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The predictive ability of the YMCA Test and Bruce Test for triathletes with different training backgrounds

Upton Dabney -- *Department of Athletics, Oregon Institute of Technology, Klamath Falls, Oregon 97601 (upton.dabney@oit.edu)*
Mike Butler -- *Department of Health, Physical Education and Recreation, Emporia State University, Emporia, Kansas 66801 (mbutler@emporia.edu)*

The purpose of this study was to examine the predictive ability of two Max VO_2 tests (the YMCA Cycle Test and the Bruce Protocol Treadmill Test) and to examine the effect of different training backgrounds of triathletes (emphasizing either cycling, running, or swimming) on the predictive ability of the tests. Fourteen triathletes (ages 19 to 41) with training backgrounds in one of three triathlon areas participated. The training backgrounds included 2 in swimming, 3 in cycling, and 9 in running. Results indicate both tests underestimate Max VO_2 by about 14% and that there is a specificity effect such that cyclists get better predictions from the cycling test (YMCA) and runners get better predictions from the treadmill test (Bruce).

Keywords: max VO_2 test, triathletes, Bruce Test.

Introduction

In response to the growing popularity of the triathlon, exercise professionals have an opportunity to work with increasing numbers of individuals interested in this emerging sport and to address the methods of testing their maximal volume of oxygen uptake (VO_2 Max). Previous studies have been performed on the testing of triathletes, but not specifically with regard to sub-maximal testing VO_2. This raises the question of how well current sub-maximal tests work for triathletes. In addition, since triathlons involve three different exercise modalities (swimming, cycling, and running) it is possible that this may introduce a factor that impacts the accuracy of VO_2 Max tests differentially, according to the exercise modality used in the test.

Exercise professionals regard VO_2 Max as the single best measurement of cardio-respiratory endurance and aerobic fitness. While other factors are important to athletic performance, VO_2 Max is accepted as the baseline predictor of endurance performance (Baechle & Earle, 2000; Noakes, 2001; Wilmore & Costill, 1999).

Direct measurement of VO_2 Max requires special, expensive equipment and requires the athlete to perform until maximal exertion has been reached (American College of Sports Medicine, 2000). The time, performance, and equipment needed to perform measured VO_2 Max testing are prohibitive for many athletes, making sub-maximal VO_2 testing more attractive. Sub-maximal VO_2 tests require less effort, time, and equipment, yet yield results that closely approximate VO_2 Max.

While many sub-maximal tests exist, many choose the mile run or mile-and-a-half run as the indicator of the aerobic fitness (Baechle & Earle, 2000; American College of Sports Medicine, 2000). The mile run and mile-and-a-half run tests are easy to administer (even to large groups) and require no special training or equipment. They are also relatively easy to score and interpret. While these tests yield estimates that are not as reliable as some of the other tests, they are generally viewed as adequate for purposes of general fitness testing. For those interested in more accurate estimates, the YMCA cycle ergometer test and the Bruce sub-maximal treadmill test are more appropriate. However, not all athletes have proper training with either apparatus in order to perform at their best on these tests (Baechle & Earle, 2000). Typically, athletes perform these tests under the supervision of sports medicine specialists or personal trainers at local health clubs for a minimal charge, often already included with club membership.

There may be many factors that affect the decision of which method to use to test max VO_2. For example, there may be time considerations. A teacher in a school setting may not have the time needed to test students individually and therefore may have to resort to a test like the mile run. Also, in many situations the equipment needed for certain tests may not be available (like a treadmill or bicycle ergometer). In situations where the necessary equipment is available, it may be desirable to choose a test where the exercise modality of the test is similar to the exercise modality most used by the individual being tested. There is some evidence to support the idea that predictive tests generate more accurate predictions of max VO_2 when the modality of the test is more familiar to the individual being tested (Wilmore & Costill, 1999).

For a multi-sport athlete such as a triathlete, where the training involves swimming, cycling, and running, the choice of which test to use becomes less clear. The athletic history of the triathlete or athletic dominance in one of the three events of the triathlon may be of value in making this determination.

The concept of VO_2 Max long has been regarded as the accepted measure of cardio-respiratory fitness. Knowledge of VO_2 Max allows for the quantification of values for training and conditioning, as well as a prediction of performance. While a higher VO_2 Max does not guarantee a better athletic performance, it provides the possibility for a superior performance (Baechle & Earle, 2000; Noakes, 2001; Noakes, Myburgh, & Schall, 1990; Wilmore & Costill, 1999).

