

Case Report

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Predictive Validity of Critical Power, The Onset of Blood Lactate and Anaerobic Capacity for Cross-Country Mountain Bike Race Performance

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ABSTRACT

Critical power is emerging as an important indicator of high intensity endurance exercise capability. Little is known regarding its ability to predict performance during high intensity intermittent events such as Olympic format cross country mountain bike racing. Therefore, the purpose of this pilot study was to assess the validity of critical power and anaerobic capacity compared to the more traditional measure of power at physiological thresholds previously related to race performance. Five nationally competitive athletes (mean±s: age:31.4±9.3 years; mass: 70.8±9.5 kg; VO_{2max} : 63.8±7.0 ml·kg⁻¹·min) volunteered for this study. Participants completed a cycle ergometry step test to exhaustion in order to determine the anaerobic threshold. On a separate occasion participants completed a 3-minute all-out test against a fixed resistance to determine critical power and anaerobic capacity. Laboratory data showed no differences ($P=0.057$) between the power output at the onset of blood lactate or critical power and neither related to anaerobic capacity ($p=0.499$ and $p=0.344$, respectively). Performance was measured via race data analysis gathered from a USA Cycling sanctioned race. Linear regression was used to assess the prediction of performance. Critical power predicts Olympic format cross country mountain bike performance ($r^2=0.943$, $p=0.006$) to a greater degree of accuracy than anaerobic threshold ($r^2=0.785$, $p=0.046$) or anaerobic capacity ($r^2=0.477$, $p=0.197$) with less error (39.413; 76.526; 118.9 s, respectively). Therefore, the ability to sustain a high intensity effort for the race duration, determined via critical power rather than the onset of blood lactate, is likely more valuable to cross country mountain bike athletes than anaerobic capacity.

KEYWORDS: Blood lactate; Strength; Participants.

ABBREVIATIONS: XCO-MTB: Olympic format cross country mountain bike racing; LT: Lactate Threshold; FTP: Functional Threshold Power; RCP: Respiratory Compensation Point; CP: Critical Power; AWC: Anaerobic Work Capacity; GET: Gas Exchange Threshold; MSE: Mean Square Error.

INTRODUCTION

Olympic format cross country mountain bike racing (XCO-MTB) is a high intensity intermittent sport lasting between 60-90 min, taking in a variety of terrains or obstacles and requiring both high rates of aerobic and anaerobic energy production.¹ Un-typical of other endurance sports starting on mass, XCO-MTB requires maximal effort from the start to gain or hold positional advantage so as not to impair overall performance. As such initial field based research identifies that 82% of total race time corresponds to power outputs greater than the Lactate Threshold (LT) equating to 90% HR_{max} and 84% VO_{2max} .² While interesting such a holistic view of power data neglects key components of the sport such as the intermittent nature of propulsive and non-propulsive work done in combination with different components of strength or power.³ More detailed field based analysis acknowledges great variability in

recorded power output data due to terrain and frequency analysis identifying 42% of logged data to be greater than the anaerobic threshold.²

