction, qualified exercise professional, risk/benefit ratio.

Résumé : La pratique de l'activité physique est un mode de vie à caractère thérapeutique pour les patients à risque ou diagnostiqués d'une maladie cardiovasculaire (CVD). Les outils de dépistage actuels (Q-AAP et X-AAP) requièrent une mise à jour sur le plan des risques et des bénéfices. Cet article présente des recommandations basées sur des données probantes pour classer les individus présentant une CVD en fonction du risque d'événements indésirables associés à la pratique de l'activité physique : faible, modéré ou élevé. Les types d'exercice physique et les milieux de pratique sont pris en considération. On effectue une recherche dans les bases de données électroniques au moyen des mots clés suivants : CVD, activité physique, risques, bénéfices. On utilise la grille AGREE (AGREE Collaboration 2001; AGREE Collaboration 2003) pour évaluer la rigueur scientifique et lui donner une cote. Selon les observations probantes, on assigne aussi une cote à la recommandation en matière de pratique de l'activité physique. On formule des recommandations en matière de pratique de l'activité physique à l'intention des groupes spécifiques de CVD. D'après les observations probantes, les patients qui sont médicalement stables et engagés dans la pratique de l'activité physique en plus d'être dotés d'une aptitude physique suffisante peuvent s'adonner à l'activité physique en situation de risque faible à modéré. Les patients à risque élevé peuvent s'adonner à la pratique de l'activité physique dans des programmes avec supervision médicale. L'évaluation systématique des données probantes révèle que les patients souffrant de CVD, mais dont l'état est stable peuvent s'adonner à l'activité physique, et ce, avec peu de risque d'événements indésirables. On devrait donc modifier le Q-AAP en conséquence et réévaluer après consultation le X-AAP. Les patients à risque faible peuvent s'adonner à l'activité physique d'intensité légère à modérée avec un minimum de supervision. Les patients à risque modéré peuvent s'adonner à la pratique de l'activité physique

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sous la supervision d'un professionnel de l'exercice certifié. Les patients à haut risque peuvent s'adonner à la pratique de l'activité physique dans des programmes avec supervision médicale.

Mots-clés : effets indésirables, arythmie, réadaptation cardiologique, insuffisance cardiaque chronique, coronaropathie, hypertension, infarctus du myocarde, professionnel de l'exercice certifié, ratio risque/bénéfice.

[Traduit par la Rédaction]

Lay synopsis

Physical activity (PA) is an effective lifestyle therapy for patients at risk for, or with, known cardiovascular disease (CVD). Numerous scientific statements and guidelines from around the world agree that regular exercise reduces sickness and death, decreases the markers of CVD risk, increases ability to function, and improves quality of life and psychological status. Our aim was to recommend how to appropriately clear people with different types and severities of CVD to participate in exercise, and to determine what level of supervision may be adopted.

A single bout of exercise increases the risk of a cardiovascular (CV) event (e.g., heart attack), but regular exercise over time decreases the risk. We systematically looked at scientific studies that examined how the risk of a CV event is affected by exercise in people with blocked vessels in the heart, high blood pressure, heart failure, and uneven heart beats. We rated how strong the evidence about risk and benefits was from all the studies, and made recommendations about who could exercise on their own and who should exercise under supervision.

The risk of an event associated with exercise is very low in the general population for men (1 sudden death per 1.51 million episodes of exertion) and women (1 per 36.5 million hours of exertion), with increased risk in patients with CVD. As in the healthy population, regular PA over time decreases the risks of ill health and death in CVD patients. Despite an overwhelming body of evidence documenting the health benefits for those with CVD, PA is too rarely a part of patients' lives. For patients with each type of CVD, we identified who should be regarded as being at lower, intermediate, or higher risk when participating in PA. Patients at lower risk may participate in low- to moderate-intensity exercise with minimal supervision, patients at intermediate risk may participate in exercise under the direction of a qualified exercise professional, and patients at higher risk should participate in medically supervised exercise programs. Specific recommendations are made for each group, but, in general, individuals are at lower risk if they are medically stable and have a current or recent history of PA.

Introduction

PA is an effective lifestyle therapy for patients at risk for, or with, documented cardiovascular disease (CVD). Numerous scientific statements and guidelines illustrate the worldwide consensus that regular exercise reduces mortality and morbidity and improves CVD risk factor profiles, functional capacity, quality of life, and psychological status (Stone 2004; Taylor et al. 2004; Kelley et al. 2006; Warburton et al. 2006*c*; Graham et al. 2007; Canadian Association of Cardiac Rehabilitation 2007; Kodama et al. 2007; Giada et al. 2008). The robust and consistent data supporting these recommendations are derived from experimental, epidemiological, clinical, and randomized controlled trials (RCTs).

The prevalence of CVD is high for populations in North America and Europe, and rises with age (American Heart Association 2008). Despite the falling age-specific prevalence, CVD remains the leading cause of death among the adult population. In addition, the well-established downward trend in CVD prevalence is being threatened by numerous factors, including population aging (American Heart Association 2008) and, more notably, the sharp increases in the incidence of metabolic syndrome and obesity (American Heart Association 2008).

Meta-analyses and RCTs have documented the significant impact of regular exercise on CVD risk factors, including blood lipids (increased high-density-lipoprotein cholesterol, and reduced total cholesterol and triglycerides) (Kelley et al. 2006), systolic and diastolic blood pressure (Blumenthal et al. 2000; Whelton et al. 2002; Dickinson et al. 2006), and diabetes (Riddell and Burr 2011). Improved function has been demonstrated for CVD in general, and for specific patient groups, including those with heart failure (HF) (McKelvie 2008), those who have undergone angioplasty (Belardinelli et al. 2001), and those who have had a stroke (Zehr 2011). Health-related quality of life is improved with regular exercise in most CVD patient groups (Meyer and Laederach-Hofmann 2003). There is also evidence that high PA levels increase life expectancy for patients with CVD over the age of 50 years, by 3.7 years for men and 3.3 years for women (Franco et al. 2005).

In patients with established CVD, regular exercise improves vascular function, may produce regression of coronary artery disease (CAD) occlusion, and reduces risk factors associated with CVD, including lipidemia, obesity, insulin resistance, and hypertension (Stone 2004). Regular PA improves functional capacity and reduces myocardial oxygen demand (American College of Sports and Medicine and American Heart Association 2007).

The following section was written by the consensus panel that guided the overall revision of the PA clearance process. This information is reprinted in each of the systematic review papers so that these reviews (Chilibeck et al. 2011; Eves et al. 2011; Goodman et al. 2011; Jones 2011; Rhodes et al. 2011; Riddell and Burr 2011; Zehr 2011) can stand alone from the paper describing the overall consensus process (Jamnik et al. 2011).

PA participation is recommended and beneficial for all asymptomatic people and for people with chronic diseases (Warburton et al. 2006*a*, 2007). However, the PA participation of people with certain chronic disease conditions or constraints may need to be restricted. The Physical Activity Readiness Questionnaire (PAR-Q) is a screening tool completed by people who plan to undergo a fitness assessment or to become much more physically active; for example, when initiating PA participation that is beyond a person's habitual daily activity level or when beginning a structured PA exercise program. Screening is also recommended when a person is joining a health club, commencing a training program with a fitness professional, or joining a sports team. If a person provides a positive response to any question on the PAR-Q, he or she is directed to consult with his or her physician for clearance to engage in either unrestricted or restricted PA.

The Physical Activity Readiness Medical Evaluation (PARmed-X) is a screening tool developed for use by physicians to assist them in addressing the medical concerns related to PA participation that were identified by the PAR-Q. Recent feedback from PA participants, fitness professionals, and physicians has brought to light substantial limitations to the utility and effectiveness of PA participation screening by the PAR-Q and PARmed-X. In short, the exercise clearance process is not working as intended and at times is a barrier to PA participation for those who may be most in need of increased PA (Jamnik et al. 2007). The aim of this project was for experts in each chronic disease, together with an expert panel, to revise and increase the effectiveness of the PAR-Q and PARmed-X screening process, using an evidence-based consensus approach that adheres to the established Appraisal of Guidelines for Research and Evaluation (AGREE).

An important objective of this project was to provide evidence-based recommendations that university-educated and qualified exercise professionals can employ in the exercise clearance process. An example of a qualified exercise professional is the Canadian Society for Exercise Physiology Certified Exercise Physiologist, which is the highest nationally recognized certification in the health and fitness industry in Canada. It recognizes the qualifications of people who possess advanced formal academic preparation and practical experience in health-related and performance-related PA exercise science fitness applications for both nonclinical and clinical populations (Jamnik et al. 2007).

The AGREE instrument was developed by a group of researchers from 13 countries to provide a systematic framework for assessing the quality and impact on medical care of clinical practice guidelines (AGREE Collaboration 2001, 2003). The AGREE collaboration published the rigorous development process and associated reliability and validity data of the AGREE instrument, based on a large-scale study focused primarily on clinical practice guidelines (AGREE Collaboration 2001, 2003). The AGREE instrument is now a commonly used tool for assessing clinical practice guidelines and other health management guidelines (Lau 2007). The AGREE guidelines were applied in this project to assess the formulation of risk stratification and PA participation clearance recommendations for each of the critical chronic diseases. One of the authors of this project (J.M.) is an AGREE instrument expert, and she was responsible for evaluating the compliance of the overall process to the AGREE guidelines.

In addition to adhering to the AGREE process, the Level of Evidence (1 = RCTs, 2 = RCTs with limitations or observational trials with overwhelming evidence, 3 = observational studies; 4 = anecdotal evidence) supporting each PA participation clearance recommendation and the Grade (A = strong, B = intermediate, C = weak) of the PA participation clearance recommendation were assigned by applying the standardized Level and Grade of Evidence detailed in the consensus document (Warburton et al. 2011).

Continuum of risk

In this series of articles, each disease condition was considered in reference to a continuum of risk, from lower-risk to intermediate- (moderate) and higher-risk categories (Fig. 1). Individuals may move across the continuum of risk, from relatively high-risk to lower-risk states, through changes in lifestyle behaviours. Particular attention was paid to the short-term (acute) risks of PA and exercise, compared with the long-term (chronic) benefits on the chronic disease. Adverse events were considered to be any adverse change in health status or side effect that resulted during PA and (or) exercise. The number of adverse events was evaluated in the context of the health benefits of PA or exercise to determine the risk/benefit ratio for each chronic condition.

