REVIEW ARTICLE

The Risks of Exercise Training

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Increased levels of physical activity, including structured exercise programming, are widely believed to be one of the most beneficial and cost-effective interventions for patients who have cardiovascular disease or are at risk for its development. There are a wide variety of epidemiologic[1-3] and intervention[4-6] studies demonstrating that a physically active lifestyle is related to a reduced incidence of cardiovascular disease development, an improved prognosis in patients with established disease, and an improved functional capacity. Data from meta-analytic studies of randomized trials,[4,5] intervention studies,[7-9] and more recent cost-effectiveness studies[10,11] have demonstrated the value of formal exercise and risk factor management programs in patients with established cardiovascular disease. It seems conservative to assert that the agreement within the healthcare community that "exercise is good for you" is nearly as universal as the assertion that "smoking is bad for you."

And yet, bad things occasionally happen during exercise. A number of individuals either die or have a myocardial infarction during exercise. Because of the incongruity of exercise-related cardiovascular complications, such events become newsworthy because they represent a "man bites dog" type of event. Beyond their immediate impact on the stricken individual, such events erode confidence in the importance of lifestyle change as a therapeutic tool in the prevention and treatment of patient's cardiovascular disease. The purposes of the following discussion are to provide perspective regarding fatal and life-threatening complications during exercise training in adults with or without known cardiovascular disease, identify the factors that might predispose adults to such complications, and examine how the exercise industry is addressing these risks.

Bad outcomes during exercise training are related to several causative factors. Exercise-related death in the young is primarily related to undiagnosed congenital abnormalities, drug use, or trauma. Although quite tragic when it occurs, the incidence of such events is rare. However, it is not the main focus of this discussion and has been reviewed adequately elsewhere.[12]

The historical risk of exercise-related complications in adults dates to antiquity, at least to the time of Phillapides' death after his historic marathon-length run to report victory over the Persians. As long ago as the 19th century, there was concern regarding the risk of overexertion injuries during rowing competitions in England. In contemporary times, concern regarding the risk of exercise increased after the quantum jump in fitness exercise by the adult public after the publication of *Aerobics* by Cooper[13] in 1968. Several reports during the decade after the publication of *Aerobics* suggested that there appeared to be a noticeable association between acute myocardial infarction and/or sudden death immediately preceded by heavy exertion.[14-17] This same literature demonstrated that most of the exertion-related deaths in adults were related to previously undiagnosed atherosclerotic coronary artery disease. In 1993, in a pair of papers published in the same issue of the *New England Journal of Medicine*, Mittleman et al[18] and Willich et al[19] demonstrated that unaccustomed heavy exertion was related to the triggering of acute myocardial infarction, with the risk being mostly during the exertion itself or in the hour after exertion. These same studies demonstrated that the relative risk from heavy exertion was strongly influenced by the individ-

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ual's habitual exercise pattern. Individuals who exercised frequently were much less likely to trigger a myocardial infarction than individuals who were relatively sedentary. In a follow-up study, Albert et al[20] demonstrated that habitual exercise strongly decreased the risk that unaccustomed vigorous exertion would trigger sudden death.

Death during recreational exercise is predominantly related to atherosclerotic disease. Rogosta et al[21] demonstrated that 88% of exertion-related deaths were consistent with atherosclerotic disease, and that only 7% of the deaths were in individuals with no known history of or risk factors for atherosclerotic disease. This suggests that a significant percentage of these exertion-related deaths might have been prevented if appropriate screening had been used. In the presence of atherosclerotic coronary artery disease, exercise-related deaths are primarily related to plaque rupture and thrombus formation, leading to myocardial infarction or arrhythmia. In individuals with no prior history of cardiovascular disease, the presentation is primarily acute myocardial infarction over sudden cardiac death, by a nearly 7:1 ratio. However, in patients with known cardiovascular disease sudden cardiac death, presumably from scar-related arrhythmia, is the more common presentation, by a 5:1 ratio over acute myocardial infarction.[22-24]

Understanding the risk of life-threatening emergencies during exercise training is complicated by the way in which the risk is computed. Most physicians and healthcare workers are accustomed to reporting the risk of graded exercise testing, which is approximately 6 in 10,000 tests according to the classic data of Rochimis and Blackburn,[25] but is significantly less in more recent studies.[26,27] However, studies of the risk of exercise training generally report the risk of exercise training in terms of events per participant hours. This represents something of an apples-and-oranges type of comparison that is hard to put into perspective. In this review, we have converted the risk of both exercise testing and exercise training into the common units of events per 10,000 participant hours. To do this we have assumed that the risk period for exercise testing is 0.75 hours (0.25 hours for testing and 0.50 hours for recovery). We have taken the reported risk for exercise training at face value because it appears from the studies that the time base included both exercise and recovery at the facility. On this basis, the risk of life-threatening complications for both exercise testing and exercise training has been calculated in common units. The key numbers to remember for contemporary exercise testing appear to be approximately 1.59/10,000 hours for clinically indicated exercise tests[26] and 1.06/10,000 hours for screening exercise tests.[27] It is important to note that the risk of exercise testing has been getting safer, thus the denominator of the equation comparing exercise testing and exercise training is not entirely constant.

