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Comparison of laboratory parameters of a mountain bike specific performance test and a simulated race performance in the field

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Abstract

Previous studies have described the need for a tailored performance test to predict mountain bike performance. This test should improve characterisation of intensive and intermittent physiological demands of mountain biking. Therefore, the aim of the study was to identify mountain bike related parameters that can more accurately explain the variance of mountain bike performance. Ten competitive mountain bike riders (age: 34 ± 8.7 years; V̇O2peak: 69 ± 11.1 ml·min−1·kg−1) participated in the following tests: (a) an incremental bicycle ergometer test to determine their individual anaerobic threshold (IAT) and maximal oxygen consumption (V̇O2peak), (b) an isometric strength test, (c) a second bicycle ergometer test consisting of time trials with maximal effort during 10-s, 1-min and 5-min trials and (d) a simulated race in the field. The laboratory parameters were scaled by body weight and subsequently compared with the mean power scaled by body weight and the race time using univariate correlations (rpower; rtime). The incremental test parameters of individual anaerobic threshold (rpower = 0.70; rtime = −0.74) and V̇O2peak (rpower = 0.85; rtime = −0.86) showed strong correlations with the mean power output during the race and the race time. This result also applies for PO of the laboratory time trials during 1 min (rpower = 0.69; rtime = −0.68) and 5 min (rpower = 0.63; rtime = −0.82). PO of the 10-s time trial (rpower = 0.20; rtime = −0.44), as well as maximal muscle strength (rpower = −0.13; rtime = −0.24), were weakly correlated. In conclusion, power outputs of the 1- and 5-min time trials showed similar correlations with race performance compared with traditional aerobic parameters. These findings underline that traditional aerobic parameters of an incremental test, as well as power output during short high intensive intervals, should be considered when analysing mountain bike performance.

Keywords: anaerobic, aerobic, laboratory-simulated time trials, performance test

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Introduction

Mountain biking includes three main disciplines: downhill (DHI), cross country (XCO) and mountain bike marathon (XCM). The Olympic discipline XCO, which has an approximate duration of 2 h, and the even longer XCM races have become increasingly popular over the last years as a recreational and competitive sport (Impellizzeri et al. 2005a). Despite the growing popularity of XCM and XCO, only a few studies have analysed methods to predict race performance and examined the physiological demands of these two disciplines (Impellizzeri et al. 2008; Impellizzeri and Marcora 2007; Impellizzeri et al. 2005a; Impellizzeri et al. 2005b; Impellizzeri et al. 2002a; Lee et al. 2002; Novak and Dascombe 2014; Stapelfeldt et al. 2004). XCO mountain bike races are characterised by differing terrain conditions with a multitude of climbs and downhill sections, as well as by the difficulty to perform overtaking manoeuvres on the narrow tracks. Apart from the requirement for high aerobic fitness, research suggests anaerobic capacity is also important for XCO performance (Impellizzeri et al. 2005a; Impellizzeri et al. 2005b; Stapelfeldt et al. 2004). A high power output (PO) at the beginning of a mountain bike race is important to get into front positions (Impellizzeri et al. 2002b). Moreover, the isometric contraction of the athlete's upper and lower body during downhill passages is crucial to balance the terrain forces (Abbiss et al. 2013; Impellizzeri et al. 2002a; Stapelfeldt et al. 2004).

The majority of existing studies have attempted to predict race performance using physiological parameters measured during a graded exercise test. This traditional approach mainly analyses aerobic parameters such as PO at the lactate threshold. Previous studies have indicated that incremental tests might predict mountain bike performance but have also outlined the need of designing a laboratory test that is better tailored to these needs. This design should consider the specific demands of mountain biking (Inoue et al. 2012; Miller et al. 2014; Prins et al. 2007). Thus, a sport-specific test may benefit from analysing anaerobic and high intensive parameters in addition to the standard incremental test procedure in order to increase the amount of explainable variance of race

performance by the use of laboratory performance testing.
Therefore, the aim of this study was to explore laboratory parameters with a multivariate performance test. This test was specifically designed in accordance to the physiological demands of mountain biking. The informative value of its laboratory parameters was quantified by correlating the results of the laboratory tests with race performance variables in a simulated mountain bike race under real-life conditions on a permanent track of a nationally ranked mountain bike race.