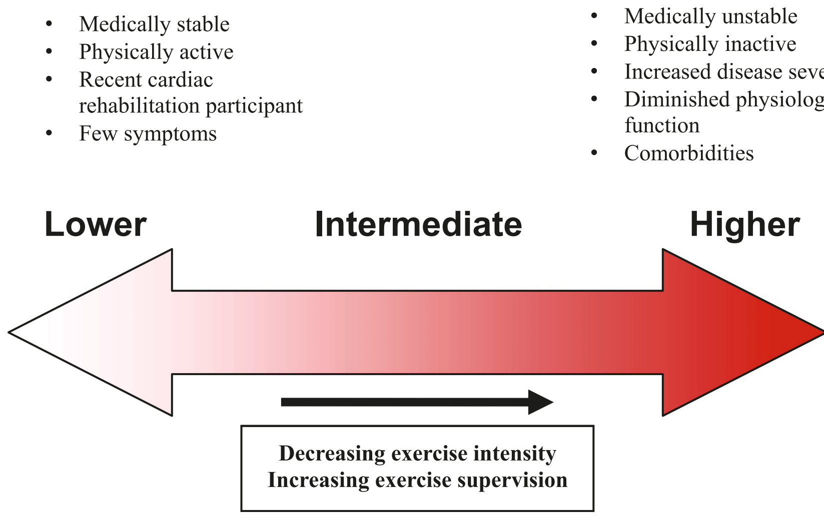
Acute exercise increases the risk of a cardiac event severalfold, but regular exercise decreases cardiovascular (CV) morbidity and mortality (Thompson et al. 2007*b*). Furthermore, the incidence of both acute myocardial infarction (MI) and sudden death is greatest in the habitually least physically active men (Albert et al. 2000; Thompson et al. 2007*b*) and women (Whang et al. 2006).

The absolute risk of an event associated with exercise is very low in the general population for men (1 sudden death per 1.51 million episodes of exertion) and women (1 per 36.5 million hours of exertion), with increased risk in patients with CVD. Nevertheless, as in the healthy population, regular physical exercise over time decreases morbidity and mortality in CVD patients (Jolliffe et al. 2001; Leon et al. 2005; Warburton et al. 2006*c*). The majority of these data reflect a combination of increased risk during and immediately following each exercise bout, and larger decreases in risk during the remainder of the day.

Can the incidence of CV events associated with acute exercise be reduced? A scientific statement from the American Heart Association sums up our current knowledge and practice: "No strategies have been adequately studied to evaluate their ability to reduce exercise-related acute cardiovascular events. Maintaining physical fitness through regular PA may help to reduce events because a disproportionate number of events occur in least physically active subjects performing unaccustomed PA. Other strategies, such as screening patients before participation in exercise, excluding high-risk patients from certain activities, promptly evaluating possible prodromal symptoms, training fitness personnel for emergencies, and encouraging patients to avoid high-risk activities, appear prudent but have not been systematically evaluated" (Thompson et al. 2007*a*, p. 2363).

The way forward is to identify the settings, degree of supervision, and form of exercise that will promote the highest degree of effective and safe PA for patients with differerent risk levels. When possible, we have provided specific information for those with general cardiac disease, hypertension, HF, and managed arrhythmias. The grouping of unspecified cardiac disease is necessary for 2 reasons: first, a large portion of the data are reported for cardiac rehabilitation programs that enroll patients with a variety of cardiac pathologies; second, a substantial portion of patients present with

Fig. 1. Continuum of cardiovascular disease exercise participation risk.



more than 1 CVD. Indeed, the frequent presentation with multiple comorbidities requires an assessment of risk that reflects the complete health profile of the individual. Recommendations regarding the most effective forms of exercise for specific CVD groups have been and continue to be developed (Stone 2004; Leon et al. 2005; Börjesson et al. 2006), and should be customized for individual patients.

Do the perceived risks limit participation unduly?

Despite an overwhelming body of evidence documenting health benefits for those with established CVD, exercise is too rarely a part of patients' lives. Participation in cardiac rehabilitation remains the exception rather than the rule, with less than half of European (Vanhees et al. 2002) and less than a third of eligible Canadian and American patients participating; rates are even lower for older patients and for women (Daly et al. 2002; Grace et al. 2002). Furthermore, cardiac rehabilitation programs are frequently less than 6 months in duration and, therefore, represent a small portion of the lifetime of those who participate. Little is known about how many cardiac rehabilitation participants continue to exercise in home or community settings. In the large TEACH cohort study (Reid et al. 2006), less than 45% of noncardiac rehabilitation participants reported expending 1500 kcal or more per week. Results from the Behavioral Risk Factor Surveillance Survey suggest that people with coronary heart disease are less likely to exercise than the rest of the surveyed European population (Ashaye and Giles 2003).

The majority of individuals will either not exercise or will exercise outside of cardiac rehabilitation programs. Can they safely participate in exercise? Various contraindications for exercise (either relative or absolute) have been based on clinical judgment and the pathophysiology of the particular CVD (American College of Sports Medicine 2006). Stratification schemes developed to categorize risk levels for people with CVD or people at greater risk for CVD (Gibbons et al. 2002; American College of Sports Medicine 2006) are often based on clinical consensus and expert opinion, because there are limited data available (Vongvanich and Bairey Merz 1996; Börjesson et al. 2006). Often, the data identify which patient groups are at risk, rather than the incremental risk of an acute exercise bout. There are concerns that a process of stratification that requires stress testing, laboratory tests, and specialist appointments poses a significant barrier to participation, particularly among older adults and those with limited access to health facilities because of geography or income (Gill 2007). Studies of exercisers who participate in cardiac rehabilitation are an important source of recommendations for safe exercise and documentation of exercise risks in selected patient populations. Broader application of these findings to facilitate noncardiac rehabilitation program participation in PA must consider issues of patient selection, exercise prescription and monitoring, staff expertise, and emergency preparedness (Wenger 2008).

A dose–response relation exists for most benefits and patient groups, so that the higher-intensity exercise is more effective (Kesaniemi et al. 2001). In their review, Swain and Franklin (2006) report that epidemiological evidence indicates that vigorous exercise (>6 METs) is more effective than moderate-intensity exercise in reducing CV risk, and clinical trial evidence documents the superior effectiveness of vigorous exercise in improving diastolic blood pressure, glucose control, and aerobic capacity.

The majority of evidence on the risk and benefits of exercise for those with CVD is based on aerobic exercise programs conducted in facility-based cardiac rehabilitation programs. However, several studies have documented benefits from alternative exercise forms (resistance (Williams et al. 2007), interval (Rognmo et al. 2004), circuit training (DeGroot et al. 1998)) and in alternative settings (facility, community- and home-based (Jolly et al. 2006)). Additional evidence has accumulated from PA interventions in the community with populations with a high prevalence of CV conditions (Ory et al. 2005; Goodrich et al. 2007). Whenever the published evidence provides guidance, recommendations will be made regarding these alternatives.

Patients with established CVD are treated with a range of medications, which may independently decrease the risk of CV events and influence acute exercise responses (American Heart Association 2008). Chronic exercise may reduce the dosage or variety of medications required by those with CVD, but little is known about how the risk/benefit ratio for

Table 1. Relative intensities for aerobic exercise prescription (for activities lasting up to 60 min).

Intensity	%HRR	%HR_{max}	RPE	Breathing rate	Body temperature	Example activity
Very light effort	<20	<50	<10	Normal	Normal	Dusting
Light effort	20–39	50–63	10–11	Slight increase	Starting to feel warm	Light gardening
Moderate effort	40–59	64–76	12–13	Greater increase	Warmer	Brisk walking
Vigorous effort	60–84	77–93	14–16	More out of breath	Quite warm	Jogging
Very hard effort	>84	>93	17–19	Greater increase	Hot	Running fast
Maximal effort	100	100	20	Completely out of breath	Very hot, perspiring heavily	Sprinting all-out

Note: The shaded area identifies intensity levels that are required for health. Adapted from Warburton et al. 2006*b*. HR_{max}, maximal heart rate; HRR, heart rate reserve; RPE, rate of perceived exertion.

exercise is affected by medications. Participants in the exercise and nonexercise arms of RCTs are typically equally exposed to the same pharmaceutical treatment; therefore, the effect of exercise is independent of medication. As a result, the interaction of drug and exercise treatment will not be addressed in this review.

The prevalence of CVD, comorbid conditions (arthritis, diabetes, obesity), and low physical capacity increases markedly with age (American Heart Association 2008). The prevalence of CVD increases from approximately 39% to 40% at 40 to 59 years of age to 71% to 75% at 60 to 79 years of age for men and women (American Heart Association 2008). Reduced physical capacity increases the relative intensity of a given activity; as a result, the training levels presented in Tables 1 and 2 are relative to capacity rather than absolute intensities. Particular effort was made to evaluate the effect of age on exercise risks and benefits, and on our ability to assess the risk of adverse effects.

Our goal was to formulate recommendations to identify patients with established CVD for whom exercise participation would produce lower-risk, intermediate-risk, and higher-risk categories of adverse events. It should be emphasized, however, that a continuum of risk exists, according to individual clinical characteristics. The second step was to identify which forms of exercise and which settings would appropriately manage the risks. Recommendations are based on a systematic evaluation of the published literature that identifies the balance of overall risk and benefit or, when possible, the risks associated with participation in various forms of exercise by patients with CVD.

Search strategy

A comprehensive computer-assisted literature search of existing evidence was performed using the following electronic databases: Medline, CINAHL, SPORT discus, EMBASE, Cochrane DSR, ACP Journal Club, and DARE. Preference was given to RCTs, but all literature — including previous systematic reviews, meta-analyses, simple reviews, and nonrandomized studies — was captured and screened for applicability and further references. The main search was supplemented with articles identified by subject matter experts aware of publications in less mainstream sources that may not have been captured.

We sought English-language articles on human subjects indexed before the second week of June 2008, and searched both keywords and MeSH headings to keep the search intentionally broad. The keywords were developed using the originally published PARmed-X terms identified as

Table 2. Relative intensities for resistance exercise.

Intensity classification	Resistance relative to maximum strength (%)	Example activities
Very light effort	<30	Watering the lawn
Light effort	30–49	General house cleaning, ironing
Moderate effort	50–69	Raking leaves, vacuuming
Hard effort	70–84	Wood splitting, carrying groceries
Very hard effort	>84	Shovelling snow
Maximal effort	100	Lifting a load you can only lift once

Note: Adapted from Warburton et al. 2006*b*.

