The anaerobic threshold of elite and novice cyclists

by

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Recently, the aerobic threshold (AerT) has been used as a guideline for determining the work load intensity.[2 4 6 9 11] Several studies had reported that training relative to the AerT (i.e., training at a percentage of the maximum oxygen uptake $\dot{V}O_2max$ that correspond to the AerT) will improve the relative AerT values, not withstanding the changes in $\dot{V}O_2max$.[2 9 11] These studies employed work intensities ranging from 75 to 85% $\dot{V}O_2max$, which actually represents the anaerobic threshold (AnT), as suggested by Skinner and MacLelland,[13] and Kinderman, Simon, and Keul,[4] since at such intensities local muscle hypoxia and an abrupt rise in the lactic acid concentration is noteworthy.

Trained individuals have a higher AnT [7] as compared with their sedentary counterparts. Thus, elite cyclists should have higher AnT values than novice cyclists. The present study compares the metabolic and physiologic parameters of elite and novice cyclists, with particular reference to their AnT values.

Methods

Subjects. Twenty three cyclists (9 class III, and IV; 13 class I and II) volunteered to serve as subjects in this study. A summary of their physical characteristics are shown in Table 1.

Apparatus and testing protocol for $\dot{V}O_2$ max. The $\dot{V}O_2max$ was measured on a progressive exercise test using a friction-type bicycle ergometer (Bodyguard 990), equipped with footclips and racing handbars. The subjects were required to pedal at an established rate of 80 rpm, being the best desirable cadence for competitive cyclists.[8] A warmup consisted of 3 minutes of pedalling at a work load of 240 kpm/min every three minutes until the subject was unable to continue pedalling.

Metabolic measurements. Open-circuit spirometric techniques were used. Expired gas samples were analyzed immediately for percent of CO_2 and O_2 in a previously

Table 1.—*Physical characteristics of subjects.*

Variable	Novice cyclists (n=9) mean±SE	Elite cyclists (n=9) mean±SE	t score between novice and elite cyclists
Age (years)	24.1±1.73	24.0±0.88	0.05
Lit. (cm)	177.2±3.79	177.3±3.17	0.42
Wt. (kg)	73.8±2.96	65.7±2.52	2.94 *

*$p<0.05$.

TABLE 2.—*Descriptive measures associated with maximal work values and anaerobic threshold (AnT) responses between novice and elite cyclists.*

Variable	Novice cyclists (n=9) mean±SE	Elite cyclists (n=10) mean±SE	t score between novice and elite cyclists
$\dot{V}O_2$max (liters/min)	4.31± 0.17	4.54± 0.15	0.22
$\dot{V}O_2$max (ml/kg/min)	58.8 ± 2.80	69.6 ± 1.60	0.08
WK output max (kgm/min)	1830.0 ±63.0	1893.0 ±66.0	0.67
AnT-$\dot{V}O_2$ (liters/min)	2.62± 0.10	3.31± 0.35	1.56
AnT-$\dot{V}O_2$ (ml/kg/min)	35.9 ± 4.30	50.4 ± 2.00	3.38 **
AnT-%$\dot{V}O_2$max (%)	61.1 ± 2.8	71.1 ± 3.5	2.07 *
AnT-WK output (kgm/min)	1290.0 ±63.0	1363.7 ±70.0	0.75

Significant difference between novice and elite cyclist (*$p<0.05$, **$p<0.01$).

calibrated (Sholander analysis) Beckman LB-2 carbon dioxide analyzer and Beckman OM-11 oxygen analyzer. Pulmonary ventilation was measured on a 350-liter non-recording gasometer (Warren E. Collins, Inc., Braintree, Mass.). Expired gas collection and analysis were performed over 45s intervals. Heart rate was simultaneously recorded from a bipolar CV_5 electrocardiographic lead. $\dot{V}O_2$max was determined as the point of no further increase in $\dot{V}O_2$ despite further increase in work load.[16]

Determination of AerT and AnT. AerT and AnT values were estimated from gas exchange variables. The criterion for AerT determination was the point of departure from linearity in $\dot{V}_E$ *vs* work intensity curve and the point of abrupt increase in F_EO_2%.[13]

Statistical analysis. All the collected data were expressed as Mean±Standard Error (M±SE). Descriptive statistics and simple regression were used to analyze the results. Correlation analysis was used to examine the relationship between AerT and $\dot{V}O_2$max and AnT and $\dot{V}O_2$max. A one-tailed t-test was performed to evaluate the differences of the variable means between the elite and novice cyclists.[3] Differences were considered significant at $p<0.05$.

