JEPonline
Journal of Exercise Physiology**online**

Fitness and Training

A SIMPLE RUNNING TEST TO ESTIMATE CARDIORESPIRATORY FITNESS

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ABSTRACT

A SIMPLE RUNNING TEST TO ESTIMATE CARDIORESPIRATORY FITNESS. **V.J. Leibetseder, C. Ekmekcioglu, P. Haber. JEPonline**. 2002;5(3):6-13. With the increasing demand to assess cardiorespiratory fitness in leisure time sports and the fitness center setting, more practical tests than the exhaustive ergometric exercise test are desirable. Various submaximal exercise tests have been introduced that estimate VO$_2$max based on the heart rate response to predetermined exercise intensities. However these tests do not estimate VO$_2$max with satisfactory accuracy or reliability. In order to find a submaximal test with acceptable accuracy, we developed a method that measures the physical work at a predetermined heart rate. Seventy-one volunteers performed an incremental exercise test to measure VO$_2$max, and two runs of 2.1 km each, substituting 1.5 km for subjects over 50. The running speeds were regulated by heart rate corresponding to 70% and 90%VO$_2$max (V70 and V90). Simple regression analyses were made between V70 and V90 and VO$_2$max and maximum Watts (Wmax), respectively (V70 vs. VO$_2$max: r^2=0.36; V70 vs. Wmax: r^2=0.48; V90 vs. VO$_2$max: r^2=0.56; V90 vs. Wmax: r^2=0.69; each: $p<0.001$). Using multiple regression analyses we added body mass, age, and resting heart rate as further independent variables which increased R^2 to 0.85 ($p<0.001$). In conclusion we suggest that this test is appropriate for general use and for documenting progress of cardiorespiratory training.

Key words. Ambulatory Monitoring, Exercise Test, Oxygen Consumption, Physical Fitness, Running

INTRODUCTION

The most reliable parameter for evaluating an individual's cardiorespiratory fitness (CRF) is the measure of maximal oxygen consumption (VO$_2$max) (1). This measure is exercise mode specific, and is performed using continuous sampling and analysis of expired air and measurement of ventilation. Common exercise modes used in such tests are treadmill running and walking, and cycle ergometry. In either case, the exercise testing protocols involve incremental increases in intensity until exhaustion (2,3), and occur within a time frame of 8-12 min. The major disadvantages of this method are the requirement of expensive exercise ergometers, gas analysis and ventilation equipment, and the need for medical attendance.

Due to the increasing demand of measuring CRF in leisure time and fitness-sports, tests designed to avoid the medical risks and equipment needs of VO_2max measurement are desirable (4-6). Furthermore, in many countries, such as Austria, guidelines for exercise testing differ to those of the United States and medical supervision is required for all individuals exercise testing to volitional exhaustion.

As submaximal tests used to estimate VO_2max lower the risks for cardiac complications and sudden death, a large number of analogous tests have been introduced (7-9). All of these procedures have evaluated the response of heart rate to predetermined exercise intensities. Another option for assessing CRF has been the "Physical Working Capacity 170" (PWC 170) (11). This test is based on the measurement of the heart rate change between two exercise intensities, and extrapolating the heart rate slope to a heart rate of 170 b/min. The higher the exercise intensity at the PWC 170, the higher the CRF. Other methods of assessing CRF are solely based on anthropometric characteristics and exclude exercise testing completely (12).

As a completely different approach to assess the CRF by a submaximal method, Eisenmann et al. (13) investigated youth and correlated cardiac dimensions and the working capacity at heart rate 150, but found few significant correlations. Additionally, they emphasized the importance of correlating aerobic fitness with body size and body mass. Based on Wahlund's "PWC 170", Gore et al (14) achieved higher correlations to VO_2max when they interpolated a subject's working capacity at 75% of the individual's maximum heart rate. However, the disadvantage of the need for expensive equipment still limits this test.