Exploratory research into the demands of such activities as XCO-MTB is usually accompanied by investigations determining the validity of performance, physiological or fitness variables used to predict performance. Typically, endurance sports have used various laboratory indices of blood lactate for determining physiological and/or performance capability.⁴ However, such testing is not readily available to all athletes or coaches due to cost of equipment and specialist training required. Demand in other sports such as team sports has led to the development of readily available, valid and reliable procedures such as the multistage fitness test and Yo-Yo tests to assess aerobic capability of performers. A more recent development in training monitoring technology has been the advent of affordable, valid and reliable power meter which have led to a performance assessment procedure for cyclists known as the Functional Threshold Power (FTP) field test.⁵ The FTP is reflective of the maximum power output that can be sustained for a 60 min period and has been shown to be equal to the power output associated with anaerobic threshold referred to as the onset of blood lactate threshold (P_{OBLA}) and/or Respiratory Compensation Point (RCP).⁴ Subsequently, FTP has been used for the determination of training zones and athlete capability, and is widely accepted in the cycling community as it can be continually estimated from training data.⁶ As such FTP's applicability to XCO-MTB may be limited due to the intermittent, high intensity nature of XCO-MTB.² Alternatively, Critical Power (CP) could be more meaningful as it demarcates the point between steady state and non-steady state exercise.⁷ To this end CP has been defined as the power output that can theoretically be sustained indefinitely when all work done is aerobic in nature and is accessed via tests to exhaustion of varying power outputs.⁷ From this data a hyperbolic Power-time (P-t) relationship can be plotted and CP therein identified at the asymptote of the curve.^{8,9} While work at or below CP can be completed at a metabolic steady state, any work above this intensity cannot, and will eventually lead to the attainment of VO_{2max} and thus exhaustion.¹⁰ Therefore, work done over CP can be presumed primarily anaerobic, is referred to as the W' (previously referred to as Anaerobic Work Capacity (AWC)) and once this capacity has been exceeded, exercise intensity cannot surpass CP.⁹ However, the W' will begin to regenerate during periods of exercise at power outputs below CP per se, the W' and CP concept has been best described as a battery that is alternately discharged (at any power > CP) and recharged (at any power < CP).¹¹ Integrating both aerobic and anaerobic indices, CP could be both a valuable performance predictor and likewise a training tool, especially for high intensity intermittent sports like XCO-MTB. While significant positive relationships between CP and road cycling time trials has been established¹² no study has ever compared CP to XCO-MTB.

Therefore, the aim of this study was to determine the relationship between a laboratory CP test, W' and XCO-MTB

performance in comparison with P_{OBLA} . We hypothesize that due to the high intensities demanded during XCO-MTB, CP will provide a more valid performance predictor than power output measures associated with the onset of blood lactate or W' .

METHODS

Participants

Five nationally competitive male XCO-MTB athletes (n=4 USA Cycling Category 1; n=1 Union Cycliste Internationale Elite; mean±s: age 31.4±9.3 years, mass 70.8±9.5 kg, height 171.6±5.1 cm, VO_{2max} 63.8±7.0 ml·kg⁻¹·min⁻¹) volunteered to participate in this study, which was approved by the University ethical committee.

All tests were completed with no less than 72 hours between tests over a three-week period. Participants were asked to come to each session having done no intense exercise over the previous 24 hours or ingested any food or caffeine in the previous three hours. Gas analysis was recorded using ParvoMedics TrueOne 2400 Metabolic Measurement System (ParvoMedics, Sandy, UT, USA) and blood lactate using Arkray Lactate Pro Test Meters (Arkray, Inc, Kyoto, Japan). All participants used their own bicycles for the XCO-MTB race.

Laboratory Trials

On the initial visit to the laboratory participants were weighed (kg), measured (cm) and the cycle ergometer (Lode, Groningen, The Netherlands,) was set to individual requirements with any minor adjustments being made prior to the initial trial and fixed for subsequent tests. The first test session included a cycle ergometry step test protocol involving a 3 min fixed effort at 120 W and increasing by 30 W every 3 min until volitional exhaustion. Throughout this test expired air was measured breath-by-breath and reduced to 10-second averages for the calculation of VO_{2peak} (highest value recorded for a 30 s average). Capillary blood samples were collected and analyzed during the last minute of each 3 min step for the determination of P_{OBLA} , indicated as the point at which blood lactate concentration exceeded 4.0 mmol·L⁻¹.

