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VALIDATION OF A QUICK, SUBMAXIMAL TEST OF MAXIMAL OXYGEN INTAKE

by

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13. ABSTRACT

The purpose of this study was to validate a submaximal treadmill test for prediction of maximal oxygen consumption in fifteen male college students. This objective was accomplished by comparing maximal oxygen intake values recorded during a maximal treadmill test with those predicted from the submaximal test. Comparisons were also made among and between the true and predicted values and those estimated from the Astrand-Rhyming nomogram. Application of the analysis of variance techniques indicated that no significant difference existed between the criterion and the two predictors. The average error of prediction; however, was 8 percent for the submaximal test and 15 percent for the nomogram. The results of the study indicated that the submaximal test yielded a valid estimate of maximal oxygen intake and is more accurate than several of the commonly used submaximal tests.

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1. Exercise physiologists generally agree that the ability to perform hard physical work is related to the maximal capacity of the cardiorespiratory system to take up, transport, and give off oxygen to the tissues (1, 5, 6). Although several effective techniques have been developed for assessing maximal oxygen uptake, the complexity of such direct measures as well as the severe physical demands made upon the subject have made them impractical for use with untrained or older individuals. Efforts have been made to develop a test in which only submaximum effort is required from the subjects (2, 3, 4, 9). Such tests are based upon the relatively linear relationship between heart rate and oxygen consumption. Heart rate and oxygen consumption are measured at from one to several submaximum levels of work. The heart rate values are then plotted against the oxygen consumption values and a straight line fitted to the plots and extrapolated to the assumed mean maximum heart rate value of the population. The oxygen consumption corresponding to the mean maximum heart rate value is similar to the individuals maximum intake measured by a direct method.

2. While numerous submaximal techniques have been developed, no agreement exists as to the best method of estimating maximal

oxygen intake. The variability and time consuming procedures of the submaximal techniques reported in the literature limit their use in physiological research.

3. The purpose of this study was to validate a quick submaximal test of maximal oxygen consumption. This objective was accomplished by comparing maximal oxygen intake values recorded during a maximal test with those predicted from data obtained during a continuous submaximal test. Comparisons were also made among and between the true and predicted values and those estimated from the Astrand-Rhyming nomogram.

Procedure

Subjects

4. The subjects for this study were fifteen male physical education majors enrolled at Texas Tech University, Lubbock, Texas. Mean age was 22.67 years (SD=1.80), mean body weight was 81.73 kilograms (SD=11.98) and mean height was 175.53 centimeters (SD=7.34). All subjects were free of physical disabilities and accustom to strenuous physical work.

Maximal Oxygen Consumption Test

5. Maximal oxygen intake was determined for each subject during a continuous multistage treadmill test similar to that described by McDonough and Bruce (8). The test consisted of a series of 3-minute runs at a constant speed (6 mph) on a grade which was gradually increased with each run. Each run

was separated by a 3-minute rest period. This procedure was continued with each work load being increased by 2.5 degree increments in grade until the oxygen consumption values between two successive work loads differed by ± 150 ml per minute or less, or until the subject was unable to complete the work load. Research indicates that the results obtained with this procedure are almost identical with those obtained with Taylor's method (12). Heart rate and oxygen consumption were recorded continuously during the run. Expired air was breathed through a triple "J" value into a one and one-half inch plastic tube connected directly to an oxygen consumption computer manufactured by Versatronics/Technology.

Submaximal Oxygen Consumption Test

6. A modification of the Maritz, et al., (10) technique was used for predicting maximum oxygen uptake. Each subject reported to the laboratory having had no strenuous physical activity for at least 12 hours and no large meal for 2 hours. The subject walked on the treadmill for 5 minutes at 3 miles per hour on a level grade. This preliminary light exercise allowed the subject to become accustomed to the equipment. Upon completion of the 5-minute walk, the treadmill speed was increased to 4 miles per hour with the grade maintained at zero degrees. Following 5 minutes of walking at this intensity, the treadmill grade was elevated to 4 degrees and the subject continued to walk at 4 miles per hour for an additional 5 minutes. At this point, the

treadmill grade was increased 4 degrees each 5 minutes while the speed remained constant at 4 miles per hour. The subject continued to walk on the treadmill until his heart rate reached 160 beats per minute. The test was continuous with no rest allowed between successive 5-minute walks.

