Exercise Prescription Methods

POINT: Is it Time to Rethink Aerobic Exercise Prescription Methods?

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ABSTRACT

Exercise prescription is complex and can vary greatly. As well, methods have their own advantages and disadvantages. The purpose of this discussion is to consider if some of these methods should be modified. We look at the concept of the heart rate and oxygen intake reserve because it is recommended by the American College of Sports Medicine. *Journal of Clinical Exercise Physiology*. 2021;10(3):94–96.

INTRODUCTION

It is useful and appropriate to ask whether we should rethink aerobic exercise prescription methods. However, because there are many ways to prescribe exercise and many reasons for prescribing exercise (e.g., health, fitness, and performance), it is a complex task. No prescription method is perfect for all persons or even for the same person over time, as his or her interests, needs, goals, health, or fitness change.

This discussion focuses on methods based on exercise testing. When variables are estimated, there is so much variation that results may be useful to estimate a group average, but they cannot predict an individual's value. For example, Sarzynski et al. (1) compared maximal heart rate (HR_{max}) measured on 762 men and women aged 17 to 65 y in the HERITAGE study with 2 age-based estimates (Fox et al. (2) and Tanaka et al. (3)) and found that the standard error of estimate was 12.4 and 11.4 $b \cdot min^{-1}$ respectively; this is too large to be useful.

The factor with most variability when prescribing exercise is *intensity*. Absolute intensity (e.g., power output [PO], speed, $kcal \cdot min^{-1}$) can be the same for everyone, but how it relates to a maximal (e.g., $\dot{V}o_2max$) or submaximal (e.g., lactate threshold) anchor point can vary. When intensity is a percentage of a maximal anchor, there is wide variation in how that relates to a submaximal anchor and vice versa. Complicating the situation is that there is little agreement on which anchor points are best and in which situations (4).

Rather than comparing anchor points or relative exercise intensities or determining which are best, we will discuss some facts and problems with several methods so readers can decide if modifications are warranted.

One method of determining exercise intensity is based on HR at a given PO or $\dot{V}o_2$. People who exercise at a HR associated with the same $\%\dot{V}o_2max$ can vary substantially in training PO, rate of increase in PO over time, and improvement in $\dot{V}o_2max$ (5). Nevertheless, training does not affect the HR-$\dot{V}o_2$ relationship. While HR at the same PO decreased after training, HR at the same $\%\dot{V}o_2max$ did not change in more than 700 men and women, blacks and whites, aged 17 to 65 y with different initial $\dot{V}o_2max$ values and different responses to training. Thus, frequent testing is not necessary to adjust exercise prescriptions once HR has been determined relative to a person's $\dot{V}o_2max$.

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Swain et al. (6) suggested that the relationship between $\%\dot{V}o_2max$ and $\%HR_{max}$ might be affected by individual differences in maximal and/or resting values. One attempt to correct for this is the Karvonen formula (7), also known as HR reserve (HRR), which considers the range from resting to maximal HR. This same reserve concept was applied to $\dot{V}o_2$ by Swain and Leutholz (8).

There have been many studies looking at the relationships among $\%\dot{V}o_2max$, $\%HR_{max}$, %HRR, and $\%\dot{V}o_2R$ in different populations, and there is evidence for (8–14) and against (9,13,15–20) the validity of the reserve concept (which assumes that %HRR and $\%\dot{V}o_2R$ are equal) for prescribing exercise intensity.

Recently, Ferri Marini et al. (21) assessed the %HRR-$\%\dot{V}o_2R$ relationship using more than 400 maximal exercise tests performed by sedentary subjects in the HERITAGE study. They found that (a) the relationship was not 1:1 and (b) %HRR was higher than $\%\dot{V}o_2R$ at 30% to 90% $\dot{V}o_2R$, suggesting that actual metabolic demands are different than those expected with exercise intensities commonly recommended for healthy individuals and various clinical groups.

Although individual linear regressions between %HRR and $\%\dot{V}o_2R$ were very strong, high interindividual variability in slope and intercept was observed (21). This implies that a single population equation to predict HR or $\dot{V}o_2$ for an individual may be inaccurate.