RESULTS

Table 2 shows the maximal work parameters and associated AnT values (M±SE) of the elite and novice cyclists. As can be seen, significant differences ($p<0.01$, $p<0.05$) between elite and novice cyclists were found in AnT-$\dot{V}O_2$ (ml/kg/min) and AnT-%$\dot{V}O_2$max. The mean $\dot{V}O_2$max of the subjects was 4.54 l/min (69.6 ml/kg/min) for the elite cyclists and 4.31 l/min

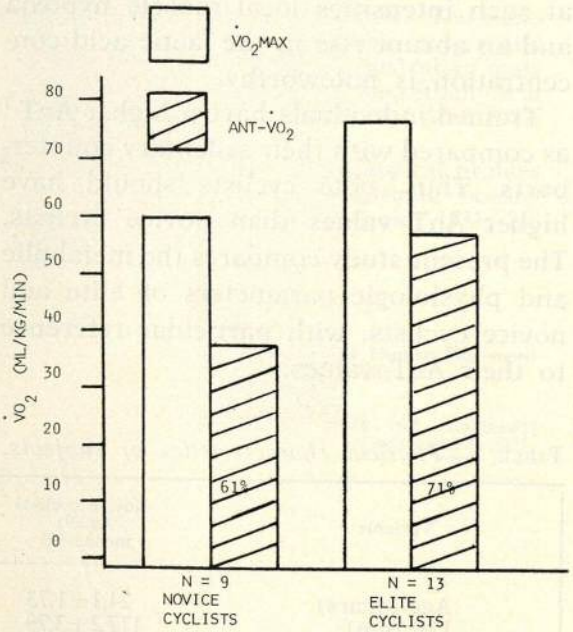

Fig. 1.—Maximum oxygen uptake ($\dot{V}O_2$max) and anaerobic threshold (AnT) relative to body weight (ml/kg/min) between novice and elite cyclists.

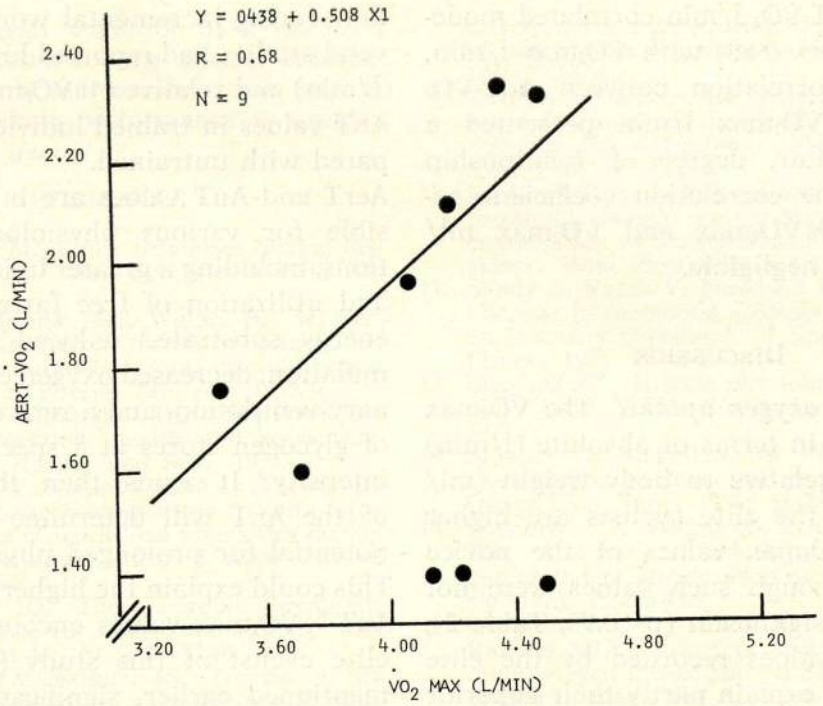

Fig. 2.—Test-retest correlation between AerT-$\dot{V}O_2$ and $\dot{V}O_2$max for the novice cyclists.

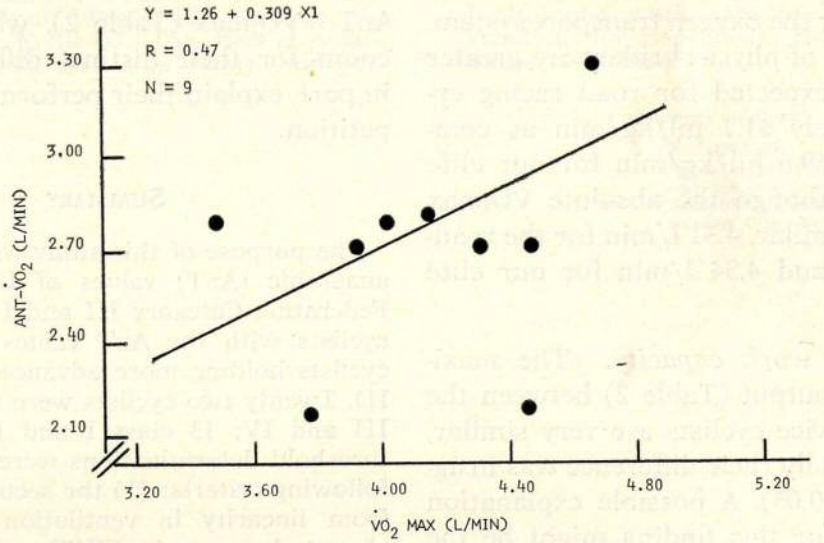

Fig. 3.—Test-retest correlation between AnT-$\dot{V}O_2$ and $\dot{V}O_2$max for the novice cyclists.