The aim of the current paper was to introduce a simple submaximal test that measured the physical work at an individually standardized (at 70 and 90% VO_2max) heart rate. We demonstrated that the running speed based on heart rate significantly correlated with CRF and therefore we suggest that this simple test is a reliable method to verify repeated training effects.

METHODS
Subjects
Seventy-one volunteers (26 females, 45 males) with a mean age of 47±11 yrs and a body mass of 75.4±10.4 kg (males) and 59.7±8.6 kg (females) were recruited after giving informed consent.
Research Design
According to the recommendation of the "Austrian Cardiological Society" all subjects had to pass a medical screening shortly before the exercise test. This screening consisted of an anamnesis including mainly cardiac problems and irregularities of blood pressure, auscultation of lungs and cardiac valves, measurement of blood pressure in a seated position, and a supine electrocardiogram (ECG). After ten minutes in a supine position in a quiet room, resting heart rate (HRrest) was monitored. Subsequently, each subject completed an ergometric exercise test with continuous measurement of ventilation and expired gases. The exercise tests consisted of cycle ergometry with an increment of 25 Watts/2 min, symptom limited by exhaustion, and cadence independent (Ergometrics 900). Open circuit indirect calorimetry was performed breath by breath using a Sensormedics Metabolic Measurement System (2.900C). The power output at VO_2max (Wmax [W]) and VO_2max (ml/min) were recorded, with VO_2max identified as the peak 30 s averaged value for VO_2.

Within two weeks after the bicycle exercise tests two test runs were performed on a 300 m cinder track. Between these runs subjects had a break of at least half an hour with *ad libitum* fluid and food (one banana) ingestion. Subjects older than 50 years of age (n=28) ran 1.5 km in each test; younger persons (n=43) ran 2.1 km. During the test runs individuals were instructed to adjust their running speed to a specific HR, which was registered and stored by an ambulatory heart rate monitor (Polar®). During the first run heart rate was constrained to 70% VO_2max from the prior laboratory incremental exercise test. The second run was constrained to a heart rate of 90% VO_2max (V90). The predetermined heart rates were determined by the following formula (16);

HR at X% VO_2max=(HRres • (X/100)) + HRrest

HR at X%VO$_2$max=Heart rate at desired percentage of VO$_2$max
HRrest=heart rate measured after ten minutes supine position before ergometry
HRres=heart rate reserve=maximum HR (HRmax) minus HRrest
X=desired percentage of VO$_2$max (70 vs 90)

Statistical analyses

The arithmetic mean and standard deviation (mean±SD) were used for descriptive statistics. To investigate whether the running speeds (V70, V90) correlated with VO$_2$max and Wmax, respectively, we primarily performed simple regression analysis. Furthermore, the additional combined contribution of body mass, age, and HRrest for predicting CRF were investigated using multiple regression. A p-value<0.001 was considered as statistically significant.

RESULTS

The results of the incremental exercise test and the field-tests are presented in Table 1.

Table 1: Maximum VO$_2$ (VO$_2$max [mL/min]), Watts at VO$_2$max, and running speeds for the field tests (V70=running speed at 70% of VO$_2$max, V90=running speed at 90% of VO$_2$max). Values are means±standard deviation. Range is presented in parentheses.

Variable	Males (n=45)	Females (n=26)	Total (n=71)
VO$_2$max (mL/min)	3156.7±618.2 (1719 – 4383)	2014.5±383.7 (1296 – 2751)	2741.3±774.4 (1296 – 4383)
Wmax (W)	240.1±45.0 (127 – 334)	155.0±29.6 (97 – 218)	210.0±57.3 (97 – 334)
V70 (m/s)	2.46±0.48 (1.58 – 3.96)	2.06±0.24 (1.55 – 2.65)	2.32±0.45 (1.55 – 3.96)
V90	3.11±0.51	2.36±0.36	2.83±0.59

Although it is a well-known and often emphasized fact that there is a high significant correlation between body mass and VO$_2$max (12,17), we calculated this relationship as a preliminary analysis, resulting in data of r^2=0.33 for body mass, and r^2=0.24 for Wmax (each p<0.001).

