Peak oxygen deficit predicts sprint and middle-distance track performance

PETER G. WEYAND, KIRK J. CURETON, DONOVAN S. CONLEY, MARK A. SLONIGER, and YI LIN LIU

Exercise Physiology Laboratory, Department of Exercise Science, University of Georgia Athens, GA 30602

ABSTRACT

WEYAND, P. G., K. J. CURETON, D. S. CONLEY, M. A. SLONIGER, AND Y. L. LIU. Peak oxygen deficit predicts sprint and middle-distance track performance. *Med. Sci. Sports Exerc.*, Vol. 26, No. 9, pp. 1174–1180, 1994. The purpose of this study was to determine the value of the peak oxygen deficit (POD) as a predictor of sprint and middle-distance track performance. POD, peak blood lactate, $\dot{V}O_{2peak}$, lactate threshold, and running economy at 3.6 $m \cdot s^{-1}$ were measured during horizontal treadmill running in 22 male and 19 female competitive runners of different event specialties. Subjects also completed running performance trials at 100, 200, 400, 800, 1500, and 5000 m. Correlations of track performances with POD ($ml \cdot kg^{-1}$) (−0.66, −0.71, −0.71, −0.62, −0.52, and −0.40) were moderately strong at the sprint and middle distances, accounting for 44–50% of the performance variance at the three shortest distances. Correlations of track performances with peak blood lactate concentration were lower than with POD and accounted for approximately one-half as much of the performance variance (21–26%) at the three shortest distances. Multiple regression analyses indicated that the POD was the strongest metabolic predictor of 100-, 200- and 400-m performance, and that $\dot{V}O_{2peak}$ was the strongest metabolic predictor of 800-, 1500-, and 5000-m performance. We conclude that the POD is a moderately strong predictor of sprint and middle-distance track performance.

AEROBIC METABOLISM, ANAEROBIC METABOLISM, BLOOD LACTATE, ENERGY METABOLISM, FEMALES, MALES, RUNNING

The physiologic determinants of performance in running events of longer duration are well established. The combination of maximal oxygen uptake ($\dot{V}O_{2peak}$), running economy, and lactate threshold account for a high proportion of performance variance at distances of 5 km or greater (4,6,26). To date, physiologic measures with equivalent predictive power for shorter events are lacking. Because such events rely more heavily on anaerobic metabolism (1,9,10), the absence of a suitable measure of anaerobic capacity may be responsible for the poorer predictions.

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At present, there is no accepted measure of anaerobic capacity (21). Traditional measures, such as the concentration of lactate in the blood or the oxygen debt after brief intense exercise, the Margaria test, and Wingate tests do not provide valid, quantitative estimates of the anaerobic energy released (21) and do not accurately predict high-intensity running performance (7,14,18,19,28,29). Hermansen and Medbø (11) proposed that the maximal oxygen deficit could be used to assess anaerobic capacity. This measure is reliable (16) and is purported to be more valid than other measures of anaerobic capacity (21).

Scott et al. (23) reported moderate correlations of maximal oxygen deficit assessed during uphill running with track sprint and middle-distance running performance in a small sample ($N = 12$) of male competitive runners. Because maximal oxygen deficit measured during uphill running is larger than the peak oxygen deficit (POD) measured during horizontal running (20), it may not reflect the potential for anaerobic energy release during horizontal running. Whether the POD measured during horizontal running is more strongly related to running performance is unknown.

The objective of this study was to determine the value of the POD assessed during horizontal running as a predictor of sprint and middle-distance track performance in a heterogeneous group of male and female competitive runners. Established predictors of distance running performance ($\dot{V}O_{2peak}$, running economy, and lactate threshold) were also measured to determine the relative importance of the POD and these measures in predicting track running performance at different distances.

METHODS

Subjects. Twenty-two males, 9 sprinters and 13 distance runners, and 19 females, 7 sprinters and 12 distance runners, 18–36 yr of age, volunteered to participate in the study. Those athletes who specialized in an event of 800 m or shorter were classified as sprinters. Those who specialized in an event of 1500 m or longer were classified as distance runners. The majority of the athletes in the male and female sprint groups were 400-m specialists, whereas the majority of the athletes in the male and female distance groups were 5,000-m and 10,000-m specialists. Both sprinters and distance runners were included in the sample in order to maximize variance in anaerobic capacity and performances at different distances. The physical characteristics of the subjects are summarized in Table 1.

