Comparison of the results of aerobic loading diagnostic while kayaking in counter-current pool and while arm crank ergometry

JAN BUSTA, MILAN BÍLÝ
Faculty of physical education and sport, Charles University in Prague, Czech Republic

Abstract
The aim of this study was to realize an aerobic loading test while kayaking in the counter-current pool and detect the cardiorespiratory endurance level of Czech elite slalom racers. The research group consisted of 8 professional kayakers. The results detected while paddling on kayak [VO2max (ml.kg-1): 38.49 (7.82); HR (min-1): 181.88 (4.99), RR (min-1) 36.63 (6.56); O2 pulse/kg (ml): 0.21 (0.04), VMAX (l.min-1): 103.03 (10.14)] were compared to the results detected while arm crank ergometry [VO2max (ml.kg-1): 66.27 (3.16); HR (min-1): 183.0 (6.02), RR (min-1) 65.38 (4.27); O2pulse/kg (ml): 0.36 (0.02), Vmax (l.min-1): 142.14 (13.50)]. Paddling kayakers reached on average about 31.13% (16.35) lower values than while arm crank ergometry although in 4 of total 5 resulting values of chosen functional indicators were made out medium to high measure of interdependence (r=0.623-0.777) between mentioned tests. Assumption of significant similarity rate of measured functional values was established merely at HR (min-1). With regard to probands feed-back, the differences between tests are primarily explained by the need for use plastic kayak and braking device due to inadequate speed and proportional parameters of the pool. These arrangements might have changed the experimental conditions so much that they led to the local exhaustion of upper limbs whilst cardiorespiratory potential of competitors did not reach its maximum. .

Key words:
aerobic loading testing, slalom, counter-current pool, arm crank ergometry, kayak

Souhrn
Cílem práce bylo zrealizovat aerobní zátěžovou diagnostiku při jízdě na kajaku v bazénu s protiproudem a zjistit úroveň kardiorespirační zdatnosti elitních českých vodních slalomářů při specifické činnosti pádlování. Výzkumný soubor tvořilo 8 kajakářů špičkové výkonnostní úrovně. Výsledky získané při pádlování na kajaku [VO2max (ml.kg-1): 38,49 (7,82); SF (min-1): 181,88 (4,99), DF (min-1) 36,63 (6,56); O2tep/kg (ml): 0,21 (0,04), Vmax (l.min-1): 103,03 (10,14)] jsme porovnávali s výsledky naměřenými při klikové ergometrii horních končetin [VO2max (ml.kg-1): 66,27 (3,16); SF (min-1): 183,0 (6,02), DF (min-1) 65,38 (4,27); O2tep/kg (ml): 0,36 (0,02), VMAX (l.min-1): 142,14 (13,50)]. Přestože u 4 z 5 výsledných hodnot vybraných funkčních ukazatelů byla mezi oběma testy prokázána střední až vysoká míra závislosti (r = 0,623 – 0,777), kajakáři dosáhli při pádlování v průměru o 31,13% (16,35) nižších výsledných hodnot než při klikové ergometrii horních končetin. Předpoklad o významné míře podobnosti naměřených funkčních hodnot fyziologických ukazatelů byl prokázán pouze u SF (min-1). S ohledem na zpětnou vazbu probandů si rozdíly mezi testy vysvětlujeme především nutností použití plastového kajaku a brzdného zařízení kvůli nedostatečným rychlostním a rozměrovým parametrům bazénu. Toto opatření ovšem pravděpodobně změnilo silové nároky jízdy natolik, že docházelo dříve k lokálnímu vyčerpání horních končetin, zatímco kardiorespirační potenciál závodníka nedosáhl svých limitů.