In a next step we correlated V70 and V90 with VO$_2$max and Wmax and found that these variables can predict exercise capacity better than body mass (Table 2). However, the most decisive increases of variance explanation for VO$_2$max and Wmax resulted from the multiple regression analyses involving combinations of body mass and each of V70 and V90 data (Table 2, Figures 1 and 2).

We were also interested in whether the inclusion of other anthropometric variables, such as age and HRrest, could further increase variance explanation of VO$_2$max and Wmax. Correlating VO$_2$max with V70 + body mass + age resulted in R^2=0.70, and V70 + body mass + age + HRrest resulted in R^2=0.74. Correlating Wmax with the same variables led to R^2=0.70 and R^2=0.75, respectively. We then assessed the prediction and variance explanation using V90; V90 + body mass + age (R^2=0.80), and V90 + body mass + age + HRrest (R^2=0.82). Finally we correlated Wmax with V90 + body mass + age (R^2=0.82), and V90 + body mass + age + HRrest (R^2=0.85) (for each analysis: p<0.001). Consequently, the addition of age and HRrest only resulted in small improvements to R^2.

Table 2: Simple and multiple regression analysis between maximum VO$_2$ (VO$_2$max [L/min]) and performable wattage (Wmax [W]) versus bm, V70, V90, V70 + bm, V90 + bm (bm=body mass [kg], V70=running speed at 70% of VO$_2$max [m/s], V90=running speed at 90% of VO$_2$max [m/s]); each: p<0.001

Variables	Regression equation	R^2-value	Beta
VO₂max vs. bm	-19.4 + 40.1 • bm	0.33	0.58
Wmax vs. bm	37.5 + 2.5 • bm	0.24	0.49
VO₂max vs. V70	408.2 + 1007.0 • V70	0.36	0.60
VO₂max vs. V90	-30.6 + 970.9 • V90	0.56	0.75
Wmax vs. V70	11.8 + 85.8 • V70	0.48	0.70
Wmax vs. V90	-20.1 + 80.7 • V90	0.69	0.83
VO₂max vs. V70 + bm	-1799.9 + 879.1 • V70 + 36.5 • bm	0.62	0.52 (V70) 0.52 (bm)
VO₂max vs. V90 + bm	-1880.3 + 861.5 • V90 + 31.4 • bm	0.76	0.67 (V90) 0.45 (bm)
Wmax vs. V70 + bm	-117.1 + 76.9 • V70 + 2.2 • bm	0.67	0.62 (V70) 0.43 (bm)
Wmax vs. V90 + bm	-128.4 + 74.6 • V90 + 1.8 • bm	0.82	0.77 (V90) 0.36 (bm)

DISCUSSION

Matthews et al. (12) introduced a model to classify five categories of CRF by using data obtained from a comprehensive questionnaire considering mainly anthropometric data. The advantage of Matthews' model is that data collection is very simple, whereas the overall accuracy of 36% must be considered as a disadvantage. Another model of estimating CRF without exercise testing was introduced by George et al. (17).

Another approach to assess CRF is its estimation from the heart rate response to predefined exercise intensities. To avoid the requirement for ergometric equipment, Cooper (4) and Conconi (5) introduced their tests. However, as mentioned before, these tests are limited in application due to their requirement for moderate to intense exercise. We tried to solve this problem by predetermining an individual level of heart rate corresponding to low to moderate exercise intensities at which subjects had to run a given distance.

The speed at the test run allowed an estimation of VO$_2$max from cycle ergometry. However, if a subject's VO$_2$max at running is of interest, the difference between VO$_2$max obtained from running and cycling becomes a limitation to our method. Consequently, our equations need to be used as predictors of cycle ergometry VO$_2$max (21,22). However, our equations remain valid when used to document training-induced changes in VO$_2$max regardless of the mode of training. This use is perhaps the most common application of prediction equations in the fitness setting.