The earliest large report of the risk of exercise training in patients with known cardiovascular disease appears to be that of Haskell in 1978.[24] His report was based on a survey of several gymnasium-based rehabilitation programs (Phase III-IV in today's classification system). At the time, many of these programs had minimal monitoring capabilities and included patients who had residual ischemia and would be considered high risk based on contemporary classification schemes.[28] He noted a risk of complications during exercise of 0.45/10,000 hours (Figure 1). This risk is approximately 17 times less than graded exercise testing according to the contemporaneous data of Rochemis and Blackburn[25] (Figure 2). Significantly, during the same time period, Hassock and Hartwig[29] evaluated risk factors for complications in a gymnasium-based rehabilitation program. They observed that patients with one or more risk factors including relatively well preserved exercise capacity, significant ischemia during exercise testing, persistence of ischemia into the recovery period after exercise testing, and frequent violation of the target heart rate during exercise training were the patients most likely to have complications during exercise training. In simple terms, exercise training in the presence of significant myocardial ischemia appeared to be a prime risk factor for exertion-related complications.

In a more recent review of the risk of complications during outpatient rehabilitation, which included monitored programs and patients with the revascularization and medical options of the early 1980s, Van Camp[23] observed a risk of complications during exercise training of 0.08/10,000 hours, which is 19 times less than the now-reduced risk estimates for graded exercise testing (Figures 1 and 2). The most recent estimates of the risk of complications during cardiac rehabilitation programs (0.08-0.15/10,000 hours) is substantially unchanged from Van Camp's estimate,[30-32] which is 10 to 17 times less than graded exercise testing. With the development of new models for delivering monitored rehabilitation, including transtelephonic monitoring, the risk appears to be somewhat higher than in facility-based programs but still quite low at 0.42/10,000 hours,[33] which is four times less than graded exercise testing.

Estimates of the risk of exercise-related complications in healthy adults is more complex in that many reports have focused on deaths, whereas the data from rehabilitation programs generally include both death and life-threatening complications. From a series of early studies, the risk of death during exercise in apparently healthy individuals appears to range from 0.01 to 0.20/10,000 hours, which is anywhere from 6 to 90 times safer than the standard risk of clinically indicated exercise tests, or 1 to 60 times safer than the lower risk of graded exercise testing conducted for screening purpose.[34-37] In very well-screened individuals and with fully qualified exercise leadership,

