The Risk in Exercise Training

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Although exercise training is unequivocally of benefit relative to the risk of cardiovascular disease, there is a definable risk of complications during exercise training. In younger individuals, the risk is almost exclusively related to the presence of congenital abnormalities, whereas in older (~40 years) individuals, the risk is largely related to atherosclerotic disease. In both groups, the risk of the underlying pathology leading to clinical presentation is increased by higher intensity exercise. In older individuals, preexercise screening is of potential benefi t but is not generally well done. Exercise prescription should favor lower intensity exercise during the early weeks of an exercise program. Subjective methods, which do not rely on the results of an exercise test, including the Rating of Perceived Exertion and the Talk Test, are to be recommended because preliminary exercise testing is performed inconsistently. There are inadequate data regarding the spontaneous exercise training intensity in both healthy individuals and patients.

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The Risk in Exercise Training

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Abstract: *Although exercise training is unequivocally of benefit relative to the risk of cardiovascular disease, there is a definable risk of complications during exercise training. In younger individuals, the risk is almost exclusively related to the presence of congenital abnormalities, whereas in older (~40 years) individuals, the risk is largely related to atherosclerotic disease. In both groups, the risk of the underlying pathology leading to clinical presentation is increased by higher intensity exercise. In older individuals, preexercise screening is of potential benefit but is not generally well done. Exercise prescription should favor lower intensity exercise during the early weeks of an exercise program. Subjective methods, which do not rely on the results of an exercise test, including the Rating of Perceived Exertion and the Talk Test, are to be recommended because preliminary exercise testing is performed inconsistently. There are inadequate data regarding the spontaneous exercise training intensity in both healthy individuals and patients.*

Keywords: exercise training; myocardial infarction; sudden death; exercise prescription

The statement that "exercise is good for you" is, in the first decade of the 21st century, noncontroversial. The volume and quality of data that demonstrate the positive health outcomes associated with either an active lifestyle[1,2] or with systematic exercise training in either healthy individuals[3] or patients with cardiovascular disease[4-6] is substantial. This concept is supported by an organizational theme used by the American College of Sports Medicine, "Exercise Is Medicine," which suggests that the health impact of regular exercise[7] is of the same order of magnitude as the benefits of pharmacologic therapy for hypercholesterolemia,[8] hypertension,[9] and smoking cessation.[4] Guidelines,[10] whether for habitual activity or structured exercise training, have been widely accepted, and there are extensive public health recommendations regarding exercise training.[11,12]

However, regardless of the benefits of exercise, there is an appreciable risk of significant morbidity and mortality during exercise. Because complications during exercise represent a "man bites dog" situation, they are highly visible and widely reported. The topic has been reviewed by us[13] and has been the subject of a recent Scientific Statement from the American Heart Association, in collaboration with the American College of Sports Medicine.[14] The risk of exercise must be interpreted against the context of classic data from the Framingham heart study demonstrating that the first presentation of cardiovascular disease is fatal in 33% of men and 10% to 15% of women. Thus, the risk of exercise, which might serve to provoke the presentation of cardiovascular disease, is not trivial. The purpose of this review is to summarize the available data concerning the risk of significant complications during exercise and to suggest strategies that clinicians can use to help their patients achieve the benefits of exercise while minimizing the risk of complications.

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Substrate for Exertional Complications

Exercise-related complications are usually observed in individuals with structural heart disease. In younger individuals, the structural heart disease is usually limited to congenital abnormalities, primarily hypertrophic cardiomyopathy; however, other common abnormalities include coronary artery abnormalities, aortic stenosis, mitral valve prolapse, aortic dissection/rupture, arrhythmogenic right ventricular cardiomyopathy, and long QT syndrome.[15-17] Myocarditis is also associated with exertion-related morbidity/mortality in young individuals. With the exception of aortic dissection/rupture associated with Marfan syndrome, most of the deaths in young individuals are arrhythmic in origin and present suddenly. Last, *comito cordis*, associated with chest wall trauma in young athletes, can provoke sudden death.[16]

In older individuals, exertion-related complications can result from congenital abnormalities but more typically are related to the sequelae of atherosclerotic coronary artery disease. The usual age of demarcation of "older" is 40 years, although some individuals with inherited lipoprotein abnormalities can develop atherosclerotic disease quite early in life. Although autopsy studies from deaths occurring in soldiers killed in combat have indicated that individuals in their late teens and early 20s may have significant atherosclerotic disease, it is comparatively rare for atherosclerotically mediated exertion-related complications to present prior to age 40.

