PHYSIOLOGICAL CORRELATES OF CYCLING PERFORMANCE IN AMATEUR MOUNTAIN BIKERS

Donvina Vaitkevičiūtė, Kazys Milašius
Lithuanian University of Educational Sciences, Vilnius, Lithuania

ABSTRACT

Research background and hypothesis. Aerobic fitness of high-performance mountain bikers explains about 40% of variance in performance. This suggests that other factors such as anaerobic power and capacity as well as technical abilities need to be considered in the physiological assessment (Impellizzeri et al., 2005 a). We found a lot studies investigating track and road cyclists, but there are no studies concerning the relationship between physiological tests and cycling performance in Lithuanian mountain bikers.

The aim of this study was to investigate the physiological correlates of cycling performance in amateur mountain bikers.

Research methods. Fifteen Lithuanian mountain bikers participated in the study. The 10-second test was performed to estimate special alactic anaerobic power output, whereas ae 30-second Wingate test was performed to estimate composite alactic anaerobic glycolytic power output. For the evaluation of the aerobic capacity, a progressive incremental laboratory cycling test to exhaustion was performed.

Research results. We found a significant negative correlation between cycling performance and alactic anaerobic relative peak power output ($r = –0.534$, $p < 0.05$) and lactate concentration after the progressive incremental cycling test to exhaustion ($r = –0.625$, $p < 0.05$). However, we did not find a significant correlation between cycling performance and VO_2max ($r = –0.024$, $p > 0.05$) and composite alactic anaerobic glycolytic power output ($r = –0.269$, $p > 0.05$).

Discussion and conclusions. Our findings suggest that alactic anaerobic power output and active glycolysis play a very important role in off-road cycling performance. This is essential because of the fast starting phase of the race and steep climbs.

Keywords: mountain bike, cycling, performance, power output, maximal oxygen uptake.

INTRODUCTION

Mountain biking (off-road cycling) is becoming increasingly popular in Lithuania. The most popular mountain biking events are cross-country (XC) and marathon, often referred to as cross-country marathon (XCM). Both events are a mass-start endurance competition. Cross country involves completing several laps of an off-road circuit, typically the course is between 6 km and 9 km long and winning time is about 120–135 minutes for men and 105–120 minutes for women (Impellizeri, Marcora, 2007). Marathons cover at least 40 kilometers of trial. Mountain biking events include repeated descents and hill climbs on gravel roads and wilderness trails.

Mountain biking is a physically demanding sport (Baron, 2001). The duration of these events suggest that high aerobic power and the ability to sustain high intensity exercises for a prolonged period is required and the fast starting phase, as well as fighting against gravity during the steep climbs, (up to 500 W) suggest that anaerobic metabolism plays a significant role (Impellizeri et al., 2002). VO_2max is considered to be a standard indicator of the integrated function of cardiovascular, respiratory and muscular systems during exercise and an important determinant of endurance performance (Bassett, Howley, 2000). T. Cramp et al. (2004) reported VO_2max values in amateur mountain bikers at 60.0 ml/min/kg, whereas elite mountain bikers have VO_2max value at 78.3 ml/min/kg (Lee et al., 2002). Aerobic fitness of high-performance mountain bikers explains about 40% of variance in performance. This suggests that other factors as anaerobic power as well as capacity and technical abilities need to be considered in the physiological assessment of these athletes (Impellizzeri et al., 2005 b).

During mountain biking competitions, different terrain conditions require mountain bikers to have a high degree of technical ability to control and stabilize the bicycle. Riders might increase their speed downhill and can gain advantage or decrease the time lost in other parts of the course (Wang, Hull, 1997).

We found a lot studies investigating the track and road cyclists, but there are very few studies on Lithuanian mountain biker's physiological profile (Vaitkevičūtė, Milašius, 2011) and none on the relationship between physiological tests and cycling performance.

The aim of this study was to investigate the physiological correlates of cycling performance in amateur mountain bikers.

