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Physiological Correlates of 10-Km Up-hill Cycling Performance in Competitive Cyclists

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ABSTRACT

Costa VP, Pertence LC, Paton CD, De Matos DG, Martins JAN, De Lima JRP. Physiological Correlates of 10-Km Up-hill Cycling Performance in Competitive Cyclists. **JEPonline** 2011;14(3):26-33. The purpose of this study was to verify the relationship between several physiological variables and performance during simulated up-hill road cycling time trial on the field in competitive cyclists. Fifteen cyclists (35.1 ± 7.0 yrs; 68.4 ± 7.7 kg; 1.73 ± 0.1 cm; 8.5 ± 1.0% of body fat; 57.9 ± 8.2 $ml \cdot kg^{-1} \cdot min^{-1}$) performed an incremental exercise test and 10-km up-hill cycling time trial using a power meter device fitted on the cyclist bicycle. Highly significant relationships were obtained between average power output during 10-km cycling time trial normalized to body mass and 10-km cycle time (-0.85; -0.80; $P<0.01$). VO_2 $max \cdot kg^{-1}$ was also significant associated with 10-km cycle time (-0.69, $P<0.05$). We concluded that for competitive cyclists the average power output during 10-km cycling time trial and VO_2 max both normalized to body mass are strongly associated with performance cycling time during 10-km up-hill cycling time trial simulated on the field.

Key Words: Cycling, Performance, Power Output

INTRODUCTION

Over the last years the winner of the major road cycling events (i.e., Tour the France) had performed with high constancy pace during hard mountain stages and time trial events. Therefore, some authors have examined the cycling performance in these events including mountain and flat stages in a tentative to explain how the cyclists are able to perform very strong in different terrain.

Several studies investigated the correlations between anthropometric, aerobic, and anaerobic variables with cycling time trial performance (2-8). In long time trial competitions (above 50 km distance), cycling performance is partly related to power output that elicits the ventilatory threshold (12). In fact, the relationship between power output at the lactate threshold and maximal power output (W_{max}) may change depending on the length of time trial completed (5). In addition, the level of ground can dramatically affect cyclist time trial performance. Therefore, rolling resistance, air resistance, and force gravity can partly explain why larger cyclists are better in flat ground and smallest cyclists are better in up-hill terrain (13).

Few studies have described the prediction of up-hill time trial performance (3,7,9,13). Davison et al. (7) found the best individual predictor of 1-km and 6-km performance times was the time for the corresponding climb at the other distance. In addition, the Wingate average power per unit of body mass was the strongest single predictor of simulated cycling hill climb performance. Later, Heil et al. (9) investigated the prediction of up-hill time-trial performance scaling a derived protocol. The authors suggested a scaling derived cycle ergometer protocol to be useful and correlated with up-hill cycling time trial performance.

More recently, Antón et al. (3) reported that flat time trial performance is mainly correlated to absolute values and anthropometric variables while up-hill climb time trial performance is associated with W max normalized to body mass. The previous studies on up-hill time trial performance examined the physiological aerobic and anaerobic parameters in the laboratory. Therefore, the aim of this study was to verify the relationship between aerobic variables with up-hill time trial performance in competitive cyclists in field.

METHODS

Subjects

Fifteen experienced competitive cyclists volunteered to participate as subjects in this study. Each subject provided written informed consent in accordance with the Federal University of Juiz de Fora ethics policy (Juiz de Fora, Brazil). The physical characteristics of the subjects are: age 35.1 ± 7.0 yrs, body mass 68.4 ± 7.7, and body fat 8.5 ± 1.0%. The athletes were in the middle of the base phase of their season. At the time of testing, they cycled between 12 to 18 hrs per week.

Procedures

All subjects reported to the laboratory for measurements of anthropometric variables and to perform an incremental cycling test that was performed on an electromagnetic braked cycle ergometer (Ergo Fit 167, Pirmansens, Germany). The cycle ergometer was modified with clip-in pedals and a racing saddle. The saddle and handle bar positions of the cycle ergometer were adjusted to resemble each subject's own bike. Each subject completed a 5-min warm-up period at 70 W followed by 2-min of passive recovery. The test began at 100 W and the intensity was increased by 15 W every 30 sec until volitional exhaustion or until each subject was unable to maintain a cadence of more than 60 rpm. Expired air was collected continuously using a pre-calibrated metabolic analyzer (VO2000, Medical Graphics Inc., Minnesota, USA).