Another consideration is that the transferability and validity of HR-$\dot{V}o_2$ relationships found during incremental exercise to prolonged exercise has been debated (22,23). Although transferability and validity may improve with specific exercise protocols (24,25), several time-dependent adjustments (e.g., cardiovascular drift and $\dot{V}o_2$ slow component, which induce increases in HR and $\dot{V}o_2$ over time (26)) occur during prolonged exercise and may alter the HR-$\dot{V}o_2$ relations.

In an unpublished study, Ferri Marini et al. studied 8 active males during randomly assigned exercise bouts (15 min at 60%HRR, 15 min at 80%HRR, 45 min at 60%HRR, and 45 min at 80%HRR). As expected, treadmill speeds decreased to maintain a constant target HR. Reductions were similar during the 15- and 45-minute bouts at the same intensity but greater at 80%HRR. The %HRR-$\%\dot{V}o_2R$ relationship was affected by exercise duration, and the 1:1 relationship was not present during longer exercise bouts. Thus, HR-$\dot{V}o_2$ relationships derived from incremental exercise tests may not be transferred to prolonged, constant-intensity exercise.

The American College of Sports Medicine (ACSM) recommends using either $\%\dot{V}o_2R$ or %HRR to establish intensity (27) because of their assumed 1:1 relationship during incremental exercise. The ACSM guidelines state that exercise intensity should be 55/65–90% HR_{max} or 40/50–85% $\dot{V}o_2R$ or HRR. The lower number reflects the suggestion that "quite unfit" people should start at lower intensities.

TABLE. Approximate mean ventilatory threshold and 40% $\dot{V}o_2$ reserve in 183 HERITAGE subjects with low levels of maximal oxygen intake ($\dot{V}o_2max$).

	$\dot{V}o_2max$ (mL·kg^{-1}·min^{-1})			
	30	25	20	15
Ventilatory threshold				
$\dot{V}o_2$ (mL·kg^{-1}·min^{-1})	16.8	14.8	12.4	9.8
$\%\dot{V}o_2max$	56	59	62	65
40% $\dot{V}o_2$ reserve				
$\dot{V}o_2$ (mL·kg^{-1}·min^{-1})	14.1	12.1	10	8.3
$\%\dot{V}o_2max$	47	48.4	50	53.3

This range of intensities corresponds well with mean $\dot{V}o_2$ at ventilatory threshold ($\dot{V}o_2vt$) relative to $\dot{V}o_2max$ ($VT\%\dot{V}o_2max$), which ranges from 52% in sedentary individuals to 85% in well-trained endurance athletes (28). However, ACSM guidelines did not consider the wide variance in $VT\%\dot{V}o_2max$. As an example, mean $VT\%\dot{V}o_2max$ of 432 sedentary subjects in HERITAGE was 55% (range: 34%–83%).

Unpublished data from 183 HERITAGE subjects with low initial $\dot{V}o_2max$ (15–30 mL·kg^{-1}·min^{-1}) show that less fit subjects had lower $\dot{V}o_2vt$ values that tended to level off at ~10–14 mL·kg^{-1}·min^{-1} (~3–4 Metabolic equivalents or METs). Interestingly, this is about the same level that Shephard (29) says is associated with activities of daily living. Because absolute values level off, while $\dot{V}o_2max$ decreases in less fit people, the relative values ($VT\%\dot{V}o_2max$) increase (see Table). Because "unfit" people already were doing enough to maintain VT at >50% $\dot{V}o_2max$ and because the 40% $\dot{V}o_2R$ values are less than their VT, it is uncertain whether lower intensities should be prescribed. For example, these HERITAGE subjects began training for 30 minutes at 50% $\dot{V}o_2max$ and had no problems.

Further complicating the discussion is the fact that genetics plays a role in determining how people respond to the same or different exercise programs (30). There are high, average, and low responders to training and no difference associated with sex, race (blacks and whites), age (17–65 y), or initial $\dot{V}o_2max$ (31). Thus, it is difficult to compare prescription methods.

Therefore, should we rethink how to prescribe exercise? As mentioned earlier, there is no perfect method and many factors to consider. Therefore, modify methods only if new information suggests that we should.