RESEARCH METHODS

Participants. Fifteen Lithuanian mountain bikers (19–29 years old) who participated in mountain biking marathons were tested during the competitive phase of their season. The marathon was a mass start event and took part in Vilnius (19 06 2011), with the course *consisting of* a *26*-kilometer lap and all participants completing two *laps.*

Anthropometry. These indices of physical development were measured: body mass, muscle and fat body mass, BMI, hand grip strength and vital lung capacity (Table 1).

Laboratory tests. Muscle power in different zones of energy production was studied. The 10-second test was performed to estimate the special alactic anaerobic power output, whereas the 30-second Wingate test was performed to estimate composite alactic anaerobic glycolytic power output *using* a *Monark* 894E *veloergometer.* For the evaluation of aerobic capacity, a progressive incremental laboratory cycling test to exhaustion was performed using Oxycon Mobile, a telemetric breath-by-breath system. During this test, pulmonary ventilation (VE), heart rate (HR), oxygen uptake (VO_2) and power output (W) was continuously registered at the anaerobic threshold and intermittent critical power intensity (PCi).

Statistical analysis. The data were analysed using descriptive statistics and are presented as the mean (±) standard deviation (s), coefficient of variation (V%) and range. We used a Pearson's correlation coefficient (r) to calculate the correlation between cycling performance and physiological

Table 1. **Anthropometric and physiometric characteristics of amateur mountain bikers**

Indices	Mean	Standard deviation (S)	Coefficient of Variation (V%)	Min	Max
Height, cm	181.90	5.45	3.00	173.00	192.00
Body mass, kg	71.61	7.21	10.07	58.30	85.50
BMI	21.62	1.67	7.72	18.90	24.45
Muscle mass, kg	37.95	4.40	11.59	28.30	45.50
Fat mass, kg	7.45	2.38	31.95	4.20	12.30
Hand grip strength, kg	63.07	5.11	8.10	50.00	71.00
VLC, l	5.81	0.64	11.02	4.40	6.70

Table 2. **Relative anaerobic power output and race time values**

Indices	Mean	Standard deviation (S)	Coefficient of Variation (V%)	Min	Max
10 s max, W/kg	21.10	1.92	9.08	18.47	24.43
10 s mean, W/kg	14.00	1.04	7.41	12.61	16.20
30 s mean, W/kg	9.40	0.66	7.01	8.38	10.37
Race time, s	7837.51	572.66	7.31	6903.35	9004.30

capacities ($r = 0.514$, $p < 0.05$; $r = 0.641$, $p < 0.01$). For performing statistical analyses we used *Microsoft Office Excel 2007* and *SPSS Statistics 17.0*.

RESEARCH RESULTS

Table 2 shows that the calculated coefficients of variations for the 10 s test, 30 s – Wingate test and cycling performance remained low (< 10% coefficient of variation). We found that the alactic anaerobic relative peak power output was 21.10 W/kg, the alactic anaerobic relative power output was 14.00 W/kg, the composite alactic anaerobic glycolytic power output was 9.40 W/kg and the average race time was 7837.51 s.

The data of aerobic capacity (Table 3) had different coefficients of variation. The V% of HR at intermittent critical power (PCi) intensity and anaerobic threshold was low, < 10% just as VO_2max at PCi. All other data (except La, which had < 30% coefficient of variation) had medium coefficient of variation (< 20%). The VO_2max at the PCi was 58.51 (48.18–73.56) ml/min/kg and at the anaerobic threshold it was 43.84 (34.90–55.20) ml/min/kg. Respectively the power output was 411.33 W and 271.33 W. *The blood lactate concentration after the* progressive incremental laboratory cycling test to exhaustion was 12.40 mmol/l (8.10–16.20 mmol/l).