The sprinters were high-caliber collegiate track athletes who were active team members at the time of the study. The distance runners competed as sponsored members of regional competitive track clubs or as unattached athletes. Almost all the distance runners had competitive track experience, excepting the few females who were exclusively road runners. Prior to testing, all subjects provided written consent and completed medical, training, and performance history questionnaires.

$\dot{V}O_{2peak}$. $\dot{V}O_{2peak}$ was determined from a discontinuous, speed-incremented treadmill test administered at 0% grade. After a 5-min running warm-up at 2.9 $m \cdot s^{-1}$, a minimum of seven 5-min bouts of running at progressively higher velocities, interspersed with 5-min recovery periods, were completed. Successive bouts were continued until the subject could not complete the 5-min period. $\dot{V}O_{2peak}$ was considered to be the highest level of oxygen uptake recorded for any single minute during the test.

Inspired air volume was measured using a dry gas meter (Model REP-9200, Rayfield Equipment, Waitsfield, VT). Expired air was analyzed for oxygen and carbon dioxide (Applied Electrochemistry models S-A/I and CD-3A, respectively). Gas analyzers were calibrated prior to testing using standard gases analyzed using a micro-Scholander. $\dot{V}O_2$ (STPD) was measured continuously throughout the test using a computerized data acquisition system (Rayfield Equipment) interfaced with the gas meter and the gas analyzers. A moving 1-min average was calculated every 15 s.

Lactate threshold. Blood samples were obtained via digit puncture immediately following each exercise bout of the progressive exercise test. Samples were assayed in duplicate for lactate using a YSI Model 27 analyzer.

TABLE 1. Physical characteristics of the subjects (means ± SD).

Variable	Males: Sprinters (N = 9)	Males: Distance Runners (N = 13)	Females: Sprinters (N = 7)	Females: Distance Runners (N = 12)
Age (yr)	20.3 ± 1.7*‡	28.2 ± 2.6†	20.3 ± 1.4‡	29.3 ± 3.7
Height (cm)	178.2 ± 4.2†‡	183.0 ± 4.7†‡	165.3 ± 4.7	162.2 ± 7.5
Mass (kg)	71.9 ± 4.0†‡	69.5 ± 6.0†‡	56.7 ± 5.6	52.0 ± 6.2
Fat-free mass (kg)	65.4 ± 3.2†‡	61.2 ± 5.4†‡	49.0 ± 3.8‡	42.6 ± 5.9
Fat (%)	7.1 ± 3.8†‡	9.7 ± 2.7†‡	13.2 ± 4.0‡	17.4 ± 3.4

* Significantly different from male distance runners.
† Significantly different from female sprinters.
‡ Significantly different from female distance runners.

Lactate threshold, defined as the rate of oxygen uptake at which blood lactate rose 1 $mmol \cdot l^{-1}$ above its resting concentration (5), was determined by interpolation of lactate concentrations and oxygen uptakes. Lactate threshold was expressed as a percentage of $\dot{V}O_{2peak}$ to minimize the variance shared with $\dot{V}O_{2max}$.

Running economy. Running economy was determined during the test used to measure $\dot{V}O_{2peak}$ by averaging the $\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$) during the 4th and 5th minutes of each bout of running. The value at 3.6 $m \cdot s^{-1}$ was used as the representative value in the data analysis.

Peak oxygen deficit. POD was determined from a modification of the procedure originally proposed by Hermansen and Medbø (11) and further developed by Medbø et al. (16). The POD was calculated as the difference between the estimated oxygen demand and oxygen uptake during exhaustive, supramaximal, constant-rate horizontal treadmill runs lasting 2–4 min. Treadmill speeds estimated to elicit exhaustion in just over 2 min were determined from past running performances of the subjects. During the runs, expired air was collected in serial meteorological balloons for the first two 30-s intervals and for 1-min intervals thereafter. The average of two runs separated by 50 min was used in the data analysis. No correction was made for the portion of the oxygen deficit estimated to be due to oxygen stores, because a linear transformation of the data would not alter the relationships with other variables.