We used a cycle ergometer instead of treadmill because there are some essential advantages for this method. Cardio-respiratory observation is facilitated as there are fewer artifacts in ECG, airflow and pressure tracings. Measurement of blood pressure is also easier and repeatedly possible at any time of the test without undue inconvenience to the subject. Furthermore, there is minimal difference in each of HRmax and maximal ventilation between cycle and treadmill based exercise testing (21). The 7% higher VO$_2$max attained during treadmill running compared to cycle ergometry (23) is not true for all individuals, as cycle trained individuals have less exercise mode disparity in VO$_2$max measurement. Consequently, our equations could be used validly to any individual who prefers cycle ergometry exercise.
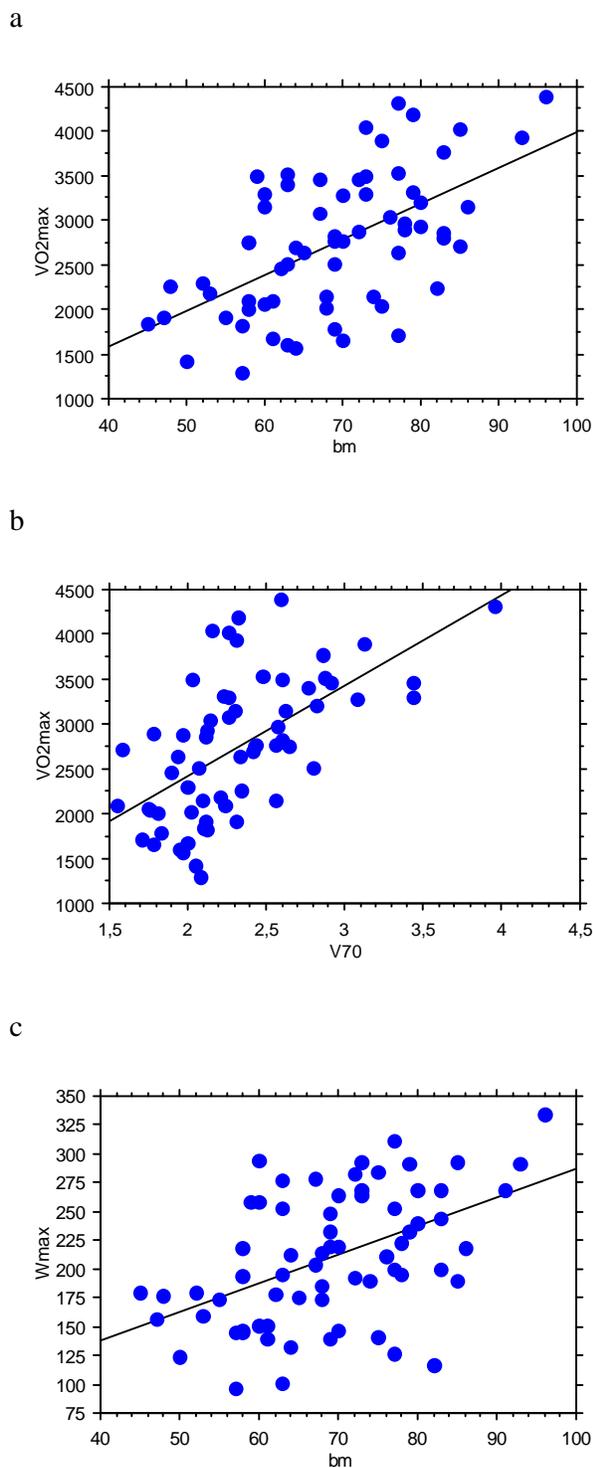
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Figure 1. Simple regression analyses depicting the random error around the line of best fit for a) VO₂max vs. body mass, b) VO₂max vs. V70, and c) Wattsmax vs. body mass.