Mechanism of Sudden Death

In adults who have been asymptomatic, the most common mechanism of exertion-related complications is rupture of atherosclerotic plaques, leading to rapid thrombus formation and near-total occlusion of the affected coronary artery downstream from the plaque.[18-23] Lesions of moderate severity, with a relatively lipid-rich matrix under the atherosclerotic plaque, are more likely to rupture. More mature lesions and/or high-grade lesions may contribute to exertional angina pectoris or may lead to slow thrombus formation, but they are comparatively less likely to provoke the sudden events that provoke acute myocardial infarction during exercise. The causative mechanism of plaque rupture is still uncertain. A variety of causes have been proposed, including mechanical wall sheer stress, flexing of the coronary arteries secondary to more vigorous contraction of the myocardium, or swelling due to increases in blood flow down the coronary artery. Fissures at the edge of atherosclerotic plaques are not uncommon[21,22] and may be increased by mechanical loading during exercise. In addition, catecholamine-induced vasoconstriction and platelet aggregation have been proposed as mechanisms during higher intensity exercise.[24] In this context, it is important to recall that catecholamine accumulation is more related to the relative, than to the absolute, exercise intensity. Accordingly, the often cited 6-MET (metabolic equivalent) definition of high-intensity exercise is probably a less than ideal definition. Indeed, in patients who develop exertional ischemia, the intensity of exercise is often greater than that at the ventilatory threshold.[25]

Although most exertion-related complications are related to acute coronary syndromes, exertional ischemia secondary to high-grade coronary lesions can provoke arrhythmias, even in the absence of plaque rupture. Particularly in individuals with a myocardial scar related to an old myocardial infarction, the scar can provide an arrhythmic substrate, particularly if coupled with exertional ischemia. Interestingly, plaque rupture in individuals who have not had a prior myocardial infarction often leads to acute myocardial infarction, chest discomfort, and circulatory collapse. In individuals with a residual scar from an old myocardial infarction, the same plaque rupture is more likely to cause an arrhythmia.

Incidence of Exertion-Related Events

In young athletes, the absolute rate of exertional sudden death may be on the order of 1/100 000 athletes,[26] although recent Italian studies suggest a higher rate of 1/33000 athletes.[27] Differences in the reported incidence may be related to whether the sudden death occurs during exertion or simply in an athlete, regardless of whether he or she is exercising at the moment.