Klíčová slova:
aerobní zátěžová diagnostika, vodní slalom, bazén s protiproudem, kliková ergometrie horních končetin, kajak

Introduction

Whitewater slalom racing is discipline of canoeing that was included in the Olympic program in 1972. It can be characterized as discipline which is conducted on whitewater. It takes place in environment that is changing not only as an external framework of a motoric activity but primarily with regard to conditions which decide on the selection of adequate motoric responses (Kratochvíl & Bílý, 1997). It is gradually shifting from the natural water flow to artificial waterway. It brings change of general conditions for the slalom race concept. Stricter demands are put on the competitors and the race technique is changing (Bílý, 2012). They must be great at speed, strength and endurance. Elite competitors can be defined by excellent development of the cardiorespiratory system and by strong capability to transfer and utilize the oxygen as well as the creation of power sources via anaerobic metabolism (Gonzáles de Suso, D´Angelo and Prono, 1999). Currently is the whitewater slalom considered as an anaerobic discipline (Endicott, 1980). The race is energetically covered by 52% anaerobically and 48% aerobically (Heller, Pultera, Bílý, Sadilová, 1995). It can be assumed that anaerobic capacity is in dominant position (Bílý, Suss, Jančar, 2010; Bílý, Suss, Heller, Vodička, 2006) which is necessary nevertheless it is not sufficient condition for whitewater slalom performance (Bílý, 2012). The investigation taken by coach Bílý (2012) pointed out that the complex structure of a sport performance is from 14% covered by endurance ability.

Diagnostic is an essential prerequisite for effective practice. It is instrumental in detecting of actual state of sportsman readiness as well as systematic control and effect recognition of chosen practice (Dovalil, 2012). Locomotion in whitewater slalom is realized by means of upper limbs and trunk whilst lower limbs are fixed in the kayak/canoe and help to direct and lean the ship (Bílý, 2012). Therefore athletes and coaches indicate the arm crank ergometry as the most reliable diagnostic while testing the spiroergometry in spite of the fact that motoric structure differs from kayaking. Possibility of specific laboratory diagnostic was missing so far. Therefore in conjunction with researchers from department of swimming sports and biomedical laboratory of FTVS UK we realized graduating test "vita maxima" in the counter-current pool. We wondered what values of functional indicators can be measured while paddling on kayak.

The aim of the study was to compare the results of newly realized method of aerobic loading diagnostic (kayaking in counter-current pool) with the results of standardized test based on arm crank ergometry and thus answer the following question: whether it is meaningful to test slalom racer while specific paddling instead of testing them while doing less specific or non-specific activities and then use the obtained results for practice controlling (to analyze the initial fitness state and to keep the practice efficiency).

Methods

At first the research group (8 elite Czech kayakers) went in for an initial check-up. It contains height measuring, weighting and pulmonary function test. The loading tests were conducted by the researches from biomedical laboratory FTVS UK. First of total two loading diagnostics was realized on the crank ergometer (KEF-12 II, company Medicor) which is calibrated on a regular basis via special device. Respiratory parameters were measured by analyzer Ergo-oxyscreen, company Jaeger. Paramagnetic measuring allows us to detect % of inspired and expired oxygen (O2) and due to infrared device it is possible to detect % of expired carbon dioxide (CO2). The device can discover the total ventilation via the distinction analysis of air pressure behind and in front of a heat-insulated sieve. The participants testing came after proper individual warmup according to precisely given and standardized order:

- Crank ergometer preparation (crank length, its height, saddle setting), probands attaching to the analyzing devices.
- One minute of rest.
- Four minutes earmarked for breaking in divided in two load periods (2 minutes 80W, afterwards 2 minutes 120W)
- One minute of rest.
- Graduating test "vita maxima"
- Initial resistance is 160W after each following minute it rises by 20W and the kayaker must keep the rotational speed at given interval.
- After reaching the "vita maxima" followed by end of the test, the proband is undressed.

Picture 1: proband while taking the "vita maxima" test on the arm crank ergometer

The second loading test was taken while paddling on the kayak in the counter-current pool (research laboratory, swimming sports department of FTVS UK). While testing in the kayak we kept the same analyzing technologies as during the crank ergometry. The order, we tried to simulate the standardized test as much as possible:

- Kayaker is sitting in the kayak after individual warmup and he is being acquainted with the test process and further he is attached to analyzing devices. The analyzing devices with the hose were mounted on the proband's helmet with regard to its weight which could cause overloading of cervical spine followed by disability to paddle (picture 2).

Picture 2: helmet with the mounted respiratory analyzer

- Four minutes of breaking in. 2 minutes during counter-current speed level 10 and next 2 minutes during counter-current speed level 12 which means speed 1.61 and 1.83 m.s-1 (Balvín and Motl, 2010). Kayaker must stay in a specific area so as he could not use wave that would allow him to rest (by "surfing"). This area is denoted by small swimming kickboard.