VO_2 max was recorded as the highest oxygen uptake (VO_2) reading averaged over 30 sec. Heart rate (HR) was continuously recorded during the test with a HR monitor (Polar S725X, Polar Electro OY, Finland). One minute after the end of the test, capillary blood samples were obtained from the right ear lob of each subject and immediately analyzed using an electromagnetic technique (YSI® 1500 Sport, Yellow Springs Instruments, Ohio, USA). The analyzer was calibrated in accordance with the manufacture's recommended procedures. All subjects (i.e., cyclists) performed a 10 km up-hill time trial held on a road with an incline variation of between 2 and 6%. The subjects performed the field test using their own bicycle fitted with a power-measuring wheel (Power tap SL 2.4 Saris, Madison, USA). Before the test the subjects performed a self-selected 30-min warm up at an intensity corresponding to ~65 to 70% of W max. All time trials took place at the same time of the day under similar environmental conditions (~25 °C, 50% Rh).

Statistical Analysis

Descriptive statistics were calculated for all measured variables from the laboratory and field tests using SPSS software 16.0. The Kolmogorov-Smirnov test was applied to ensure a Gaussian distribution of the data. Comparisons between physiological variables during incremental exercise test and the 10-km cycling time trial performance were analyzed using paired t-test. Spearman Rank product moment correlation was used to establish the relationship between measured variables. For all analyses, the level of statistical significance was established at an alpha level of $P<0.05$.

RESULTS

Table 1 shows the physiological submaximal and maximal responses during the incremental exercise test and the performance variables from the time trial. Significant correlations were found when performance was measured by the time (Table 2). The W avg normalized to mass exponent 1.0 and 0.79 was strongly associated to up-hill time trial performance (-0.80 and -0.85, respectively; $P<0.01$) while VO_2 max was significantly correlated with performance time (-0.69; $P<0.05$).

DISCUSSION

The aim of this study was to determine the relationship between laboratory-based performance measures and hill-climb cycling time trial performance time and power with competitive cyclists. The main findings indicate there were significant relationships between hill-climb performance and several laboratory determined performance measures. The largest correlates between laboratory measures and time trial performance time were for VO_2 max and W max both scaled to body mass. Strongly correlates were found between performance power and both absolute VO_2 max and W max. The correlations increased significantly when both performance power and laboratory variables were normalized to body mass. Smaller but significant correlations were also established between hill climb performance and incremental power output at VT_2 normalized to body mass.

Table 1. Measured variables from the laboratory and performance tests.

Physiological Variable	Mean ±SD
W max (W)	376.0 ± 23.0
W max·kg^{-1} (W·kg^{-1})	5.5 ± 0.8
VT_1 (W)	199.0 ± 26.0
VT_2 (W)	287.0 ± 24.0
VO_2 max (ml·kg^{-1}·min^{-1})	58.2 ± 7.5
HR max (beats·min^{-1})	188 ± 8
$HRVT_1$ (beats·min^{-1})	149 ± 12
$HRVT_2$ (beats·min^{-1})	171 ± 10
[La] max (mmol·l^{-1})	10.1 ± 1.1
Performance Variable	**Mean ±SD**
Time (s)	1375 ± 85
Speed (km·h^{-1})	26.3 ± 1.6
HR peak (beats·min^{-1})	186 ± 6
HR avg (beats·min^{-1})	177 ± 6
Cadence (rpm)	83 ± 5
W avg (W)	276.0 ± 25.6

W max = maximal power output; W max·kg^{-1} = maximal power output relative to body mass; VT_1 = first ventilatory threshold; VT_2 = second ventilatory threshold; VO_2 max = maximal oxygen uptake; HR max = maximal heart rate; [La] max= maximal blood lactate; HR peak= peak heart rate; HR avg = average heart rate; W avg = average power output.

Table 2. Correlations for selected physiological and performance variables.

	Time (s)	W avg	W avg.kg^{-1}	W avg.kg$^{-0.79}$
Time (s)	1	-0.61*	-0.80**	-0.85**
W max	-0.51	0.89**	0.41	0.55*
W max·kg^{-1}	-0.59*	0.04	0.91**	0.83**
W max·kg$^{-0.79}$	-0.64*	0.16	0.93**	0.88**
VO_2 max·kg^{-1}	-0.69**	0.43	0.80**	0.81**
VO_2 max	-0.46	0.81**	0.25	0.39
VT_2	-0.51	0.49	0.17	0.25
VT 2·kg^{-1}	-0.56*	-0.11	0.68**	0.59*
VT 2·kg$^{-0.79}$	-0.59*	-0.02	0.64**	0.58*

W max = maximal power output; ·kg^{-1} = relative to exponent of mass 1; ·kg$^{-0.79}$ = relative to exponent of mass 0.79; VO_2 max = maximal oxygen uptake; VT_2 = second ventilatory threshold; W avg = power average during time trial.

Previous authors have shown that absolute measures from laboratory tests are good predictors of time trial performance when races are held on flat terrain. Hawley and Noakes (8) reported that W max was a good predictor of cycling time over 20 km in a heterogeneous group of cyclists (r = -0.91). Similarly, Antón et al. (3) found a strong correlation (r = -0.90) between time in a 14-km time trial race and W max determined in a laboratory test. Measures of absolute VO_2 max in cyclists have also been reported to strongly correlate with performance during laboratory based time trials of 20 min and 60 min (5,6,8). However, these results contrast to ours, which found no significant correlations between absolute W max or VO_2 max measured in the laboratory and up-hill time trial performance.