We found a significant negative correlation between cycling performance and alactic anaerobic relative peak power output ($r = –0.534$, $p < 0.05$) and lactate concentration after the progressive incremental cycling test to exhaustion ($r = –0.625$, $p < 0.05$) (Table 4). Also alactic anaerobic relative power output had a significant negative correlation with VO_2max at anaerobic threshold ($r = –0.516$, $p < 0.05$). However, we did not find a significant correlation between cycling performance and VO_2max ($r = –0.024$, $p > 0.05$) and composite alactic anaerobic glycolytic power output ($r = –0.269$, $p > 0.05$). Composite alactic anaerobic glycolytic power output had no significant positive correlation with lactate concentration ($r = 0.255$, $p > 0.05$), either.

Oxygen pulse (OP) had strong significant positive correlation with power output at intermittent critical power (PCi) intensity and anaerobic threshold ($r = 0.721$, $p < 0.01$; $r = 0.682$, $p < 0.01$). VO_2max at intermittent critical power (PCi) intensity was significantly positively correlated with VO_2max at anaerobic threshold ($r = 0.761$, $p < 0.01$).

DISCUSSION

We believe this is the first time physiological correlates of cycling performance are reported in amateur mountain bikers. A few studies investigated correlations between physiological

Table 3. **Responses to progressive incremental laboratory cycling test to exhaustion at anaerobic threshold and PCi**

Indices		Mean	Standard deviation (S)	Coefficient of Variation (V%)	Min	Max
Response to exercise at intermittent critical power intensity (PCi)	VE, l/min	159.80	22.71	14.21	122.00	203.00
	HR, bpm	187.07	10.09	5.39	163.00	200.00
	VO_2max, l/min	4.19	0.56	13.48	3.27	5.48
	VO_2max, ml/min/kg	58.51	5.80	9.91	48.18	73.56
	O_2 pulse, O_2/HR	22.52	3.84	17.06	16.35	30.61
	W	411.33	45.65	11.10	330.00	510.00
	La, mmol/l	12.40	3.00	24.16	8.10	16.20
Response to exercise at anaerobic threshold	VE, l/min	75.33	11.16	14.81	55.00	95.00
	HR, bpm	166.73	9.73	5.83	153.00	185.00
	VO_2, l/min	3.14	0.52	16.65	2.03	3.91
	VO_2, ml/min/kg	43.84	5.95	13.58	34.90	55.20
	O_2 pulse, O_2/HR	18.92	3.67	19.40	11.47	25.56
	W	271.33	45.65	16.82	170.00	330.00

Table 4. **Correlations (Pearson's r) between race time and physiological variables**