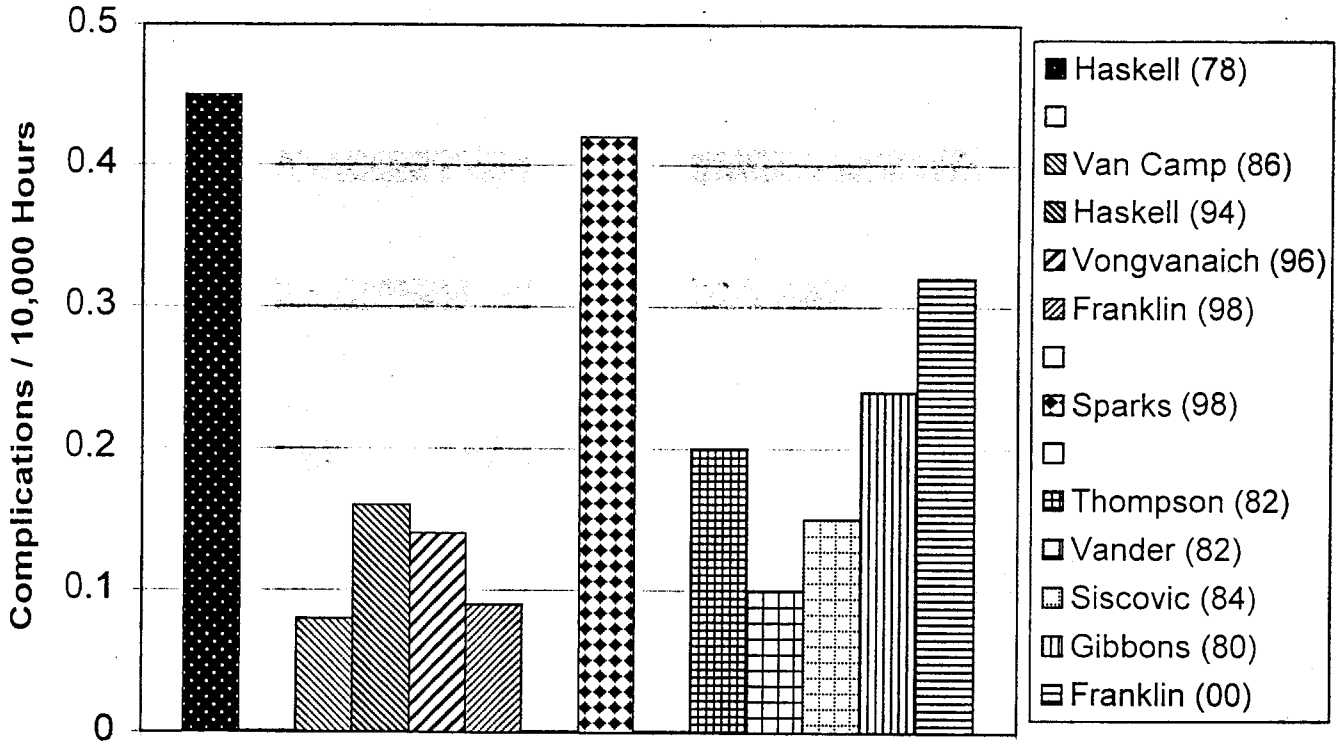

Figure 1. Risk of serious complications during exercise training per 10,000 patient hours in patients with cardiovascular disease (left) and healthy individuals (right). The number next to each author's name denotes the year of publication. Note that the absolute risk in patients is, if anything, less than in healthy individuals. Also note the markedly lower rate of complications in rehabilitation programs after the beginning of the 1980s, potentially attributable to better clinical experience with exercising patients, more stable patients given the surgical and pharmacologic options developed during the 1980s, and the availability of telemetry during exercise sessions.

Gibbons et al[38] reported a risk of death of 0.03/10,000 hours in healthy individuals. Assuming that the risk of life-threatening complications is approximately seven-times the risk of death, then the risk of fatal and life-threatening complications in healthy individuals is approximately 0.24/10,000 hours, which is actually higher than that observed in contemporary cardiac rehabilitation populations (0.10/10,000 hours). However, because healthy individuals are likely to be performing higher intensity exercise, and with less professional supervision than patients in rehabilitation programs, this does not seem unreasonable. The most recent data in healthy individuals are based on a retrospective review of member deaths in a large commercial health club chain,[39] which approximates 0.04 deaths/10,000 hours. Assuming a 7:1 complication: death ratio, the net risk of complications is approximately 0.32/10,000 hours, which also is higher than observed in cardiac rehabilitation populations. Significantly, in this data set a large proportion of the deaths were in members who exercised infrequently or who had only recently begun to exercise, which is consistent with the data on triggering myocardial infarction by exercise[18-20] and on the risk-related to exercise above the ischemic threshold.[29] Further evidence of the risk of unaccustomed strenuous exercise can be found in the data concerning snow shoveling as a trigger for acute coronary syndromes.[40]

To further understand the risk of exercise, one needs to appreciate the practical realities of 10,000 person hours. In an idealized world where each exerciser was exercising 30 minutes per day, 5 days per week, each person would accumulate 130 hours of exercise a year. On this basis, 77 individuals exercising for 1 year equals 10,000 person hours. Using a complication rate of 0.10/10,000 person hours, which seems to be the median for contemporary clinical populations, one would expect 1 complication per 770 participants per year. Assuming that each exerciser accumulates only 2.5 sessions per week, which seems more in line with reality, one might then expect one complication per 1500 participants per year. Using the most idealized complication rate of approximately 0.03/10,000 person hours in prospectively healthy, fully screened, and well-supervised participants, one life-threatening complication might be expected in every 2564 participants per year if one assumes a high frequency of exercise. If one assumes a lower frequency of exercise (2.5 sessions per week), then one complication might be expected in every 5000 participants. The higher risk estimate (1 in 2564) may be spuriously high as in the 2.9 million members evaluated by Franklin,[39] one would expect 1136