A likely reason for the non-significant correlations between performance and absolute laboratory measures is due to the up-hill nature of the course. On flat courses the major retarding factor is related to overcoming aerodynamic drag. However, at the slower speeds of up-hill cycling, overcoming gravitational forces due to body mass becomes more important. In accordance with our study, Heil et al. (9) reported that correlations between VO_2 max and 12.5 km up-hill time trial performance increased from 0.54 to 0.89 when performance values were scaled to body mass. Similarly, the correlation between performance time and laboratory W max increased from 0.71 to 0.97 when power was scaled to take into account subject's body mass. In the current study, scaling laboratory measures relative to body mass significantly increased the strength of the correlations with time trial performance.

To our knowledge, only three studies (3,9,14) have examined the relationship between laboratory measures and outdoor up-hill cycling. Only one study measured actual power output during the hill climb trial. Values of absolute W max and VO_2 max were strongly correlated with the average speed the athletes could maintain during the time trial (r > 0.8). The correlation was enhanced slightly when both laboratory and hill climb parameters were scaled to account for body mass. Data reported in the present study show that average power output provided a more valid assessment than time during uphill cycling time trial.

The finding that peak power was better correlated to performance power than time is not surprising when the effects of individual aerodynamics and variable environmental conditions are considered (4). Indeed, the relationship between outdoor power output and speed is dependent on factors such as wind speed and direction, incline variation of the terrain, ambient temperature, and atmospheric pressure as well as body size, racing position, and bicycle design. However, a previous study has reported a strong, significant relationship (r = -0.99) between performance time and average power output during a flat 40-km cycling time trial (10). In the current study, the relationship between performance time and average power output during the hill-climb increased from -0.61 to -0.85 when average power output was scaled to take into account subject's body mass.

The strong correlations between W max and performance power both normalized to body mass suggest that a change in peak power or body weight has a direct affect on 10-km up-hill time trial performance. However, Lindsay et al. (11) found that well-trained cyclists who completed a 4-wk high intensity interval training program with an enhancement of ~5% in W max; the authors did not find an improvement in 40-km cycling time trial. Westgard-Taylor et al. (15) reported that high intensity training increased W max, however, there was no significant correlation between peak power and 40-km time trial performance. It is worth noting that the assessment of peak power in these two studies above involved different protocols for incremental exercise test. Amann et al. (1) reported that the assessment of peak power can be affected by the method of testing. Further investigation is required to establish whether a change in peak power due to effects of training/detraining leads to a change in time trial performance.

The ventilatory threshold is a non-invasive method based in the assumption of a casual relationship between lactate production and increased ventilation. Several studies have used the workload at ventilatory threshold to correlate with long and flat time trial performance during cycling (1,10,12). The significant correlation between ventilatory threshold variables and actual cycling time trial performance in these studies varied from 0.73 to 0.92. Hopkins and McKenzie (10) found that absolute power at ventilatory threshold was correlated with 40 km cycling performance time and estimated power output (r = -0.81 and r = 0.81; respectively). Similarly, Amann et al. (1) found that absolute values of submaximal power output at various methods of ventilatory thresholds were significantly associated with 40 km performance power (0.73 to 0.81). However these results disagree with the present study, which found no significant correlations between absolute VT_2 and uphill time trial performance. When performance power and laboratory values were scaled to body mass, significance of the correlations increased. This was probably due to the climb hill nature of the course. In accordance with our study, Heil et al. (9) reported that correlations between ventilatory thresholds and 6.2 km and 12.5 km up-hill time trial performance increased from 0.75 to 0.97 when laboratory values were scaled to body mass. Therefore, these results may represent conditions that can aid in up-hill cycling performance because the physiologic parameters are frequently normalized by alometric scale (13).

A wide variety of studies report the relationship between VT and time trial performance. Typically, most investigations only report correlation coefficient and do not compare the actual power output at VT with time trial performance power. However, the correlation only measures the strength of a relationship between two variables, not the absolute agreement between then (1). In our study, the criteria for a certain VT assessment method to be considered a valid predictor of climb-hill time trial performance was, therefore, not only a significant correlation but also a non-significant comparison against the power output average during time trial. In hill climb riders maintained ~73% of their laboratory achieved peak power output, this value is similar to the power output the athletes achieved at VT (~76%). Indeed, results showed that there was no significant difference between time trial power and VT_2 power output. It appears that VT_2 may predict an athlete's sustainable power in hill climb time trials of around 25 min in duration.

CONCLUSIONS

In summary, it is reasonable to conclude that for competitive cyclists the average power output during 10-km cycling time trial and VO_2 max both normalized to body mass are strongly associated with performance cycling time during 10-km up-hill cycling time trial simulated on the field.

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