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ABSTRACT

The validity of selected lab and field tests of physical working capacity was investigated. Forty-four male college students were administered a series of lab and field tests of physical working capacity. Lab tests include a test of maximum oxygen uptake, the PWC 170 test, the Harvard Step Test, the Progressive Pulse Ratio Test, Margaria Test of Anaerobic Power, the Harvard Fitness Test, and Oxygen Debt following the Harvard Fitness Test. Field tests were the 10-yard dash; 50-yard dash; Sum 50's test; 300-yard, 600-yard, and 1-mile run; and the 12-minute run. Variables were intercorrelated using the Pearson product moment correlation method. Highly significant correlation was found between the maximum oxygen uptake expressed in ml/kg/min and the 12-mi ute run, 600-yard run, 1-mile run, Balke Test, and All-Out Treadmill Run. Moderate correlation was found between maximum oxygen uptake and the Harvard Fitness Test, the 300-yard run, the Astrand-Rhyming Test, Harvard Step Test, PWC 170, and the Progressive Pulse Test. Using Multiple Stepwise Regression, the following multiple correlation coefficients were found: from submaximal tests, .78; from maximal tests, .91; from field tests, .91; from other lab tests, .86; from all tests, .92. Within the limitations of the study, it was concluded that (a) maximal tests of greater than 1 minute in duration may be valid measures of aerobic capacity, and (b) maximal tests are better predictors of aerobic capacity than are submaximal tests. (Author/HMD)

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Validity of Selected Lab and

Field Tests of Physical

Working Capacity



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## Introduction

An important phase of the physical education profession is applied to testing of an individual's ability to meet the demands of varying types of work. Tests of working capacity have been developed for use in laboratory and field situations to assist the scientist, physical educator or coach in the determination of an individual's potential for a given sporting activity, the effects of a training program or the quantification of one of the components of physical fitness (15).

The investigator who goes to the exercise physiology literature in search of an appropriate instrument is met with a great many tests from which to choose. An analysis of the available tests of physical working capacity will reveal that they differ in several respects. Some rely primarily on the use of aerobic energy sources while others call primarily for the use of anaerobic reserves. Some tests require an all out maximal performance in contrast with others which require varying degrees of submaximal effort. Tests vary widely in the duration of effort required to complete the test. Some tests of physical working capacity are appropriate only to the modern fully equipped exercise physiology laboratory and usually make use of ergometry such as the treadmill, bicycle or step. In contrast, the investigator may choose a field which is usually performance based and may be easily administered by personnel in the field. Within lab and field tests there are noticeable differences as to the criterion measure used. Some lab tests rely on heart rate measurement either during or following exercise and are based on the linear relationship between heart rate and $\dot{V}O_2$. Some tests rely on actual measures of $\dot{V}O_2$ either during or following an exercise period. Perhaps the most important of these is the $\dot{V}O_2$ max test which is the most widely used criterion measure among exercise physiologists for the measurement of aerobic capacity. Field tests usually rely on time needed to complete a given amount of work, however some rely on amount of work performed in a given time period.

While such considerations as the tests' administrative feasibility and cost are of importance in selection for use, primary concern should be given to its validity. The present study has attempeted to draw together at least one test from each of the types of tests described above in an effort to assess their validity.

Review of Literature

Based on data from 11 college-age males, Ribisl and Kachadorian (27) obtained correlation coefficients between a treadmill test of $\dot{V}O_2$ max and a series of performance based field tests. Highest correlation coefficients obtained were between $\dot{V}O_2$ max expressed in ml/kg/min and the 880-yard run (r=-.67), the 1-mile run (r= -.67) and the 2-mile run (r= -.85). Using untrained college-age males, Wiley and Shaver (29) obtained correlation coefficients between a treadmill test of $\dot{V}O_2$ max expressed in ml/kg/min and the 2-mile run (r= -.47), the 3-mile run (r= -.43) and the Astrand-Rhyming prediction of $\dot{V}O_2$ max expressed in ml/kg/min (r= -.43). Molnar (26) determined the relationship between $\dot{V}O_2$ max expressed in ml/kg/min obtained from a bicycle test and the mile run (r= -.80) in 122 male college students.