A limitation for the use of "PWC 170" test in people over 40 years of age is the variability in the decrease in HRmax with increasing age (10). The V70/V90 test overcomes this problem by using a percentage of an individual's HRmax as a marker for the standard load. Gore et al. (14) also reflected on a certain percentage of a subject's HRmax, but the V70/V90 additionally considers an individual's HRrest. This further reflection might be an important point for improving the test's variance explanation, as HRrest varies significantly with different levels of CRF. Nevertheless, for tests like the "PWC 170" and that proposed by Gore, the requirement of expensive equipment remains a major limitation.

For estimating VO₂max or Wmax the use of body mass and age in addition to V70/V90 in a multiple regression equation improves the accuracy of prediction. We recommend that the V90 equations be used for younger and fit individuals, and the V70 equations be used for individuals of increasing age or low fitness.

We did not perform a retest for assessing the test-retest reliability for VO₂max as such statistics are well documented (24,25). The test-retest reliabilities of submaximal running tests are much less evaluated (26,27). Considering bicycle exercises, Wilmore et al. (27) found sufficient test-retest reliability of submaximal tests, especially when relative (60% of VO₂max) rather than absolute (to a fixed wattage) exercise intensities were used. We assume that because our test was also administered with relative exercise intensities, we would also have acceptable test-retest reliability.

In conclusion, we recommend that for medical and health related reasons, individuals should perform a physician supervised maximal exercise test prior to commencing an exercise training program. During the training program, such maximal tests no longer need to be performed, and we suggest that our simple running test can be used to document training effects throughout with relatively high accuracy of VO2max prediction.
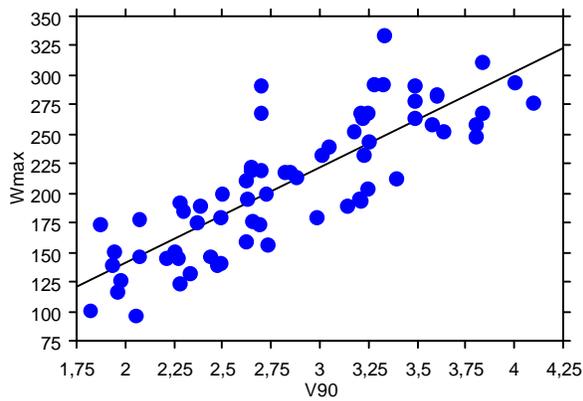
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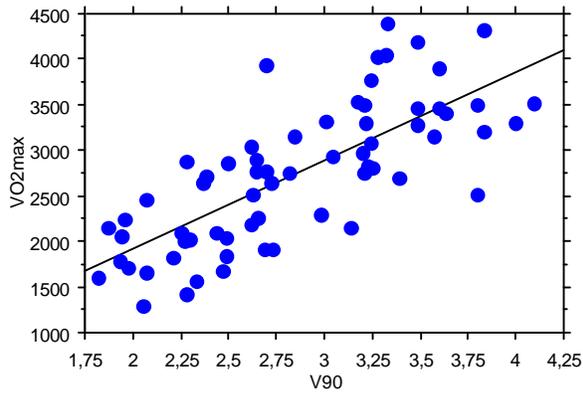
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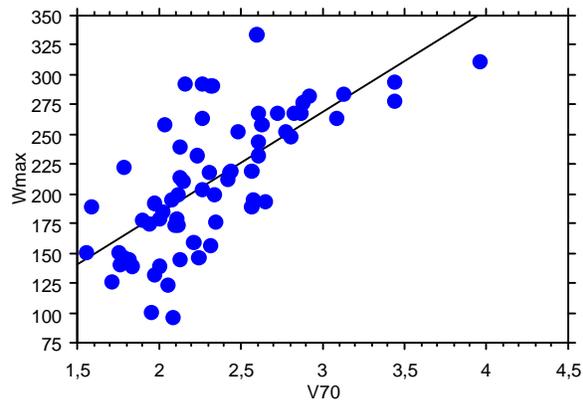
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Figure 2. Simple regression analyses depicting the random error around the line of best fit for a) VO₂max vs. V90, b) Wattsmax vs. V70, and c) Wattsmax vs. V90.

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