THE DIFFERENCES BETWEEN CONSTANT HEART RATE - AND VELOCITY - CONTROLLED ENDURANCE TRAINING INTENSITY OF WILD WATER KAYAKERS

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Abstract:

The aim of the study was to ascertain lactate concentration ([LA]) and heart rate (HR) kinetics during standardized interval endurance training on the flat water on the intensity corresponding to the onset of blood lactate accumulation criterion (OBLA). Eight members of the national slalom wild-water kayak team performed two experiments. The first experiment consisted of paddling 8x500 m on flat water through all the gates with the intensity that corresponded to the heart rate determined by OBLA (HR_{OBLA}). The second experiment consisted of paddling 8x500m on flat water with the intensity corresponding to the paddling velocity determined by OBLA (v_{OBLA}). The results showed that HR_{OBLA} intensity influenced the increase of lactate concentration ([LA]) to 4.4 ± 1.1 mmol/l after the first repetition, however, with a continuous decrease to 3 ± 1.1 mmol/l ($P<0.01$) after the eighth repetition. When v_{OBLA} was applied, then HR exceeded HR_{OBLA} after the second repetition by 8 ± 6 b/min ($P<0.05$) and further increased until the end. The [LA] reached steady individual values but at very different individual levels which in most subjects exceeded the level of 4 mmol/l (4.8 ± 1.6 mmol/l). In spite of the same phenomena (OBLA), the HR_{OBLA}-based endurance training on flat water represents a less intense, and v_{OBLA}-based training a more intense training response.

Key words: *wild-water kayak, endurance training, lactate, heart rate*

UNTERSCHIEDE ZWISCHEN KONTINUIERLICHER HERZFREQUENZ UND GESCHWINDIGKEITSKONTROLLIERTER AUSDAUERTRAININGSINTENSITÄT BEI WILDWASSERRENNEN - - KAJAKFAHRERN

Zusammenfassung:

Das Ziel dieser Studie war, sowohl die Laktatkonzentration ([LA]) und die Herzfrequenzkinetik während des standardisierten Ausdauertrainings beim Paddeln auf stillen Gewässern als auch ihren Einfluss auf die Intensität laut dem Blutlaktatakkumulationsbeginnkriterium *[Onset of Blood Lactate Accumulation Criterion (OBLA)]* zu determinieren. Acht Mitglieder der Nationalmannschaft im Wildwasserkajakslalom führten zwei Experimente durch. Das erste Experiment bestand aus dem 8x500-Meter-Paddeln durch die Tore auf stillen Gewässern mit der Intensität, die der laut dem Blutlaktatakkumulationsbeginnkriterium determinierten Herzfrequenz (HR_{OBLA}) entsprach. Das zweite Experiment bestand aus dem 8x500-Meter-Paddeln auf stillen Gewässern mit der Intensität, die der laut dem Blutlaktatakkumulationsbeginnkriterium determinierten Paddelngeschwindigkeit (v_{OBLA}) entsprach. Die Resultate zeigten, dass HR_{OBLA}-Intensität die Steigerung von Laktatkonzentration ([LA]) bis zum 4,4 ± 1,1 mmol/L nach der ersten Wiederholung beeinflusste, jedoch mit der kontinuierlichen Verringerung bis zum 3 ± 1,1 mmol/L ($P<0,01$) nach dem achten Wiederholung. Wenn v_{OBLA} verwendet wurde, überstieg die Herzfrequenz die HR_{OBLA} nach der zweiten Wiederholung um 8 ± 6 Schläge pro Minute ($P<0,05$) und stieg weiter bis zum Ende. [LA] erreichte konstante individuelle Werte aber auf sehr unterschiedlichen individuellen Niveaus, die bei meisten Sportlern das Niveau vom 4 mmol/L (4,8 ±1,6 mmol/L) überstiegen. Trotz derselben Phänomene (OBLA) das auf der HR_{OBLA}-basierte Ausdauertraining auf stillen Gewässern stellt einen weinger intensiven und das v_{OBLA}-basierte Training einen mehr intensiven Trainingstyp dar.