Several studies have determined the relationship between $\dot{V}O_2$ max obtained from a treadmill test expressed in ml/kg/min and the 12-minute run. Cooper (6) tested 115 U.S. Airforce men, age 17 - 52 finding a correlation coefficient of .90. Maksud and Coutts (22) obtained a correlation coefficient of .65 using 80 boys, 11-14 years old. Doolittle and Bigbee (11) obtained a correlation coefficient of .90 using the Spearman rank-difference formula.

Several studies have determined the correlation coefficient between $\dot{V}O_2$ expressed in ml/kg/min and the 600-yard run. Utilizing 57 middle age men, Falls, et al. (13) obtained a correlation coefficient of -.64 between these tests. Doolittle and Bigbee (11) found a correlation of .62 between these two variables.

deVries and Klafs (10) obtained a series of correlation coefficients from data on 16 male physical education majors. Correlation coefficients were obtained between $\dot{V}O_2$ max expressed in ml/kg/min and each of the following tests: $PWC_{170}$ (r= .88), Harvard Step Test (r= .77). Progressive Pulse Ratio (r= .71) and the Astrand-Rhyming Prediction of $\dot{V}O_2$ max expressed in L/min (r= .52). Knuttgen (21) reported correlations of .77 and .75 between $\dot{V}O_2$ max and $PWC_{170}$ and the Astrand Rhyming Test (L/min).

Kearney and Byrnes (20) obtained a correlation coefficient of .61 between the Astrand-Rhyming test expressed in ml/kg/min and the 12-minute run. Dahlstrom (9) found a correlation coefficient of .61 between the Astrand-Rhyming Test expressed in L/min and $PWC_{170}$.

Fleishman (14) tested 201 U.S. Navy recruits with a mean age of eighteen years, in a study designed to determine the factors involved in performance. A correlation coefficient of .69 was obtained between the 10-yard and 50-yard dashes. Hunsicker (18) reported correlation coefficients from .18 to .50 between the 50-yard dash and the 600-yard run in a large group of U. S. public school children ages 10-17 years.

Procedures

The procedures for the study consisted of the administration of a series of tests of working capacity to 44 college men between the ages of 17 and 30. On most testing days, only one test was administered to each subject so as not to affect performance on a subsequent test. Prior to a particular testing session involving the use of respiratory apparatus, treadmill or bicycle ergometer, the subject was given a practice session in which to become acquainted with the use of the equipment. The order of test administration was randomly varied among subjects in an attempt to control for sequential effects. The average time required to administer all tests to one subject was about four weeks. All data was collected in a four month period.

Heart Rate Measurement

All tests involving the measurement of heart rate were conducted using bipolar chest electrodes connected to a NARCO physiograph chart recorder. This method permitted accurate permanent records to be kept for all heart rate tests.

Gas Analysis

Expired air was collected in 100-liter plastic Douglas bags. Ventilation was measured using a Parkinson-Cowan dry gas meter calibrated throughout the study using a Tissot gasometer. Expired air was analyzed using a Beckman Oxygen Analyzer Type F-3 and a Beckman Carbon Dioxide Analyzer Type LB-1. Gas analyzers were calibrated using certified gas samples (Puritan Compressed Gas Corp., Baltimore, Md.), checked for accuracy during the study by the Scholander method.

Tests

$\dot{V}O_2$ max which is widely accepted as the test which best measures the individual's aerobic capacity (2,27) was conducted using a modification of a method described by Mitchell, et al. (25). Following a 12-minute submaximal warmup period the subject was given a series of 3-minute workloads. The treadmill speed was set at 7 MPH and was increased by 2-½% grade with each run. Expired air was collected during the last 30 seconds of each run. $\dot{V}O_2$ max was defined as $\dot{V}O_2$ at which exhaustion occured or when there was less than 150 ml increase between work loads.

$\dot{V}O_2$ max (L/min) was converted to ml/kg lbm/min following measurement of lean body mass by an underwater weighing technique. Residual volume was estimated during submersion by the $O_2$ dilution method (30) using a modified Collins 13-1/2 liter respirometer and a Med Science 505 Nitralizer.

