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# Validity of using functional threshold power and intermittent power to predict cross-country mountain bike race outcome

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## Abstract

Validity of using functional threshold power and intermittent power to predict cross-country mountain bike race outcome. Purpose: Field tests are important for athletes and sport practitioners as they offer valuable information on performance without demanding the time and cost to visit a laboratory. This study tested the ability of relative functional threshold power (FTP) and intermittent power (IP) field tests to be used as predictors of cross-country mountain bike (XCO-MTB) race finishing time. Methods: Eleven well-trained male XCO-MTB cyclists (mean age: 35.8 ± 8.2 yr; mean mass: 80.8 ± 13.4 kg) volunteered for this study. Relative (W/kg) FTP and relative IP were collected from field tests with the mean of all intermittent work intervals recorded as IP and FTP calculated from 95% of mean maximal 20-minute power. Race performance time was collected during a mass-start 17.4 km simulated XCO-MTB race in the field. Results: Both IP ($r^2$=0.786) and FTP ($r^2$=0.736) models were able to significantly predict race performance ($p < 0.001$). However, the prediction errors were less when using Relative IP than Relative FTP (273.5 s versus 303.6 s). Conclusion: A field-based IP test can be used as a benchmark for the determination of XCO-MTB athlete ability and preparedness. Considering IP can be measured on a stationary trainer in any location and independent of expensive equipment, coaches can easily use this model to track athlete training.


**Keywords:** cycling, mountain bike, off-road, functional threshold power, cross country, intermittent power

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## Introduction

Cross-country mountain bike racing (XCO-MTB) is a popular sport among both elite and recreational cyclists alike. The physiological demands of competition and thus predictors of performance are less understood in XCO-MTB than in road cycling. Research available shows that power output during XCO-MTB racing to have a high degree of oscillation due to terrain and race course conditions (Impellizzeri & Marcora, 2007; MacDermid & Stannard, 2012; Stapelfeldt *et al.*, 2004). Accordingly, the literature suggests XCO-MTB requires high rates of aerobic and anaerobic energy production with an average heart rate during competition to be 90% of maximum corresponding with 84% of maximum oxygen uptake (Impellizzeri *et al.*, 2002). Some 82% of total race time is spent above the lactate threshold (LT) (Impellizzeri & Marcora, 2007) and 22% of power produced is supra-maximal (Stapelfeldt *et al.*, 2004). Taken simplistically, these data tend to suggest that success in the sport will be related to a high sustainable power output and may be closely related to the LT.

The LT is well accepted as an important endurance performance indicator (Gavin *et al.*, 2012; Allen & Coggan, 2006; Sjödin & Karlsson, 1981; Coyle *et al.*, 1995; Bassett & Hawley, 2000; McNaughton *et al.*, 2006). Good correlations between the LT and road cycling performance (Coyle *et al.*, 1995; Bishop *et al.*, 1998) as well as the LT and XCO-MTB performance have been expressed (Costa *et al.*, 2008; Impellizzeri *et al.*, 2005). With the increasing availability of on-the-bike personal power measuring devices, cycling coaches developed functional threshold power (FTP) as a field test to estimate the LT (Allen & Coggan, 2006). FTP can easily be measured during a twenty-minute maximal-power time-trial and tracked throughout a training program with training intensity zones and athlete ability subsequently estimated (Allen & Coggan, 2006). Despite FTP being historically not well understood, it has recently been shown to be equivalent to the onset of blood lactate concentration of 4.0 $mMol \cdot L^{-1}$ (Gavin *et al.*, 2012). No study was found that compared the FTP field test to any cycling performance even though some cycling publications recommend testing it regularly to track fitness (Carmichael & Rutberg, 2009).

However well the LT has been shown to correlate with cycling, previous literature has suggested that intermittent performances are not best predicted from continuous tests (Morton & Billat, 2003). With relation to the variables of interest in this study, the LT as indicated by the FTP test can be considered a continuous test and XCO-MTB deemed an intermittent performance.