No.	Muscle power			Exercise response at intermittent critical power (PCi) intensity							Exercise response at anaerobic threshold						
	10 s max, W/kg	10 s mean, W/kg	30 s mean, W/kg	VE, l/min	HR, bpm	VO_2max, l/min	VO_2max, ml/min/kg	O_2 pulse, O_2/HR	W	La, mmol/l	VE, l/min	HR, bpm	VO_2, l/min	VO_2, ml/min/kg	O_2 pulse, O_2/HR	W	Race time, s
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1		0.915**	0.795**	0.270	0.083	–0.169	–0.349	–0.158	0.140	0.232	–0.038	0.103	–0.246	–0.381	–0.242	–0.159	–0.534*
2	0.915**		0.771**	0.309	0.117	–0.047	–0.388	–0.076	0.282	0.078	–0.236	–0.061	–0.236	–0.516*	–0.182	–0.142	–0.336
3	0.795**	0.771**		0.470	–0.033	–0.118	–0.103	–0.086	0.242	0.255	–0.186	–0.108	–0.324	–0.347	–0.244	–0.242	–0.269
4	0.270	0.309	0.470		–0.105	0.316	0.230	0.276	0.500	0.237	0.125	–0.302	0.014	–0.092	0.105	–0.002	–0.156
5	0.083	0.117	–0.033	–0.105		–0.495	–0.357	–0.732**	–0.478	0.076	–0.313	0.809**	–0.489	–0.390	–0.674**	–0.602*	0.296
6	–0.169	–0.047	–0.118	0.316	–0.495		0.701**	0.953**	0.741**	–0.101	0.551*	–0.524*	0.862**	0.617*	0.901**	0.796**	–0.161
7	–0.349	–0.388	–0.103	0.230	–0.357	0.701**		0.679**	0.278	0.164	0.540*	–0.242	0.577*	0.761**	0.584*	0.421	–0.024
8	–0.158	–0.076	–0.086	0.276	–0.732**	0.953**	0.679**		0.721**	–0.124	0.549*	–0.682**	0.841**	0.618*	0.936**	0.816**	–0.217
9	0.140	0.282	0.242	0.500	–0.478	0.741**	0.278	0.721**		0.159	0.181	–0.630*	0.596*	0.258	0.682**	0.739**	–0.317
10	0.232	0.078	0.255	0.237	0.076	–0.101	0.164	–0.124	0.159		–0.159	0.123	–0.241	–0.060	–0.261	–0.073	–0.625*
11	–0.038	–0.236	–0.186	0.125	–0.313	0.551*	0.540*	0.549*	0.181	–0.159		0.057	0.749**	0.797**	0.629*	0.580*	–0.237
12	0.103	–0.061	–0.108	–0.302	0.809**	–0.524*	–0.242	–0.682**	–0.630*	0.123	0.057		–0.337	–0.094	–0.598*	–0.475	0.050
13	–0.246	–0.236	–0.324	0.014	–0.489	0.862**	0.577*	0.841**	0.596*	–0.241	0.749**	–0.337		0.834**	0.954**	0.929**	–0.121
14	–0.381	–0.516*	–0.347	–0.092	–0.390	0.617*	0.761**	0.618*	0.258	–0.060	0.797**	–0.094	0.834**		0.743**	0.709**	–0.021
15	–0.242	–0.182	–0.244	0.105	–0.674**	0.901**	0.584*	0.936**	0.682**	–0.261	0.629*	–0.598*	0.954**	0.743**		0.925**	–0.103
16	–0.159	–0.142	–0.242	–0.002	–0.602*	0.796**	0.421	0.816**	0.739**	–0.073	0.580*	–0.475	0.929**	0.709**	0.925**		–0.294
17	–0.534*	–0.336	–0.269	–0.156	0.296	-0.161	–0.024	–0.217	–0.317	–0.625*	–0.237	0.050	–0.121	–0.021	–0.103	–0.294	

Note. * – $p < 0.05$; ** – $p < 0.01$

variables and performance in elite off-road cyclist (Impellizzeri et al., 2005 a, b; Costa, De-Oliveira, 2008; Costa et al., 2011). Cross country marathon (XCM) is a mass-start competition. Starting position is defined according to UCI (International Cycling Union) points during international events or national points system during national events. This system lets the best athletes start the race at the front of the group, so they are not being slowed down by lower performing bikers. Different starting positions have influence on race time and its correlation to the physiological variables.

Up to now, there have been no studies investigating the alactic anaerobic peak power relationship to cross country marathon (XCM) performance. As we know, only one study reports about the correlation between Wingate test and cross country (XC) performance (Costa, De-Oliveira, 2008). During Wingate test both the phosphagen and glycolytic systems are fully activated (Boobis et al., 1982), and during a 10 s test the phosphagen system plays the most important role (Gaitanos et al., 1993). V. P. Costa, F. R. De-Oliveira (2008) and we found no significant correlation between Wingate test variables and cycling performance. Still we discovered that alactic anaerobic relative peak power is significantly correlated to cycling performance.

F. M. Impellizeri et al. (2005 a) reported that VO_2max, power output, anaerobic threshold expressed both in absolute terms and relative to body mass were significantly correlated to race time. Thirteen national and international off-road cyclists (under 23 in the UCI classification) participated there. Later, F. M. Impellizeri et al. (2005 b) studied fifteen elite off-road cyclists and the results were different. This group was more homogeneous, but they found no significant correlation between VO_2max and power output. They concluded that the physiological predictor of performance in a heterogeneous group of athletes cannot be applied to elite athletes who are characterized by a more homogeneous performance ability.