REFERENCES

1. Sarzynski MA, Rankinen T, Earnest CP, Leon AS, Rao DC, Skinner JS, Bouchard C. Measured maximal heart rates compared to commonly used age-based prediction equations in the Heritage Family Study. Am J Hum Biol. 2013;25(5):695–701. doi:10.1002/ajhb.22431

2. Fox SM, 3rd, Naughton JP, Haskell WL. Physical activity and the prevention of coronary heart disease. Ann Clin Res. 1971;3(6):404–32.
3. Tanaka H, Monahan KD, Seals DR. Age-predicted maximal heart rate revisited. J Am Coll Cardiol. 2001;37(1):153–6. doi:10.1016/s0735-1097(00)01054-8
4. Jamnick NA, Pettitt RW, Granata C, Pyne DB, Bishop DJ. An examination and critique of current methods to determine exercise intensity. Sports Med. 2020;50(10):1729–56. doi:10.1007/s40279-020-01322-8
5. Skinner JS, Wilmore KM, Krasnoff JB, Jaskólski A, Jaskólska A, Gagnon J, Province MA, Leon AS, Rao DC, Wilmore JH, Bouchard C. Adaptation to a standardized training program and changes in fitness in a large, heterogeneous population: the HERITAGE Family Study. Med Sci Sports Exerc. 2000;32(1):157–61. doi:10.1097/00005768-200001000-00023
6. Swain DP, Abernathy KS, Smith CS, Lee SJ, Bunn SA. Target heart rates for the development of cardiorespiratory fitness. Med Sci Sports Exerc. 1994;26(1):112–6.
7. Karvonen MJ, Kentala E, Mustala O. The effects of training on heart rate; a longitudinal study. Ann Med Exper et Biol Fenn. 1957;35(3):307–15.
8. Swain DP, Leutholtz BC. Heart rate reserve is equivalent to $\%\dot{V}o_2$ reserve, not to $\%\dot{V}o_2$max. Med Sci Sports Exerc. 1997;29(3):410–4.
9. Brawner CA, Keteyian SJ, Ehrman JK. The relationship of heart rate reserve to $\dot{V}O_2$ reserve in patients with heart disease. Med Sci Sports Exerc. 2002;34(3):418–22.
10. Byrne NM, Hills A. Relationships between HR and $\dot{V}o_2$ in the obese. Med Sci Sports Exerc. 2002;34(9):1419–27. doi:10.1249/01.MSS.0000027629.94800.17
11. Colberg SR, Swain DP, Vinik AI. Use of heart rate reserve and rating of perceived exertion to prescribe exercise intensity in diabetic autonomic neuropathy. Diab Care. 2003;26(4):986–90.
12. Dalleck LC, Kravitz L. Relationship between %heart rate reserve and $\%\dot{V}o_2$ reserve during elliptical crosstrainer exercise. J Sports Sci Med. 2006;5(4):662–71.
13. Davenport MH, Charlesworth S, Vanderspank D, Sopper MM, Mottola MF. Development and validation of exercise target heart rate zones for overweight and obese pregnant women. Appl Physiol, Nutr Metab. 2008;33(5):984–9. doi:10.1139/H08-086
14. Lounana J, Campion F, Noakes TD, Medelli J. Relationship between $\%HR_{max}$, %HR reserve, $\%\dot{V}o_2$max, and $\%\dot{V}o_2$ reserve in elite cyclists. Med Sci Sports Exerc. 2007;39(2):350–7. doi:10.1249/01.mss.0000246996.63976.5f
15. Cunha FA, Midgley AW, Monteiro WD, Farinatti PT. Influence of cardiopulmonary exercise testing protocol and resting $\dot{V}o_2$ assessment on $\%HR_{max}$, %HRR, $\%\dot{V}o_2$max and $\%\dot{V}o_2R$ relationships. Intl J Sports Med. 2010;31(5):319–26. doi:10.1055/s-0030-1248283
16. Hui SS, Chan JW. The relationship between heart rate reserve and oxygen uptake reserve in children and adolescents. Res Quart Exerc Sport. 2006;77(1):41–9. doi:10.1080/02701367.2006.10599330
17. Pinet BM, Prud'homme D, Gallant CA, Boulay P. Exercise intensity prescription in obese individuals. Obesity. 2008;16(9):2088–95. doi:10.1038/oby.2008.272