Interestingly, there is limited research comparing the relationship between intermittent laboratory tests and XCO-MTB performance (Inoue *et al*., 2012; Prins *et al*., 2007), and there were no intermittent field tests located that explore these variables. Due to the high intensity and intermittent nature of XCO-MTB and the given physiologic parameters surrounding current field test standards, it seems sensible to tailor a field test specific to the demands of XCO-MTB for use in the prediction of performance and determination of athlete ability. Notably, Prins *et al*. (2007) made a call for the design of a XCO-MTB-specific test. In such a test, cyclists would perform a discontinuous effort during which the majority of the time is spent above the LT and recovery periods are well below the LT. The purpose of this study therefore is to investigate the validity of using continuous (i.e. FTP) and intermittent power (IP) field tests to predict XCO-MTB race performance.

## Materials and methods

### Participants and procedures

Eleven regionally competitive male XCO-MTB cyclists (mean age: 35.8 ± 8.2 yr; mean mass: 80.8 ± 13.4 kg) volunteered to participate in this study. All participants reported to be healthy and free of injury and had been cycling regularly (≥ 4 sessions per week). Ethical approval was granted after review from the Institutional Review Board for the Protection of Human Subjects of East Stroudsburg University. All participants completed a written consent form and received notification of potential risks and benefits of the study.

Participants completed three separate testing sessions in random order and were asked to arrive to testing three-hours post-absorptive and with no heavy exercise in the previous 24 hours. During one session the participants performed a FTP test following the procedure explained by Allen and Coggan (2006) with a modified warm-up. The second session was an intermittent test (IP) with 20 intervals of 45 seconds work and 15 seconds recovery. The final testing session was a mass-start mountain bike race. Subjects completed all sessions within a maximum of 14 days and no less than 72 hours between tests.

### Data collection

Prior to testing, body mass was recorded for each subject. All participants used their own bikes for all testing sessions. Each bike was fitted with a CycleOps PowerTap rear wheel (G3 or Pro XCO-MTB Disc) and mounted on a stationary trainer (CycleOps Supermagneto Pro) for both FTP and IP testing. Data was collected onto a mobile recording unit (CycleOps Joule 2.0) and analyzed using PowerAgent software. Race time was recorded using a stopwatch to the nearest second. Each testing session began with a shortened warm-up protocol derived from that explained by Allen & Coggan (2006) and included ten minutes of easy pedaling followed by five minutes of a steady self-determined ‘hard’ effort and culminating with ten minutes of easy pedaling.

Two elite cyclists were selected to gather anecdotal pilot data from actual international and regional race performances. All data were gathered on the participants’ own XCO-MTB using a PowerTap Pro XCO-MTB hub and recorded on a Joule 2.0. Data analysis was done in PowerAgent software. During these races it was determined that approximately 25% of race time was spent either coasting or in recovery power zone based on zones relative to FTP and outlined by PowerAgent software. Throughout the race, many efforts were completed above FTP and lasted approximately less than one minute before coasting or easy pedalling of varying duration. It is from this data that work:rest ratios were determined for

**Table 1.** Values for relative FTP, IP, and race time. Values are means ± standard deviations.

| Relative FTP (W/kg) | Relative IP (W/kg) | Race Time (s) |
|---|---|---|
| 3.32 ± 0.74 | 4.19 ± 0.83 | 4153 ± 561 |

Note: Relative FTP = Functional threshold Power; Relative IP = Intermittent Power
* Both models p < 0.001

**Table 2.** Linear regression models for predicting race time from Relative FTP and Relative IP.

| Variable | Model | r | $r^2$ | MSE | Error |
|---|---|---|---|---|---|
| Relative FTP | Race time = 6317.224 + (-655.688 Relative FTP)* | 0.858 | 0.736 | 92,190 | 303.6 |
| Relative IP | Race Time = 6662.768 + (-598.752 Relative IP)* | 0.886 | 0.786 | 74,773 | 273.5 |