Schlüsselwörter: *Wildwasserkajakrennen, Ausdauertraining, Laktat, Herzfrequenz*

Introduction

The criteria which are used most frequently for the prescription of endurance training intensity are based on a fixed blood lactate concentration ([LA]) of 4 mmol/l, usually named Onset of Blood Lactate Accumulation (OBLA) (Karlsson & Jacobs, 1982), aerobic-anaerobic transition (A-AnT) (Kindermann, Simon & Keul, 1985), and/or Anaerobic Threshold (AT) (Janssen, 1987; Stegeman & Kindermann, 1982). Additionally, there is also the Individual Anaerobic Threshold (IAT) (Schnabel et al., 1982; Urhausen et al., 1993), which uses a different principle. It was reported that the OBLA and AT criteria frequently determined the maximal level of [LA] steady state (maxLAss), when such a principle was applied in a continuous endurance exercise on the treadmill and cycle-ergometer (Coen et al., 1991; Jannsen, 1987; Kindermann, Simon & Keul, 1985; Schnabel et al., 1982; Stegeman & Kindermann, 1982; Urhausen et al., 1993). Some authors did not support such a conclusion, because the maxLAss was not reached if exercise intensity determined by OBLA, IAT or AT, was repeated during a prolonged continuous exercise (Mognoni et al., 1990; Orok et al., 1989; Oyono-Enguelle et al., 1990).

The interval method was mainly applied at endurance training in the wild-water kayak slalom discipline. The above mentioned also basically holds when a continuous method is applied during the paddling through all the gates, because there are different turns of the boat which means changes of its velocity during paddling on flat water, and especially when the paddling direction changes in adverse direction of the water flow on flowing and/or wild water. The training intensity control should be different in any of the two conditions: the constant HR and/or paddling velocity can be used on flat water (time intervals on selected distances), while on flowing water only the constant HR is possible during paddling. The question is whether HR_{OBLA} or v_{OBLA} training intensity produce a similar response of the organism, and therefore present a similar training stimulus. The HR usually increases during continuous, constant intensity (velocity, power) exercise (Astrand & Rodahl, 1986). Therefore it may be assumed that HR_{OBLA} training intensity has a different influence on [LA] kinetics than the v_{OBLA}-based training. This hypothesis was verified during standardized interval endurance training on flat water.

Material and methods

The subjects (N= 8, age = 21 ± 3 years, height 173 ± 7cm, weight 63 ± 8 kg) were members of the national wild-water kayak slalom team; they were also highly ranked at an international level. They participated voluntarily in two experiments after they had given a written consent approved by the National Ethic Committee.

All the subjects first participated in the standardized incremental test on flat water. The test consisted of five repetitions of 600 m distances with velocities regulated and controlled so as to reach the constant HR of 110, 130, 150, 165 and the maximal possible heart rate. HR was monitored by using PE3000 Sport Tester (Polar Electro, Finland). The velocity and HR corresponded to OBLA were calculated (Karlsson & Jacobs, 1982, Ušaj & Starc, 1996).

The HR_{OBLA} was then used as a training intensity criterion in a 8x 500 m interval session, separated by 1 min breaks, on flat water in the first experiment. The course was repeated twice to complete each 500-m distance. After the 2^{nd}, 4^{th}, 6^{th}, 7^{th} and 8^{th} repetition, a sample of about 20-40 ml of capillary blood was taken from a hyperemied ear-lobe and used to determine the blood lactate concentration ([LA]) by using the Mini 8 (Lange, Germany) instrument.

The second experiment consisted of 8 x 500 m interval training with 1 min breaks on flat water through all the standardized gates position. This time, the training intensity was controlled by intermediate time intervals which had to be reached at a particular gate, and the whole distance with a velocity corresponding to v_{OBLA}. The HR was continuously measured by using the PE3000 Sport Tester (Polar Electro, Finland). Blood samples for the [LA] determination were taken after the 2^{nd}, 4^{th}, 6^{th}, 7^{th} and 8^{th} repetition in the same manner as during the first experiment.

The ΔHR was calculated as the difference between the heart rate determined by OBLA, and values reached at each repetition during the training session. The ΔTime was calculated as the difference between time intervals corresponding to v_{OBLA} and the times actually reached for each repetition during the training session, for each subject.

These data were represented as mean ± standard deviations (SD). The paired *t*–test was used to compare the HR and [LA] data between different repetitions throughout the training session in both experiments. A *t*–test was also used to compare HR and [LA] data between both experiments. A significant level of 0.05 was

selected. All statistical parameters were calculated using the graphical statistical packages Sigma Plot and Sigma Stat (Jandel, Germany).