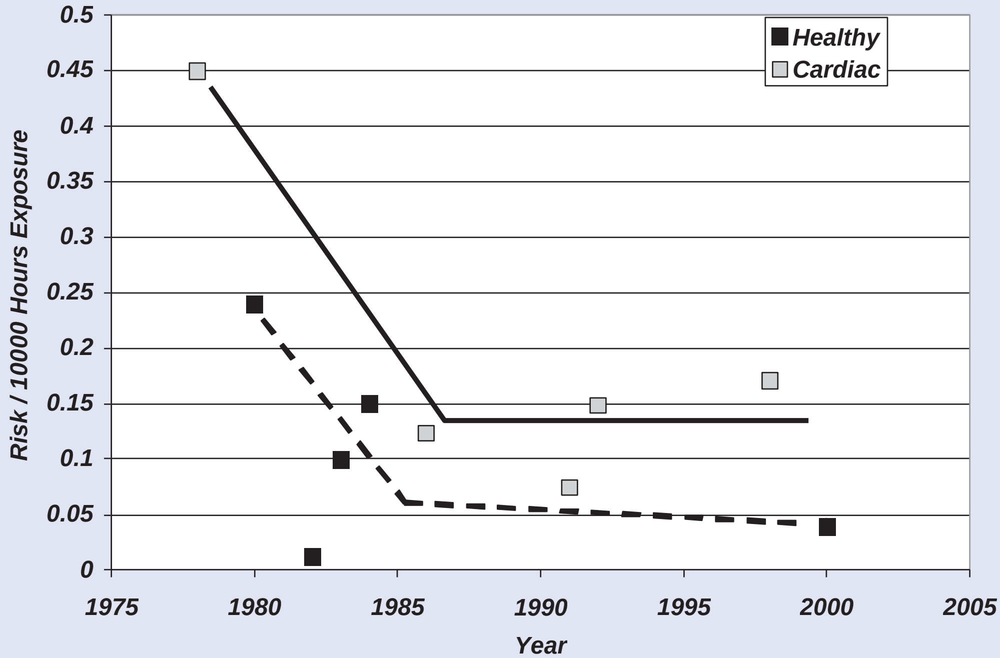
Complication rates in adults, whether healthy or with known cardiovascular disease, have generally been viewed in terms of person-hours of risk. In this regard, it is probably more appropriate to convert the risk into the number of life-threatening complications occurring per 10 000 hours because this is more comparable to the risk of graded exercise testing, which is more familiar to most physicians. Classic studies by Rochemis and Blackburn[28] suggest a fatal or life-threatening complication rate of 6/10 000 tests. Assuming a period of risk from the test and the immediate posttest period of ~30 minutes, this yields a serious complication rate of ~12/10 000 hours. More recent estimates from Myers et al[29] suggest a complication rate of ~1.5/10 000 tests, or ~3/10 000 hours. There appears to have been a significant decline in the complication rate during exercise training across time in both patients[30-34] and healthy individuals[18,20,35-37] (Figure 1). The improved safety is likely attributable to several sources, including better identification of individuals who should not exercise, better education about prodromal symptoms, and a more conservative approach to exercise prescription (eg, lower intensity at the beginning of exercise programs). In any case, the complication rate during exercise training is ~20 times less than during exercise testing in patients with known cardiovascular disease, for whom comparable risk estimates can be made. As detailed below, the incidence of exertion-related complications is lower in more active individuals.

Cause of Complications

The risk of complications during exercise is generally predictable and, at least in sedentary adults, is related to exercise intensity. Classic studies from Willich et al,[38] Mittleman et al,[39] and Albert et al[40] have shown that the risk of triggering an acute myocardial infarction during exercise is positively related to unaccustomed heavy exertion (using 6 METs as a reference in adult populations who typically have an exercise capacity of 8-10 METs). In this regard, 6 METs can be understood to include exercise intensities that are likely to be greater than the highest achieved

Figure 1.

Temporal risk estimates, expressed as incidents per 10 000 hours of exposure, based on various reports of fatal and life-threatening complications during exercise training in healthy individuals[35-37] and patients with cardiovascular disease.[30-34]



by very fast walking. The importance of unaccustomed severe exercise as a trigger for acute myocardial infarction is reinforced by the data of Franklin et al[41-43] showing the risk of snow removal. This concept is consistent with the data from Hassock and Hartwig,[44] who demonstrated that the risk of complications in early cardiac rehabilitation programs was related to exercising with myocardial ischemia. More recent data from Franklin et al[45] have shown that essentially 50% of the exertion-related complications in healthy individuals occur during the first few exercise bouts. It is arguable that the low complication rates observed in patients with known cardiovascular disease in exercise-based rehabilitation programs are attributable to the conservative use of exercise intensity during rehabilitation programming. Furthermore, it is arguable that the tendency to walk rather than run at the beginning of exercise programs by healthy individuals is substantially responsible for the reduction in the risk of exercise by healthy individuals. It is notable that many of the early reports of exertion-related sudden death were made in the years following the substantial increase in adult exercise following the publication of Cooper's *Aerobics*[46] in the late 1960s. Despite the presence of tables in this classic work suggesting the value of walking, the dominant exercise idiom of the time was "jogging," which probably has a minimal intensity requirement of 8 to 10 METs (eg, nearly maximal for the average sedentary middle-aged man).