The second testing session involved a 3 min all-out test for the determination of CP.¹³⁻¹⁵ From values measured during the ramp protocol, 50Δ power was defined as the power output halfway between the Gas Exchange Threshold (GET) and VO_{2peak} . The ergometer was set using the linear mode so that the participants would attain 50Δ power upon reaching their preferred cadence ($\alpha=50\Delta$ power/preferred cadence).^{14,16} Following a 3 min unloaded baseline epoch, participants were asked to accelerate their cadence to approximately 110 rpm during the last 5 s preceding the all-out period. Participants were encouraged to maintain the highest cadence possible during the 3 min all out portion of testing through strong verbal encouragement, but no indication of elapsed time was given. CP was determined as

the mean power during the final 30 s of all-out testing, and W' (kJ) as the total of all work completed above this value. CP and P_{OBLA} were recorded relative to body mass ($W \cdot kg^{-1}$) as relative measures have been shown to be more reliable for predicting XCO-MTB performance.¹⁷

Field Test Trial

Participants completed a regional mass start XCO-MTB competition (Greenbrier Challenge, American Mountain Bike Challenge, Mid Atlantic Super Series, Boonsboro, MD, USA) sanctioned by USA Cycling. Each lap was 7.5 km, had 266 m of elevation gain and was of moderately technical terrain (Figure 1). Quantification of performance via race time using radio frequency identification timing chips (Mid Atlantic Timing, Downingtown, PA, USA). As participants completed this race as part of their own racing schedule and were given no protocol of which to adhere before, during or after the race regarding pacing or strategy. All participants completed the race without mechanical incident on their own bicycles. Lap times were reduced to mean time across four laps, as XCO-MTB athletes have been shown to have little between-lap variation during races.¹⁸

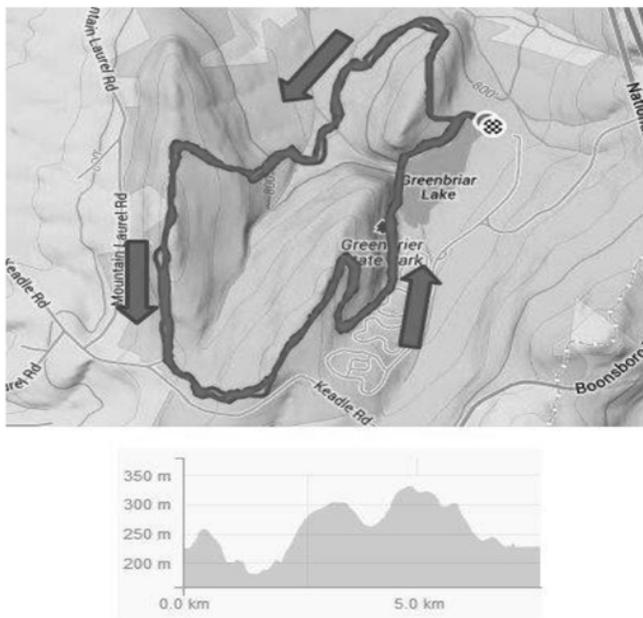


Figure 1: Lap outline and profile with Start/Finish area indicated.

Statistical Analysis

All data is expressed as mean \pm SD unless otherwise stated. Statistical differences between CP and P_{OBLA} were assessed using Student's t-test. Linear regression model were used to evaluate the coefficient of determination and standard error when using relative measures ($W \cdot kg^{-1}$) of CP and P_{OBLA} in the prediction of mean race lap time. Mean Square Error (MSE) was calculated as the residual sum of squares divided by the degrees of freedom and used to determine estimation error. Estimation error (Error) was calculated as the square root of MSE and is expressed in unit time (s).

All statistical analysis were performed using (SPSS 19.0), where statistical significance was set at $p < 0.05$.

RESULTS

Power data (1 Hz) collected during the 3 min max test and the interaction between CP and W' are expressed as mean \pm 95% CI for CP and W' for all participants (Figure 2). Mean \pm SD values for both P_{OBLA} and CP showed no overall difference for relative power output (3.9 ± 0.7 and $4.4 \pm 1.0 W \cdot kg^{-1}$, $t_{(4)} = 2.468$, $p = 0.057$). However, P_{OBLA} and CP were significantly correlated ($r = 0.943$, $p = 0.016$) with each while W' (14.27 ± 3.96 kJ) was found not to relate to either P_{OBLA} ($r = 0.405$, $p = 0.499$) or CP ($r = 0.543$, $p = 0.344$).

