The Effectiveness Ratio: Refining Exercise Prescription for Optimal Health Benefit

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ABSTRACT

Exercise prescription is quantified based on frequency, intensity, time, type, volume, and progression, but differing injury rates associated with various modalities and types of exercise are often not accounted for. We propose an *effectiveness ratio*, a quantification of benefits associated with exercise relative to the injury risk associated with training. *Journal of Clinical Exercise Physiology.* 2016;5(2):28–31.

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The health benefits of a physically active lifestyle are well established, as individuals who exercise regularly exhibit reductions in all-cause and disease-specific morbidity and mortality relative to their sedentary counterparts (1). Moreover, certain types of exercise training can be as, if not more, effective than pharmacological interventions for mitigating metabolic and cardiovascular disease risk and progression (2). For example, the average reduction in systolic blood pressure with aerobic exercise training approximates that achieved with antihypertensive monotherapy (3). Consequently, some clinicians have advocated that the exercise prescription should be as prevalent and monitored in the clinic as drug prescriptions because patients serve to benefit from both types of prescriptions (4,5). Moreover, since exercise is a pleiotropic treatment—that is, it beneficially impacts multiple systems (e.g., cognitive, musculoskeletal, metabolic, cardiovascular)—one prescription for physical activity can be considered effective "polypharmacy" to optimize health.

Typically, the exercise prescription is based on what is known as FITT-VP recommendations; that is, a formula for routine exercise according to frequency, intensity, time, type, volume, and progression (6). For example, the American College of Sports Medicine (ACSM) advises the following for aerobic exercise:

> "Adults should get at least 150 min of moderate-intensity exercise per week. Exercise recommendations can be met through 30–60 min of moderate-intensity exercise (5 d per week) or 20–60 min of vigorous-intensity exercise (3 d per week). One continuous session and multiple shorter sessions (of at least 10 min) are both acceptable to accumulate desired amount of daily exercise. Gradual progression of exercise time, frequency, and intensity is recommended for best adherence and least injury risk" (6).

The ACSM has established similar guidelines for resistance and flexibility exercise and recommend that adults engage in "resistance training 2–3 d per week (each major muscle group, 60–70% of 1 repetition max [RM], 2–4 sets of 8–12 repetitions) and flexibility exercise training ≥2–3 d per week (10–30 s to the point of tightness or discomfort)" (6). The ACSM recommends tailoring these prescriptions based on expert opinion and review of the exercise literature for treatment of clinical conditions such as hyperlipidemia, hypertension, and coronary artery disease. Guidelines developed by other organizations and/or working groups, such as the American College of Cardiology (ACC); the American Heart Association (AHA) (7); the European Society of Cardiology (8); and the Joint National Committee on

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Prevention, Detection, Evaluation, and Treatment of High Blood Pressure (9) have taken a less specific approach towards prescribing exercise. Several of these guidelines, for example, have referred to the 2013 AHA/ACC Guideline on Lifestyle Management to Reduce Cardiovascular Risk, which advises that, to lower blood pressure and low density lipoprotein cholesterol (LDL-C), adults should engage in aerobic physical activity of "3 to 4 sessions per week, lasting on average 40 min per session, and involving moderate- to vigorous-intensity physical activity" (7).

To date, though, the exercise prescription literature lacks a critical piece of evidence: establishment and publication of injury rates. No physical activity is without risk of injury, no matter how small, just as no pharmacological therapy is without side effect, no matter how minimal. A critical step in the drug development process is to establish the side effects of a drug in order to determine whether the side effects exceed the therapeutic effects. As Glasgow et al. states, this phase "gets to the fundamental issue of efficacy versus effectiveness. A drug's efficacy is a measure of the ability of the drug to treat the condition for which it is indicated. It is not a statement about the drug's tolerability or ease of use. Effectiveness is a measure of how well the drug works and encompasses all three of these issues" (10). A similar approach then is to establish the "side effects" of exercise, which predominantly involves reporting of injury rates. If exercise efficacy is how well a type of exercise works in a standardized and supervised research setting, with trained exercise physiologists to modify training intensities and modalities accordingly, then exercise effectiveness will establish how well this type of exercise works in the standard patient in a population-based setting in which exercise is likely unsupervised (10). While the latter is impossible to predict with certainty, it can be estimated by establishing the likelihood that an individual will get injured performing a certain type of exercise within a fixed time period of initiating the exercise. Existing resources, such as those from the ACSM, provide recommendations dedicated to risk of exercise, risk stratification, and injury mitigation (6), but calculating or predicting exercise effectiveness when injury risk is taken into account is not commonly undertaken.