Preexercise Screening

Given the importance of underlying structural heart disease as a risk factor for complications, as well as the presence of unequivocal professional society recommendations,[47] it is remarkable that the evidence consistently indicates that health and fitness facilities are inconsistent at the process of screening. McInnis et al[48,49] have shown that screening procedures at health and fitness facilities in both Massachusetts and Ohio probably identify less than half the individuals at risk for exertion-related complications, and even those who are identified are not properly processed. Given that simple preexercise screening tools are widely available, it is surprising that the ownership of many health and fitness facilities has actively resisted efforts to improve screening and supervision.

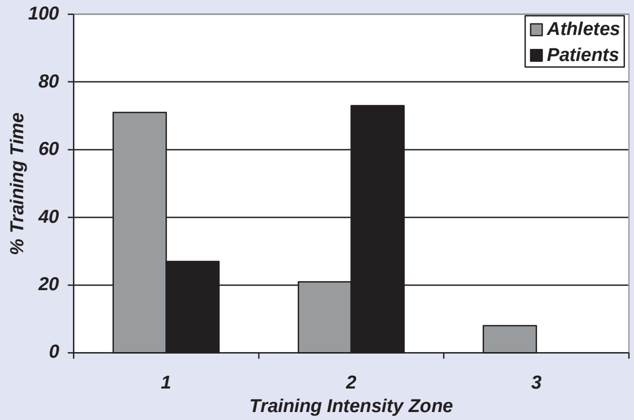
Similarly, given the accepted value, economic practicality, and the presence of professional society position statements[50]—and indeed laws in some states—it is essential to expect that health and fitness facilities have automated external defibrillators, which their staff are trained to use.

Exercise Prescription

It is clear that the risk of complications during exercise is related to exercise intensity. Regardless of whether the substrate contributing to the risk is from congenital abnormalities or from acquired atherosclerotic disease, complications are much more frequent when exercise intensity is

Figure 2.

Percentages of training time at easy (eg, below the ventilatory threshold, zone 1), moderately hard (eg, between the ventilatory and respiratory compensation thresholds, zone 2), and hard (eg, above the respiratory compensation threshold, Zone 2) intensities in athletes[62] and in a sample of patients in a cardiac rehabilitation program. The difference in pattern, primarily in the relative percentage of zone 2 training in the patients, is remarkable.



high. The "gold-standard" method of exercise prescription is based on a percentage of either maximal exercise capacity or maximal heart rate achieved during an exercise test.[10,11] However, the number of individuals who have had a recent exercise test, even within clinical populations, is comparatively low. Age-predicted maximal heart rate, although useful in terms of interpreting exercise test results,[51] is not particularly useful in terms of exercise prescription and may even increase the risk of complications in individuals with low maximal heart rates. Accordingly, subjective methods of exercise prescription are probably the method of choice for most individuals.

The 2 best subjective methods are perceived exertion (RPE) and the talk test. Perceived exertion can be judged from 1 of 2 widely accepted scales.[52,53] These are tied to verbal anchors of perceived exercise intensity. In the simplest scenario, if the RPE is associated with terms such as *easy*, the exercise intensity is probably too low to provoke adaptations to training. If the RPE is associated with terms such as *hard*, then exercise intensity is probably too high to ensure either safety or good compliance with the exercise prescription. Verbal anchors such as *moderate* and *somewhat hard* are appropriate for most exercisers. In a general sense, RPE works well for about 90% of individuals. People who seem to have particular difficulty with appropriately using the RPE scale are those who are muscularly strong. These individuals will often underrate the intensity, as they tend to cue on muscular tension rather than breathing effort. The talk test is an old concept[54] that has been studied systematically recently.[55-59] The highest intensity at which speech is just "comfortable" is close to the ventilatory threshold in a variety of individuals ranging from patients with cardiovascular disease to athletes,[55-59] and the ability to speak comfortably appears to be lost prior to the development of ischemia in patients who develop exertional ischemia.[59] The technique appears to work well with different types of ergometry[58] to track changes in ventilatory threshold[60] and to work with a variety of speech-provoking stimuli.[61] Given its simplicity and potential for avoiding exertional ischemia,[59] the talk test may be very useful in terms of improving the safety of exercise training.