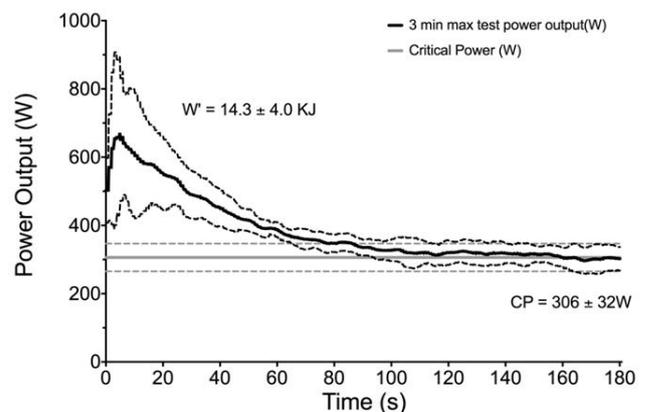


Figure 2: Graphical representation of the mean \pm 95% CI power output data (1Hz) for the 3 min max test and the interaction between CP and W' .

Race data showed considerable variation between participants with mean \pm SD overall time of 6852 ± 569 s with a range of 6040 - 7268 s with lap times equal to 1713 ± 142 s.

Comparison of laboratory data with race performance indicates that CP is better able to explain variance in mean lap time than P_{OBLA} and W' ($r^2 = 0.943$, $p = 0.006$; $r^2 = 0.785$, $p = 0.046$; and $r^2 = 0.477$, $p = 0.197$, Figures 3A-3C). Error associated with performance estimations from mean lap time are also less when using CP than P_{OBLA} or W' (76.3; 39.4; and 118.9 s), respectively.

DISCUSSION

The purpose of this study was to determine the relationship between a laboratory CP test, W' and XCO-MTB performance in comparison with P_{OBLA} . The main findings show: (i) relative measures of aerobic capacity (CP and P_{OBLA}) are better predictors of XCO-MTB race performance than laboratory measures of anaerobic capacity (W'); (ii) CP can explain more variance in performance, with less error than P_{OBLA} .

CP has previously been shown to occur at a higher work rate than the maximal lactate steady state^{19,20} while being signifi-

cantly correlated to P_{OBLA} .²¹ The results of this study support the strong association of XCO-MTB performance with P_{OBLA} previously reported.⁶ However, CP predicted performance to a greater extent (Figures 3A-3B). This is due to the greater power output (0.54 ± 0.46 , 95% CI -0.03 - 1.11 $W \cdot kg^{-1}$) associated with CP compared to P_{OBLA} ²¹ and the higher intensity sustained during XCO-MTB. Therefore, prescription of training zones determined from laboratory testing for CP would increase the training stimulus response compared to P_{OBLA} . Theoretically, the hyperbolic P-t relationship developed through the measurement of CP offers a more sensitive insight into the changes in fitness brought about through training. Specifically, XCO-MTB performance would benefit from either sustainable aerobic performance (CP) and/or anaerobic capacity (W') improvements.

steady state and non-steady state variables. Interestingly, the non-steady state component (W' , Figure 2) previously referred to as AWC was a poor predictor of overall XCO-MTB performance (Figure 3C) and did not relate to either of the steady state variables within this study. This is an aspect that requires further investigation given the frequency of occurrence of maximal and supra-maximal efforts occurring during XCO-MTB races.³ One possibility is that the ephemeral nature of supra-maximal efforts while race defining based around positional advantage³ is minimal with regards to physiological contribution. Indeed, total anaerobic contribution, including the start effort, is less than 5% of overall race duration.¹ Consequently, the results from this study show that the upper limit of XCO-MTB performance is dictated by CP with less regard for the W' . Corroborating this is the fact that the completion of intermittent work such as that seen in XCO-MTB is highly dependent on aerobic metabolism and type 1 muscle fibres.²⁴ As such, it might be prudent that future research investigates the relationship of much shorter bouts of supra-maximal efforts and the capability to reproduce such efforts in relation to XCO-MTB performance.