The Harvard Fitness Test and Cureton all-out run described by Hebbelinck (16) were administered separately and consisted of an all-out run on a treadmill at 7 MPH, 8.6% grade and 10MPH, 8.6% grade, respectively. $O_2$ Debt (expressed in liters) was defined as the difference between $\dot{V}O_2$ during recovery from the Harvard Fitness Test and $\dot{V}O_2$ during mild exercise (1.5 MPH and 0%). Continuous measurement of $\dot{V}O_2$ was made from the end of the run until the subjects $\dot{V}O_2$ had reached a level within 50 ml of the pre-exercise level. Alactate $O_2$ Debt was defined as the $O_2$ Debt during the first 3 minutes of recovery. The Balke Treadmill Test and Harvard Step Test were administered in a manner described earlier (7). $PWC_{170}$, the Astrand Bicycle Test and the Progressive Pulse Test were administered using methods described by deVries and Klafs (16). The Margaria Test of Anaerobic power relative to body weight in climbing a set of stairs. After being weighed the subject sprinted 6 meters to a set of stairs (17.5 cm/stair), two at a time as fast as possible. Photocells connected to an electric timer were placed at the second and sixth step. Five trials were given to each subject with the best time to the nearest .001 sec. being used. The vertical component of the speed in m/sec was used to compute the mechanical power in kilogram-meters/ kg/sec.

A series of performance based field tests were selected because of their ease of administration and wide range of times needed for performance. Included were: the 10-yard dash (14), the 50-yard dash (14), the 300-yard run, the 600-yard run (13), the 1-mile run and the Cooper 12-minute run (6). In addition the Sum 50's test was included which consisted of a series of three 50-yard dashes interrupted by 10-second rest intervals with the score obtained by adding the time in the first and third runs.

## Statistical Techniques

Twenty-one variables were intercorrelated using the Pearson product-moment correlation method. Stepwise multiple regression (using raw scores) was used to predict $\dot{V}O_2$ max expressed in ml/kg/min. t-tests were computed between selected correlation coefficients (17) in an attempt to determine validity of tests. Partial correlations were obtained to determine the effects of weight and body density on $\dot{V}O_2$ max.

## Results and Discussion

Means and standard deviations for each of the tests are presented in Table 1. Comparisons with previous standards in past research indicate that the subjects used in this study were above average in working capacity measures (6,7,10,13,14,20,23). Using $\dot{V}O_2$ max expressed in ml/kg/min as the criterion measure it may be noted that there is a rather uniform improvement in variance accounted, as the time needed for performance increases. Table 2 summarizes selected tests of the significance of the differences between correlation coefficients. Although no formal tests of significance between correlation coefficients have been found in the literature, these findings are in general agreement with earlier studies (10,27) and may be explained by the progressively greater aerobic metabolic involvement with tests of longer duration (2).

The 12-minute run had the highest correlation with $\dot{V}O_2$ max, sharing 81% of the variance ($r^2$). In general the performance based field test had greater shared variance with $\dot{V}O_2$ max than did the submaximal heart rate tests. Several factors may be responsible for this apparent trend. The ergometry used may have played a strong role. Americans are not used to riding bicycles or stepping up and down on benches. When the subjects were asked to walk up a progressively steeper slope as in the Balke test, heart rate was a good indicator of aerobic capacity (r= .78). Secondly, these findings appear to be indicative of the advantages of maximal tests as opposed to submaximal tests in measuring aerobic capacity. There may be important individual differences which adversley effect the hypothesized linear relationship between heart rate and $\dot{V}O_2$ in these tests. Finally, it should be noted that when these tests are submitted to factor analysis they load most heavily on an orthongonal factor which may be termed heart rate response to exercise (4).

There was a high degree of shared varied variance between $\dot{V}O_2$ max expressed in L/min and body weight. This is in agreement with earlier research which has indicated that $VO_2$ max expresses in L/min is strongly biased by body weight (5,8,12,28). Although there are two studies in the literature reporting conflicting results using a bicycle ergometer (1,19), it would appear to be prudent for researchers to express $\dot{V}O_2$ in ml/kg/min or ml/kg lbm/min when comparing between individuals or comparing the same individual before and after training. From Table 3 it can be noted that $\dot{V}O_2$ max expressed in ml/kg/min is relatively unaffected by body weight or % body fat — as it relates to selected tests of working capacity. Table 4 summarizes the regression equation and multiple correlation coefficients obtained from the prediction of $\dot{V}O_2$ max in ml/kg/min.