18. Swain DP, Leutholtz BC, King ME, Haas LA, Branch JD. Relationship between % heart rate reserve and $\%\dot{V}o_2$ reserve in treadmill exercise. Med Sci Sports Exerc. 1998;30(2):318–21.
19. Gaskill SE, Bouchard C, Rankinen T, Rao DC, Wilmore JH, Leon AS, Skinner JS. %heart rate reserve is better related to $\%\dot{V}o_2$max than to $\%\dot{V}o_2$ reserve: the HERITAGE Family Study. Med Sci Sports Exerc. 2004;36(5):S3.
20. Skinner JS, Gaskill S, Gagnon J, Leon AS, Rao DC, Wilmore JH, Bouchard C. Accuracy of the Karvonen formula in a large heterogeneous population: the HERITAGE Family Study. Med Sci Sports Exerc. 2001;33(5):S136.
21. Ferri Marini C, Sisti D, Leon AS, Skinner JS, Sarzynski MA, Bouchard C, Rocchi MBL, Piccoli G, Stocchi V, Federici A, Lucertini F. HRR and $\dot{V}o_2R$ fractions are not equivalent: is it time to rethink aerobic exercise prescription methods? Med Sci Sports Exerc. 2021;53(1):174–82. doi:10.1249/MSS.0000000000002434
22. Cunha FA, Midgley AW, Monteiro WD, Campos FK, Farinatti PT. The relationship between oxygen uptake reserve and heart rate reserve is affected by intensity and duration during aerobic exercise at constant work rate. Appl Physiol, Nutr Metab. 2011;36(6):839–47. doi:10.1139/h11-100
23. Wingo JE, Ganio MS, Cureton KJ. Cardiovascular drift during heat stress: implications for exercise prescription. Exerc and Sport Sci Rev. 2012;40(2):88–94. doi:10.1097/JES.0b013e31824c43af
24. Iannetta D, de Almeida Azevedo R, Keir DA, Murias JM. Establishing the $\dot{V}o_2$ versus constant-work-rate relationship from ramp-incremental exercise: simple strategies for an unsolved problem. J Appl Physiol (1985). 2019;127(6):1519–27. doi:10.1152/japplphysiol.00508.2019
25. Keir DA, Paterson DH, Kowalchuk JM, Murias JM. Using ramp-incremental $\dot{V}o_2$ responses for constant-intensity exercise selection. Appl Physiol, Nutr Metab. 2018;43(9):882–92. doi:10.1139/apnm-2017-0826
26. Zuccarelli L, Porcelli S, Rasica L, Marzorati M, Grassi B. Comparison between slow components of HR and $\dot{V}o_2$ kinetics: functional significance. Med Sci Sports Exerc. 2018;50(8):1649–57. doi:10.1249/MSS.0000000000001612
27. Pollock ML, Gaesser GA, Butcher JD, Després J, Dishman RK, Franklin BA, Garber CE. American College of Sports Medicine position stand. The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in healthy adults. Med Sci Sports Exerc. 1998;30(6):975–91.
28. Gaskill SE, Walker AJ, Serfass RA, Bouchard C, Gagnon J, Rao DC, Skinner JS, Wilmore JH, Leon AS. Changes in ventilatory threshold with exercise training in a sedentary population: the HERITAGE Family Study. Intl J Sports Med. 2001;22(8):586–92. doi:10.1055/s-2001-18522
29. Shephard RJ. Independence: a new reason for recommending regular exercise to your patients. Phys Sportsmed. 2009;37(1):115–8. doi:10.3810/psm.2009.04.1691
30. Bouchard C. DNA sequence variations contribute to variability in fitness and trainability. Med Sci Sports Exerc. 2019;51(8):1781–5. doi:10.1249/MSS.0000000000001976
31. Skinner JS, Jaskólski A, Jaskólska A, Krasnoff J, Gagnon J, Leon AS, Rao DC, Wilmore JH, Bouchard C. Age, sex, race, initial fitness, and response to training: the HERITAGE Family Study. J Appl Physiol (1985). 2001;90(5):1770–6. doi:10.1152/jappl.2001.90.5.1770