LIMITATIONS

Using a one off race that was part of participants' competition schedule meant that each participant was appropriately motivated and had no intervention with regards to preferred strategy. This increases the validity of the study. However, this did result in a low number of available participants and as such reduces the overall power of the results.

Efficacy of laboratory testing using different equipment in regards to real world performance is always questionable. The tests used within this study, could quite easily be completed in the field with athletes own power meters, and as such may be more valuable to athletes and coaches.⁶ CP and W' can be reliably determined by plotting a curve from best power-for-time results,¹⁰ and has been shown to equate to laboratory estimates like the 3 min all out test used in this study.²⁵ Succinctly, we would expect the given results to be similar to those collected from field measures of the same tests, but this needs confirming. The participants in this study were nationally competitive (USA Cycling registered) XCO-MTB athletes and as such had lower mean VO_{2max} (63.8 ± 7.0 versus 78.3 ± 4.4 $ml \cdot kg^{-1} \cdot min^{-1}$) in addition to greater body mass (74.5 ± 9.5 versus 65.3 ± 6.5 kg) compared to internationally competitive XCO-MTB athletes, respectively.¹⁶ While this could be viewed as a limitation of the present investigation, similar correlates to performance have been observed among elite and amateur XCO-MTB athletes.²⁵ As such we are confident the results are transferable to a range of abilities, but this needs confirming. Further, results of this study should be corroborated among a more homogenous group of athletes.

CONCLUSION

This study set out to assess the impact of aerobic and

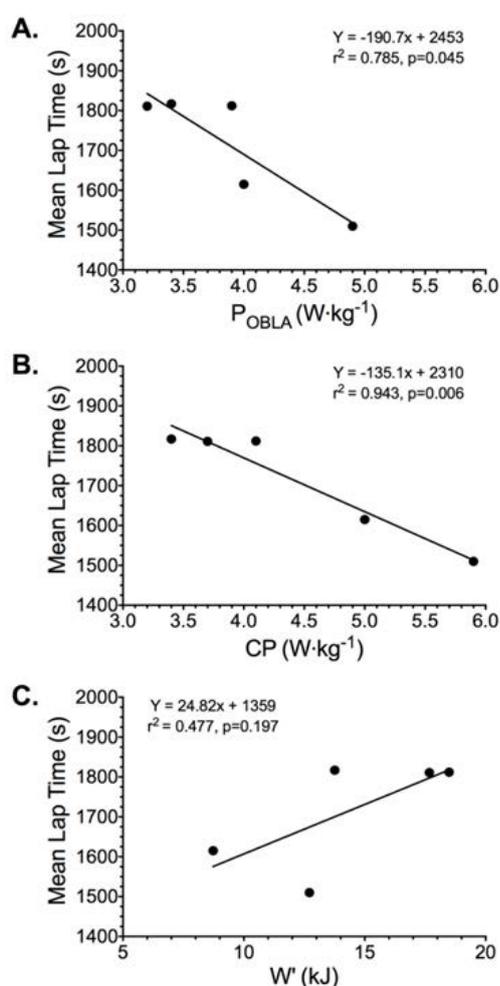


Figure 3: Scatter plot of lap time versus measures of A. P_{OBLA} ; B. CP; and C. W' , with regression equation and correlation coefficient displayed.

Power profiles reported for XCO-MTB^{1,22} highlight the importance of both aerobic and anaerobic indices of performance. Additionally both anaerobic and intermittent tests have been shown to predict performance to a greater extent than steady state tests.^{6,16,17,23} However, while associated with various other thresholds, CP delineates the boundary between steady state and non-steady-state exercise by way of utilizing both

anaerobic capacity on XCO-MTB bike performance. As such, only the aerobic variables measured related to performance, in which critical power displayed greater importance than the onset of blood lactate threshold. Future work needs to assess the efficacy of such findings over a more diverse group and explore the multi-linear relationship between indices of XCO-MTB performance.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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