It is important to note that injury rates for various modalities of exercise and physical activity are difficult to assess because they differ by the definition of injury itself, the number of people involved, and the time engaged in activity (11). For example, injury reporting may include all events that reduce exercise participation, such as muscle strains or soreness, or may be limited to only severe events, such as fractures and muscle tears, that result in the individual being unable to participate in exercise for the duration of the reporting period. Organized sports injury data are often reported as incidence rates—injuries per hours played—whereas injury data from clinical trials may be reported as the percent of participants who dropped out due to injury (9). Moreover, many clinical trials of exercise interventions do not report injury rates. Equally problematic is the distinction between recurrent injuries and new injuries, as well as injury rates among experienced versus novice exercisers. Nearly 50% of sports-related injuries are estimated to be recurrences of previous problems, and newcomers to a sport are substantially more likely to be injured than individuals who have been training for many years (12,13).

Reporting of injuries is also confounded by poor reliability of reporting methodology (i.e., self-report versus survey data versus injury surveillance databases) as well as difficulty determining the true cause of the injuries (i.e., attributable to exercise itself or influenced by a combination of other environmental, physical, personal, geographical, or psychological factors). Therefore, the lack of rigorous evidence establishing injury rates from different modalities of exercise is likely attributable in part to the difficulty of quantifying injury. Nonetheless, available evidence suggests that injury rates differ widely between populations, exercise protocols, and modalities, ranging from reports of 5% over a year of biking (14) to 30% and 40% over a year of running and weightlifting, respectively (15,16). Similarly, data from military service members over a year show that injury rates vary from 45% for running to 8% for weight training and 3% for soccer (17). Although these data are limited to relatively healthy (and nonclinical) populations, they suggest that the effectiveness of an exercise prescription for treatment of cardiovascular and metabolic risk could differ from the efficacy of that exercise prescription when both health benefit and injury risk are taken into account.

Therefore, the field of exercise prescription for the treatment and prevention of disease will not produce fully complementary data to pharmacological studies or for successful and personalized exercise prescription until clinicians and patients can directly compare the benefit to risk for physical activities that differ according to frequency, intensity, time, type, volume, and progression. How can this be done? First, injury rates associated with exercise trials could be reported routinely and regularly. Second, we propose a possible methodology, termed the *effectiveness ratio*, in which the benefits of exercise for health outcomes are expressed as a ratio to injury rates for that type of exercise. This can be accomplished by calculating, for any physical activity intervention trial, both the change in health outcome as well as the number of participants who were injured during the exercise training protocol (attributable to the physical activity). For ease of calculation, both numerator and denominator could be published as the absolute value of the percent change, as has been demonstrated in the examples taken from published data (18,19) shown in Tables 1 and 2. Thus, the effectiveness ratio would be a unitless expression of the impact of various modalities of exercise on a health outcome when relative risk of injury is taken into account. This is particularly important for longer-duration exercise training trials, where injury rates tend to increase and contribute to subject dropouts and reduced compliance.