7. Oxygen uptake was continuously monitored using an oxygen consumption computer manufactured by Versatronics/Technology. Heart rate was determined each minute from the ECG tracings. Heart rate and oxygen uptake measures recorded during the last minute of each 5 minute work interval were criterion scores. This procedure produced 4 to 6 pair of heart rate and oxygen consumption points. Maximum oxygen uptake was determined by utilizing the essentially linear relationship between heart rate and oxygen consumption. Paired heart rate and oxygen uptake values recorded at each submaximal work level were plotted on the ordinate and abscissa, respectively. A linear extrapolation was then made to the assumed maximum heart rate of the subject which was determined according to the procedure reported by Maritz, et al. (8). The aerobic capacity of the individual was predicted from the intersection of the maximum heart rate line and the line of at least squares for the measured values.

Astrand-Rhyming Nomogram

8. Maximal oxygen uptake was predicted from the Astrand-Rhyming nomogram (2) using the paired heart rate and oxygen intake values recorded during the last minute of work on the submaximal test. The heart rate values recorded during this

time interval were approximately 160 beats per minute. Values of this magnitude reportedly will yield a more accurate estimate of maximal oxygen intake than will predictions based on lower heart rate scores (14).

Results and Discussion

9. The results of the three aerobic capacity tests are presented in Table 1. Inspection of this table indicates that the mean maximal oxygen intake was 4.49 $\pm$ .79 liters/minute while it was predicted to be 4.24 $\pm$ .73 liters/minute by the submaximal test and 3.99 $\pm$ .83 liters/minute by the Astrand-Rhyming nomogram. Expressed in ml/kilogram of body weight per minute, these mean values were 55.06 $\pm$ 7.52, 52.06 $\pm$ 6.90 and 48.91 $\pm$ 8.59, respectively. Comparison of the mean results for the three tests by analysis of variance yielded a non-significant F-ratio ($F=1.59$) among test means.

10. A matrix of intra- and intervariable zero order correlations was computed as a means of evaluating the extent of the relationship among and between body weight and the three oxygen intake tests (Table 2). The coefficient of correlation between maximum oxygen intake (liters/minute) and the submaximal prediction was .83. The coefficient of correlation between the criterion (liters/minute) and the Astrand-Rhyming prediction was .68, while that between the two submaximal predictions was .91. Although each of these relationships was significant beyond the .05 level of confidence, when oxygen intake was expressed

relative to body weight (ml/kg/min), these correlations were reduced to .68, .43, and .84, respectively. These reductions were expected and, according to Wilmore (13), may be due in part to the significant positive relationship of body weight to absolute maximal oxygen intake and its inverse relationship to relative aerobic capacity.

11. In order to examine the influence of body weight on the relationships between the three tests utilized in this study, correlation coefficients were computed holding body weight constant through the use of a partial correlation analysis (Table 3). The correlation between true and predicted maximal oxygen intake (ml/kg/min) while holding body weight constant was .68, also the value observed for the zero order correlation between the relative values for these two tests. Apparently once zero order correlations are computed between the relative oxygen intake values (ml/kg/min), no further statistical gains are observed by holding body weight constant.

12. While a higher correlation coefficient is obtained by expressing the relationship between the criterion and predictor in absolute terms (liters/minute) the relationship is misleading since body weight is positively correlated with both true and predicted oxygen intake expressed in liters/minute (Table 2). This hypothesis is further substantiated by observing that after adjusting for body weight the relationship between true and predicted oxygen intake (liters/minute) does indeed decrease from $r=.84$ to $r=.68$ (Table 3).

13. The regression equations for maximal oxygen intake (liters/minute) predicted from the submaximal test and the Astrand-Rhyming nomogram are presented in Table 5. Regression equations for the criterion and the two predictors expressed in relative terms (ml/kg/min) are also presented in this table.

14. The average error of prediction observed in this study was 8.02 percent for the submaximal test and was markedly lower than that (14.26 percent) obtained on the same subjects for the Astrand-Rhyming nomogram. The average (8.02 percent) error reported in this investigation was also similar to or less than the error values reported in the literature for other submaximal predictors. The error values reported in the literature ranged from approximately 8 percent for predicted scores of Bantu miners working with the step test (8) to 27 percent for sedentary adults tested on the bike and predicted by the Astrand-Rhyming nomogram (11). The average error of prediction (14.26 percent) for the Astrand-Rhyming nomogram used in this study was consistent with that reported by Astrand and Rhyming (2).