Materials and methods

Participants

The study was approved by the local ethics committee of the university hospital and is in agreement with the ethical standard of the journal (Harriss and Atkinson 2009). All participants provided written informed consent to engage in the study. The study sample consisted of 10 participants (gender: 9 male, 1 female; age: 34 ± 8.7 years; BMI 22 ± 1.4 [kg/m²]; V̇O2peak: 69 ± 11.1 ml·min−1·kg−1) who participated regularly in official mountain bike races during the current season. The study was conducted during the participants' competitive phase of their biking seasons. The participants were tested during 2 days of laboratory testing and one simulated race within a maximal period of 4 weeks (16 ± 5.8 days). The participants were asked not to perform intense exercises 24 h prior to each test day.

Test protocols

a) Incremental tests

The first day of the tests started with a medical examination. After the anthropometric measurements were recorded, the participants performed an incremental exercise test on a calibrated SRM Ergometer (SRM GmbH, Schoberer Rad Messtechnik, Jülich, Germany) starting at 80 watt (W). The resistance was increased by 40 W every 3 min until exhaustion. The ergometer settings were individually adjusted and the participants were advised to hold a cadence between 80 and 100 revolutions per minute (revs.min-1). The test ended when the participants could not keep the cadence higher than 80 revs.min-1 or when they finished the test voluntarily. The heart rate was continuously monitored (Custo Cardio 100, Custo med GmbH, Ottobrunn, Germany). Expired gases were analysed breath-by-breath using an online automated gas analysis system (MetaLyzer® 3B–R2; Cortex Biophysik GmbH, Leipzig, Germany) and accompanying software (MetaSoft® 3). Peak oxygen uptake (V̇O2peak) was defined as the highest 15-s average oxygen uptake. Lactate was measured and analysed (Biosen S-Line, EKF, Cardiff, UK) by collecting capillary blood samples (20 µl) during the last 20 s of each stage. The individual anaerobic threshold (IAT [W]) was calculated using the method described by Dickhuth et al. (1999).

b)Strength testing

The isometric maximal strength test was performed on a separate day and included bilateral knee extensors (KE), bilateral knee flexors (KF), back extensors (BE) and abdominal flexors (AF) using strength training devices with resistance strain gauges to quantify peak torque (Future Line DMS-EVE series, DAVID Health Solutions Ltd.). Isometric measurements were tested in 60° knee flexion for KE, 30° knee flexion for KF, 30° trunk flexion for BE and 0° trunk flexion for AF. The participants were allowed to get familiarised with the testing procedure for each muscle group and subsequently instructed to push twice with maximal effort against the fixed lever of the device. All the tests were conducted in a seated position. The mean value of both attempts for each muscle group was calculated and used for further analysis. The results of each muscle group were scaled by body weight. Moreover, the strength values of all tested muscle groups were summarized in the variable 'maximal strength index,' which was also scaled by body weight [Nm·kg−1].

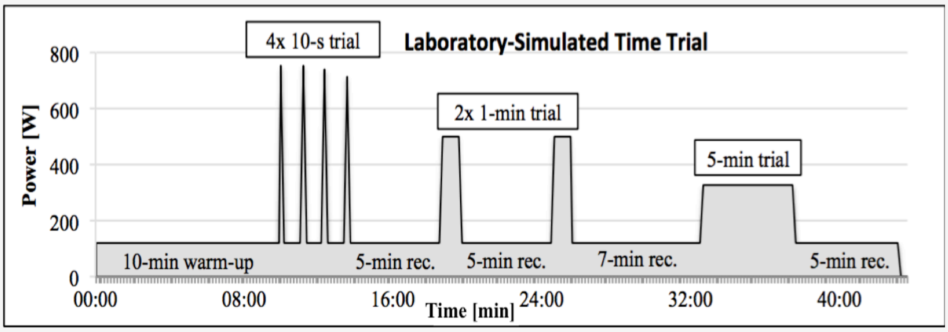

Figure 1. Overview of the laboratory-simulated time trial (rec. = recovery at 1.5 W·kg−1 body weight)