When this methodology is used, one can see that certain modalities of exercise may be more beneficial for cardiovascular and metabolic health due not to their absolute

TABLE 1. The impact on effectiveness ratio for evaluation of aerobic training, resistance training, or combined training on cardiometabolic risk markers in obese adolescents.[a]

	Exercise Training Group			Effectiveness Ratio[b]		
	Combined	Aerobic Only	Resistance Only	Combined	Aerobic Only	Resistance Only
n	75	75	78	—	—	—
Injury rate (%)	9	4	8	—	—	—
% Change from baseline						
WC	-4	-3	-2	0.44	0.75	0.25
BMI	-3	-2	-1	0.33	0.50	0.13
SBP	-1	-4	-3	0.11	1.0	0.38
DBP	-3	-4	-3	0.33	1.0	0.38

BMI = body mass index; DBP = diastolic blood pressure; SBP = systolic blood pressure; WC = waist circumference
[a]Description of exercise interventions: The training study lasted 6 months. The aerobic group exercised four times per week on treadmills, elliptical machines, or bicycle ergometers, progressing induration from 20 to 45 min per session and intensity from 65 to 85% of maximum heart rate. The resistance group exercised four times per week, performing seven exercises using weight machines or free weights, progressing from two sets of 15 repetitions at moderate intensity to three sets of eight repetitions at the maximum resistance that could be moved eight times. The combined group performed the full aerobic training program plus the resistance training program four times per week. Injury rates were reported by study authors as the percent of participants in each group reporting musculoskeletal injuries related to participation in the trial. Data and description of exercise intervention adapted from publication (18).
[b]Calculated as the percent change from baseline for each variable divided by the injury rate.

impact on health but their favorable effect in relation to low likelihood of injury. For example, as shown in Table 1, although changes in blood pressure, body mass index, and waist circumference among adolescents appear greater with 6 months of combined resistance and aerobic training compared to either resistance or aerobic training alone (18), the injury rates for combined aerobic and resistance training were approximately double that of aerobic training alone. Therefore, the effectiveness ratio supports a more beneficial impact of aerobic training alone for improving cardiometabolic health in this adolescent population. Similarly, Table 2 presents study data demonstrating that high-intensity interval training evokes similar blood pressure reductions, but a twofold greater maximal oxygen uptake improvement than sustained endurance training in men (19). However, when injury rates of interval training (which were almost double that of prolonged aerobic training) are taken into account with the effectiveness ratio, the favorable impact of high-intensity interval training in these healthy adults appears less compelling.

TABLE 2. Impact of effectiveness ratio for evaluation of high-intensity interval training versus prolonged moderate-intensity training on cardiovascular risk markers in untrained healthy men.[a]

	Exercise Training Group		Effectiveness Ratio[b]	
	Interval	Prolonged	Interval	Prolonged
n	8	9	—	—
Injury rate (%)	38	22	—	—
% Change from baseline				
SBP	-6	-6	0.16	0.27
DBP	-3	-6	0.08	0.27
VO_2max	14	7	0.37	0.32

DBP = diastolic blood pressure; SBP = systolic blood pressure; VO_2max = maximal oxygen uptake
[a]Description of exercise interventions: The training study lasted 12 weeks. The high-intensity training consisted of a 5-min warmup with light jogging followed by five intervals of 2 min of near-maximal running (heart rate above 95% of individual maximum at the end of the 2-min period; total exercise time per session = 20 min, including warmup). The prolonged running sessions consisted of 1 h of continuous running at 80% of individual maximum heart rate (19).
[b]Calculated as the percent change from baseline for each variable divided by the injury rate.

Admittedly, a concept such as the effectiveness ratio needs rigorous testing and discussion, especially in clinical populations, where information on injury rates over time is very limited and intensity of exercise may be lower. The effectiveness ratio is a simplified approach to assessing the benefits, risks, and adherence factors that influence the impact of exercise training on health outcomes. Much as pharmacological interventions need to balance the number needed to treat with the number needed to harm, exercise interventions should be evaluated with effect size considered relative to injury rates. Better establishment and publication of injury rates in exercise studies is a critical first step, such that injury rates are reported over the same time period over which health outcomes are assessed. With improvements in reporting and methodology, exercise as a prescription for good health may be optimized in much the same way that pharmacological therapy has been quantified—benefits in relation to costs—with the end result a more personalized, effective outcome for the patient.

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