VO_2 Max is the product of arterial-venous oxygen difference (measured in mL O_2/L) and the maximal cardiac output (measured in L/min). The arterial-venous oxygen difference is measured through an open-circuit spirometry in which the individual breathes through a low-resistance valve. During this time pulmonary ventilation is measured for O_2 and CO_2 levels as the lactate begins to accumulate in the blood causing increased ventilation (Gaskill, Ruby, & Walker, 2001).

Pulmonary ventilation is measured while the athlete exercises on either a treadmill or a stationary bike. The work rate of the athlete is started at a low rate and increased gradually and progressively at regular intervals, between 1 to 3 minutes. The absolute maximum work rate that the athlete can achieve is comparable to the work rate of a 100-m sprint, but such a short event does not allow sufficient time for testing. The measured VO_2 Max of the athlete should be done in a progressive fashion to exhaustion (Noakes, 2001).

The term VO_2 Max is understood as the value of the athlete's maximum oxygen consumption during the maximum rate of work and is considered a predictor of athletic performance (Baechle & Earle, 2000; Noakes, 2001). During a complex interaction between the heart and skeletal muscles factors combine to establish the maximum rate of oxygen use by the muscles at the maximum work rate, which results in the maximum work rate achieved. The measured peak rate of oxygen consumption is the result, not the cause of peak work rate achieved (Noakes, 2001). The limitation of the pulmonary system or the cardiovascular system in regard to maximal exercise was resolved when research showed ventilation was only at 65% of maximal capacity while cardiac output had reached 90% of its maximum. According to Silverthorn (1998), exercise physiologists concluded that the cardio-vascular system's ability to deliver oxygen and nutrients to muscles at a rate that supports aerobic metabolism is a major factor in the determination of VO_2 Max. The emphasis in research of human performance has focused on the measurement of VO_2 Max in elite athletes and the effects of various interventions, i.e., training, diet, altitude, on the VO_2 Max. The higher VO_2 Max values generally reflect the capacity to reach higher maximum work rates (Noakes, 2001).

The accepted view is that oxygen deficiency limits exercise performance and that VO_2 Max measures the capacity to offset that limitation. Because it is the result of a complex interaction between the heart and skeletal muscle factors, VO_2 Max is not synonymous with athletic potential. There are numerous factors that influence athletic potential by altering one or more of the complex factors of the heart and muscle and indirectly VO_2 Max (Noakes, 2001).

The first factor that influences athletic potential and VO_2 Max is age. Starting in the late teens for women and mid-twenties for men, a decline of about 10% per decade is seen in measured VO_2 Max in those who remain relatively consistent in activity (Noakes, 2001; Wilmore & Costill, 1999). Some studies have shown that maintaining vigorous exercise for life may reduce the age-related fall in VO_2 Max to an estimated 5% per decade in lifelong athletes (Heath et al., 1981; Pollock et al., 1987). Former athletes who stopped training have shown a decrease of 5-10% per decade in VO_2 Max (Wilmore & Costill, 1999).

Gender is the next factor, which influences VO_2 Max. Men have higher VO_2 Max values of 20% to 25% more than women, because of higher muscle mass and lower body fat content (Baechle & Earle, 2000; Manore & Thompson, 2000; Noakes, 2001; Wilmore & Costill, 1999).

Relative fitness level of individuals is another factor for athletic potential and VO_2 Max. People who normally exercise have a higher VO_2 Max than their sedentary counterparts by 5% to 45% depending on the mode of exercise (Wilmore & Costill, 1999). Sedentary people who start a fitness program can normally gain as much as 5% to 15% improvement in VO_2 Max (Daniels, Yarbough, & Foster, 1978).

Heredity is a major determinant of aerobic capacity, accounting for as much as half of the variation in VO_2 Max (Wilmore & Costill, 1999). Interestingly, in studies of exercise programs with participants ranging from sedentary individuals to elite athletes, increases in VO_2 Max have been found to range anywhere from 0% to 60%. It has been found that there is a genetic basis for these high and low responders to endurance training (Thomis et al., 1998). The low responders cannot improve with training, regardless of efforts, showing no adaptation to training (Lortie et al., 1984; Prud'Homme et al., 1984). Several studies attempting properly to identify genetic markers for superior athletic performance (Rivera, Dionne, Simoneau et al., 1997; Rivera, Dionne, Wolfarth et al., 1997; Bilé et al., 1998; Hagberg et al., 1998; Manning & Pickup, 1998; Rivera et al. 1998; Alvarez et al., 1999; Rivera et al., 1999; Taylor et al., 1999;

Bouchard, Wolfarth et al., 2000; Williams, Armstrong & Powel, 2000; Wolfarth et al., 2000;) and for high and low adapters to training (Bouchard et al., 1989; Dionne et al., 1991; Bouchard et al., 1999; Bouchard, Rankinen et al., 2000) are still in progress.