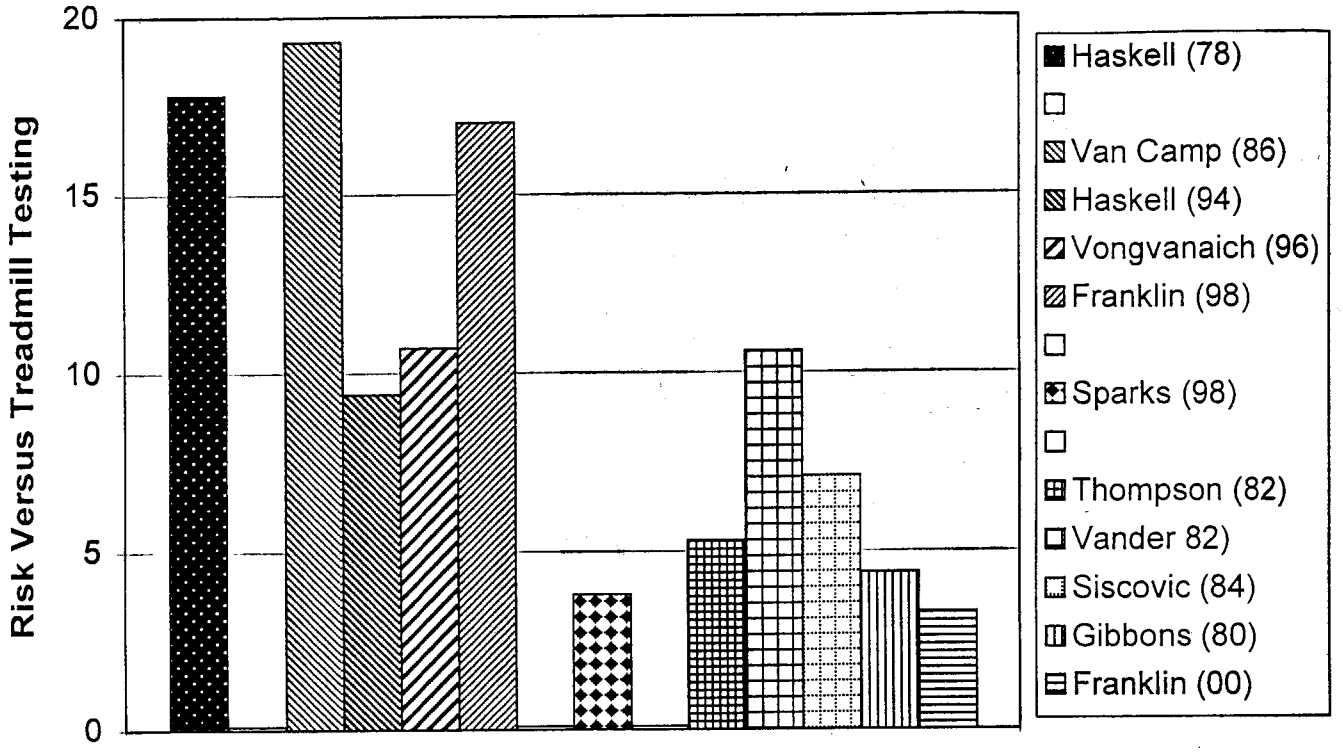

Figure 2. Risk of serious complication during exercise training in patients with cardiovascular disease (left) and healthy individuals (right), normalized to estimates of the risk of exercise testing contemporary with the report. Note that exercise training is relatively safer in patients than in healthy individuals, partially because the risk of exercise testing in this population is very low.

life-threatening complications, versus 71 fatal events and a projected 568 serious complications (at a 7:1 life-threathening:fatal ratio). However, at a lower frequency of exercise, and with an expected complication rate of 1 for every 5000 participants, Franklin's observations fit predictions reasonably well.

Can the risk of complications during exercise training be reduced? The data are in broad agreement that both exertion-related sudden cardiac death and acute myocardial infarction are related to pre-existing coronary artery disease, often not diagnosed, and that the risk strongly depends on exercise intensity. The data also broadly indicate that once the initial weeks of exercise are completed, more intense exercise is of less relative risk. These observations suggest that the two primary strategies for minimizing risk are appropriate screening of prospective exercisers to identify individuals with a high risk of occult coronary artery disease and appropriate control of exercise intensity, particularly during the first few weeks of an exercise program.