Aerobic fitness of high-performance mountain bikers explains about 40% of the variance in performance. This suggests that other factors such as anaerobic power and capacity and technical abilities need to be considered in the physiological assessment of these athletes (Impellizzeri et al., 2005 b). Our results are similar, we found no significant correlation between aerobic fitness and cycling performance, except for lactate concentration after a progressive incremental laboratory cycling test to exhaustion. V. P. Costa et al. (2008) notified that the intermittent nature of cross country could promote larger demand and utilization of anaerobic metabolism during training and/or races. B. Stapelfeldt et al. (2004) quantified the intensity during cross country races and indicated that 42% of the race time was above anaerobic threshold. This explains that *active glycolysis plays a very important role in off-road cycling performance.*

Our further studies should investigate the influence of physiological parameters and the technical ability in the cycling performance of homogeneous mountain bikers' group.

CONCLUSIONS AND PERSPECTIVES

Significant negative correlation between alactic anaerobic relative peak power output and race time ($p < 0.05$) proves that alactic anaerobic power output is crucial for amateur mountain bikers because of the quick starting phase and steep climbs during race time.

Significant negative correlation between lactate concentration after a progressive incremental cycling test to exhaustion and race time ($p < 0.05$) suggests that glycolysis plays a very important role in off-road cycling performance, which requires high anaerobic power and capacity of amateur mountain bikers.

This group of amateur mountain bikers should be characterized by heterogeneous performance level.

REFERENCES

Baron, R. (2001). Aerobic and anaerobic power characteristics of off-road cyclists. *Medicine and Science in Sports and Exercise*, 33, 1387–1393.

Bassett, D., Howley, E. (2000). Limiting factors for maximum oxygen uptake and determinants of endurance performance. *Medicine and Science in Sports and Exercise*, 32, 70–84.

Boobis, L. H., Williams, C., Wooton, S. A. (1982). Human muscle metabolism during brief maximal exercise. *Journal of Physiology,* 338, 21–22.

Costa, V. P., Carminatti, L. J., Nakamura, F. Y., De-Oliveira, F. R. (2008). Morpho-physiological similarities between road cyclists and mountain bikers. *Italian Journal of Sport Sciences*, 1, 1–11.

Costa, V. P., De-Oliveira, F. R. (2008). Physiological variables to predict performance in cross-country mountain bike races. *Journal of Exercise Physiology Online*, 11, 14–24.

Costa, V. P., Pertence, L. C., Matos, D. G. et al. (2011). Physiological correlates of 10km up-hill cycling performance in competitive cyclists. *Journal of Exercise Physiology Online*, 14, 26–33.

Cramp, T., Broad, E., Martin, D., Meyer, B. J. (2004). Effects of pre-exercise carbohydrate ingestion on mountain bike performance. *Medicine and Science in Sports and Exercise*, 36, 1602–1609.

Gaitanos, G., Williams, C., Boobis, L., Brooks, S. (1993). Human muscle metabolism during intermittent maximal exercise. *Journal of Applied Physiology*, 75, 712–719.

Impellizzeri, F. M., Marcora, S. M., Rampinini, E. et al. (2005 a). Correlations between physiological variables and performance in high-performance cross-country off-road cyclists. *British Journal of Sports Medicine,* 39, 747–751.

Impellizzeri, F. M., Marcora, S. M. (2007). The physiology of mountain biking. *Sports Medicine*, 37, 59–71.

Impellizzeri, F. M., Rampinini, E., Sassi, A. et al. (2005 b). Physiological correlations to off-road cycling performance. *Journal of Sports Sciences,* 23, 41–47.

Impellizzeri, F. M., Sassi, A., Rodriguez-Alonso, M. et al. (2002). Exercise intensity during off-road cycling competitions. *Medicine and Science in Sports and Exercise*, 34, 1808–1813.

Lee, H., Martin, D. T., Anson, J. M. et al. (2002). Physiological characteristics of successful mountain bikers and professional road cyclists. *Journal of Sports Science*, 20, 1001–1008.