Any exercise prescription is only as good as the professional who is delivering advice to the prospective participant. Because few states have professional licensure for exercisephysiologists, it is sometimes hard to decide who to seek for advice. Even formal academic training in physical education, kinesiology, or sports science is inconsistent in terms of producing a reliable exercise professional. Probably the best recommendation is to determine whether the exercise professional who is developing the exercise prescription is certified, on the basis of a competency-based examination from a society accredited by the National Commission for Certifying Agencies (NCCA). At the present time, certifications from one or more of the following can be taken as evidence of reliable qualification: the American College of Sports Medicine, the American Council on Exercise, the Cooper Clinic, the National Academy of Sports Medicine, the National Strength and Conditioning Association, the National Council on Strength and Fitness, and the National Federation of Professional Trainers.

How Do Patients Train?

Given the nontrivial risk of complications during exercise training, as well as the association between exercise intensity and training risk, there are surprisingly few data in the literature regarding how hard patients and healthy individuals actually exercise during training. In athletes, it is common to record heart rate continuously and to normalize the heart rate response to metabolic zones defined by the ventilatory and respiratory compensation thresholds measured during exercise testing. On this basis, the heart rate response during competition[62,63] and training[63] has been reported. Remarkably, athletes spend the majority (~70%) of their training time at low relative intensities, about 20% at moderately hard exercise intensities (eg, between the ventilatory and respiratory compensation thresholds), and about 10% of their training time at high relative intensities (eg, above the respiratory compensation threshold). There are few similarly collected data in individuals training for general fitness or in patients in cardiac rehabilitation programs. Preliminary data that we have collected in a rehabilitation program are presented in Figure 2. These patients had performed a graded exercise test without evidence of exertional ischemia. Still, it is remarkable that an appreciable percentage of their training was at moderately hard intensities (eg, zone 2, between the ventilatory and respiratory compensation thresholds). Given that other middle-aged individuals with clinically occult cardiovascular disease may not have the natural reluctance to undertake higher intensity training as patients with known pathology, it is not surprising that inappropriately high exercise intensity is still a common observation.

Summary

1. Exercise training is generally quite safe. Although a certain number of complications are associated with exercise training, the rate is probably no greater than 0.2/10 000 hours.
2. In younger individuals, complications are associated with congenital abnormalities. In older individuals, complications are usually associated with underlying atherosclerotic disease, whether known or occult.
3. Complications are primarily related to inappropriately high intensity, particularly in beginning adult exercisers.
4. Unless exercise test results are available, exercise prescription based on either RPE or the talk test appears to be the most defensible method of prescribing exercise training intensity.
5. If exercise is conducted at a health/fitness facility, the recommendations of the American College of Sports Medicine and the American Heart Association are reasonable and defensible. These recommendations include appropriate preexercise screening to identify individuals who should consult their physician prior to exercise and the availability of automated external defibrillators.
6. As in any other aspect of health care, appropriately trained staff are essential to minimizing the risk of exercise training. In the absence of licensure for exercise professionals, individuals certified from an organization endorsed by the NCCA is the best advice. These organizations include the following:

   American College of Sports Medicine

   American Council on Exercise

   Cooper Clinic

   National Academy of Sports Medicine

   National Strength and Conditioning Association

   National Council on Strength and Fitness

   National Federation of Professional Trainers

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