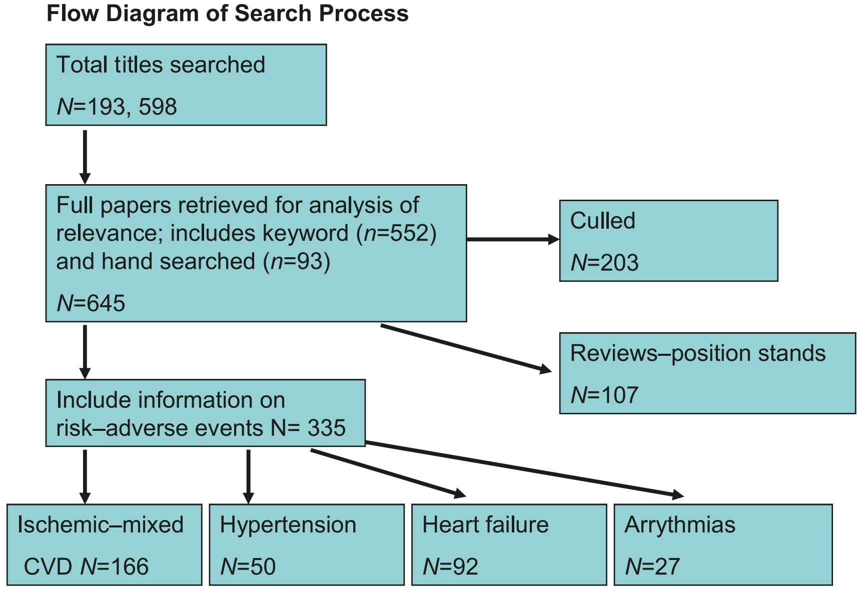
contraindications to exercise, and included other potentially relevant cardiac complications identified by the authors and the project steering committee. The general topics of the search included ischemic heart diseases, acute MI, hypertensive diseases, atrial fibrillation (AF) and flutter, HF (congestive and unspecified), aortic aneurysm and dissection, peripheral vascular disease unspecified, atherosclerotic heart disease and(or) atherosclerosis (general), angina (as an addition to ischemic heart disease in searching), postexercise syncope, and valvular heart disease.

One author (J.F.B.) reviewed titles and abstracts of the identified articles, removed duplicates, and retrieved all potentially relevant literature (n = 645). When there were uncertainties, full text copies of the articles were obtained. The 2 other authors (J.M.G. and S.G.T.) reviewed the selected articles to ensure agreement on article relevance and significance. Retrieved articles that were not relevant were culled (n = 203). Specific attention was given to articles examining the risks of exercise and reports of adverse events. Review articles and position stands (n = 107) were explicitly identified, since they compile previous evidence and may represent expert consensus at the time of publication.

The quality of evidence of identified articles was first assessed by considering each article as a stand-alone study. Referenced articles were re-evaluated by the authors with consideration of the article in and of itself and in the context of this project. This distinction was felt to be an important step because, although a study may have met the criteria for level 1 evidence on its own, often the outcome measure was not specifically designed to address the issue of the risk of participating in exercise; thus, the evidence for or against this point was of a lower level.

As indicated in Fig. 2, a large body of literature was identified and then grouped as outlined above.

Fig. 2. Results of systematic search and evaluation of literature on cardiovascular disease (CVD), exercise, and risk.



Cardiac disease

Cardiac rehabilitation programs and community-based PA programs for older adults admit individuals with a range of CVD and comorbidities. The majority of program participants have a history of CAD, which may have resulted in MI, angina, or interventional procedures, such as coronary arterial bypass grafting, percutaneous coronary intervention, or stenting of the vessels. A substantial amount of the literature reports on the risks and benefits of exercise participation for all program participants, rather than for patients with specific cardiac pathologies (Ory et al. 2005; Pavy et al. 2006; Goodrich et al. 2007; Giada et al. 2008; Wenger 2008). In this section, we review the evidence with the intent of developing recommendations for those with CAD, given that it represents the largest subset of patients involved in cardiac rehabilitation programs. Our search identified 166 papers related to exercise testing and training in CVD. We selected 154 of these for review and present recommendations based on all of those papers. Table 3 presents a selection of those that were methodologically strong (RCTs, meta-analyses, or previous clinical guidelines) or that addressed particular topics considered to be highly relevant (age, gender, exercise format).

Exercise testing

Exercise testing provides information that can be used to formulate a diagnosis or prognosis, but our particular interest is in its use for judging risk of exercise participation and in creating an exercise prescription. As detailed below and in agreement with American Heart Association–American College of Cardiology guidelines (Gibbons et al. 2002), it appears that exercise testing provides only a small improvement in our ability to predict the risk of an exercise-related adverse event. Additional information regarding the risk of exercise testing in those at risk for CVD or in the apparently healthy population can be found in the article by Goodman, Burr, and Thomas (Goodman et al. 2011).

In 6213 consecutive male patients (mean age, 59 years) referred for exercise testing, Prakash and colleagues (2001) observed no complications. Over a median follow-up of 7 years, they found that mortality was significantly related to limited exercise capacity (<5 METs), older age (65+ years), and a history of chronic HF or CAD. More than three quarters (78%) of the sample were referred for chest pain or ischemic heart disease.

A recent study of cardiac-rehabilitation-associated exercise testing in France identified the occurrence of 5 CV events in a total of 42 419 exercise tests (Pavy et al. 2006). All 5 events occurred in patients who had undergone a recent percutaneous coronary intervention with stent implantation. The majority of the sample (78%) was comprised of men (mean age, 61 years), and there were a variety of CV pathologies (coronary arterial bypass grafting, 34%; valvular surgery, 18%; percutaneous coronary intervention, 22%). The overall rate of 1 event per 8 484 exercise stress tests (Pavy et al. 2006), or 1.18 per 10 000 h, is in rough agreement with previous studies, which have suggested a rate of 1.59 per 10 000 h for clinically indicated exercise tests (Myers et al. 2000). Goto and colleagues (2002) report a CV event rate of 1 in 947 for maximal exercise testing, with no events for submaximal testing in patients with stent following an MI.

Despite recent efforts to evaluate the risks of exercise testing, PA participation, and exercise training in women, the majority of data documented in Table 3 are for male patients. However, emerging data support the case that, although specificity and sensitivity of testing may be less for women and although age of onset of CVD differs, the risk/benefit ratio for women is similar to that observed for men with CVD.

One hundred older adults (age, 75 to 94 years) who were referred for treadmill stress testing experienced no complications (Vacanti et al. 2004), although many (37%) experienced arrhythmias and several (18%) were positive for myocardial ischemia. However, a growing body of clinical opinion questions the utility of routine exercise stress testing for older adults (Gill et al. 2000; Ory et al. 2005), given the high prev-

Table 3. Risks associated with exercise training in general cardiovascular disease (CVD).

Source	Study type: sample	Adverse events	Conclusions–comments	Level of Evidence
Ades et al. 1996	Case control: n = 70; mean age 68 y	Intervention had 2 subjects drop out for nonexercise-related cardiac problems; 3 dropped out for noncardiac problems	Older coronary patients successfully improve aerobic fitness with a vigorous program. Mechanism of improvements almost exclusively peripheral skeletal muscle adaptations	3
Belardinelli et al. 2001	RCT: n = 118; 16% women PTCA–CS; mean age 56 y	Control group: 19 events; exercise group: 7 events. Follow-up at 33 months	Benefits: moderate to vigorous exercise improves functional capacity and QOL. Trained patients had fewer events and lower hospital readmission rate	1
Franklin et al. 1997	Retrospective; n = 3 335; 292 254 exercise hours	5 major events (3 nonfatal MIs, 2 cardiac arrest)	Overall rates of complication per hour of exercise = 1 per 49 315 for CR phase 3 and 1 per 58 451 for CR phases 2and 3 combined. Low frequency. MD presence during sessions not necessary	3
Hambrecht et al. 2004	RCT: n = 101; 0% women; mean age 61 y	CV events: 6 for exercise; 15 for PCI	Exercise training at moderate effort for 12 months decreased relative risk to 0.61, compared with PCI.	1
Iellama et al. 2000	RCT: n = 97; 0% women	No significant CV events	Benefits: exercise training increases baroreflex sensitivity and HR variability in patients with CAD	2
Jolliffe et al. 2001	Review, meta-analysis	Not reported	Exercise rehabilitation effective in reducing cardiac deaths by 27%	2
Kirwan et al. 2003	Case control: n = 25; 100% women	7 worsening cardiac illness; 4 respiratory; 2 orthopaedic, not related to training	Training responses are consistent, regardless of HRT status. Training in women with CAD undergoing HRT is safe and effective	3
Krittayaphong et al. 1996	Cohort: n = 58; 20% women; mean age 61 y	22 patients experienced angina during exercise testing. Inclusion required positive exercise test showing ischemia	Patients with depressed mood had a greater perception of angina. Not explained by differences in ischemia	3
McConnell et al. 1998	Cohort: n = 500; 19% women; mean age 61 y	No serious CV events	Effective and safe exercise training for cardiac patients achieved with or without exercise testing	2
Meyer and Laederach-Hofmann 2003	Pilot-RCT: n = 13; 0% women; mean age 54 y	Training well tolerated, no patient demonstrated signs or symptoms of ischemia or arrhythmia	Eccentric resistance training is safe for low-risk patients with CAD. Allows for greater muscle torque, with similar hemodynamic and metabolic response to concentric training	2
Nieuwland et al. 2000	RCT: n = 130; 12% women; mean age 52 y	1 patient from high-frequency group (n = 63) had an occurrence of unstable angina	High-frequency training is more effective in terms of anaerobic threshold and QOL. Aerobic fitness improved equally in high- and low-frequency training. Younger patients benefit more from high-frequency training	2
Pavy et al. 2006	Prospective cohort: n = 25 420; 22% women; mean age 61 y	1 serious CV event in 49 565 patient-hours. Cardiac arrest rate: 1.3 per million patient-hours of exercise; 743 471 h exercise	65 French CR sites contributed to registry. Mixed CVD population (34% CABG, 18% valvular, 22% PCI). Primarily aerobic exercise (treadmill, cycle, walk)	2
Taylor et al. 2004	Meta-analysis: n = 8 940; 20% women; mean age 55 y	Not applicable	Exercise training in a CR program reduces mortality, independent of CVD diagnosis. Relative risk of death is 0.80 for CR vs. usual care	1

Table 3 (*concluded*).

Source	Study type: sample	Adverse events	Conclusions–comments	Level of Evidence
Unverdorben et al. 2007	Cohort survey: n = 1935; 22% women; mean age 66 y	CV symptoms (dypnea, 40%; dizziness, 18%; palpation, 16%; 10%, angina) reported by 57% of participants; 1 symptom per 800 h	Survey mailed to CR phase 3 participants; 15% response rate. Symptoms reported more often by those who perceive exercise level too high (63%), by heart failure patients (40%), and by those with low exercise capacity	2

Note: CABG, coronary arterial bypass grafting; CAD, coronary artery disease; CR, cardiac rehabilitation; CS, coronary stenting; CV, cardiovascular; HR, heart rate; HRT, hormone replacement therapy; MD, physician; MI, myocardial infarction; PCI, percutaneous coronary intervention; PTCA, percutaneous transluminal coronary angioplasty; QOL, quality of life; RCT, randomized controlled trial.

alence of CVD and comorbidities and the low treadmill test completion rates. An alternative screening paradigm for older adults has been proposed that would direct older individuals with known CVD to participate in a heart-healthy PA program (Resnick et al. 2008).