Results

In the 1st experiment, HR_{OBLA} was the target training intensity during the 8x 500 m paddling. The relative average values of the group obtained as the difference between HR_{OBLA} and the measured values during training (ΔHR) (Table 1, Fig. 1A) showed that the paddlers achieved a relatively accurate target HR_{OBLA}. In spite of mean blood [LA] (4.4 ± 1.1mmol/l) which was different to the reference 4 mmol/l, there were two other characteristics which showed that the [LA] response was different from the expectations (Table 1, Fig. 1B). The first was a great standard deviation of [LA] (± 1.1 mmol/l) which resulted from the large differences in individual values. The second showed a continuous [LA] decrease throughout the training session (Table 1, Fig. 1B). [LA] decreased from 4.3 ± 1.2 mmol/l during the second repetition to a 3.4 ± 1.4 mmol/l ($P<0.01$) and continuously decreased to a value of 3 ± 1.1 mmol/l after the final 500 m. Therefore, the maximal level of intensity where [LA] reached constant values was not even reached.

Table 1. Absolute and relative values of lactate concentration and heart rate during OBLA-determined constant velocity or constant heart rate

		REPETITIONS				
TRAINING REGIME		2.	4.	6.	7.	8.
V_{OBLA} = const	LA (mmol/l)	4.8 ± 1.6	5.2 ± 2.1	5.2 ± 1.5	4.9 ± 1.5	4.9 ± 2.1
	ΔHR (b/min)	1.7 ± 4.8	8.1 ± 6.4	7.6 ± 5.9	10.1 ± 9.3	14.7 ± 9.5
HR_{OBLA} = const	LA (mmol/l)	4.4 ± 1.1	4.3 ± 1.4	3.4 ± 0.8	3.1 ± 1.0	3.0 ± 1.1
	ΔHR (b/min)	1.2 ± 3.1	0.2 ± 4.3	-0.9 ± 3.7	-0.2 ± 3.0	0.1 ± 3.4

LEGEND: values are means ± SD
For other abbreviations see METHODS

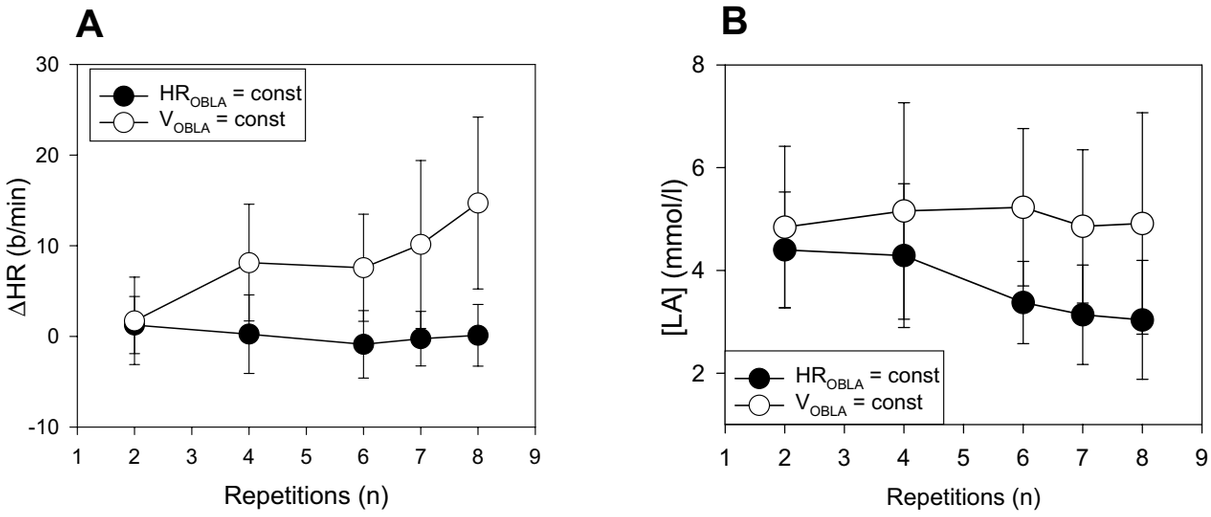

Figure 1. A constant HR_{OBLA} training intensity (A – filled circles) influenced the significant ($P<=.01$) reduction of [LA] during the 6th, 7th and 8th repetition (B – filled circles). Differently, a constant v_{OBLA} influenced Δ HR to increase from an HR_{OBLA} level to significantly higher values ($P<0.05$) during the 4th, 6th, 7th and 8th repetition (A – open circles), however at constant but elevated [LA] (B – open circles).