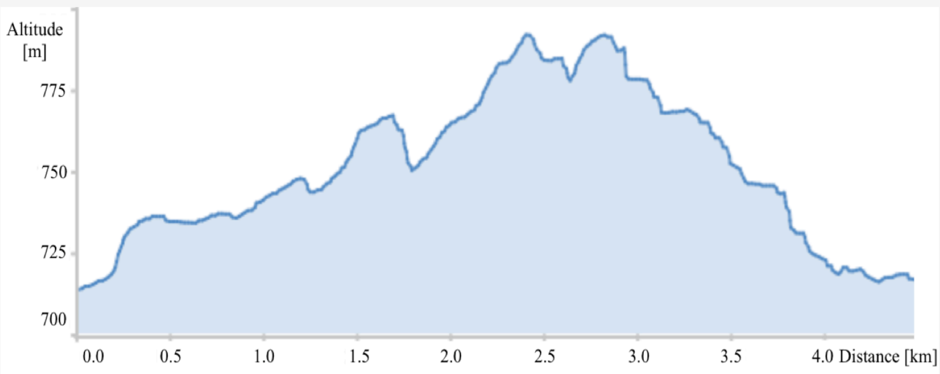

Figure 1: Elevation profile of one lap

c) Laboratory-simulated time trial

The laboratory-simulated time trial was undertaken on the same day on the SRM ergometer, after strength testing in order to ascertain the anaerobic and intermittent power characteristics of the participants. An isokinetic approach was selected because it has proven to be valid and reliable for investigating the maximal PO in similar studies (Bar-Or 1987; Baron et al., 1999; Hachana et al., 2012). The test consisted of trials with different durations (4× 10 s, 2× 1 min, 1× 5 min), according to Stapelfeldt et al. (2004), and preliminary internal testing. The participants were asked to perform with maximal effort throughout all time trials. The default power was defined by 1.5 W·kg−1 body weight for the 10 min of warm-up and during all recovery periods between time trials. This is similar to the intensity of the recovery periods in Quod et al. (2010).

Following the warm-up, four 10-s time trials were conducted with resting periods of 1 min between each trial. After the fourth 10-s trial and a recovery period of 5 min, the participants performed two 1-min trials with a resting period of 5 min between. Following another 7 min recovery period, the test ended with a 5-min time trial followed by a 5-min recovery period.

Cycling PO was recorded every 0.5 s. The mean PO of all 10-s trials, both 1-min trials and the single 5-min trial was calculated. Moreover, the PO of the best 1-min trial was analysed.

According to the results of the study by Baron (2001), the 10-s trials were performed with a cadence of 100 revs.min-1. The 1- and 5-min trials were conducted with a cadence of 90 revs.min-1. This seems to be an appropriate cadence for the slightly longer trials and thus, a lower cycling PO. The duration of the recovery periods between trials were determined on the basis of the preliminary results of several test runs. The participants remained seated in the saddle throughout the test and kept pedalling during recovery and warm-up in-between 70 and 100 revs.min-1. The entire laboratory-simulated time trial, including recovery and warm-up periods, is shown in Figure 1.

d) Simulated race

The participants' race performances were examined with a simulated mountain bike race under real life conditions (hereafter referred to as 'race'). The race was conducted on a slightly modified regular XCO course for national bike races over 6 laps. Each lap had a length of 4.42 km and an elevation gain of 119 m (total distance: 26.5 ± 1.67 km, total elevation gain in metres: 711 ± 70 m. The track profile was measured with a GPS receiver (Edge 510, Garmin International, Olathe, KS, USA). Figure 2 shows the elevation profile of one lap.