An extensive body of literature on assessing risk of future CV mortality and morbidity with exercise testing has been reviewed by several organizations, and clinical guidelines have been developed (Gibbons et al. 2002). Frequently, one of the strongest risk predictors of CV morbidity and mortality in men (Gibbons et al. 2002; Kavanagh et al. 2002) and women (Kavanagh et al. 2003) is aerobic fitness. Aerobic fitness of less than 5 METs is associated with increased mortality and morbidity (Peterson et al. 2008).

Relative and absolute contraindications for exercise testing have been published by several organizations (Gibbons et al. 2002; American College of Sports Medicine 2006) (see Table 4). The contraindications are largely based on clinical judgment. Franklin and colleagues (1997) found no difference in the complication rate between exercise tests conducted before 1995 that were directly supervised by a physician (3.38/10 000) and those supervised by nonmedical personnel (2.65/10 000) (exercise physiologists, physiotherapists, nurses). Guidelines suggest that critical skills for exercise testing include knowledge of exercise physiology, indications and contraindications, principles of interpretation, and emergency procedures (Pina et al. 1995). It is beyond the scope of this paper to review the clinical indications for various forms of exercise testing, electrocardiograph (ECG) monitoring, and imaging that can be employed for diagnostic or prognostic purposes.

The American Heart Association–American College of Cardiology recommends exercise stress testing for diagnosis of CAD, but does not recommend it for patients with a documented MI or for those with an established diagnosis of CAD; however, it may be used to assess the risk of a CV event. In contrast, the American College of Sports Medicine recommends exercise testing before participation in vigorous exercise for men 45 years of age or older and for women 55 years of age or older, and for all individuals with known CV, pulmonary, or metabolic disease. Identification of the exercise intensity associated with cardiac ischemia or the onset of arrhythmia is employed in formulating an exercise prescription. Limited evidence suggests that submaximal testing is associated with less risk and can be employed to estimate aerobic capacity, but does not identify anginal thresholds.

Table 4. Contraindications for exercise participation for patients with established CVD.

Contraindication
Angina pectoris (unstable)
Aortic aneurysm
Aortic stenosis (severe)
Acute myocardial infarction
Active myocarditis
Ventricular tachycardia (uncontrolled)
Multifocal premature ventricular contractions
A 2 kg or more increase in body mass over 1 to 3 days

Exercise testing can provide important information for formulating exercise prescriptions and identifying symptoms and clinical responses that limit exercise intensity. Exercise prescription limits can be established relative to the intensity at which symptoms occur during testing.

Recommendation no. 1a: Using exercise testing to identify the risk of participating in PA for people with established CVD is a matter of judgment (Level 3, Grade C).

Exercise training

Table 3 presents a selection of papers that provide particular guidance in identifying patient risk or program features that affect benefits or risks. Previous clinical guidelines were examined as sources of literature and summaries of data on benefits and risks. The studies reported either incidence rates for adverse responses or the reduction in risk with increased participation rates.

Epidemiological studies have consistently documented reduced CVD morbidity and mortality in groups with higher PA. In the Caerphilly study (Yu et al. 2008), both fatal and nonfatal CV events (MI, stroke, or both) were recorded for 90% of the older male population (n = 2 398) from a defined geographical area. Men in the highest third of vigorous PA experienced a decreased risk of MI, relative to men in the lowest third, regardless of their baseline CVD status. Hazard ratios were 0.71 for those with symptomatic CAD, 0.42 for those with asymptomatic CAD, and 0.60 for men with no evidence of CAD at baseline.

Foster and Porcari (2001) reviewed studies of the risks of exercise training in cardiac rehabilitation programs up to the year 2000. The majority of studies indicate that the risk of serious complications in patients with CVD was approximately 0.08 to 0.15 per 10 000 h of exercise training. Examination of the occurrence of CV events in cardiac rehabilitation programs places the risk of a CV event at 0.08 to 0.2 per 10 000 patient-hours and 2 fatal events per 1.5 million patient-hours (Leon et al. 2005). These studies suggest that the event rate for patients with established CVD in cardiac rehabilitation is approximately double that of the general public. Higher exercise intensities increase both the magnitude of benefits (Swain and Franklin 2006) and the risk associated with a bout of exercise (Willich et al. 1993). The majority of CVD patients are prescribed moderate to vigorous exercise (Stone 2004; Giada et al. 2008). Exercise intensity can be limited by the onset of symptoms, including angina, and prescribed limits can be articulated as absolute intensity, heart rate, or ratings of perceived exertion (see Tables 1 and 2).

Both aerobic and resistance exercise are effective and safe therapies for individuals with CVD. Both aerobic exercise, as employed in cardiac rehabilitation programs, and walking, as is frequently recommended in community- and home-based programs, are effective in increasing functional capacity and decreasing CVD risk. Resistance exercise is effective in increasing muscular strength, muscular endurance, and quality of life, and is safe as prescribed in cardiac rehabilitation programs (McCartney and McKelvie 1996; Williams et al. 2007). Resistance exercise may be particularly important for older adults, because it aids in maintaining or regaining functional capacity and mobility (Gill 2007).

The setting for exercise or PA participation has been more recently explored. Exercise programs that are clinically supervised appear to be equally effective and safe in facilities or home-based settings, according to randomized trials (Dalal et al. 2007) and systematic meta-analysis (Jolly et al. 2006). A study of PA in the community found that men participating in vigorous PA decreased their risk of MI, relative to men in the lowest third of activity level, irrespective of baseline CVD status (Yu et al. 2008).

PA interventions for older adults produce important benefits to functional capacity, quality of life, and CV health, as indicated by a review of observational and RCT studies (Gill et al. 2000). In the Myocardial Infarction Onset Study, comprised of 327 men older than 70 years (Mittleman et al. 1993), the relative risk of an MI during and in the hour following exercise at an intensity greater than 6 METs was 12.7. Gill and colleagues (2000) estimate that if older adults exercised 3 days per week at 6 METs, the annual risk of an MI would increase from 1.3% to 1.6% in a 79-year-old women and from 3.9% to 4.8% in a 90-year-old man. A study of 11 sites with PA programs for 5 518 older adults carefully recorded all adverse events, documented severity, and identified whether events were related to the PA intervention. A total of 467 minor events were recorded, of which 50 were intervention-related, and 45 major adverse events were recorded, of which none were study-related. Of the 45 major events, the majority were cardiovascular in nature. The program centres employed various screening methods, including the revised PAR-Q, but few included exercise stress testing as part of their screening process (Ory et al. 2005). Candidate participants were not excluded if CVD or other comorbidities were present (Thompson et al. 2003).

Conclusions and recommendations for cardiac disease

Conclusion no. 1: Prescribed exercise and PA have well-defined benefits for individuals with CVD (Level 1 Evidence).

Conclusion no. 2: The risk of prescribed physical exercise is highest for those who have not engaged in regular exercise and lowest for those who participate in supervised programs, whether they take place in a facility or are based in the home or community (Level 2 Evidence).

Conclusion no. 3: The absolute risk of light- to moderate-intensity exercise is very low for CAD patients who have an aerobic power greater than 5 METs. The risk of adverse events may be further reduced with ongoing participation in these forms of exercise. Aerobic fitness is a strong predictor of CVD-associated morbidity and mortality (Peterson et al. 2008) (Level 2 Evidence).

Conclusion no. 4: While the absolute levels may be higher for men, the balance of risk and benefit between men and women does not appear to differ. Benefits accrue from both aerobic and resistance exercise, and walking programs can be safe and effective for CVD patients (Level 1 Evidence).

The most consistent and robust finding is that the risk of exercise is decreased by regular participation and increased aerobic fitness. It is not clear how long the protective effect of recent participation persists. The substantial body of Levels 1 and 2evidence allows the following recommendations, which are also embodied in a flow chart (Fig. 3).

Clinical guidelines for patients with CVD and cardiac rehabilitation programs typically indicate that patients should be medically stable before participating in exercise (Stone 2004; American College of Sports Medicine 2006; Graham et al. 2007). Since the majority of the data are derived from studies where this practice was observed, it is prudent to follow this practice.

Recommendation no. 1b: People with established CVD may be regarded as lower risk (Level 2, Grade B) if

i. they are medically stable *and*
ii. they have completed a cardiac rehabilitation program without adverse events related to exercise *or* are currently physically active (e.g., walking) for more than 20 min at least 3 times per week without eliciting symptoms (e.g., angina, palpitations, shortness of breath) *and*
iii. aerobic power is known to be >5 METs *and*
iv. age is 75 years or younger.

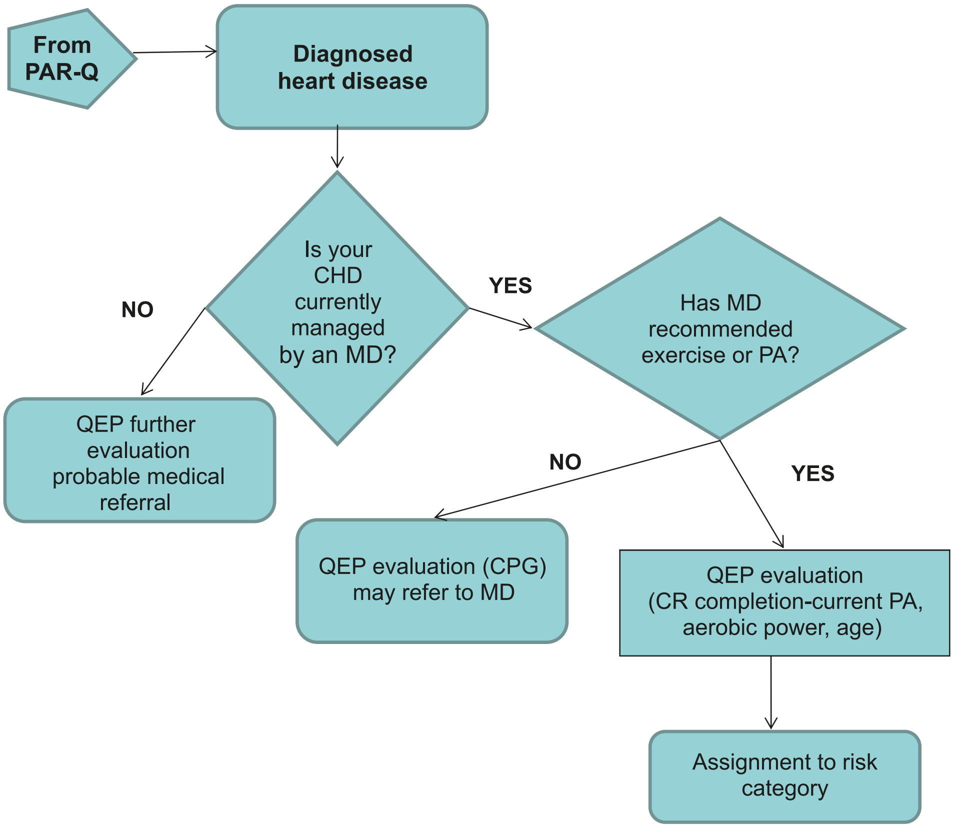
Recommendation no. 1c: People with established CVD may be regarded as intermediate risk (Level 2, Grade B) if

i. they are medically stable *and*
ii. they are currently physically active for more than 20 min at least once per week without eliciting symptoms (e.g., angina, palpitations) *and*
iii. aerobic power is not known *or*
iv. age is older than 75 years.