Picture 3: 4 minutes of locomotive preparation. The top of the kayak must be kept at the level of the kickboard

-

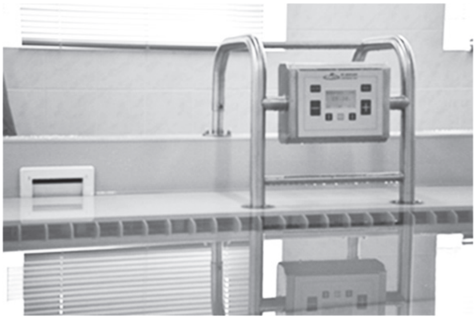
- One minute of rest.

Picture 4: one minute of rest

- Graduating test "vita maxima" with the initial speed of 1.83m-1 (speed level 12). Every minute the speed grows by 1 speed level whereas the last 16th speed level corresponds to the current speed of 2.12 m.s-1 (Balvín and Motl, 2010). Kayaker who reached the last 16th level tries to paddle against the current as long as possible.

Picture 5: maximum; the test is going to be over any moment

- After reaching "vita maxima" the test is over and the kayaker is released from devices. The blood sample is taken after three minutes and the lactate level is measured.
  Velocity stages of the counter-current were changed via control panel that is placed in front of the pool (picture 6). The test was realized on a plastic kayak whose bottom was burdened by brake. It was necessary to increase the ship resistance because the current speed was low even on the max speed level. Plastic kayak Prijon (approximately 17kilos) had a slide fixed by slight strap at the bottom (picture 4). The cuboid shape slide was made of light and stiff expanded plastic (width 30cm, length 35cm and height 9cm).



Picture 6: the control panel with velocity stages

It was difficult to place all analyzing devices so that none of them was in danger of being splashed. Simultaneously, we did not want to expose our probands to any obstructions while giving their best. We carried this out after several experimental testing due to extension of cableway and due to using of a mobile device placed upon the pool (picture 5). On the mobile device you can see respiratory analyzer and stuffs. Researcher of biomedical laboratory of FTVS UK operated the machine and conducted the whole diagnostic. The biomedical laboratory researchers made protocols about every single measurement containing all gained data. The data were analyzed by means of descriptive (average, standard deviation, percentage) and exploring statistics (Pearson correlation coefficient).

Results and discussion

In table 1 you can see data obtained from the entrance examination that give the basic characterization of the research group. Average height of the group was 180.09 (4.04) and weight 73.3 (5.24).

Basic data, measuring results- weighting- spirometry									
Person	1	2	3	4	5	6	7	8	
Basic data	Age (year)	20.70	26.40	22.8	20	24.10	22.60	25.10	23.10
	Weight (kg)	67.7	67.3	83.6	70.6	75.5	69.8	74.0	77.9
	Height (cm)	177.9	179.7	186.2	172.2	181.5	177.3	182.9	183.0
Spirometry	FVC (I)	4.66	3.93	4.84	4.45	4.81	5.13	5.18	4.72

Table 1: Basic data about tested persons. The data from entrance examination.

Test results of the arm crank ergometry are shown in the table 2.

Results of the loading test- arm crank ergometry										
Person	1	2	3	4	5	6	7	8	average (SD)	
Basic data	Age (year)	20.7	26.4	22.8	20	24.1	22.6	25.1	23.1	23.1 (1.99)
	Weight (kg)	67.7	67.3	83.6	70.6	75.5	69.8	74.0	77.9	73.3 (5.24)
	Height (cm)	177.9	179.7	186.2	172.2	181.5	177.3	182.9	183.0	180.09 (4.04)