All participants practiced the racetrack once at an easy pace, followed by an individual warm-up according to their own personal preferences. Then, the participants were instructed to prepare for the simulated race similar to how they would normally do for a real competition. They were further instructed to complete the race as fast as possible. Two to three participants with comparable cycling performance started simultaneously the race to enhance the spirit of competition. The mean PO scaled by body weight [W·kg−1] during the race and the race time were used to quantify the participants race performances. The PO was monitored with PowerTap PRO MTB power meters (CycleOps, Madison, WI, USA), which have shown to be valid to measure the cycling PO in the field (Bertucci et al. 2005).

Statistical analysis

Because the relative parameters are better predictors of race performance, all the laboratory parameters were scaled by body weight (Gregory et al. 2007; Impellizzeri and Marcora 2007; Swain 1994). According to the Shapiro–Wilk test, the assumption of normally distributed data could be sustained for all data. Pearson's correlation coefficient (r) was used as quantitative measurement for correlations between the power output during the race (POr) and race time (dependent variables) and each laboratory parameter. The coefficients were analysed using a scale proposed by Hopkins (1997) that was successfully used in a previous mountain bike study (Inoue et al. 2012): correlation coefficient < 0.1, trivial relationship; 0.1–0.3, low; 0.3–0.5 moderate; 0.5–0.7, strong; 0.7–0.9, very strong; > 0.9, nearly perfect. JMP® was used for statistical analysis (SAS Institute Inc., JMP®, Version 10.2.2, Cary, NC, USA).

Results

Correlations between laboratory parameters and race performance are shown in Figure 3 and 4 and Table 1. Despite the small sample size, some laboratory parameters demonstrated practical and relevant correlations with race performance (rmean power; rrace time). IAT [$W\cdot kg^{-1}$] ($r = 0.70$; $r = -0.74$) and $\dot{V}O^2$peak [$ml\cdot min^{-1}\cdot kg^{-1}$] ($r = 0.85$; $r = -0.86$) showed very strong correlations with race performance. The parameters of the laboratory-simulated time trial were also correlated. The mean PO of both the 1-min trials ($r = 0.69$; $r = -0.68$) and PO of the 5-min trials ($r = 0.63$; $r = -0.82$) showed strong to very strong correlations. Low to moderate correlations were found between the mean PO of the 10-s trials and race performance ($r = 0.20$; $r = -0.44$). The maximal strength of each muscle group and the maximal strength index ($r = -0.13$; $r = -0.24$) only correlated weakly with race performance.

Discussion

Despite the strong correlations between incremental test parameters and race performance in previous studies, authors claimed the need of designing a less traditional and more sport-specific laboratory test to predict race performance in mountain biking (Miller et al. 2014; Prins et al. 2007). In particular, anaerobic power may have implications for testing off-road cyclists (Impellizzeri and Marcora 2007). Therefore, in this study, we examined the informative value of various laboratory parameters of a novel mountain bike specific test. We aimed to verify whether these additional variables should be considered in future performance tests aside from the traditional ones to allow a more sophisticated insight into relevant components of race performance. The results show that traditional aerobic parameters measured in an incremental test, as well as PO during short high intensive intervals of 1- and 5-min should be considered when analysing the performance of mountain bike riders.

Incremental test

Previous studies have used incremental tests to predict race performance in mountain biking by analysing aerobic performance. Aerobic power and capacity are correlated with cross-country off-road performance (Costa and De-Oliveira 2008; Impellizzeri et al. 2005a; Impellizzeri et al. 2005b; Prins et al. 2007). In this regard, correlation coefficients for $\dot{V}O2peak$, as an important determinant of endurance, ranged from r = 0.30 to r = 0.80 (Costa and De-Oliveira 2008; Gregory et al. 2007; Impellizzeri et al. 2005a; Impellizzeri et al. 2005b; Prins et al. 2007). These values are slightly lower compared with the results of the present study (rpower = 0.85; rtime = −0.86). Correlation coefficients values for lactate threshold and total race time are similar between previous studies (r = 0.64 to 0.86) and our results (rtime = −0.74), indicating moderate to strong correlation between these two variables (Gregory et al. 2007; Impellizzeri et al. 2005b). Irrespective of methodological differences among studies related to the determination of the lactate threshold and its validation in the context of a (simulated) race, PO at the lactate threshold has constantly shown to be correlated with race performance. Therefore, this parameter seems to be a stable measurement to predict race performance and should be retained in laboratory mountain bike performance tests.