The oxygen (energy) demand during the supramaximal treadmill runs was estimated by extrapolating the linear relation of oxygen uptake to treadmill velocity during submaximal exercise. The $\dot{V}O_2$-velocity relation was established by averaging the oxygen uptake during the 4th and 5th minutes of horizontal running at each velocity during the test that was used to measure $\dot{V}O_{2peak}$. $\dot{V}O_2$ was measured during minutes 4 and 5, rather than during minutes 9 and 10 as proposed by Medbo et al. (16), to ensure that the $\dot{V}O_2$-power output relation remained linear at higher exercise intensities as discussed previously (30). Points from the initial velocity above 2.9 $m \cdot s^{-1}$ through the next to last velocity the subject completed were used. Not less than five points, and generally seven points, were used in the formulation of individual regression lines (20,30). The average correlation between $\dot{V}O_2$ and speed was 0.99, indicating the relationships were highly linear. The relation between $\dot{V}O_2$ and treadmill speed for all subjects was: $\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$) = 2.67 (speed, $m \cdot s^{-1}$) − 5.9.

Peak blood lactate. Blood samples obtained via digit puncture 3 min after each of the exhaustive, supramaximal treadmill tests (22) were assayed in duplicate for lactate using a YSI Model 27 analyzer. An average of the values following the two tests was used to represent the peak concentration.

Body composition. Body density was determined through underwater weighing with residual volume measured simultaneously using the nitrogen-dilution, oxygen-rebreathing method (8). Percent fat was estimated from body density using the Siri (24) equation (%fat = 495/Db − 450).

Track performance. Run performance times were determined at three sprint distances, 100, 200, and 400 m; two middle distances, 800 and 1500 m; and one long distance, 5000 m. Most of the performance tests occurred in competitive group settings on 400-m all-weather tracks. These events were hand timed. A small number of performances took place in actual competitions that were automatically timed. These times were adjusted to equivalent hand times. There were a small number of time trials during which subjects performed alone. Three of the female sprinters performed 200-, 400-, and 800-m time trials on indoor tracks. One male sprinter did not complete the 100-m trial, three female sprinters did not complete the 1500-m trial, and six male and six female sprinters did not complete the 5000-m trial.

Statistical analyses. The significance of mean differences between the male and female sprinter and distance runner subgroups for the physical characteristics, metabolic variables, and run performances was determined using a one-way ANOVA with the Student-Newman-Keuls *post-hoc* test. Simple linear regression analysis and correlations, and partial correlations with the effect of sex and event specialty held constant, were used to determine the accuracy of predicting run performances from individual independent variables. Standardized regression coefficients from multiple regression analyses predicting track performances from the metabolic variables (POD, $\dot{V}O_{2max}$, lactate threshold, and running economy at 3.6 $m \cdot s^{-1}$) and design variables (sex and event specialty) were used to indicate the relative importance of the independent variables in accounting for performance variance at each of the distances. Statistical analyses were performed using the Statistics Analysis System version 6.06. The 0.05 level was used for all tests of significance.

TABLE 2. Means (±SD) of metabolic variables.

	Males		Females	
Variable	Sprinters	Distance Runners	Sprinters	Distance Runners
Peak oxygen deficit ($ml \cdot kg^{-1}$)	55.1 ± 5.7*†‡	46.8 ± 11.0	45.3 ± 6.0	37.8 ± 7.5
Peak blood lactate ($mmol \cdot l^{-1}$)	10.6 ± 1.4*†‡	7.9 ± 1.9	8.3 ± 1.2	7.8 ± 2.1
$\dot{V}O_{2peak}$ ($ml \cdot kg_{-1} \cdot min^{-1}$)	60.1 ± 3.6*†	70.9 ± 3.3†‡	49.3 ± 3.1‡	59.4 ± 3.3
Lactate threshold (% $\dot{V}O_{2peak}$)	79.7 ± 4.4*‡	85.4 ± 4.4	84.0 ± 4.0	87.2 ± 5.4
Running economy ($\dot{V}O_2$ $ml \cdot kg^{-1} \cdot min^{-1}$ at 215 $m \cdot min^{-1}$)	44.0 ± 3.2*	39.9 ± 2.5†‡	43.0 ± 2.3	42.9 ± 2.9

* Significantly different from male distance runners.
† Significantly different from female sprinters.
‡ Significantly different from female distance runners.