Note: Relative FTP = Relative Functional Threshold Power (W/kg); Relative IP = Relative Intermittent Power (W/kg); MSE = mean square error, calculated as the residual sum of squares divided by the degrees of freedom; Error = estimation error, calculated as the square root of MSE.
* Both models p < 0.001

**Table 3.** Multiple regression models for predicting Race time from Relative IP and a combination of Relative IP and Relative FTP.

| Variable | Model | r | $r^2$ | MSE | Error |
|---|---|---|---|---|---|
| Relative IP | Race Time = 6662.768 + (-598.752 Relative IP)* | 0.886 | 0.786 | 74,773 | 273.5 |
| Combined | Race Time = 6662.768 + (-537.759 Relative IP) + (-71.950 Relative FTP)* | 0.887 | 0.787 | 83,841 | 289.6 |

Note: Relative IP = Relative Intermittent Power (W/kg); Combined = regression model combining Relative FTP and Relative IP; MSE = mean square error, calculated as the residual sum of squares divided by the degrees of freedom; Error = estimation error, calculated as the square root of MSE.
* Both models p < 0.001

IP testing. Duration of total time for IP testing was set at 20 minutes to have an equal duration as FTP testing.

From their own training, all participants were familiar with the FTP test that required a sustained maximal effort for 20 minutes. Athletes were instructed to perform at their highest sustainable power for the duration of the FTP test. FTP was recorded as 95% of mean power across the duration of the test. The IP protocol consisted of 20 intervals of 45 seconds work and 15 seconds rest. Participants were told to 'visualize covering the most distance possible' during each work interval. Participants could sit or stand whenever necessary and maintain any cadence or gearing throughout testing. The beginning and end of each work bout was indicated by telling the subject to either start or stop and measured by pressing the 'INTERVAL' button on the Joule 2.0 head unit. Feedback related to elapsed time and power output were available to the participants at any time during testing just as they would be during self-intended field testing. During recovery intervals in IP testing, participants were instructed to pedal at an easy rate or coast; these intervals were not recorded.

The race was conducted across nine laps consisting of approximately 40% grass fields and 60% moderately difficult singletrack trails on rolling terrain with 43 m of elevation change each. Total distance covered for all participants was 17.4 km.

### Calculation of variables

Mean power was recorded during all work bouts. FTP was calculated as 95% of mean 20-minute power and was recorded relative to body mass. The mean of all work bouts during IP was recorded relatively. Race time was recorded to indicate performance and measured in seconds after the completion of all laps.

Linear regression models (SPSS 19.0) were used to evaluate the coefficient of determination and standard error when using relative measures (W/kg) of FTP and IP in prediction of XCO-MTB race performance. 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 expressed in unit time (s).

## Results

The data for the relative FTP, relative IP and the race time are shown in Table 1. The correlation coefficient between the values achieved in the Relative FTP and those in the Relative IP was 0.964 ($r^2 = 0.929$).

Table 2 shows the linear regression models created using relative FTP and relative IP to predict race time. Both models were able to significantly predict race performance ($p < 0.001$). However, the prediction errors were less when using relative IP than relative FTP (273.5 s versus 303.6 s).

Multiple regression models were developed to assess the prediction of race performance from Relative FTP and Relative IP combined. The effect of combining relative FTP and relative IP ($r^2$=.887) did not enhance the variance in XCO-MTB performance explained by the relative IP ($r^2$=.886) model substantially. Furthermore, the error associated with the combined model was in excess of that associated with the model containing only relative IP (289.6 s and 273.5 s, respectively).

## Discussion

To the best of our knowledge, this is the first study to use field-based tests to predict XCO-MTB performance. Field tests are particularly practical to athletes and coaches who do not have access to laboratory equipment. The development of power-based field tests that are highly correlated with actual performance could help those with access only to a portable power meter gain valuable insight into potential for performance. Considering this study presents strong correlations between XCO-MTB performance and tests completed on a stationary trainer, the repeatability of these tests stands independent of weather conditions, expensive equipment and laboratory practitioners.