Purpose of the study

The purpose of this study was to examine the ability of the YMCA test and the Bruce test to predict max VO_2 for triathletes and to examine the impact of training focused on either cycling, running, or swimming on the two sub-max tests.

Hypotheses

There will be no difference between VO_2 max predicted by the YMCA test and VO_2 max predicted by the Bruce test.

For those with a cycling background, the YMCA test will produce a higher estimate of VO_2 Max than the Bruce Protocol Test.

For those with a running background, the Bruce test will produce a higher estimate of VO_2 Max than the YMCA Test.

Method

Participants

Participants were highly trained male (n = 7) and female (n = 7) triathletes from the Charleston, South Carolina area who had competed in the Charleston Sprint Triathlon Series in the past two years, with ages ranging from 19 to 41. Participants were selected based on their response to a posting on the Charleston Triathlon Club web-site message board. From an original 19 participants who responded, 14 are included in the results. (5 failed to complete the testing for various reasons.)

Procedures

At an initial interview each participant completed an Informed Consent for Graded Exercise Testing form (see Appendix A), a Modified PAR-Q form (see Appendix B), and a personal information sheet (see Appendix C). Participants were given a brief overview of the study, the opportunity to ask questions, and an explanation of the information they would gain as a result of participation in the study (measured VO_2 Max and estimated lactate threshold). Participants also were given information about the sub-maximal tests to be used in the study, the YMCA Cycle test and the Bruce Protocol Treadmill test. Participants were informed on how the measured VO_2 Max would be attained using a metabolic cart in conjunction with the Bruce Protocol Treadmill Test. All participants then made appointments to start the testing cycle using the same order of testing: first the YMCA Cycle Sub-Maximal Test, then the Bruce Protocol Treadmill Sub-Maximal Test, and finally the measured VO_2 Max using the Bruce Protocol Treadmill Test and metabolic cart.

Each participant performed each of the tests on different days (but not consecutive days), in the same testing order, as best fit into the schedules of each participant—around work and training regimen. Participants were given opportunity to have testing done alone or with another test participant present, but encouraged to test alone to help prevent competition and raising heart rate response during the sub-maximal tests.

Upon arrival for testing, each participant was given an opportunity to stretch and to review the instructions for each of the tests prior to the start of any of the tests. Participants were asked to acknowledge verbally an understanding of the testing procedures. Then, each participant was seated for a short time during which the participant's blood pressure and heart rate were monitored in an attempt to ensure that participants were in a relatively rested state prior to any testing. When the heart rate and blood pressure information indicated that the participant was in a relatively steady state, testing began for that session.

For the YMCA Bicycle Test using the Monark cycle, testing followed ACSM guidelines for execution of procedures and protocol. Results were recorded at the completion of each test with a follow-up appointment made for the second test, the Bruce Protocol Treadmill Sub-Maximal Test.

The Bruce Protocol Sub-Maximal Treadmill Test was also done in accordance with ACSM guidelines (Table 1) and results were recorded (see Appendix D). Because the Bruce Protocol would be used for the max test, each participant was given the opportunity to go on to the next few levels of Bruce Protocol to gain familiarity with higher speed treadmill running.

On the day of each VO_2 Max test, each participant was given an extra opportunity to stretch and because this was a max test, further precautions were taken including having an MD on call and an AED available on site. Prior to testing, participants reviewed the Borg Scale of rated perceived exertion used during the max test. Participants were encouraged to go as long as possible during the test to obtain the best possible (most valid) measurement of VO_2 Max. Prior to each session of testing the metabolic cart was calibrated, and each participant was measured and weighed to ensure accuracy in the data entered into computer for the necessary computations. Participants were fitted with headgear and a breathing tube, as well as a heart rate monitor, and then allowed a couple of minutes to adjust to breathing with the tube. Participants then began the Bruce Protocol Maximal Test. During this test a computer controlled the elevation and

Table 1. Chart for Bruce Protocol treadmill sub-maximal test.

Stage	Speed (mph)	Grade (%)	VO_2 (ml/kg/min)
1	1.7	10	13.4
2	2.5	12	21.4
3	3.4	14	31.5
4	4.2	16	41.9

speed changes of the treadmill, but the researcher had the option of manual override control in case of emergency. Participants were asked to report RPE during each stage, with frequency increasing as RPE reached 15, until the participant signaled for the end of the test. Testing was then completed and the participant was allowed to cool down on the treadmill. Results were printed from the computer and a copy given to the participant with a graph of the Ventilatory Threshold Report, which located the participant's lactate threshold to aid them in training with heart rate monitors.