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## TABLE 1

### Intercorrelation Matrix [1,2]

| | $\bar{X}$ | S.D. | S. E. of Estimate [3] | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. $\dot{V}O_2$ max ml/kg/min | 52.79 | 6.09 | | | | | | | | | | | | | | | | | | | | | | | |
| 2. $\dot{V}O_2$ max l/min | 4.13 | .71 | 4.87 | 61 | | | | | | | | | | | | | | | | | | | | | |
| 3. $\dot{V}O_2$ max ml/kg lbm/min | 63.22 | 6.60 | 2.11 | 94 | 65 | | | | | | | | | | | | | | | | | | | | |
| 4. 10-yd Dash (sec) | 1.65 | .10 | 5.94 | -23 | -07 | -14 | | | | | | | | | | | | | | | | | | | |
| 5. 50-yd Dash (sec) | 6.18 | .36 | 5.84 | -29 | -18 | -24 | 84 | | | | | | | | | | | | | | | | | | |
| 6. Sum 50's Test (sec) | 13.28 | .81 | 5.34 | -48 | -30 | -36 | -69 | 82 | | | | | | | | | | | | | | | | | |
| 7. 300 yd (sec) | 45.24 | 3.33 | 5.20 | -52 | -41 | -49 | 63 | 69 | 72 | | | | | | | | | | | | | | | | |
| 8. 600 yd (sec) | 113.50 | 10.68 | 3.80 | -78 | -45 | -72 | 21 | 26 | 47 | 52 | | | | | | | | | | | | | | | |
| 9. 1-mile (sec) | 404.27 | 40.28 | 4.09 | -74 | -44 | -66 | 22 | 26 | 44 | 57 | 66 | | | | | | | | | | | | | | |
| 10. 12 Min Run (yds) | 2934.09 | 279.00 | 2.65 | 90 | 47 | 85 | -14 | -24 | -42 | -51 | -77 | -82 | | | | | | | | | | | | | |
| 11. Harvard Step Test | 90.06 | 12.87 | 5.09 | 55 | 39 | 46 | -04 | -14 | -30 | -25 | -48 | -45 | 56 | | | | | | | | | | | | |
| 12. A-R Test l/min | 3.31 | .73 | 5.20 | 52 | 69 | 48 | -06 | -26 | -38 | -31 | -33 | -37 | 44 | 57 | | | | | | | | | | | |
| 13. A-R Test ml/kg/min | 42.93 | 8.24 | 4.80 | 62 | 28 | 51 | -09 | -27 | -44 | -27 | -42 | -39 | 59 | 66 | 75 | | | | | | | | | | |
| 14. PWC 170 | 3.12 | .64 | 4.95 | 58 | 23 | 46 | -16 | -29 | -43 | -26 | -39 | -44 | 60 | 64 | 72 | 88 | | | | | | | | | |
| 15. Progressive Pulse Test | 169.18 | 20.86 | 5.38 | -47 | -36 | -37 | 11 | 18 | 32 | 24 | 31 | 44 | -43 | -66 | -51 | -57 | -55 | | | | | | | | |
| 16. Margaria Test | 49.38 | 4.00 | 5.58 | 41 | 22 | 34 | -47 | -58 | -65 | -48 | -39 | -32 | 32 | 25 | 30 | 33 | 37 | -25 | | | | | | | |
| 17. Balke Test (min) | 18.84 | 2.68 | 3.90 | 77 | 43 | 62 | -14 | -18 | -36 | -36 | -60 | -66 | 73 | 60 | 55 | 67 | 70 | -63 | 30 | | | | | | |
| 18. 7 MPH - 8.6% (sec) | 235.05 | 144.29 | 4.39 | 69 | 34 | 63 | -27 | -25 | -32 | -43 | -60 | -64 | 71 | 51 | 37 | 49 | 60 | -49 | 43 | 65 | | | | | |
| 19. 10 MPH - 8.6% (sec) | 69.64 | 26.13 | 4.09 | 74 | 36 | 67 | -33 | -32 | -40 | -53 | -69 | -67 | 71 | 41 | 34 | 43 | 50 | -40 | 43 | 63 | 75 | | | | |
| 20. Alactate $O_2$ Debt. | 3.25 | .76 | 5.65 | 38 | 67 | 39 | 20 | -00 | -13 | -26 | -34 | -38 | 30 | 21 | 55 | 27 | 18 | -28 | 17 | 33 | 23 | 26 | | | |
| 21. $O_2$ Debt | 7.37 | 3.08 | 5.90 | 25 | 38 | 23 | 02 | -04 | -09 | -18 | -23 | -27 | 20 | 06 | 28 | 11 | 11 | -12 | 14 | 11 | 16 | 62 | 62 | | |
| 22. Body Wt (lbs) | 172.34 | 24.29 | 6.09 | -07 | 74 | 03 | 10 | 02 | 03 | -10 | 09 | 06 | -11 | 02 | 44 | -18 | -21 | -04 | -05 | -10 | -13 | -14 | 59 | 28 | |
| 23. % Lean Body Mass | .84 | .03 | 5.84 | 29 | 22 | 05 | -43 | -34 | -42 | -25 | -00 | -15 | 18 | 28 | 39 | 40 | 38 | -30 | 24 | 32 | 21 | 23 | 11 | 08 | 03 |