Recommendation no. 1d: People with established CVD may be regarded as higher risk (Level 3, Grade C) if

i. they are not medically stable *or*
ii. they are not currently physically active *and*
iii. aerobic power is not known or is known to be 5 METs or lower.

Fig. 3. Flow chart for physical activity (PA) clearance in lower-, intermediate-, and higher-risk categories for individuals with cardiac disease. CHD, coronary heart disease; CPG, clinical practice guidelines; CR, cardiac rehabilitation; MD, physician; PAR-Q, Physical Activity Readiness Questionnaire; QEP, qualified exercise professional.



Hypertension

Following the widely accepted cut-off for hypertension (140/90 mm Hg), the age- and sex-adjusted prevalence of hypertension was 28% in the United States and Canada and 44% in European countries in the 1990s. Between the age ranges of 35–44 and 65–74, the prevalence of hypertension increases from approximately 23% for men and 18% for women, to 64% for men and 74% for women (American Heart Association 2008). Hypertension is a strong risk factor for CVD, including stroke and ischemic heart disease (Chobanian et al. 2003). The seventh Joint National Committee (JNC VII) classifies those with blood pressure in the range of 120–139/80–89 mm Hg as prehypertensive, and recommends lifestyle interventions to prevent further rises in blood pressure and risk. Hypertension is frequently associated with CAD, stroke, and HF, so clinical assessment should first exclude their presence before providing hypertension-specific exercise recommendations.

Chronic exercise training is known to elicit reductions in hypertension that vary widely in magnitude between patients, but meta-analyses identify reductions as being 3 to 5 mm Hg (Cornelissen and Fagard 2005). While the relative importance of mechanisms in specific populations remains under investigation, contributing structural and neurohumoral mechanisms have been identified (Hamer 2006). Reduced systemic vascular resistance likely occurs secondary to increased lumenal diameter, enhanced endothelial function, and increased arterial compliance. Changes in vascular function are independent of weight loss (Blumenthal et al. 2000; Cornelissen and Fagard 2005). Neurohumoral changes include decreased plasma norepinephrine and renin levels and reduced autonomic nervous activity (Cornelissen and Fagard 2005).

Our search identified 50 papers related to hypertension, exercise testing, and participation. We present a summary of the studies that were RCTs or meta-analyses in Table 5.

Exercise testing

Exercise testing in patients with hypertension is used primarily to determine whether other CV disease is present and to assess exercise capacity prior to the initiation of exercise training, pharmacological intervention, or both. While several studies have used blood pressure responses during exercise testing to stratify the risk of future CV events (Erikssen et al. 2004; Laukkanen et al. 2006; Mundal et al. 1996), the relation between hypertension and the risk of an acute CV event during exercise testing has not been systematically determined. Based on clinical judgment (Level 4 Evidence), current guidelines suggest that exercise tests should be terminated if blood pressure exceeds 250/115 mm Hg, or if there is a decline in systolic blood pressure with increasing work rate (American College of Sports Medicine 2006).

Exercise training

There is clear evidence that chronic exercise reduces systolic and diastolic blood pressure in hypertensive men and women (see Table 5). Epidemiological studies have identified

Table 5. Summary of evidence of exercise effect on hypertension and adverse effects in patients with hypertension.

Source	Study type: sample	Adverse events	Conclusions–comments	Baseline BP (mm Hg)	Level of Evidence
Blumenthal et al. 1991	RCT: n = 99; 46% women; mean age 45 y	None reported	16 wk of moderate walking exercise difference of –1.0±16 mm Hg and –1.2±10 mm Hg at α = 0.05 for systolic and diastolic BP, respectively. Exercise alone not a replacement for pharmacologic therapy in patients with mild hypertension	142/95	1
Blumenthal et al. 2000	RCT: n = 133; 56% women; mean age 47 y	None reported	24 weeks of vigorous exercise reduced clinic systolic BP by –4.4 mm Hg, exercise and weight management by –7.4	141/94	2
Cornelissen and Fagard 2005	Meta-analysis: n = 28 trials; 492 trained; mean age 53 y	None reported	Aerobic training significantly reduces resting BP (–6.9/–4.9 mm Hg) in hypertensives. Effect correlates with change in aerobic fitness	147/92	1
Cooper et al. 2000	RCT: n = 90; 20% women; mean age 48 y	None reported	6-week walking program. Ambulatory BP. Estimated effect magnitude (systolic = –1.9 mm Hg, 95% CI = –5.4 to 1.7, p = 0.31; diastolic = –2.2 mm Hg, 95% CI = –4.9 to 0.5, p = 0.11)	139/89	2
Dickinson et al. 2006	Meta-analysis of RCTs: n = 6 805; 43% women; mean age 52 y	None reported	Mostly aerobic, some resistance training. Mean decrease in systolic BP, 4.6 (95% CI 2.0–7.1) mm Hg. Pharmacological therapy mean decrease, 9.1 mm Hg	141/90	1
Kelley 1999	Meta analysis: n = 732; 100% women	None reported	Aerobic exercise results in small reductions in resting systolic (95% CI, –3 to –1 mm Hg) and diastolic (95% CI, –2 to –1 mm Hg) among adult women. Few were hypertensive	120/74	1
Kelley and Kelley 2000	Meta analysis: n = 320; 50% women; mean age 47 y	None reported	Resistance exercise results in small reductions in resting systolic (95% CI, –4 to –1 mm Hg) and diastolic (95% CI, –4 to –1 mm Hg) BP among adult women. Few were hypertensive	125/76	1
Moreau et al. 2001	RCT: n = 24; 100% women; mean age 54 y	None reported	Walking decreased systolic BP by 6 mm Hg at 12 wk and 11 at 24 wk in postmenopausal women. Diastolic not significantly changed. Supports 10 000 steps a day and use of pedometers	142/85	2
Pardaens et al. 1996	Longitudinal, observational: n = 216; 34% women; mean age 40 y	Not applicable	Nonexercise 53 first events with 16.4-y follow-up. $\dot{V}O_{2\,peak}$ (L·min^{-1}) has prognostic value for CV events in hypertensives. Adjustment for traditional CV risk factors still meant reduced relative hazard ratio = 0.44 (with higher $\dot{V}O_{2\,max}$ of 1.0 L·min^{-1})	180/112	2
Staffileno et al. 2007	RCT: n = 24; 100% women; mean age 39 y	None reported	Lifestyle PA intervention reduces systolic (–6.4 mm Hg) and diastolic (–3.4 mm Hg) BP in young African American women with high-normal and stage 1 hypertension	136/91	3
Steffen et al. 2001	RCT: n = 112; 55% women; mean age 48 y	None reported	6 mo of aerobic exercise or exercise plus weight control PA has significant hypotensive effect (~5 mm Hg) during emotional stress or PA	141/93	2
Sui et al. 2007	Cohort: n = 9415; women 13%; mean age 64 y	Not applicable	450 CV deaths over 31 236 person-years of exposure. Higher cardiorespiratory fitness in hypertensive patients reduces risk of CVD events. Men and women of low, moderate, and high fitness have relative risks of 1.00, 0.88, 0.70, and 1.00, 0.87, 0.41, respectively	>140/90	2

Fig. 4 (*concluded*).

Source	Study type: sample	Adverse events	Conclusions–comments	Baseline BP (mm Hg)	Level of Evidence
Taylor et al. 2003	RCT: n = 17; 41% women; mean age 67 y	None reported	10 weeks of isometric training (handgrip) reduces resting systolic BP by 11 mm Hg, relative to controls	154/84	2
Whelton et al. 2002	Meta analysis: n = 15; trials in hypertensives	Not applicable	In hypertensive patients, aerobic exercise reduces BP (systolic, 4.9 mm Hg; diastolic, 3.7 mm Hg). Breaks down the effects of PA on BP for distinct groups (e.g., race, BMI)	>140/90	1

Note: BMI, body mass index; BP, blood pressure; CI, confidence interval; PA, physical activity; $\dot{V}O_{2\,max}$, maximal oxygen consumption; $\dot{V}O_{2\,peak}$, peak oxygen consumption.

a lower risk of CV events in hypertensive patients who are aerobically fit (Pardaens et al. 1996; Sui et al. 2007). A small but significant reduction in systolic (typically 3 to 5 mm Hg) and diastolic (3 mm Hg) blood pressures is observed in most RCTs and meta-analyses of aerobic exercise training (Whelton et al. 2002; Cornelissen and Fagard 2005; Dickinson et al. 2006). In contrast, Blumenthal and colleagues (2000) observed little change in pressures in a 16-week trial of moderate intensity (70% of initial maximal oxygen consumption) walking or jogging. Treatment effects are observed with light, moderate, and vigorous aerobic activity. Some data suggest that moderate intensity may be the most effective (Whelton et al. 2002). An anti-hypertensive effect was observed with resistance training in meta-analyses (Kelley and Kelley 2000) and with a small PA lifestyle intervention RCT (Staffileno et al. 2007), but the evidence was less extensive and the magnitude of effect may be smaller than for aerobic training.

The participants in studies of exercise intervention for hypertension are typically drawn from diverse populations. As a result of study inclusion and exclusion criteria, the majority of participants have baseline systolic blood pressure between 140 and 180 mm Hg, and mean pressure for the study sample at entry is often near 140/90 mm Hg (Table 5). One analysis suggests that the anti-hypertensive effect is greatest in blacks for systolic pressure and in Asians for diastolic pressure (Whelton et al. 2002). The majority of studies (Table 5) focus on middle-aged participants (mean age, 35 to 55 years). Subgroup analyses in the meta-analytic publications indicate that the hypotensive exercise effect exists for men and women and across a wide age range. One small RCT (Taylor et al. 2003) observed a significant reduction for older adults (mean age, 67 years); however, few data are available for patients older than 75 years. Overall, the effect is robust and appears to be strongest in those who need it the most — patients with hypertension (Whelton et al. 2002).