TABLE 3. Means (±SD) of track running performances.

	Males		Females	
Variable	Sprinters	Distance Runners	Sprinters	Distance Runners
100 m (s)	11.7 ± 0.8*†‡	13.4 ± 0.8‡	13.1 ± 0.7‡	15.7 ± 1.0
200 m (s)	23.0 ± 1.4*†‡	27.4 ± 1.7‡	26.4 ± 1.5‡	32.4 ± 2.0
400 m (s)	50.5 ± 2.5*†‡	58.5 ± 3.0‡	57.9 ± 1.9‡	70.6 ± 3.7
800 m (s)	121.6 ± 4.6†‡	126.9 ± 5.6†‡	151.9 ± 5.6	156.3 ± 9.0
1500 m (s)	271.4 ± 14.3†‡	257.9 ± 14.5†‡	340.0 ± 22.3‡	319.3 ± 19.7
5000 m (s)	1037.0 ± 39.9*†‡	932.2 ± 35.9†‡	1503.0 ± 0.0‡	1137.9 ± 54.0

* Significantly different from male distance runners.
† Significantly different from female sprinters.
‡ Significantly different from female distance runners.

RESULTS

Tables 2 and 3 contain the means and standard deviations for the metabolic responses to horizontal treadmill running and track running performances for the groups of male and female sprinters and distance runners. Relationships between POD and run performances are shown in Figure 1. The correlations of run performances with POD were statistically significant at all run distances and were moderately strong at the sprint and middle-distances, accounting for 44–50% of the performance variance at the three shortest distances (Table 4). For the predictions of 100-, 200-, 400-, 800-m performances from POD, the standard errors of estimate (1.2, 2.7, 5.7, and 13.0 s, respectively) were substantially lower than the performance standard deviations (1.7, 3.8, 8.0, 16.8, 36.0, and 86.2 s). Progressively less performance variance was accounted for with increases in event length beyond 400 m. Partial correlations were lower, indicating that within the sex-event specialty subgroups the relationships were less strong, but reflected the same pattern except that the correlation with 5000-m performance was not statistically significant.

Peak blood lactate was a significant predictor of running performance at 100, 200, and 400 m, accounting for 21–26% of the performance variance for the sprint events. Peak blood lactate was not a significant predictor of performance for the three longest events. Partial correlations for the sprint events were lower and not statistically significant.

The pattern of correlations of track performance with the other metabolic variables was, for the most part, in accordance with expectations for a heterogeneous group of runners. $\dot{V}O_{2peak}$ correlated significantly with middle- and long-distance run performances, but was unrelated to sprinting performance. Partial correlations were lower and statistically significant only at the two longest distances. There was little correlation of running economy and lactate threshold (expressed as %$\dot{V}O_{2peak}$) with performance at the middle and long distances. The significant correlations of lactate threshold with the sprint and middle-distance run performances were not expected; they resulted from the distance runners having higher values on the physiological variables and poorer sprint