Results

The raw data for each of the tests can be seen in Table 2. All measures of max VO_2 are reported in ml/kg/min. One of the purposes of this study was to examine the ability of the YMCA test and the Bruce test to predict max VO_2 for triathletes. The hypothesis was that there would be no differences between the predictions from each test. The results provide partial support for this hypothesis. A paired t test revealed no significant difference between the predictions of max VO_2 from the YMCA test and the predictions of max VO_2 from the Bruce test, t (13) = -0.546, p = 0.594. The means and standard deviations for the predictions from YMCA test and the Bruce test were 50.69 (9.81) and 51.89 (6.97). Both of the sub-max tests seem to underestimate the actual Max VO_2 (as measured by the Max test). The max test produced a mean of 62.46 with a standard deviation of 12.93. The average amount of prediction error across both tests was about 14% below the measured value.

Neither predictive test correlated strongly with the max test. The Pearson correlation coefficient between the YMCA test and the max test was 0.115. The Pearson correlation between the Bruce test and the max test was higher at 0.396. Interestingly, the correlation between the two sub-max tests was substantially larger at 0.559. This suggests that the two sub-max tests tend to predict max VO_2 equally well but considering that neither test was strongly correlated with the actual max test the additional suggestion is that neither test does a particularly good job predicting max VO_2 as compared with a "true" max test.

Table 2. Raw data resulting from testing triathletes.

Participant	Background	YMCA Bike	Bruce Sub-Max	Max VO_2
1	Swimming	50.8	50.0	69.0
2	Running	31.7	43.5	58.0
3	Swimming	52.0	68.5	69.7
4	Running	40.4	48.5	74.8
5	Running	51.0	54.7	80.4
6	Cycling	67.7	54.8	86.1
7	Running	45.2	47.5	56.0
8	Cycling	54.2	44.0	43.6
9	Running	43.0	45.6	53.6
10	Cycling	48.3	48.2	47.9
11	Running	69.9	61.2	51.6
12	Running	49.9	51.4	63.0
13	Running	54.7	51.1	50.1
14	Running	50.8	57.5	70.6

Another purpose of the study was to examine the impact of training focused on either cycling, running, or swimming on the two sub-max tests. The hypothesis was that there would be a specificity effect such that for those with a cycling background, the YMCA test would produce the better estimate of VO_2 max and for those with a running background, the Bruce test would produce a better estimate of VO_2 max. The results provide fairly strong support for this hypothesis. The mean percent error of the estimates for the cyclists was -1.26% on the YMCA test compared to 11.60% on the Bruce test. Conversely, the mean percent error for the runners was 15.40% on the Bruce test compared to 19.02% on the YMCA test. The swimmers showed some of the largest percent errors with 25.89% on the YMCA test and 14.63% on the Bruce test.

Discussion

The results provided partial support for both of the hypotheses. There was little difference between the mean max VO_2 as predicted by the YMCA test (50.69) and the mean max VO_2 predicted by the Bruce test (51.89). A difference of only 1.2 ml/kg/min between the tests suggests that the tests produce quite similar estimates. The correlation between the predictive tests was reasonable high as well at 0.5586. These findings suggest that the tests may be interchangeable because they produce similar results. However, both tests produced estimates that were substantially less then the max VO_2 as measured by the max Bruce test. Furthermore, neither predictive test was significantly correlated with the max test.

This part of the results casts some doubt as to the efficacy of either test to produce a reasonably accurate prediction.

On the other hand, the results also showed that the predictive tests that were more closely aligned with the training background of the athlete produced more accurate results. No hypothesis was made concerning the swimmers because neither predictive test was similar to their training modality. Therefore, neither test should show any bias related to specificity. It does seem reasonable, though, to suspect that a swimming max VO_2 test might produce significantly better predictions than either the bike test or the treadmill test. In addition, it is possible that a max test using swimming might produce a more valid measure of max VO_2 for swimmers than a treadmill-based test.

When all of the results are considered collectively, the data seem to support the idea that while either test will produce a somewhat reliable estimate, it is desirable to use a test where the exercise modality is more compatible with the expertise and training of the athlete. This finding is not so surprising in light of what is known about the specificity of training and does support the idea that there is a strong correlation between sports background and method of sub-maximal testing (Wilmore & Costill, 1999).