None of the studies identified reported any adverse effects; however, none of the studies were specifically designed to identify CV events in the hypertensive population. Exercise training of patients with hypertension produces a net reduction in morbidity and mortality through a combination of some increased risk with acute exercise and training-related cumulative risk reduction. Several studies have identified hypertensive responses to acute exercise testing as a predictor of future risk of a CV event, but they have not documented the increased risk of exercise participation. Currently, Canadian (Jamnik et al. 2005), American (American College of Sports Medicine 2006), and European (Graham et al. 2007) societies recommend PA as part of the treatment strategy for patients with hypertension, and suggest aerobic exercise of moderate intensity.

Conclusions and recommendations for hypertension

Conclusion no. 1: Strong evidence (Levels 1 and 2) points to a net benefit from exercise participation for individuals with high-normal (prehypertension) through stage 1 or 2 hypertension who do not have other CV comorbidities. Such patients should be encouraged to exercise.

Conclusion no. 2: Weak evidence (Levels 3 and 4) suggests caution for some hypertensive patients. Very high resting systolic (200 mm Hg) and diastolic (110 mm Hg) blood pressures have been identified as a relative contraindication to exercise testing (Gibbons et al. 2002; American College of Sports Medicine 2006). Since the data are limited, it is prudent to follow clinical judgment for both exercise testing and training, and to group patients with blood pressures of 200/110 mm Hg or greater in the higher-risk category. Hypertension increases the probability that other CV disease may be present. The presence of additional CVD risk factors (e.g., family history, lipidemia) further increases the probability, and signals a higher risk of an adverse event (Gibbons et al. 2002; American College of Sports Medicine 2006) (Fig. 4).

Recommendation no. 2a: People with hypertension may be regarded as lower risk (Level 1, Grade A) if:

i. they are medically stable *and*
ii. blood pressure is less than 160/90 mm Hg with or without medication *and*
iii. age is 75 years or younger.

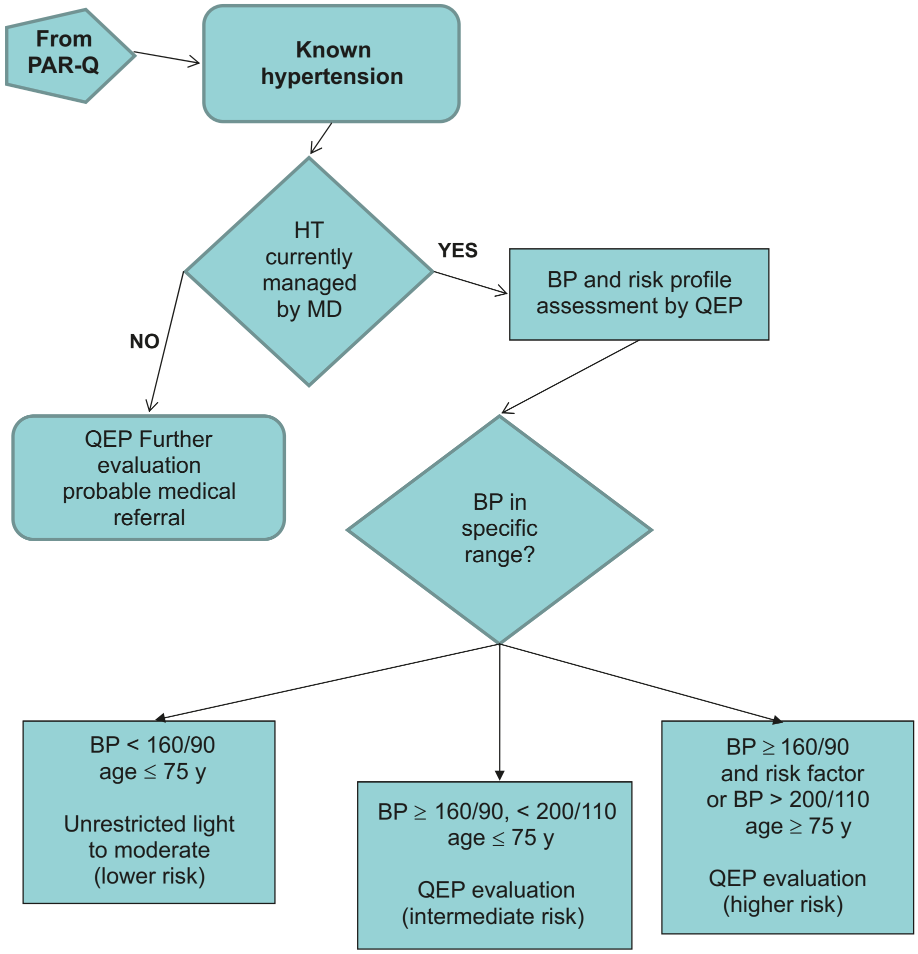
Recommendation no. 2b: People with hypertension may be regarded as intermediate risk (Level 3, Grade B) if:

i. they are medically stable *and*
ii. blood pressure is between 160/90 and 200/110 mm Hg *and*
iii. age is 75 years or younger.

Recommendation no. 2c: People with hypertension may be regarded as higher risk (Level 4, Grade B) if:

i. they are not medically stable *or*
ii. blood pressure is greater than 200/110 mm Hg *or*
iii. blood pressure is 160/90 mm Hg or higher *and*
iv. they have additional cardiovascular risk factors or age is older than 75 years.

Fig. 4. Flow chart for physical activity clearance in lower-, intermediate-, and higher-risk categories for individuals with hypertension (HT). BP, blood pressure. QEP, qualified exercise professional.



Heart failure

The prevalence of HF continues to increase as the population ages and survival from CAD improves. Incidence rises dramatically with increasing age, with a lifetime risk for congestive heart failure of approximately 30% at age 55 years (Bleumink et al. 2004). HF is the common final pathway for many patients with ischemic heart disease and hypertension. Functional capacity is often very limited in patients with HF (McKelvie 2008) as a consequence of limited cardiac function, peripheral vascular dysfunction, and skeletal muscle and autonomic nervous system abnormalities (Warburton et al. 2007). The majority (53%) of patients with HF report that they do not engage in regular PA (van den Berg-Emons et al. 2001).

Our search identified 92 papers related to HF and exercise participation. We present a summary of those that were RCT's or meta-analyses in Table 6.

Exercise testing

Guidelines (Piepoli and Gruppo Italiano 2006) recommend exercise testing for prognosis, evaluation of exercise tolerance, and prescription. Patients with a peak oxygen consumption ($\dot{V}O_{2\ peak}$) of less than 10 mL·kg^{-1}·min^{-1} have a poor prognosis, and those with a capacity greater than 18 mL·kg^{-1}·min^{-1} (~5 METs) have good 1-year outcomes. Additional results and clinical information are needed to guide exercise recommendations for patients with intermediate results ($\dot{V}O_{2\ peak}$, 10 to 18 mL·kg^{-1}·min^{-1}).

The safety of exercise testing in patients with congestive heart failure has not been widely reported, and most studies report results that include other CVD conditions or relate to pharmacologic stress tests or stress echocardiography tests, which may be considerably different than conventional graded exercise testing protocols.

Exercise training

The mortality and morbidity rates in patients with HF are high (Bardy et al. 2005), and there is clear evidence that exercise training reduces both rates. Recent meta-analyses and systematic reviews (Braith and Beck 2008) pooled previous findings and suggest that the relative risk of a composite morbidity and mortality score for exercise participants is reduced by approximately 30%. A more limited pool of studies indicates that health-related quality of life is enhanced (Rees et al. 2004). The magnitude of the exercise benefit may be greater in patients who are older and more severely impaired

Table 6. Summary of exercise effect of outcomes and safety in patients with congestive heart failure (CHF).

Source	Study type: sample	Adverse events	Conclusions–comments	Level of Evidence
Braith and Beck 2008	Critical review	Not applicable	Rationale and physiological adaptations to RT in CHF. Muscle atrophy predictor of survival, RT slows loss or increases. Contraindications listed. Patients classified as NYHA Class IV should not participate in classical RT programs. Recommend initial intensity is 50%–60% 1RM for NYHA Class I, 40%–50% 1RM for Class II-III	3
Belardinelli et al. 1999	RCT: n = 99; 10% women; mean age 55 y	Lower rate of morbidity and mortality in exercise vs. control groups	1 y of endurance training (60% of $\dot{V}O_{2\ peak}$). See improved aerobic power and QOL. With exercise training, see lower relative risk (RR) for hospital readmission (RR = 0.29) and mortality (RR = 0.37)	2
European Heart Failure Training Group 1998	RCT: n = 134; 6% women mean age 60 y	No adverse events with exercise	Review of studies to identity patients most likely to benefit or have adverse response. No baseline patient factor correlated with outcome. Moderate-intensity, home-based program of cycle ergometer and calisthenics safe and beneficial	2
Giannuzzi et al. 2003	RCT: n = 90; mean age 60 y	Lower rate of clinical events in exercise (9%) vs. control (15%)	6 mo of cycle ergometer training at 60% $\dot{V}O_{2\ peak}$ in patients at NYHA Class II or III improved aerobic power (19%), 6-min walk test distance (20%), and QOL. End diastolic volume was reduced	2
Goebbels et al. 1998	RCT: n = 67; 0% women; mean age 57 y	No complication during testing or training	Train for 8 wk with twice daily walking. Stratified randomization on ejection fraction. Observe larger gains in low (<40%) than in high (>50%) ejection fraction group	2
Hambrecht et al. 2000	RCT: n = 73; 0% women; mean age 55 y	No difference in mortality and morbidity between control and exercise groups	6 mo of cycle training at 70% $\dot{V}O_{2\ peak}$ (initial in-hospital, then home training) vs. inactivity control. Observe improved NYHA Class, increased $\dot{V}O_{2\ peak}$, and increased LVEF in the training group	2
McKelvie et al. 2002	RCT: n = 181; 19% women; mean age 66 y	No difference in mortality and morbidity between control and exercise groups.	3 mo of supervised and additional 9 mo of home training for patients in NYHA Class I to III produced significant gains in $\dot{V}O_{2\ peak}$. 6-min walk test distance. Increased arm and leg strength. Home program adherence was limited	2
Piepoli et al. 2004	Meta-analysis: n = 801; 9 studies	Exercise reduced mortality (hazard ratio, 0.65)	After mean follow-up of approximately 2 y, exercise reduced mortality and admissions to hospital. Supervised program reduces risk	1
Rees et al. 2004	Cochrane analysis: n = 1126; <15% women; age range 51 to 77 y	17/29 studies with no adverse events: 1 report of complications with training	Significant improvement in outcomes in 9 trials ($\dot{V}O_{2\ peak}$, 6-min walk test) and health-related QOL in 7 of 9 trials	1
Selig et al. 2004	RCT: n = 39; 15% women; mean age 65 y	No adverse effects	Moderate-intensity RT for 3 mo increased strength, $\dot{V}O_{2\ peak}$, enhanced HR variability, and blood flow	2
Smart and Marwick 2004	Systematic review: n = 1197; 17 studies	Composite measure odds ratio of 0.68 for exercise groups	Average increase in $\dot{V}O_{2\ peak}$ of 17% for aerobic, 9% for RT, 15% for combined training. No reports of death related to exercise in 60 000 patient-hours of exercise training	1
Wisløff et al. 2007	RCT: n = 27; 26% women; mean age 75 y	1 death not exercise related	12 wk of either aerobic interval (four 4-min intervals at 90%–95% HR peak) or continuous aerobic (70%–75% HR peak for 47 min) or control. Weekly, 2 sessions supervised and 1 at home	2

Note: LVEF, left ventricular ejection fraction; NYHA, New York Heart Association; RM, repetition maximum; RT, resistance exercise.