Strength testing

Maximal strength of back muscles, abdominal muscles, knee flexors and knee extensors showed no relevant relationships with POr or race time (rpower = −0.13; rtime = −0.24). We therefore concluded that isometric maximal strength tests of the lower limb do not sufficiently predict mountain bike race performance and thus there is no justification for their regular use in mountain bike specific performance tests. At this point, it has to be mentioned that this study limited its conclusions to lower limb and core strength testing only. However, upper body strength is important to manoeuvre the bike during downhill riding (Hurst et al. 2012) and should be analysed in future studies to explore its influence on mountain bike race performance, especially in technically demanding race courses.

Laboratory simulated test trial

This test was designed to explore additional laboratory parameters with relevant explorative power aside from the well-established outcomes of the incremental test to determine mountain bike performance. The mean PO of 10-s laboratory-simulated time trials was weakly correlated with POr (rpower = 0.20; rtime = −0.44). Baron (2001) used similar laboratory 10-s simulated time trials to investigate optimal cadence for maximal PO. Correlation coefficients of mean PO during the 1-min (rpower = 0.69; rtime = −0.68) and 5-min trials (rpower = 0.63; rtime = −0.82) and race performance were similar to PO at lactate threshold and race performance. This finding indicates that our test design with physiological measurements of anaerobic components is more promising to predict mountain bike performance than using mainly aerobic measurement alone.

Previous studies have examined anaerobic PO in mountain biking by using a 30 s Wingate-Test. Costa and De-Oliveira (2008) analysed six mountain bike riders and found weak correlations between mean PO scaled by body weight over 30 s and total time when analysing two mountain bike races (r = −0.12; r = −0.29). In Inoue et al. (2012), the Wingate test of ten mountain bike riders did not significantly correlate with race time (r = −0.33). However, a stronger correlation (r = 0.63) was found between race time and relative mean PO of five repeated Wingate tests with 30 s rests between trials. In our study, the best PO over a single 1-min trial correlated less with race performance when compared with the mean power of both 1-min trials (rmeanpower = 0.59; rtime = −0.53 vs. rmeanpower = 0.69; rtime = −0.68). Our results corroborate Inoue et al. (2012) findings, indicating that the PO of repeated trials with maximal efforts correlates stronger than the PO of a single trial. Therefore, it can be suggested that the intermittent and highly intense characteristic of

Table 1. Physiological parameters of laboratory testing and its relationships with race performance

	Values of the parameters (mean ± SD)	Race performance: Mean power [W·kg^{-1}]	Race performance: Time [min:s]
Incremental test			
Individual anaerobic threshold [W·kg^{-1}]	3.55 ± 0.30	*r* = 0.70	*r* = −0.74
VO_2peak [ml·min^{-1}·kg^{-1}]	68.60 ± 11.12	*r* = 0.85	*r* = −0.86
Laboratory-simulated time trial			
Mean PO 10-s trials [W·kg^{-1}]	11.58 ± 1.20	*r* = 0.20	*r* = −0.44
PO Best 1-min trial [W·kg^{-1}]	7.52 ± 0.59	*r* = 0.59	*r* = −0.53
Mean PO 1-min trials [W· kg^{-1}]	7.20 ± 0.48	*r* = 0.69	*r* = −0.68
PO 5-min trials [W·kg^{-1}]	4.53 ± 0.48	*r* = 0.63	*r* = −0.82
Strength testing			
Maximal strength index [N·m·kg^{-1}]	16.8 ± 2.09	*r* = −0.13	*r* = −0.24

mountain biking can be tested through repeated high intensive intervals rather than a single anaerobic interval. This should be considered when define a test that is better tailored to evaluate mountain bike performance