(58.8 ml/kg/min) for the novice cyclists (Table 2). The mean values of AnT-$\dot{V}O_2$ and AnT-%$\dot{V}O_2$max for the elite cyclists were 3.31 l/min or 50.4 ml/kg/min and 71.1% respectively, and for the novice cyclists were 2.62 l/min or 35.9 ml/kg/min and 61.1% respectively (Table 2).

Figure 1 shows that the $\dot{V}O_2$max (ml/kg/min) values and the AnT variables between the elite and novice cyclists were significant ($p<0.01$, $p<0.05$). The test-retest correlation between AerT-$\dot{V}O_2$max l/min for the novice and $\dot{V}O_2$max l/min, and between AnT-$\dot{V}O_2$ l/min and $\dot{V}O_2$max l/min for the novice cyclists are shown in Figures 3 and 4 respectively. As can

be seen, AerT-$\dot{V}O_2$ l/min correlated moderately high (r=0.68) with $\dot{V}O_2$max l/min, while the correlation between AnT-$\dot{V}O_2$ l/min and $\dot{V}O_2$max l/min presented a lower, yet fair, degree of relationship (r=0.47). The correlation coefficient between AnT-%$\dot{V}O_2$max and $\dot{V}O_2$max ml/kg/min was negligible.

Discussion

Maximum oxygen uptake. The $\dot{V}O_2$max values, both in terms of absolute (l/min) values and relative to body weight (ml/kg/min), of the elite cyclists are higher than the $\dot{V}O_2$max values of the novice cyclists. Although such values were not statistically significant ($p<0.05$, Table 2), the higher values recorded by the elite cyclists may explain partly their superior level of competition. Moreover, it is known that the $\dot{V}O_2$max represents the peak energy output for the oxygen transport system, i.e., an index of physical riders are greater than those expected for road racing cyclists,[12] namely 61.7 ml/kg/min as compared with 69.6 ml/kg/min for our elite riders even though the absolute $\dot{V}O_2$max values are similar, 4.31 l/min for the road-race riders and 4.54 l/min for our elite cyclists.

Maximum work capacity. The maximum work output (Table 2) between the elite and novice cyclists are very similar, and statistically their difference was insignificant ($p<0.05$). A possible explanation to account for this finding might be the fact that maximum work output does not necessary indicate the physical fitness of an individual; indeed, while the $\dot{V}O_2$max is reached, the work output can continue.

Anaerobic threshold values. The AnT represents a higher work intensity where lactic acid increases up to 4 mmol/l and is accompanied by an excess of CO_2, which is manifested by a marked hyperventilation during incremental workloads.[4 13] Several studies had reported higher absolute (l/min) and relative (%$\dot{V}O_2$max) AerT and AnT values in trained individuals as compared with untrained.[1 2 7 10 15] These higher AerT and AnT values are in part responsible for various physiological adaptations, including a greater lipid metabolism and utilization of free fatty acids as an energy substrate,[5] reduced lactate accumulation, decreased oxygen cost of pulmonary ventilation, and a retarded depletion of glycogen stores at a specific workload intensity.[9] It seems, then, that the point of the AnT will determine the athlete's potential for prolonged physical activity. This could explain the higher AnT-$\dot{V}O_2$ and AnT-%$\dot{V}O_2$max values encountered in the elite cyclist of this study (Table 2). As mentioned earlier, significant differences ($p<.001$) between elite and novice riders were found in AnT-$\dot{V}O_2$ (ml/kg/min) and AnT-%$\dot{V}O_2$max (Table 2), which may account for their distinct differences and, in part, explain their performance in competition.

Summary

The purpose of this study was to compare anaerobic (AnT) values of United Cycling Federation Category III and IV road racing cyclists with the AnT values measured in cyclists holding more advanced standing (I, II). Twenty two cyclists were tested (9 class III and IV; 13 class I and II). Anaerobic threshold determinations were based on the following criteria: (1) the second breakaway from linearity in ventilation and (2) the abrupt decrease in $FECO_2$ coinciding with incremental workloads. Mean values of $\dot{V}O_2$-max between elite and novice cyclists did not differ significantly ($p<0.05$), namely 4.54 l/min (69.6 ml/kg/min) and 4.31 l/min (58.8 ml/kg/min) respectively. The correlation between AnT-$\dot{V}O_2$ l/min and $\dot{V}O_2$max l/min was 0.47 for the novice cyclists. Meaningful differences ($p<0.01$) between elite and novice cyclists was found in AnT-$\dot{V}O_2$ ml/kg/min. While AnT-%$\dot{V}O_2$max for experienced cyclists (I, II) was 71%, the novice cyclists

recorded a mean value of 61% ($p<0.05$) which may account for the distinct differences between elite and novice riders and, in part, explain their performance in competition.

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