Results of the loading test- arm crank ergometry										
Maximal loading test - crank ergometry	VO_2 (l.min^{-1})	4.62	4.69	5.66	4.64	4.60	4.63	4.57	5.45	4.86 (0.41)
	VO_2/kg (ml.kg^{-1})	68.19	69.62	67.76	65.71	60.98	66.37	61.72	69.97	66.29 (3.16)
	VMAX (l.min^{-1})	140.5	121.9	165.9	133.7	138.5	160.7	134.8	141.2	142.14 (13.50)
	RR (min^{-1})	67	73	66	64	59	65	60	69	65.38 (4.27)
	HR (min $^{-1}$)	190	179	186	174	174	186	189	186	183.0 (6.02)
	O_2 pulse (ml)	24.30	26.17	30.46	26.66	26.46	24.90	24.17	29.30	26.55 (2.13)
	O_2 / pulse/kg (ml)	0.36	0.39	0.36	0.38	0.35	0.36	0.33	0.38	0.36 (0.02)
	R	1.11	1.08	1.12	1.13	1.15	1.13	1.11	1.11	1.12 (0.02)
	Treshold VO_2 (l.min^{-1})	2.88	3.37	2.79	3.31	3.14	2.76	2.75	4.00	3.13 (0.40)
	Treshold HR (min^{-1})	159	168	165	153	156	158	160	169	161 (5.38)
	HR aerobic (min^{-1})	135	142	140	130	133	134	136	144	137 (4.57)
	HR anaerobic (min^{-1})	168	178	174	162	166	167	169	179	170 (5.70)
	LA (mmol/l^{-1})	14.70	8.70	11.10	10.50	11.30	11.40	10.90	12.10	11.34 (1.57)

Table 3: The results obtained from kayaking in the counter-current pool.

We compared average measured results and consequently we reckoned the difference between measured values in particular units and percents (table 4).

Average measured results obtained while crank ergometry and while paddling in the counter-current pool		
Basic data	Age (year)	23.10 (1.99)
	Height (cm)	180.09 (4.04)
	Weight (kg)	73.3 (5.24)
Spirometry	FVC (l)	4.72 (0.39)

Average measured results obtained while crank ergometry and while paddling in the counter-current pool				
		Crank ergometry- average values (SD)	Paddling in the counter-current pool- average values (SD)	The difference in particular units and percents (%)
Maximal graduating loading test	VO_2 ($l.min^{-1}$)	4.86 (0.41)	2.80 (0.48)	2.06 (42.38 %)
	VO_2/kg ($ml.kg^{-1}$)	66.29 (3.16)	38.49 (7.92)	27.8 (41.93 %)
	VMAX ($l.min^{-1}$)	142.14 (13.50)	103.03 (10.14)	39.11 (27.51 %)
	RR (min^{-1})	65.38 (4.27)	36.63 (6.56)	28.75 (43.97 %)
	HR (min^{-1})	183.0 (6.02)	181.88 (4.99)	1.12 (0.61 %)
	O_2 pulse (ml)	26.55 (2.13)	15.36 (2.54)	11.19 (42.14 %)
	O_2 /pulse/kg (ml)	0.36 (0.02)	0.21 (0.04)	0.15 (41.66 %)
	R	1.12 (0.02)	1.08 (0.04)	0.04 (3.57 %)
	Threshold VO2 ($l.min^{-1}$)	3.13 (0.40)	1.88 (0.40)	1.25 (39.93 %)
	Threshold HR (min^{-1})	161 (5.38)	161 (5.35)	0 (0 %)
	HR aerobic (min^{-1})	137 (4.57)	136 (4.55)	1 (0.72 %)
	HR anaerobic (min^{-1})	170 (5.70)	170 (5.67)	0 (0 %)
	LA ($mmol/l^{-1}$)	11.34 (1.57)	7.09 (0.78)	4.25 (37.47 %)

Table 4: comparison of both test (average values)

We stated total percentage distinction in connection with chosen functional values (table 5)

Total distinction among chosen values of functional indicators of two loading tests				
	Crank ergometry- average (SD)	Kayaking in the counter-current pool- average (SD)	Distinction (%)	Total distinction %
VO_2max ($ml.kg^{-1}$)	66.27 (3.16)	38.49 (7.82)	41.93 %	31,13%
HR (min^{-1})	183.0 (6.02)	181.88 (4.99)	0.61 %	
RR (min^{-1})	65.38 (4.27)	36.63 (6.56)	43.97 %	
O_2/pulse/kg (ml)	0.36 (0.02)	0.21 (0.04)	41.66 %	
V_{MAX} ($l.min^{-1}$)	142.14 (13.50)	103.03 (10.14)	27.51 %	

Table 5: Percentage distinction of both tests.

We mention the comparison of same chosen functional values by means of correlation analysis (table 6).