Study sample

Impellizzeri et al. (2005a) described diverging results for different performance levels of the participating athletes: In a heterogeneous group of twelve mountain bike riders ($\dot{V}O_2peak = 72.1 \pm 7.4$ ml·min^{-1}·kg^{-1}), who compete in regional, national or international events, it could be shown that about 80% of variance in performance was explained by aerobic fitness normalised to body mass (Impellizzeri et al. 2005b). In contrast, correlation coefficients of the same parameters of a homogenous group of thirteen high level, internationally competitive mountain bike riders ($\dot{V}O_2peak = 76.9 \pm 5.3$ ml·min^{-1}·kg^{-1}) were smaller ($r = 0.46$). Other physiological factors, including anaerobic parameters or technical abilities, may play a more important role compared with heterogeneous groups (Impellizzeri et al. 2005a). According to the variation in mountain bike experience and to the $\dot{V}O_2peak$ within the sample of our study, this population group should be classified as heterogeneous as well. If the previous mentioned authors' conclusion can be extended to the results of our investigation, the laboratory-simulated time trials even seem more important for a more homogenous sample to predict race performance.

Aside from this more likely theoretical assumption, results of the present study are valid to complement the existing knowledge on mountain bike specific performance, which is mainly based on studies with only few participants. However, generalising study results with small sample sizes can be limited and the use of multivariate statistics is not appropriate. Therefore, further studies with larger sample sizes are needed to use multivariate regression analysis including traditional aerobic and high intensive parameters. Traditional aerobic parameters include PO at the individual anaerobic threshold and high intensive parameters include PO of a 1-min as well as 5-min time trial with maximal effort to enhance the explorative power of laboratory tests to predict race performance.

Simulated race

Another potential variation source of results from different studies may relate to the (simulated) type of mountain bike races that are used to define race performance. Their physiological demands may vary as indicated by Costa and De-Oliveira (2008). Official national or international mountain bike races were frequently used to validate laboratory parameters. In these studies, race performance was measured by analysing the participants' race time (Costa and De-Oliveira 2008; Impellizzeri et al. 2005a; Impellizzeri et al. 2005b; Inoue et al. 2012). Prins et al. (2007) demonstrated a significant correlation ($r = 0.79$; $P < 0.05$) between an outdoor test trial and an official mountain bike race. In contrast, our study compared results from laboratory bicycle ergometer tests as well as strength tests with the results of a simulated

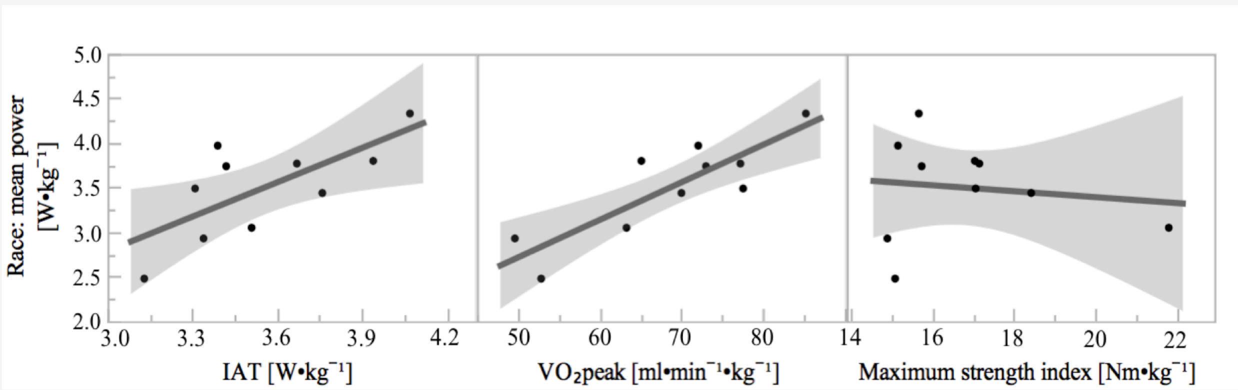

Figure 3: Relationships between mean race POr and parameters of the incremental test and strength testing (IAT: individual anaerobic threshold).