The interpretation of the results of this study should include a consideration for the rather limited sample size, particularly for the swimmers. Perhaps future research could further test the ideas suggested by these results by using both larger sample sizes, and also perhaps by including a swimming test to explore further the specificity notion.

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Appendix A: Informed Consent for Graded Exercise Testing

I understand that I will perform graded sub-maximal tests on a stationary cycle ergometer and on a motor-driven treadmill, and a graded maximal exercise test on a motor driven treadmill. The exercise intensity will begin as a level I can easily accomplish and will be advanced in stages, depending on my ability to continue exercise. The testing personnel may stop the test at any time because of signs of fatigue or abnormal symptoms, or I may stop when I wish to because of feelings of fatigue or discomfort. I need not exercise at a level which extremely uncomfortable for me; however, I recognize that for maximum benefit from this test, I need to exercise as long as possible.

I understand that there exists the possibly of certain abnormal and potentially harmful physical changes occurring during the test. They include abnormal changes in blood pressure, fainting, disorders of heartbeat, and, in rare instances, heart attack. Every effort will be made to protect me from having harmful problems through the preliminary examination and through close observation by trained professionals during testing. It is my understanding that emergency equipment and trained personnel are available to deal with unusual situations, which may arise.

I understand that the results obtained from the exercise test will be used primarily to measure my physical fitness level, i.e. VO^2 Max, to help understand the amount of exercise that is safe for me, and to assist an future training.

I have been encouraged to ask questions about the procedures used in the graded exercise tests, and all my questions, if asked, have been answered to my satisfaction.

I understand that the information, which is obtained from me during this test, will be treated as privileged and confidential and will not be released or revealed to any person without an expressed written consent. The information obtained, however, will be used for statistical analysis or scientific purposes with my right of privacy retained.

I grant my permission to perform this graded exercise test voluntary. I understand that I am free to deny consent if I so desire.

I have read this form and I understand the test procedures that I will perform. By my signature, I hereby give consent to participate in this test.

____
Signature of Participant

____
Signature of Witness

____
Date

Appendix B: Modified Physical Activity Readiness Questionnaire (PAR-Q)

Name			Date
DOB	Age	Home phone	Work phone

Regular exercise is associated with many health benefits, yet any change of activity may increase the risk of injury. Completion of this questionnaire is a first step when planning to increase the amount of physical activity in your life. Please read each question carefully and answer every question honestly:

Yes	No	1) Has a physician ever said you have a heart condition and you should only do physical activity recommended by a physician?
Yes	No	2) When you do physical activity, do you feel pain in your chest?
Yes	No	3) When you were not doing physical activity, have you had chest pain in the past month?
Yes	No	4) Do you ever lose consciousness or do you lose your balance because of dizziness?
Yes	No	5) Do you have a joint or bone problem that may be made worse by a change in your physical activity?
Yes	No	6) Is a physician currently prescribing medications for your blood pressure or heart condition?
Yes	No	7) Are you pregnant?
Yes	No	8) Do you have insulin dependent diabetes?
Yes	No	9) Are you 69 years of age or older?
Yes	No	10) Do you know of any other reason you should not exercise or increase your physical activity?

If you answered yes to any of the above questions, talk with your doctor BEFORE you become more physically active. Tell your doctor your intent to exercise and to which questions you answer yes.

If you honestly answered no to all questions you can be reasonably positive that you can safely increase your level of physical activity **gradually**.

If your health changes so you then answer yes to any of the above questions, seek guidance from a physician.

Participant signature	Date

Appendix C: Personnal Information Form

Name: ________________________________
Age: ____________ Weight: __________
Running / Biking / Swimming / Other:_______________
Age Grouper / Open Elite

Appendix D

Bruce Protocol Recording Form						
Name						Date
DUR min	**Speed mph**	**Grade**	**Heart rate beat/min**	**Blood pressure mm/Hg**	**Relative perceived exertion**	**Comments**
sup sit hypv std						
1	1.7	10%				
2	"	"				
3	"	"				
4	2.5	12%				
5	"	"				
6	"	"				
7	3.4	14%				
8	"	"				
9	"	"				
10	4.2	16%				
11	"	"				
12	"	"				
13	5.0	18%				
14	"	"				
15	"	"				
16	5.5	20%				
17	"	"				
18	"	"				
19	6.0	22%				
20	"	"				
21	"	"				
Max						Time
Reason for test termination: Key: CP = chest pain; D = dizziness; SOB = shortness of breath; P = palpitations; GF = general fatigue; LF = leg fatigue; MJP = muscle joint pain						