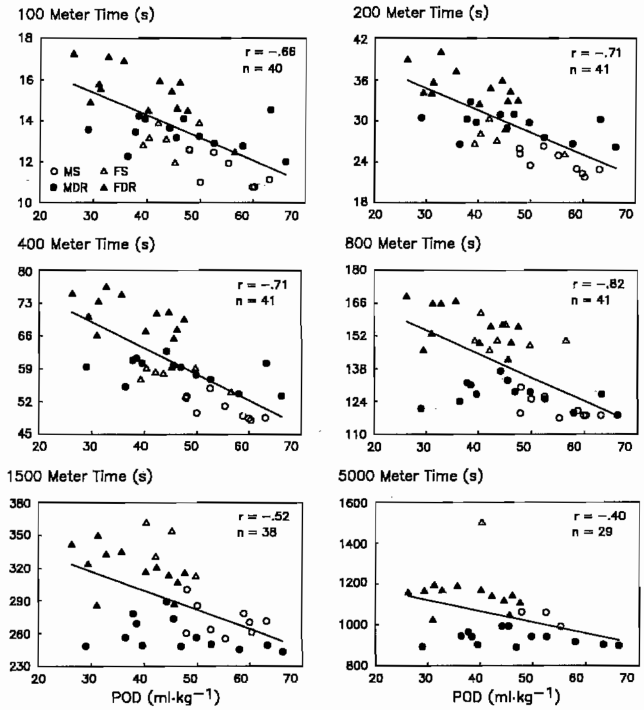

Figure 1—Performance during 100-, 200-, 400-, 800-, 1500-, and 5000-m runs versus peak oxygen deficit. MS = male sprinters; MDR = male distance runners; FS = female sprinters; FDR = female distance runners.

times, and sprinters had the reverse pattern, regardless of gender. Partial correlations were not statistically significant at any distance.

Results from multiple regression analyses predicting run performances from the metabolic variables, and from the metabolic variables plus design variables, appear in Table 5. Regression coefficients for POD in the former set of equations show the effect of the POD on run performance with the effects of the other independent variables held constant. In the second set of equations, the interpretation is the same except that systematic differences among the sex-event specialty subgroups are also held constant. For the predictions including the metabolic variables only (first column under each event), POD contributed significantly to the prediction of performance at 100, 200, 400, 800, and 1500 m, but not at 5000 m. For the sprint and middle distances, the standard errors of estimate (1.3, 2.6, 5.7, 10.1, and 16.2 s) were substantially lower than the performance standard deviations (1.7, 3.8, 8.0, 16.8, and 36.0 s). Standardized regression coefficients indicated that POD was the strongest predictor of performance for the 100-, 200-, and 400-m events. With increases in event length beyond 400 m, POD became progressively less related to performance. In contrast, $\dot{V}O_{2peak}$ was not significantly related to sprinting performance, but was related to performance in the three longest events. As expected, its predictive power increased progressively with increases in event length beyond 400 m. Unexpectedly, the lactate threshold was positively related to performance at 100, 200, 400, and 800 m. Running economy was unrelated to performance at any distance.

With the effect of gender and event specialty held constant, the pattern of findings was basically the same, except that POD was a significant predictor only of 200- and 400-m performance, $\dot{V}O_{2peak}$ was significantly related to performance only at 1500 and 5000 m, and lactate threshold (%$\dot{V}O_{2peak}$) did not contribute significantly to the prediction at any distance. POD was the only significant metabolic predictor of the sprint events (200 and 400 m). The lower regression coefficients for POD indicated that within the relatively homogeneous sex-event specialty subgroups, POD was a less powerful predictor than in the total group of runners.

DISCUSSION

We have found that POD, which has been proposed as a measure of anaerobic capacity, is a moderately strong predictor of sprint and middle-distance track performance among a heterogeneous group of competitive runners. As would be expected for a measure of anaerobic capacity, the predictive power decreases in parallel with the relative contribution of anaerobic metabolism for events lasting longer than 60 s. It accounts for approximately twice as much of the variance in performance as peak blood lactate, a more traditional indicator of anaerobic capacity. These results support the suggestion that the peak oxygen deficit is a valid measure of anaerobic capacity, and indicate that it may be a useful measure in monitoring the training status and predicting the performance capabilities of competitive runners.

The mean POD of the male sprinters and distance runners in the present study were 22–42% lower than those reported for a group of active men (16) and for comparable groups of sprinters and distance runners (23). The reason for the lower values appears to be that the POD was assessed during horizontal running in the present study, whereas it was assessed during running up approximately a 10% grade in the other studies. Olesen (20) recently reported that POD is approximately 50% higher when measured during inclined running up a 10% grade than when measured during near-horizontal running (1% grade) in the same subjects. In the present study, the POD was measured during horizontal running so that it would be representative of the anaerobic energy available during track running.