[1] Correlations are rounded to two places and decimals omitted.

[2] $r = .38$, $p < .01$; $r = .29$, $p < .05$

[3] Standard Error of Estimate for each of the variables in predicting $\dot{V}O_2$ max expressed in ml/kg/min.

Table 2

t-Test Analysis Between
Selected Correlation Coefficients

| Test | Correlation With $\dot{V}O_2$ max | | Correlation With $\dot{V}O_2$ max | T-Score |
|---|---|---|---|---|
| 12-Min | .90 | 600 | -.78 | 2.73** |
| 12-Min | .90 | 1-mile | -.74 | 3.69** |
| 12-Min | .90 | Balke | .77 | 2.58** |
| 12-Min | .90 | A-R (ml/kg/min) | .62 | 4.61** |
| Balke | .77 | 600 | -.78 | .20 |
| Balke | .77 | 1-mile | -.74 | .41 |
| Balke | .77 | A-R (ml/kg/min) | .62 | 1.87* |
| Balke | .77 | Harvard Step | .55 | 2.52** |
| 600 | -.78 | 1-Mile | -.74 | .58 |
| 600 | -.78 | A-R (ml/kg/min) | .62 | 1.76* |
| 600 | -.78 | Harvard Step | .55 | 5.66** |

** P = <.01

* P = <.05

TABLE 3

Correlations between $\dot{V}O_2$ max and Selected Work Tests with Weight and Body Density Partialed Out

| | 600 | 1-Mile | 12-Min | A-R Ml/Kg/Min | HST | $PWC_{170}$ | Balke |
|---|---|---|---|---|---|---|---|
| $r_{12}$ | -.78 | -.74 | .90 | .62 | .55 | .58 | .77 |
| $r_{12.3}$ | -.78 | -.74 | .90 | .62 | .55 | .58 | .77 |
| $r_{12.4}$ | -.81 | -.73 | .90 | .58 | .51 | .53 | .74 |

1 = $\dot{V}O_2$ max

2 = Selected Test

3 = Weight

4 = Body Density

Table 4

Regression Equations* for Prediction of $\dot{V}O_2$ max ml/kg/min

| Types of Predictor Variables | Number of Predictor Variables | Multiple R | Regression Equation |
|---|---|---|---|
| Using all variables | 18 | .92 | $\hat{Y}$ = .015 (12-Min Run) + .488 (Balke Test) -.183 (Margaria Test) - 10.616 |
| Using Maximal Tests | 12 | .91 | $\hat{Y}$ = .017 (12-Min Run) + .047 (7 mph - 8.6%) Run + 1.016 |
| Using Submaximal Tests | 6 | .78 | $\hat{Y}$ = 1.448 (Balke Test) + 1.44 (Astrand Test ml/kg/min) + 19.313 |
| Using other Lab Tests | 11 | .86 | $\hat{Y}$ = .941 (Balke Test) + .105 (7 mph - 8.6%) Run + .310 (Astrand Test ml/kg/min) - 2.88 ($PWC_{170}$) + 23.439 |
| Using Field Tests | 7 | .91 | $\hat{Y}$ = .018 (12-Min Run) -.077 (600-yard run) + 9.295 |

*Proportion of sum of squares used to limit entering variables = 1%

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