Indeed, the primary purpose of this study was to determine the validity of using FTP and IP field tests to predict XCO-MTB race performance. Based on the intermittent nature of XCO-MTB, it was questioned whether a steady-state physiologic indicator was the best option for assessing athletes of the sport. The FTP test was chosen for a condition of comparison based on the previous research relating the LT and XCO-MTB performance (Costa *et al*., 2008; Impellizzeri *et al*., 2005). Given the findings of Gavin *et al.* (2012) indicating FTP to be equal to a commonly used laboratory LT indicating the onset of blood lactate (4 $mmol·L^{-1}$), and the strong face validity of the FTP field test among cyclists in general, this relationship suggested FTP was suitable for means of use in this study.

Our pilot data and revealed that XCO-MTB cyclists spend approximately 25% of race time either coasting or pedaling in a recovery zone during a race. This is relatable to the finding of Stapelfeldt *et al*. (2004), who determined 39% of XCO-MTB race power to be less than the aerobic threshold. With this information, the IP test protocol for this study entailed work: rest ratios set at 45 s: 15 s and was designed to be completed in the same amount of time as the FTP field test (20 minutes). This ensured the IP field test was effective means of blending the demands of XCO-MTB racing found during pilot testing with the time constraint of the FTP field test.

After a thorough search of published peer-reviewed literature on cycling, this is the first intermittent field test found that was designed to assess XCO-MTB. One of our first findings was that IP is strongly correlated with FTP. This can be explained by previous work showing that the ability to complete intermittent exercise to be reliant on aerobic metabolism and oxygen uptake (Bogdanis *et al*., 1996; Gaitanos *et al.*, 1993; Bishop, 2012, Bishop *et al*., 2004), and that the LT is strongly correlated to the percent of Type I muscle fibers (Coyle *et al*., 1992). This suggests that IP performance is at least in part based on the parameters surrounding an athlete's FTP. Moreover, interval training can improve aerobic-dependent time-trial performance (Stepto *et al*., 1999; Lindsay *et al*., 1996; Padilla *et al*., 1999). While the training of the participants in this study was not recorded, it can be postulated that the strong relationship between these two tests is at least in part due to the combination of training benefits of off-road cycling and the upper limit of intermittent exercise capacity as constrained by aerobic efficiency.

The main finding of this study is that when using relative power output to predict XCO-MTB, IP has a stronger correlation than FTP. This agrees with the finding of Inoue *et al.* (2012) where a 5 x 30-s Wingate (at 50% Wingate load) could predict XCO-MTB performance. Interestingly, when Prins et al., (2007) had athletes perform a time trial on the same course as race performances were recorded, a similar correlation was found as that in this study when comparing IP with race time. In the same study, variable intensity and 1-km time trials were performed and compared with the same XCO-MTB performance. While these trials were completed with a high degree of control in the laboratory, the results shown here suggest IP field test can better predict race performance. This supports the IP field test as it suggests that performance can be predicted at least as well as any other previously used model and independent of weather conditions and expensive laboratory equipment.

The error associated with the regression models used in this study indicates that IP can predict XCO-MTB performance with less error than FTP. This is important given that finish rankings were often determined by smaller time margins than the error associated with both tests, and could mean the difference between finishing first and third or getting pulled from UCI races where the 80% rule is in effect.

Two potential criticisms of the IP test from a laboratory practitioner could be lack of control for the workload and the selection of the work:rest ratios. However, we feel that given the relationship of IP and race performance, the ease of execution of the IP field test, and the suggestion that the IP field test is at least as good at predicting XCO-MTB performance as other, more difficult field and laboratory measures, future research can potentially point towards fine-tuning a similar test to the one used in this study. This area needs more research.

## Practical applications

This is the first study to relate power-based field tests of FTP and IP to XCO-MTB performance. While the FTP test can explain much of the variation in performance, a field-based IP test is a better predictor of XCO-MTB race time than FTP. The astute coach should use this test as a criterion when determining the ability and preparedness of an athlete for competition.

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