Considered alone, POD was a significant and moderately good predictor of sprint and middle-distance running performance. The correlations of the POD with 200- and 400-m run performance in the present study are similar to those between the peak oxygen deficit and running performance at 300 and 400 m reported by Scott et al. (23), and support their suggestion that performance

TABLE 4. Simple and partial correlation coefficients between the metabolic variables and track performances.

Variable	100 m (N = 40)	200 m (N = 41)	400 m (N = 41)	800 m (N = 41)	1500 m (N = 38)	5000 m (N = 27)
Peak oxygen	−0.66*	−0.71*	−0.71*	−0.62*	−0.52*	−0.40*
deficit ($ml \cdot kg^{-1}$)	(−0.36*)	(−0.48*)	(−0.46*)	(−0.39*)	(−0.40*)	(−0.22)
Peak blood lactate	−0.46*	−0.51*	−0.48*	−0.41	−0.24	−0.01
($mmol \cdot l^{-1}$)	(0.26)	(−0.25)	(−0.21)	(−0.41*)	(−0.29)	(−0.09)
$\dot{V}O_{2peak}$	0.01	0.04	−0.08	−0.55*	−0.79*	−0.93*
($ml \cdot kg^{-1} \cdot min^{-1}$)	(0.19)	(0.14)	(−0.11)	(−0.26)	(−0.54*)	(−0.65*)
Lactate threshold	0.56*	0.55*	0.52*	0.41*	0.26	0.19
(% $\dot{V}O_{2max}$)	(0.26)	(0.26)	(0.17)	(0.25)	(0.05)	(0.03)
Running economy	0.08	−0.05	−0.03	0.15	0.26	0.34
($\dot{V}O_2$ in $ml \cdot kg^{-1} \cdot min^{-1}$ at 215 $m \cdot min^{-1}$)	(0.29)	(0.18)	(0.16)	(0.04)	(0.08)	(−0.17)

Partial correlations with the effect of sex and event specialty (sprinter, distance runner) held constant are in parentheses below simple correlations.
* Significant at the 0.05 level.

TABLE 5. Multiple regression equations predicting track performances from the metabolic variables, and from the metabolic variables, sex, and event specialty.

Independent Variable	100 m (N = 38)		200 m (N = 39)		400 m (N = 39)		800 m (N = 39)		1500 m (N = 36)		5000 m (N = 27)	
Peak oxygen	−0.09*	−0.03	−0.23*	−0.10*	−0.47*	−0.16*	−0.71*	−0.24	−1.14*	−0.51	0.88	0.38
deficit ($ml \cdot kg^{-1}$)	(−0.52)	(−0.19)	(−0.60)	(−0.26)	(−0.59)	(−0.20)	(−0.43)	(−0.15)	(−0.34)	(−0.15)	(0.07)	(0.03)
$\dot{V}O_{2peak}$	0.01	0.04	0.02	0.08	−0.08	−0.11	−1.20*	−0.61	−3.61*	−2.99*	−12.65*	−14.29*
($ml \cdot kg^{-1} \cdot min^{-1}$)	(0.03)	(0.18)	(0.03)	(0.15)	(−0.07)	(−0.22)	(−0.55)	(−0.28)	(−0.74)	(−0.61)	(−0.92)	(−0.73)
Lactate threshold	0.11*	0.03	0.22*	0.06	0.42*	0.06	0.90*	0.30	−0.93	0.13	1.61	1.25
(% $\dot{V}O_{2peak}$)	(0.33)	(0.10)	(0.29)	(0.08)	(0.27)	(0.04)	(0.28)	(0.09)	(−0.14)	(0.02)	(0.05)	(0.04)
Running economy	−0.00	0.05	−0.12	0.01	−0.27	0.12	−0.26	0.08	−0.72	1.19	7.64*	4.42
($\dot{V}O_2$ in $ml \cdot kg^{-1} \cdot min^{-1}$ at 3.6 $m \cdot s^{-1}$)	(−0.00)	(0.08)	(0.10)	(0.08)	(−0.11)	(0.05)	(−0.05)	(0.01)	(−0.07)	(0.11)	(0.16)	(0.09)
Sex (M=1, F=2)		1.98*		4.21*		7.39*		20.63*		25.4*		55.9
		(0.58)		(0.54)		(0.46)		(0.61)		(0.36)		(0.20)
Event specialty (sprinters=1,		1.44*		3.33*		9.87*		7.68		11.2		−47.4
distance runners=2)		(0.41)		(0.42)		(0.60)		(0.23)		(0.15)		(−0.12)
Intercept	8.2	2.8	24.1	10.4	62.6	36.8	178.4	115.2	456.6	382.1	1712.5	1664.9
R	0.72	0.90	0.77	0.93	0.76	0.94	0.83	0.95	0.90	0.95	0.95	0.95
R^2	0.52	0.81	0.60	0.86	0.57	0.89	0.69	0.90	0.82	0.90	0.90	0.91
SEE (s)	1.3	0.8	2.6	1.6	5.7	3.0	10.1	5.8	16.2	12.3	46.4	47.1