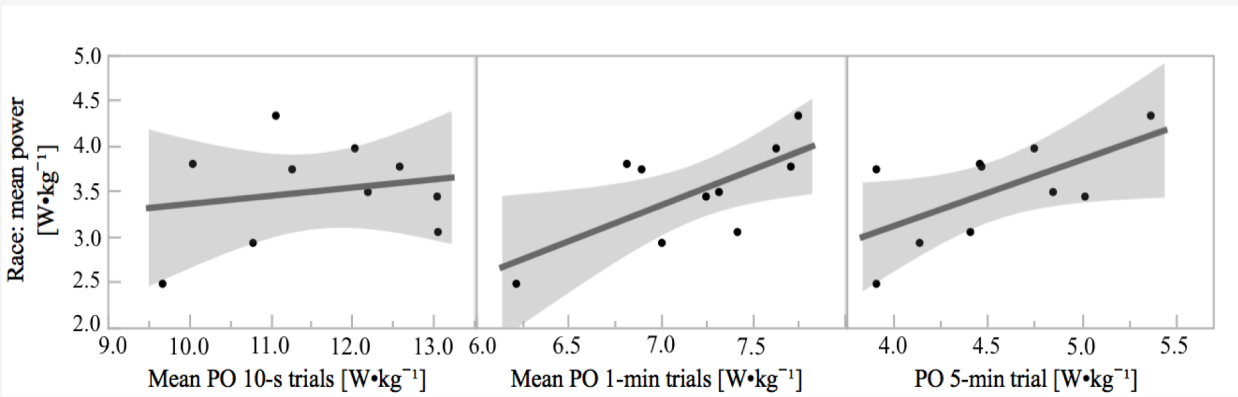

Figure 4: Relationships between PO during the laboratory trials and mean race POr (PO: power output).

mountain bike race. This approach has advantages and disadvantages. Despite the fact that all participants were asked to perform with maximal effort during the race, competition was simulated by stimulating a race atmosphere with competitive riders starting at the same time, delivery of maximal performance may only be possible during a real mountain bike race. However, several advantages counteract this limitation of the methodological design. In this study, PowerTap power meters were used to determine cycling PO. Therefore, PO could be measured independently from external factors, such as weather and surface conditions that influence race time. This is an advantage of the simulated race because the use of such instruments in official races is not feasible as they add weight to the system and could lead to conflicts with the athletes' sponsor. Race performance is further dependent on the start position and overtaking may be difficult in a peloton in narrow track trials as well (Impellizzeri and Marcora 2007; Macdermid and Morton 2012). The design of our simulated race was controlled for the aforementioned confounding covariates as the test trials were conducted with two to three participants only. However, changing weather and terrain conditions in the different races could have influenced the total race time. Therefore, race time and POr were used to validate laboratory parameters. In this study, the afforded power and race time were strongly correlated ($r = 0.88$).

Practical Applications

In accordance with previous findings, results of this study underline the importance of two incremental test variables: 'PO at lactate threshold' and 'peak oxygen uptake' for the determination of race performance in mountain biking. Aside from these measurements, which are mainly related to athletes' aerobic capacity, mean PO in high intensive intervals with durations of 1 and 5 min are significant variables for predicting race performance. Therefore, we conclude that traditional aerobic parameters measured in an incremental test, as well as PO during short high intensive intervals, should be considered when analysing the performance of mountain bike riders. On the other hand, maximal strength testing of the lower limb can be neglected to predict race performance.

Future prospects

Further studies with larger sample sizes are warranted to underline these findings and to explore a multivariate model of parameters for the prediction of mountain bike race performance in laboratory. The finally proposed test method may be additionally improved by the addition of maximal strength tests for the upper body.

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Conflict of interest

No potential conflicts of interest exist.

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