Statistic comparison of resulting functional values of the crank ergometry with the kayaking in the counter-current pool- Pearson correlation coefficient									
Proband	1	2	3	4	5	6	7	8	Pearson correlation coefficient
VO_{2max} crank	68.19	69.62	67.76	65.71	60.98	66.37	61.72	69.97	0.628
VO_{2max} kayak	43.35	50.61	27.29	32.47	31.96	44.89	32.13	45.24	
HR crank	190	179	186	174	174	186	189	186	0.777
HR kayak	180	182	185	172	177	186	188	185	
RR crank	67	73	66	64	59	65	60	69	0.625
RR kayak	42	42	27	32	31	44	31	44	
V_{MAX} crank	140.5	121.9	165.9	133.7	138.5	160.7	134.8	141.2	-0.229
V_{MAX} kayak	88.8	104.7	88.7	97.3	105.2	112.8	119.0	107.8	
O_2pulse/kg crank	0.36	0.39	0.36	0.38	0.35	0.36	0.33	0.38	0.623
O_2pulse/kg kayak	0.24	0.28	0.15	0.19	0.18	0.24	0.17	0.24	

Table 6: Correlation analysis of chosen values of functional indicators.

If compared the crank ergometry to the kayaking, all participants reached significantly lower values of all indicators in the mentioned kayaking (table 4). For instance average value of maximal oxygen demand (VO_{2max}) while kayaking was merely 38.49 (7.92) ml.kg^{-1} whilst crank ergometry was 66.9 ml.kg^{-1}. Only heart rate (HR) indicated values that differ by 0.61%. 4 of total 5 physiological indicators showed medium to high correlational rate (VO_{2max}: r = 0.628, HR = 0.777, RR: 0.625, 02pulse/kg: 0.623) of both loading tests (table 6). It is necessary to remind that regarding mere amount of probands the correlational results are very informative.

Average difference of measured values of chosen indicators is 31.12% (table 5). This is a significant difference and with regard to the probands feed-back, we assume that the results distinctiveness was caused by usage of relatively heavy plastic kayak (9 kilos heavier than kayak slalom) and big braking surface which brought a big change of power demand on stroke. Nevertheless the usage of the plastic kayak with the brake was absolutely essential regarding inadequate proportional and speed parameters of the pool. According Bílý (2008), his study concerned with locomotive speed of elite kayakers on flatwater states that they are able to reach speed of 4.14 m.s-1 but the maximal counter-current speed was merely 2.12 m.s^{-1}. This means that the counter-current speed would be boldly higher to take the diagnostic on kayak slalom without the brake. Further, it would also be proper to have a bigger pool (not only 5 meters) because the kayak slalom is at least 350 cm long. Nevertheless there are not any devices of such speed and proportional parameters in the area of the Czech Republic. Even the German company LD Pool (producer of the used pool) cannot fill our demand.

Melin and Ecleche (1982) recorded heart rate 171-182 bpm during a slalom racing. In the laboratory conditions while riding the bicycle ergometer, they found direct dependence between oxygen demand (VO_2) and heart rate. They used this dependence VO_2/HR to determine energy output while slalom racing and they discovered that it quadrates with 90% VO_{2max} of competitors. Carré and col. (1994) measured nearly the same values of VO_{2max} in graduating loading test while kayaking on flat- water [3.87 (0.73)] as in arm crank ergometry [3.78 (0.71)]. Nevertheless our research emphasizes that there does not have to be linear relation between heart rate (HR) and oxygen demand (VO_2) while paddling in the laboratory conditions. While kayaking, we measured practically same HR as in arm crank ergometry although measured values of VO_{2max} were significantly lower in all cases (table 4). Because the diagnostic taken in the counter-current pool differs from the whitewater slalom racing we cannot draw clear conclusions from our results and thus further diagnostics are recommended.

It worth noticing that the research group (elite kayakers) reached very good results while arm crank ergometry (table 2). The kayakers achieved average value 66.9 (3.16) ml.kg-1 of maximal oxygen demand (VO_{2max}) which shows high level of endurance ability (Dovalil, 2012). It is boldly higher value than Heller (2004) published. 14 elite slalom racers reached average value of VO_{2max} 47.1 (3.4) ml.kg-1 within his research. Also Carré and col. (1994) tested group consisting of 15 slalom racers (average weight 66.7kg) via the arm crank ergometry. He detected average Vmax 3.78 (0.71) $l.min^{-1}$ which resembles our findings. Partially it could be explained by high quality of the research group that was solely composed of representational slalom racers.