Given these recommendations, it is interesting to note that the health club industry does a very poor job of screening prospective participants. If only young and prospectively healthy individuals used these facilities, there might be less concern. However, there is clear evidence that the health club industry is attracting a progressively older clientele and is beginning to serve a significant number of patients with stable cardiovascular disease. McInnis et al[41] evaluated pre-enrollment screening at both association (eg, higher quality) and nonassociation health clubs in Massachusetts using a survey that addressed a description of the facility, the number and qualifications of the staff, the size and demographics of the membership (including whether special populations were being served) the programs offered, the policies and practice patterns for emergency procedures, and the history of emergency events. Disturbingly, they noted that only 61% of clubs always screen their participants, with the association clubs being no better than nonassociation clubs. Of the 61% of clubs that screened participants, only 49% required some sort of physician clearance when the screening indicated a potential problem. Of the 61% of clubs that screened clients, only 77% required some sort of physician clearance in clients with known cardiovascular disease. Clearly, despite clear professional society guidelines indicating that participants should be screened and that the patient's physician should be involved when screening indicates potential problems,[42] health clubs are not identifying potential problems before they get to the exercise floor. Most disturbingly, 45% of the clubs never practice or review emergency procedures, and only 24% practice more than twice a year. Recommendations from the American Heart Association/American College of Sports Medicine indicate that emergency practice should occur a minimum

of four times per year. Although still not very encouraging, association clubs did somewhat better than nonassociation clubs regarding staff qualifications: 43% versus 16% of clubs had fitness staff with at least bachelor's degree in a relevant major. However, in facilities that offered special programs for the elderly or patients with known heart disease, only 38% of facilities had fitness staff composed completely of individuals with formal academic training. Other, potentially more definitive, evidence of the professional competence of the staff such as professional society certification was not addressed in this study. In a more recent survey or 122 clubs in Ohio, representing more than 110,000 members and with special population programs offered in 52% of clubs, McInnis et al[43] found that 17% had a documented cardiovascular emergency in the previous 12 months. Despite this clear risk to the safety of their participants, 28% failed to use pre-entry screening, 53% had no written emergency plan, and 92% failed to practice quarterly emergency drills. Interestingly, 82% of the staff members were unaware of the AHA/ACSM guidelines,[42] and only 3% of facilities had automated external defibrillator. On the basis of these data, we can only note that it is a good thing that the risk of exercise is intrinsically low, because the health club industry is apparently doing little to reduce the risk.

Although abnormal screening exercise electrocardiogram findings do identify a population at an increased risk for activity-related acute cardiac events, the sensitivity of the procedure is not very high,[22] particularly for identifying unstable plaques that can rupture and lead to acute myocardial infarction. Thus, it may be argued that a preliminary period of comparatively lower intensity exercise training at the onset of a training program, which is known to be associated with a reduced risk of triggering acute events,[18-20] may be a more effective strategy for reducing the risk of exercise-related complications than screening exercise tests, which are likely to be too expensive to be practical in any case.

CONCLUSION

Although exercise-related acute myocardial infarction and sudden cardiac death occur with more than occasional frequency, the absolute risk is quite low. In general, the risk in patients with known cardiovascular disease participating in medically supervised programs is on the order of 0.10/10,000 patient hours, or approximately 10 to 12 times less risky than graded exercise testing in clinical populations. In this population sudden cardiac death is likely to be the predominant manner of presentation, which suggests that an appropriate emergency response system, including the ability to deliver electrical therapy, be in place. The risk seems to be higher in patients who have just begun to exercise or who develop significant myocardial ischemia during exercise, suggesting that well-qualified exercise leadership is essential in terms of minimizing the risk. Because there is some evidence that the physiologic ventilatory threshold occurs before the ischemic threshold,[44] and because simple monitoring strategies such as the ability to talk comfortably during exercise seem to mark the ventilatory threshold well,[45] it may be that keeping exercise intensity at a level where the patient is comfortable speaking may meaningfully contribute to the safety of exercise training. In apparently healthy individuals, the risk of exercise training may vary significantly. In well-screened and well-supervised individuals, it may be as low as 0.03/10,000 hours, although a risk of approximately 0.2/10,000 patient hours seems to be a more defensible median value, which is approximately four times less than the already low risk of exercise testing in this population. This risk is the same, or perhaps slightly higher, as in cardiac rehabilitation programs, probably because the intensity of training usually is higher, is much less well regulated, and the participants are very much less well screened than patients in rehabilitation programs. In this population, acute myocardial infarction seems to be the more likely presentation of complications. Complications are related to the frequency of exercise and how long the participant has been participating, with relatively inexperienced participants being at particular risk. Clearly, better screening of participants, improved supervision aimed at moderating the intensity of the early weeks of exercise, and the employment of demonstrably qualified staff will contribute to reducing this risk.

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