Equations have the following form: 100-m time = −0.09(POD) + 0.01($\dot{V}O_{2peak}$) + 0.11 (lactate threshold) + 0.00(running economy) + 8.2. Standardized regression coefficients appear in parentheses beneath unstandardized coefficients. Equations including the metabolic variables only appear in the left column under each event. Equations including sex and event specialty in addition to the metabolic variables appear in the right column under each event.
* Regression coefficient is significant at $P < 0.05$.

on a run of approximately 300 m is a good field test of anaerobic capacity. However, the correlation between the maximal oxygen deficit and 600-m run time reported in their study (−0.00) was much lower than the correlation of POD with 800-m performance in the present study (−0.62). This discrepancy is probably due to differences in the samples of runners in the two studies.

POD accounted for approximately twice as much of the variance in sprinting performance as peak blood lactate, although the differences between the correlations were not statistically significant. Significant correlations of peak blood lactate with sprint running performance have been reported by others (7,18,28), but this finding is not universal (19). The correlations of POD with sprint performance also were greater than those previously reported between sprint running performance and other measures of anaerobic capacity, such as the Wingate test (13,27) and maximal oxygen debt (14), indirectly supporting the contention that the POD may be a more valid estimate of anaerobic capacity than other traditional measures (21).

Previous studies have found that the percentage of POD used in brief exhaustive efforts of a given duration does not vary appreciably among individuals. This finding suggests that the POD should reflect anaerobic power as well as capacity (15,16). Thus, one would expect POD would account for a high proportion of the performance variance in sprint events that rely heavily on anaerobic metabolism. However, POD accounted for only 50% of the performance variance in these events. The magnitude of the relation of POD to high-intensity running performance is substantially weaker than the relation between measures of aerobic power output ($\dot{V}O_{2peak}$ or lactate threshold expressed as $\dot{V}O_2$) and long-distance running performance. The relatively poorer predictive power of POD for high-intensity exercise performance is probably a consequence of the portion of energy provided aerobically during such events. Gollnick and Hermansen (9) estimated that aerobic metabolism supplies nearly 20% of the energy during exhaustive exercise of 10 s, and 40% of the energy for exhaustive exercise lasting 60 s. In contrast, the contribution of anaerobic metabolism to energy expenditure in a typical long-distance event, such as the 10-km run, is less than 3%. We believe the substantial contribution of aerobic metabolism to energy output even during very brief high-intensity exercise limits the prediction of performance from a measure of anaerobic capacity alone, and explains much of the performance variance in the present study not accounted for by POD.