Conclusion

Testing of actual fitness state is one of the key principles and conditions leading to effective practice in which we want to observe the relation between physical load (stimulant) and body adaption and by virtue of this relation modify the practice properly (Dovalil, 2012).

The idea of aerobic loading diagnostic while kayaking in the counter-current pool comes from demand for exact, adequate and especially specific method of finding essential functional indicators of racers fitness. Even though the diagnostic realization is possible we would have to provide our kayakers with better and more technological devices (more efficient and proportional pool) to prove the results reliability.

We found that observed kayakers, while paddling in pool, reached in chosen functional physiological indicators on average 31.13% lower values than during the arm crank ergometry. Whilst the distinctions regarding heart rate (HR) were minimal between both loading tests, the maximal oxygen demand reached while kayaking was nearly 42% lower than during the arm crank ergometry. The distinctions are explained by faster accession of the local exhaustion caused by using the brake and technological demandingness of paddling which does not allow such a big effort investment like arm crank ergometry.

It is necessary to investigate further specific methods which would be usable in practice and especially in either of seasons. Aerobic loading diagnostic while kayaking in the counter-current pool is not very useful in practice. We believe though that in case of appropriate counter-current speed or during the test on flat-water with mobile and waterproof devices these results might provide us with a very useful information for practices of slalom racers.

References

1. Balvín, P. & Motl, O. (2010). *Vyhodnocení rychlostí proudění v bazénu s protiproudem*. Výzkumný ústav vodohospodářský.
2. Bílý, M. (2002). *Komplexní analýza techniky pádlování a jízdy na divoké vodě*. Rigorózní práce. Praha: UK FTVS.
3. Bílý, M. et al. (2008). Evaluation of specific speed and endurance preconditions of white – water canoeists. *Internation Journal of Fitness*. Vol. 4, no.1, pp. 15 – 25.
4. Bílý, M. (2012). *Výkonové aspekty ve vodním slalomu*. Dizertační práce. Praha: UK FTVS.
5. Bílý, M., Süss, V., Jančar, D. (2010). Influence of selected fitness and mental factors on the sport performance of a competitor in white water slalom. *Acta Universitatis Carolinae Kinanthropologica.* Vol. 46, no. 1, pp. 123-132.
6. Carre, F., Dassonville, J., Beillot, J., Prigent, J. & Rochcongar, P. (1994). Use of oxygen uptake recovery curve to predict peak oxygen uptake in upper body exercise. *European Journal of Applied Physiology.* Vol. 69, Issue 3, pp. 258-261.
7. Dovalil, J. et al. (2012). *Výkon a trénink ve sportu.* Praha: Olympia.
8. Ensicott, W. (1980). *To Win The World.* Baltimore: Mariland.
9. Gonzáles-de-Suso, JM., D´Angelo, R. & Prono, JM. (1999). Physiology of slalom training In *Internati-*

onal coaching konference, Sydney.
10. Heller, J., Bílý, M., Pultera J. & Sadilová, M. (1995). Funktional and energy demands of elite female kayak slalom: a comparison of training and competition performances. *Acta Universitatis Carolinae*. Vol. 30, Issue 1, pp. 59 - 74.
11. Kratochvíl, J. & Bílý, M. (1997). Analýza sportovního výkonu ve vodním slalomu a sjezdu na divoké vodě se zaměřením na některé fyziologické charakteristiky s přihlédnutím k věkovým zvláštnostem sportovců. In. *Kinantropologie 97*: Nové tváře – nové pohledy: sborník referátů z mezinárodní vědecké konference. Praha: FTVS UK, pp. 173 - 177.
12. Melin, B. & Eclache, J.P. (1993). Etude de la contrainte énergétique du slalom en canoe -kayak. *In. Bulletin E.I.S."Les Journées Médico – Sportives á lˇE.I.S. Fontainbleau. E.I.S*

Author:
Bc. Jan Busta
e-mail: buster@centrum.cz