(Goebbels et al. 1998). Despite the high mortality rates for congestive heart failure and the complex etiology of this condition, exercise training appears to be safe. Smart and Marwick (2004) observed that no exercise-related cardiac events occurred in a total of 60 000 participant-hours. The majority of clinical trials documenting improved morbidity and mor-

Fig. 5. Flow chart for physical activity clearance in lower-, intermediate-, and higher-risk categories for individuals with chronic heart failure. CHF, congestive heart failure.

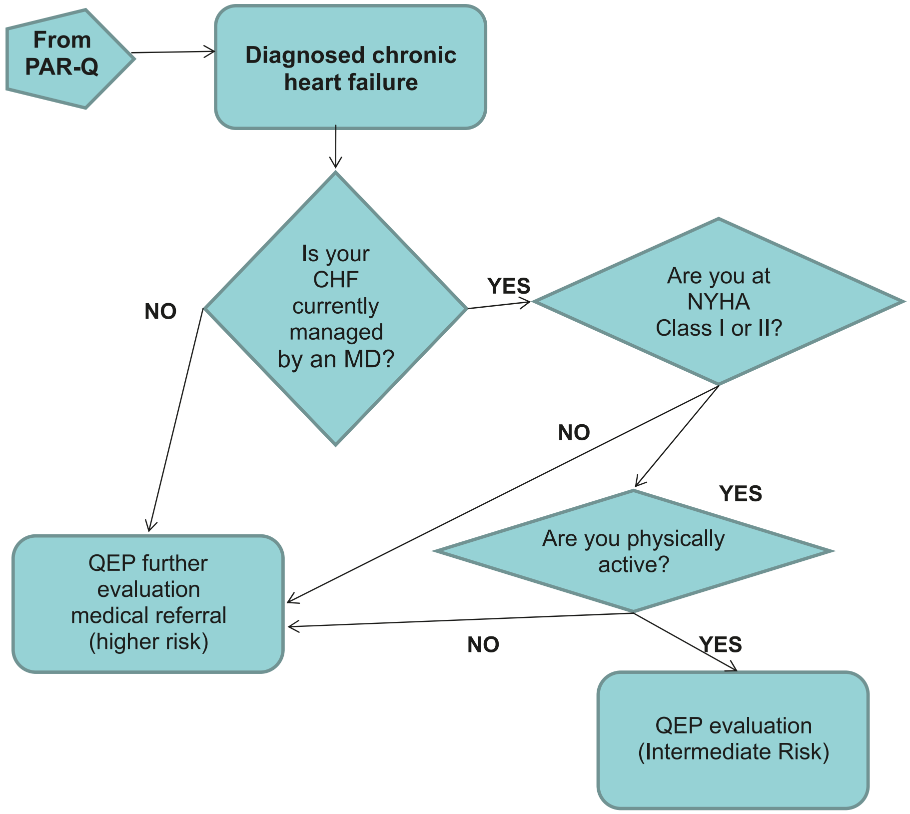
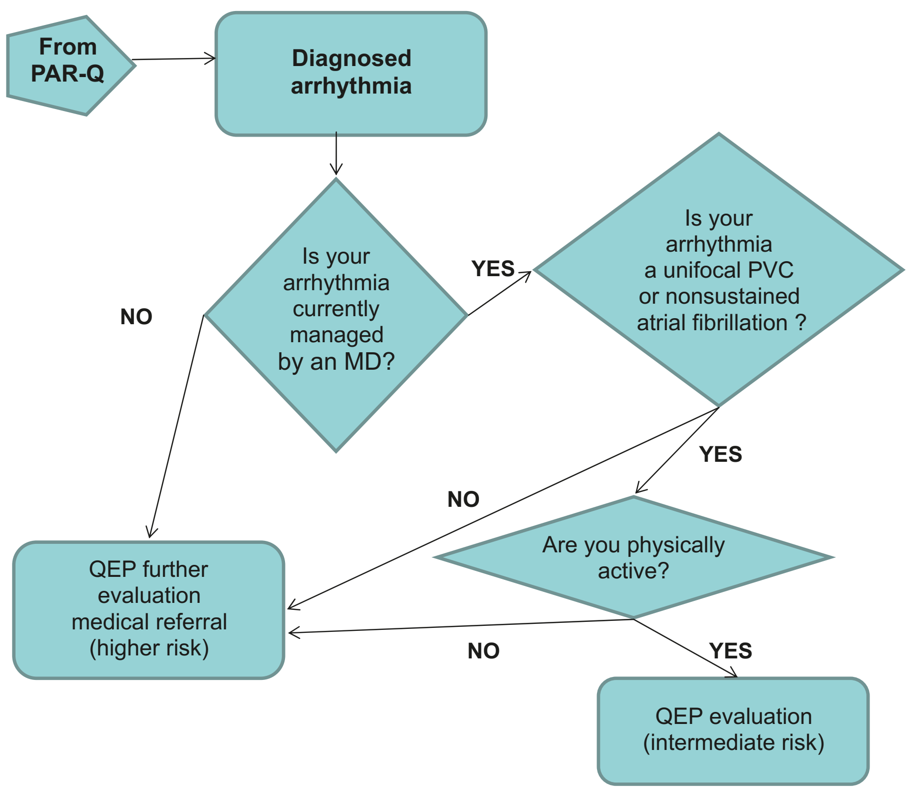


Fig. 6. Flow chart for physical activity clearance in lower-, intermediate-, and higher-risk categories for individuals with arrhythmia. PVC, premature ventricular contraction.



tality and increased function and quality of life have been performed in patients who fall into New York Heart Association (NYHA) Classes I, II, and III. Data are positive, but very limited, for Class IV patients. The incidence of ventricular arrhythmias for patients with HF is low, and generally the events do not prevent return to cardiac rehabilitation (Belardinelli 2003).

Endurance and resistance exercise training programs have been employed with success in HF patients (Selig and Hare 2007; McKelvie 2008; Myers 2008), and both are safe (Braith and Beck 2008). The muscle dysfunction associated with HF is a target for both types of exercise (McKelvie 2008). Intensities are typically set at approximately 60% of peak aerobic power for endurance exercise and 50% of 1 repetition maximum strength for resistance exercise (Smart and Marwick 2004). High-intensity aerobic interval training may provide a more effective stimulus; 4 sessions of 4-min intervals at 90%–95% of peak heart rate 3 times per week produced larger gains (46%) than an equivalent continuous program (14%) (Wisløff et al. 2007). The majority of rehabilitation programs have been based in healthcare settings, although some have included an at-home component (Wisløff et al. 2007). McKelvie and colleagues (2002) incorporated a home-based program for 9 months after 3 months of exercise in a rehabilitation centre, but found decreased adherence and reduced gains. Conversely, the European Heart Failure Training Group (1998) observed no exercise-related adverse events and increased aerobic fitness with physician-directed home exercise. Previous participation in a medically supervised rehabilitation program that included exercise seemed to decrease risk for the HF population (see Fig. 5).

Recommendation no. 3a: People with heart failure may be regarded as intermediate risk (Level 2, Grade A) if

i. they are medically stable and are NYHA Class I or II *and*
ii. they are currently physically active (e.g., walking) for more than 20 min at least 3 times per week *and*
iii. aerobic power is known to be greater than 5 METS.

Recommendation no. 3b: People with heart failure may be regarded as higher risk (Level 4, Grade C) if

i. they are not medically stable and have NYHA Class III or IV function *or*
ii. they have NYHA Class I or II function and are not currently physically active for more than 20 min at least 3 times per week *or*
iii. aerobic power is not known or is known to 5 METs or less.

Arrhythmias

The identification and treatment of certain arrhythmias in young and long-standing older athletes in the absence of structural disease remains problematic. The increased presence of various ECG abnormalities in such individuals is likely secondary to increased vagal tone and training-induced morphological changes (Maron and Pelliccia 2006). Most anomalies of this type do not warrant follow-up (Estes et al. 2001), particularly when no symptoms are evident, yet their presence poses additional challenges in ruling out an increased risk of CV events or more significant arrhythmias later in life. The growing body of literature describes a very small number of athletes who have disturbed ECG patterns, some of which may indicate structural disease and (or) pathology, including hypertrophic cardiomyopathy, arrhythmogenic right ventricular cardiomyopathy, and prolonged QT syndrome (Pelliccia et al. 2008*a*). Abnormal repolarization patterns are seen in 1%–4% of athletes 18–35 years of age (Pelliccia et al. 2000, 2008*b*). From a database of 12 500 athletes, 81 had abnormal ECGs (0.65%); of these, 4 developed structural heart disease within 12 years, whereas none of those who had normal ECG recordings did (Pelliccia et al. 2008*a*). In younger athletes, PVCs at rest do not typically worsen during exercise and, consequently, athletes with this arrhythmia alone are not considered to be at risk for competitive sport (Pelliccia et al. 2008*b*). Challenges and controversies associated with screening young athletes are well documented and remain beyond the scope of this study; additional insights can be found in the article by Goodman and colleagues (2011).

Exercise testing

The presence of nonsustained exercise-induced ventricular arrhythmias observed during exercise testing in the absence of known structural disease has uncertain prognostic value, but likely elevates risk (Kwok et al. 1999; Nishime et al. 2000). The increasing frequency of ectopic beats may be associated with poor clinical outcomes and increased likelihood of atherosclerosis (Marieb et al. 1990), although the short-term prognosis is not necessarily worsened.