In the multiple regression analyses that included only the metabolic variables, POD was the strongest predictor of performance in the three sprint events. It also was a significant predictor for the two middle-distance events, but not of 5000-m performance. This pattern of relationships conforms to theoretical expectations based on the progressive decrease in the reliance on anaerobic metabolism with increases in event length. The results of the multiple regression analyses are consistent with the simple regression analysis, and suggest that the POD is a useful predictor of performance in sprint and middle-distance track events in a heterogeneous group of runners. Our results also suggest that anaerobic capacity is not an important predictor of performance for longer events such as the 5000 m. This is at odds with the suggestions of others that anaerobic capacity (2,12) and power (17) are significant predictors of running performance at distances of 5 km or longer among runners homogeneous in performance. The difference between our findings and others may result from smaller sample sizes (<13 or not reported) of the other studies, the use of different measures of anaerobic capacity or power, or differences in subject homogeneity.

The magnitude of the regression coefficients for $\dot{V}O_{2peak}$ also conformed to theoretical expectations. $\dot{V}O_{2peak}$ was significantly related to performance in the three longest, but not the three shortest, events. With increases in event length beyond 400 m, the importance of $\dot{V}O_{2peak}$ as a predictor became progressively greater. These results are consistent with the theoretical expectation that the predictive power of $\dot{V}O_{2peak}$ should increase with event length and the proportion of energy supplied aerobically and with other studies showing a strong relation of $\dot{V}O_{2peak}$ to distance running performance (4,6). However, our results extend previous findings by demonstrating that $\dot{V}O_{2peak}$ also is a valuable predictor of performance in shorter middle-distance running events as well. The simple and multiple regression analyses suggest that $\dot{V}O_{2peak}$ is a stronger predictor than POD of 1500-m run performance, and that $\dot{V}O_{2peak}$ and POD are roughly equivalent predictors of 800-m run performance.

In the multiple regression analyses including only the metabolic variables, as for the total correlations, the lactate threshold was unexpectedly positively related to performance at 100, 200, 400, and 800 m, indicating that subjects with higher lactate thresholds, expressed as $\%\dot{V}O_{2peak}$, had slower performance times for these events. This finding resulted from combining data of sprinters and distance runners; there is no physiological explanation for the positive regression coefficients in these equations. Sprinters had faster performance times for these events and lower lactate thresholds, whereas distance runners had slower performance times and higher lactate thresholds. This interpretation is supported by the fact that there was no significant relation of lactate threshold to sprint and middle-distance run performance in the equations in which event specialty was held constant. Lactate threshold, expressed as a percentage of $\dot{V}O_{2peak}$, was not related to distance run performance as might have been expected. Previous studies have shown the lactate threshold expressed as a velocity is a stronger predictor of distance running performance (6,26) than $\dot{V}O_{2peak}$. The greater redundancy with $\dot{V}O_{2peak}$ that results from expressing the threshold as a velocity, rather than as a percentage of $\dot{V}O_{2peak}$, explains the stronger relation of the velocity measure to performance.

Running economy at 3.6 $m \cdot s^{-1}$ contributed significantly to prediction of 5000-m run performance, but did not contribute significantly to the prediction of sprint and middle-distance running performance when the effects of the other metabolic variables were held constant. The lack of relation of running economy with the middle-distance or sprint events may have resulted from a poor association between running economy measured at 3.6 $m \cdot s^{-1}$ and running economy at the faster speeds utilized in these events (25). The significant effect for 5000-m run resulted from this event being performed at a velocity closer to that at which running economy was measured. The lack of relation of running economy and distance running performance when the design variables were held constant is consistent with other studies on distance runners heterogeneous in $\dot{V}O_{2peak}$, although by statistically holding constant the effects of $\dot{V}O_{2peak}$ and design variables, results more similar to those on distance runners homogeneous in $\dot{V}O_{2peak}$ might have been expected (3,4,6,26).

In summary, there are currently a number of tests used to assess anaerobic capacity and power, but none are regarded as totally satisfactory. Saltin (21) concluded that the maximal or POD is the best measure of anaerobic capacity available, but relatively little research has been conducted using this measure. The present study has shown that POD assessed during horizontal running is a moderately good predictor of sprint and middle-distance running performance in a heterogeneous group of male and female track athletes, and suggests it may be useful for evaluating the physiological status of competitive sprint and middle-distance runners.

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Address for correspondence: Peter G. Weyand, Concord Field Station, Harvard University, Old Causeway Road, Bedford, MA 01730.

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