15. On the basis of the results of this study and other studies cited it would seem that at least for physically trained college men, maximal oxygen intake can be determined with a reasonable error of prediction from submaximal tests. For the population tested in this investigation, the higher predictive value was realized from the submaximal test. The use of 4 to 6 work loads to determine a slope line in the submaximal test appears to offer an advantage over the Astrand-Rhyming procedure in

which the maximal oxygen intake is predicted from one submaximal work load. The test-retest reliability coefficient for the submaximal test was r=.91 which was significant at the .05 level of confidence. The data obtained in this investigation support the conjecture of other investigators (7, 13) that when evaluating the true relationship between actual and predicted maximal oxygen intake, greater interpretive significance may be obtained when the influence of body weight is held statistically constant or adjusted.

TABLE 1

OXYGEN INTAKE FOR MAXIMAL TEST, SUBMAXIMAL TEST, AND ASTRAND-RHYMING NOMOGRAM

Subject	Liters/Min.			ml/kg/min.		
	True	Predicted	A-RN	True	Predicted	A-RN
1	3.90	3.20	2.30	50.47	41.41	29.77
2	4.28	4.42	4.30	50.90	52.56	51.14
3	5.21	4.96	4.40	52.10	49.66	44.00
4	3.42	3.42	3.25	48.55	48.55	46.13
5	4.47	3.72	3.70	54.63	45.47	45.22
6	4.56	3.97	3.20	59.72	51.98	41.91
7	3.03	3.39	3.58	49.38	55.25	58.34
8	4.72	4.40	4.50	56.13	52.32	53.51
9	4.66	4.94	4.30	64.88	68.78	59.87
10	5.42	4.26	3.70	70.14	55.21	47.88
11	3.81	3.49	3.30	50.80	46.53	44.00
12	5.73	5.28	5.50	67.54	63.44	66.12
13	4.57	4.23	4.15	50.27	46.53	45.65
14	3.91	4.25	4.20	47.79	51.94	51.33
15	5.59	5.66	5.38	50.61	51.24	48.71
$\bar{X}$	4.49	4.24	3.99	55.06	52.06	48.91
SD	.79	.73	.83	7.52	6.90	8.59

TABLE 2

INTERCORRELATIONS BETWEEN AND AMONG BODY WEIGHT AND THE THREE OXYGEN INTAKE TESTS (N=15)

Variable	2	3	4	5	6	7
1. Weight	.68	.71	.61	-.13	-.19	-.13
2. Maximal Test (liters/min)		.84	.68	.64	.34	.22
3. Submaximal Test (liters/min)			.91	.39	.56	.51
4. A-R Nomogram (liters/min)				.28	.54	.70
5. Maximal Test (ml/kg/min)					.68	.43
6. Submaximal Test (ml/kg/min)						.84
7. A-R Nomogram (ml/kg/min)						

$r \geq .51$ necessary for significance at .05 level

TABLE 3

PARTIAL CORRELATION COEFFICIENTS BETWEEN THE OXYGEN INTAKE TESTS

Paired Variables	Zero Order	First Order
True (liters/min) vs Predicted (liters/min)	.84	.68
True (liters/min) vs A-RN (liters/min)	.68	.43
True (liters/min) vs P(ml/kg/min)	.34	.66
True (liters/min) vs A-RN(ml/kg/min)	.22	.43
True (ml/kg/min) vs P(ml/kg/min)	.68	.68
True (ml/kg/min) vs A-RN(ml/kg/min)	.43	.43

$r \geq .51$ necessary for significant at .05 level

TABLE 4

REGRESSION COEFFICIENTS BETWEEN

THE OXYGEN INTAKE TESTS

Tests	r	Slope	Constant	S.E. of Prediction
Maximal against Predicted (liters/min)	.84	.89	.70	.45
Maximal against Predicted (ml/kg/min)	.68	.65	1.90	.60
Maximal against A-RN (liters/min)	.68	.74	16.59	5.74
Maximal against A-RN (ml/kg/min)	.43	.38	36.49	7.32

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Submaximal						
Oxygen consumption						
Cardiorespiratory system						
Treadmill						
Astrand-Rhyming nomogram						
Physiological						
Predictors						
Aerobic capacity						
Maximal oxygen intake						