An early study (McHenry 1977) of clinically normal men observed that single or consecutive PVC occurrences during exercise testing were related to age and the presence of disease, but did not increase with exercise intensity. To examine the safety of maximal exercise testing in patients with malignant ventricular arrhythmias, 263 patients who underwent 1 377 maximal exercise tests were studied (Young et al. 1984). Complications were compared with those in 3 444 cardiac patients (tested 8 221) without arrhythmias. The authors reported adverse events in 0.12% of the patients, suggesting that clinical state is not predictive of complications during maximal exercise.

Exercise training

Patients with coronary heart disease are more likely to have exercise-induced arrhythmias, yet it remains unclear if certain less-severe abnormalities increase the risk of adverse events. AF increases significantly with age, affecting as much as 15% of the population older than 80 years of age. However, there does not appear to be an increased risk of adverse responses to exercise. Mertens (2006) examined 17 patients with AF and reported significant improvements in functional capacity after vigorous exercise without complications, including serious arrhythmias during exercise testing or training. Similar improvements following exercise training (2 months) were recently reported in 15 patients who were compared with a control group (Hegbom et al. 2006). Exercise performance and quality of life improved, as did vagal tone, and no adverse responses were reported. More profound abnormalities, including multifocal PVCs, are known to be high risk, and many programs restrict vigorous exercise in these cases (Jelinek 1980). The prognostic significance of supraventricular arrhythmias during exercise testing was examined in 5 375 patients over approximately 3 years. Atrial arrhythmias provoked by exercise are not associated with long-term adverse events, including death and MI (Bunch et al. 2004).

The available evidence (level 3) indicates that patients with arrhythmias that are not potentially lethal (unifocal PVC, nonsustained AF) may exercise without increased risk (Fig. 6).

Recommendation no. 4a: People with the above types of arrhythmias (unifocal PVC, nonsustained atrial fibrillation) may be regarded as intermediate risk (Level 3, Grade B) if

i. they are medically stable *and*
ii. they are currently physically active (e.g., walking) for more than 20 min at least 3 times per week.

Recommendation no. 4b: People with the above types of arrhythmias may be regarded as higher risk (Level 3, Grade B) if

i. they are not medically stable *or*
ii. they have arrhythmias other than those noted above.

Contraindications to exercise in established CV disease

Guidelines, position statements, and training documents identify relative and absolute contraindications to exercise (Table 7). These are largely based on an understanding of the underlying pathology, and clinical experience and judgment. The absence of evidence for RCTs is understandable, given the ethics of risk exposure. Given that these contraindications are successfully used in cardiac rehabilitation programs, which demonstrate a low incidence of adverse events, it is prudent to continue following them until further evidence is available.

Recommendation no. 5: People with the conditions identified in Table 7 may be regarded as higher risk and should only exercise when permitted and under medical supervision (Level 4, Grade C).

Discussion

Can patients with CVD safely participate in exercise? Systematic review indicates a net benefit of routine exercise for patients with CAD, hypertension, and HF across a range of disease severities. Adverse responses to acute exercise are infrequent, and the benefits of regular exercise are substantial. Systematic examination of the evidence suggests that many individuals with established CVD of lower or moderate risk may participate. For most patients, participation in regular exercise of at least moderate intensity can be recommended on the basis of Levels 1, 2, or 3 Evidence. Patients with more severe CVD are at greater risk at rest and during acute exercise. A substantial body of evidence, based largely on supervised programs with prudent guidelines, clearly indicates that chronic exercise produces a net decrease in risk over time. Recommendations requiring further evaluation, supervision, or restricted participation in exercise are most often based on Levels 3 or 4 Evidence.

A revised PAR-Q will be used to identify those who have a CV disease. Those with or at risk of CVD then enter a process that involves a qualified exercise professional assigning them to a lower-, intermediate-, or higher-risk category. Indicators based on the systematic review are a first level of screening, which should be more completely specified in clinical practice guidelines. The systematic review suggests that 3 factors consistently affect the risk of acute exercise precipitating a CV event: medical stability, current PA participation, and aerobic fitness. The literature on exercise testing has documented a low event rate for patients who are currently active and for patients with an aerobic power greater than 5 METs (Kavanagh et al. 2002, 2003; Peterson et al. 2008). A more limited body of literature indicates that age increases the risk of events but confirms a net improvement in the risk/benefit ratio. The scarcity of studies with patients older than 75 years suggests that caution be exercised in identifying their risk level.

Contraindications for exercise testing and training have been established in guidelines from several organizations (CACR 2007; Gibbons et al. 2002; American College of Sports Medicine 2006). While these are seldom based on meta-analyses or RCTs, the consistency of clinical judgment suggests that patients with a contraindication should be allocated to the higher end of the risk continuum (higher risk) until more evidence is available.

Emerging literature supports the view that exercise can be safe and effective in facility, home, and community settings. These studies indicate differences in patient preferences, accessibility, and need for direct supervision, and monitoring can be accommodated to increase participation in PA and exercise with diminished concern for safety. Uncertainty about the level of required supervision remains. A limited body of literature has documented the safety and effectiveness of home programs that are directed by physicians and staffed by a variety of qualified exercise professionals.

This review has focused on the risk/benefit ratios for CV events. The risks of musculoskeletal injury with PA participation and exercise have not been addressed. However, evidence suggests that patients can increase their participation in walking activity without increased risk of injury (Colbert et al. 2000). Data from studies of community-based PA for older adults suggest that minor adverse events are frequent life events but are rarely tied to PA programs. The presence of additional health conditions, such as arthritis and back pain, may provide further rationale for exercise, but may also suggest additional cautions (Chilibeck et al. 2011).

The flow charts in Figs. 3 to 6 identify paths of action, starting from a positive response to PAR-Q questions, which indicates that the person has heart disease, hypertension, congestive heart failure, or specific arrhythmias. While we start from the premise that the patient has established CVD, there are numerous cases in which CVD is a possibility but not confirmed. In those cases, the pathways indicated in Figs. 3 to 6 will be useful in the identification of individuals who do not have CVD, have established CVD, or require additional follow-up to determine their clinical status. These efforts may focus on ensuring the person has appropriate healthcare follow-up, in addition to determining their risk of an exercise-related adverse event. Further elaboration of the process for follow-up will be the subject of clinical guidelines.

Table 7. Arrthymias and exercise associated cardiovascular event risk.

Source	Study type: sample	Adverse events	Conclusions–comments	Level of Evidence
Bunch et al. 2004	Retrospective (5 y): n = 5375 CAD; mean age 61 + 12 y; 40% women	During GXT, 1272 developed atrial ectopy, 185 SVT, 43 AF	Occurrence of atrial ectopy during exercise test predictive of MI; however, not significant after adjustment for known adverse CV predictor outcomes. Long-term cardiac death or revascularization not influenced by development of stress-induced atrial arrhythmias.	3
Furui et al. 1987	Case control: lone AF	Not reported	Enhanced platelet activity and lower anticoagulant anti-fibrinolytic activity were observed in patients with lone AF at rest and after near maximum treadmill exercise. Hypercoaguable state may reflect risk of thromboemboli, suggesting risk is enhanced with exercise.	3
Goette et al. 2004	RCT: n = 26; mean age 53 y; 5% women	Not reported	Heavy PA increases the procoagulatory state in patients with AF. Heavy exercise may be an additional risk factor for atrial thrombus; however, this is currently speculative. Extreme exercise should be assessed as a risk factor for thromboembolism and stroke in larger cohorts of patients with AF.	2
Hegbom et al. 2006	RCT: n = 30; mean age 64 y; 4% women	Reported as none	Short-term training improved exercise capacity and QOL; 2 months of exercise improved exercise capacity, HR variabilty, QOL in chronic AF patients. HR at rest and during exercise decreased.	2
Mertens 2006	Cohort: n = 20; mean age 61 y; 35% women	Not reported	Patients with chronic AF can achieve significant functional gains from exercise rehabilitation program	3
Mont et al. 2002	Case control: n = 70; mean age 46 y; 0% women	Lone AF,<65 y; 32/70 engaged in long-term sport	A high proportion of men with lone AF (63%) had practised sport regularly for many years. This is much higher than the number expected based on sport practise in the general population (15%). Limitation: possible selection bias.	3
Vanhees et al. 2000	Retrospective case control: n = 63; mean age 63 y;, 8% women	2 cardiac deaths, 1 stroke in AF group (n = 19); all at least 48 h postexercise	Benefits: exercise training (3× a week for 3 mo) increased $\dot{V}O_2$ and performance; AF sign independent predictor of $\dot{V}O_{2\ peak}$ but not of change	3

Note: AF, atrial fibrillation; GXT, graded exercise testing; CAD, coronary artery disease; QOL, quality of life; $\dot{V}O_2$ oxygen consumption; SVT, supraventricular tachycardia.

Areas of research requiring additional evidence

As indicated in the introduction, further research to identify the range of settings, the type and intensity of supervision, and the forms of exercise that produce acceptable ratios of risk/benefit will be useful in guiding and informing choices made by patients and health practitioners. Research that prospectively explores the effects on the risk of increasing the acceptable range of options will be critical.

The majority of evidence documents the net benefit of PA participation or prescribed exercise. Studies are required that directly compare the risk of events at rest and during acute exercise in CVD patients who are sedentary and in CVD patients who are regularly active. Delineation of the impact of exercise type and intensity on risk in patients who differ in age and aerobic fitness will assist in the development of future recommendations. Studies of the way etiology and pathology affect prognosis would be particularly useful if they distinguish between events that are exercise-associated and those that are not. Careful, and likely CVD-population-specific, definitions of what constitutes minor and serious adverse events are required. Further refinement of study designs to assess the impact of setting and supervision would provide greater confidence for allied health practitioners and those responsible for community-based PA programs.

Medications to treat CVD may reduce the risk of adverse events, both at rest and during exercise. Studies that identify how they interact with acute and chronic exercise to modify the incidence of adverse events and risk/benefit ratios are required.

Studies to examine specific issues related to the identified patient groups (cardiac, hypertension, chronic HF, and arrhythmias) are required, as is extension of the systematic assessment for additional conditions, including claudication, congenital heart disease, and CVD risk factors such as lipidemia. Studies of people with multiple morbidities are required in light of their high prevalence and the association of CVD with conditions such as diabetes (Riddell and Burr 2011), respiratory disease (Eves et al. 2011), and stroke (Zehr 2011), particularly as individuals age.

Our underlying hypothesis that less onerous clearance procedures will lead to increased participation while maintaining participant safety requires careful examination. While current evidence suggests that physician visits and laboratory testing is a barrier to participation, the impact of reducing those barriers has not been systematically assessed. Patient preferences for exercise setting and supervision may differ by age, pathology, gender, ethnicity, and socioeconomic status (Jolly et al. 2007).

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