Stapelfeldt, B., Schwirtz, A., Schumacher, Y., Hillebrecht, M. (2004). Workload demands in mountain bike racing. *International Journal of Sports Medicine*, 25, 294–300.

Union Cycliste Internationale (UCI) [2012 01 12]. Internet link: < http://www.uci.ch>

Vaitkevičiūtė, D., Milašius, K. (2011). Lietuvos kalnų ir plento dviratininkų fizinių ir funkcinių galių charakteristika. *Sporto mokslas*, 66 (4), 26–31.

Wang, E. L., Hull, M. L. (1997). A dynamic system model of an off-road cyclist. *Journal of Biomechanical Engineering*, 119, 248–253.

MĖGĖJŲ KALNŲ DVIRATININKŲ FIZIOLOGINIŲ RODIKLIŲ IR VARŽYBŲ REZULTATO KORELIACINIAI RYŠIAI

Donvina Vaitkevičiūtė, Kazys Milašius
Lietuvos edukologijos universitetas, Vilnius, Lietuva

SANTRAUKA

Tyrimo pagrindimas ir hipotezė. Didelio meistriškumo kalnų dviratininkų aerobinė ištvermė varžybų rezultatą lemia tik 40%. Tai rodo, kad tokie veiksniai kaip anaerobinis pajėgumas ir ištvermė, techniniai gebėjimai turi būti vertinami atliekant šių sportininkų fiziologinius tyrimus (Impellizzeri et al., 2005 a). Nors Lietuvos plento ir treko dviratininkų klausimais mokslinių publikacijų yra paskelbta nemažai, Lietuvos kalnų dviratininkų fiziologinių rodiklių ryšių su varžybų rezultatu mokslinių tyrimų duomenų literatūros šaltiniuose neaptikome.

Tikslas – ištirti mėgėjų kalnų dviratininkų fiziologinių rodiklių ryšius su varžybų rezultatu.

Metodai. Tirta 15 Lietuvos kalnų dviratininkų. Specialiajam anaerobiniam alaktatiniam pajėgmui nustatyti buvo taikomas 10 s trukmės didžiausių pastangų testas, o mišriam anaerobiniam alaktatiniam-glikolitiniam pajėgumui – Vingeito 30 s trukmės didžiausių pastangų testas. Aerobinis pajėgumas nustatytas atliekant nuosekliai didinamo krūvio testą veloergometru.

Rezultatai. Nustatyti statistiškai patikimi atvirkštiniai koreliaciniai ryšiai tarp varžybų rezultato ir santykinio didžiausiojo anaerobinio alaktatinio pajėgumo ($r = –0,534$; $p < 0,05$) bei laktato koncentracijos po nuosekliai didinamo krūvio testo ($r = –0,625$; $p < 0,05$). Visgi neaptikome statistiškai patikimo ryšio tarp varžybų rezultato ir VO_2max ($r = –0,210$; $p > 0,05$) bei mišraus anaerobinio alaktatinio-glikolitinio pajėgumo ($r = –0,269$; $p > 0,05$).

Aptarimas ir išvados. Tyrimo duomenys leidžia teigti, kad santykinis anaerobinis alaktatinis pajėgumas ir aktyvi glikolizė yra būtini kalnų dviračių sporte, kuriam būdinga greito starto fazė ir stačios įkalnės varžybų metu.

Raktažodžiai: kalnų dviračių sportas, varžybų rezultatas, pajėgumas, didžiausiasis deguonies suvartojimas.

Gauta 2012 m. gegužės 8 d.
Received on May 8, 2012

Priimta 2012 m. birželio 8 d.
Accepted on June 8, 2012

Corresponding author **Donvina Vaitkevičiūtė**
Lithuanian University of Educational Sciences
Studentų str. 39, LT – 08106 Vilnius
Lithuania
Tel +370 5 273 4858
E-mail v.donvina@gmail.com