During the second experiment, the target training intensity was v_{OBLA}. It was re-calculated to time intervals necessary to reach the gates throughout the course with a target velocity. The subjects reached the individual target times in ± 5 sec. A relative HR was obtained as a difference between the HR_{OBLA} and the one reached during each repetition (ΔHR). It showed values similar to HR_{OBLA} (2 ± 5 b/min) at the first repetition (Fig. 1A). The HR increased continuously thereafter. The ΔHR reached significantly ($P< 0.05$) higher values at the fourth repetition (8 ± 6 b/min) which further increased to 15 ± 9 b/min. The average values of blood [LA] showed constant values. However, the values exceeded the 4 mmol/l (Table 1, Fig. 1B). Therefore, the v_{OBLA} or equivalent time intervals did not reflect the [LA] response in an expected manner (4 mmol/l). It may be concluded that v_{OBLA} training intensity influenced the [LA] increase followed by steady fluctuations in contrast to HR which was continuously increasing.

The following hypothesis of this study was adopted: the HR_{OBLA} training intensity influenced the [LA] kinetics differently than the v_{OBLA} intensity, when interval training on 500 m distances with 1 min breaks is applied during paddling both on flat and flowing water.

Discussion

The OBLA criterion and other criteria obtained from lactate curves are frequently used for the prescription of endurance training intensity at different endurance sports events (Farrel et al., 1979; Karlsson & Jacobs, 1982; Olbrecht et al., 1985; Weltman, 1995; Yoshida et al., 1982). The criterion OBLA determines the intensity usually similar to the maximal [LA] steady state, which permits adequate duration of the exercise, therefore a good background for increasing endurance (Fahrenbach et al., 1987). However, the duration of exercise intervals during an incremental test should be carefully selected (Ušaj & Starc, 1993). We have not found any published data where endurance training intensity of wild-water slalom paddlers would be investigated by using the OBLA criterion in spite of our belief that it is usually applied in training practice. Nevertheless, we assumed that there are two possible ways of keeping the training intensity on flat and flowing water during paddling at a selected level: by controlling the exercise velocity and/or by applying HR (Gilman & Wells, 1993; Jannsen, 1987; Katch et al., 1979). In contrast, to achieve and control the training intensity during wild-water paddling is very difficult or even impossible, depending on the "wildness" of the water and the degree of the technically complicated and difficult paddling course. Therefore, the maximal possible intensity is usually applied during such training sessions for simulating the competition-specific endurance.

Our results show that [LA] initially increases to a certain level and later decreases slowly throughout the training session to lower values practically with all subjects, although HR fluctuated at a steady level if HR_{OBLA} was used. Therefore, the HR_{OBLA} may represent the paddling intensity, which was lower than the one when [LA] fluctuated at the similar values between repetitions.

When the paddling velocity v_{OBLA} was used as a target training intensity during interval endurance training, most subjects showed steady [LA] fluctuations between the repetitions in spite of their higher values (>4 mmol/l). Therefore, such specific [LA] steady values were reached although it is not possible to confirm that this was a maximal intensity where [LA] did not increase throughout the repetitions.

It may be concluded that HR_{OBLA} intensity corresponded to lower and v_{OBLA} to higher training stimulus if [LA] kinetics has been taken as a reference. The possible reason is a continuous increase of HR during the training due to the decrease of stroke volume (Astrand & Rodahl, 1986). This phenomenon did not occur during HR_{OBLA} intensity in our experiment, because the paddling velocity probably continuously decreased to achieve the HR constant. On the other hand, a constant velocity (v_{OBLA}) training influenced the [LA] so as to reach its steady state. This phenomenon was accompanied by a constant HR increase. It may be assumed that the intensity may be near the maximal [LA] values which did not increase throughout the 8 x 500 m interval training. Such results may be unexpected because OBLA criterion is frequently selected for the prescribed training intensity corresponding to maxLAss during a continuous, not interval exercise. Possibly, similar testing and training characteristics - 5 x 600 m paddling with an incremental velocity and 1 min breaks, and 5 x 500 m with a constant velocity v_{OBLA} and 1 min breaks - influenced the [LA] to reach a constant [LA] level, which is probably a specific phenomenon in the applied testing and training.

The presented differences support rather the v_{OBLA} principle for the application in the endurance training of wild-water slalom paddlers, because it

represents a more intense training stimulus. Since v_{OBLA}-determined intensity may be applied only in flatwater training, the HR_{OBLA}-based training may also be used in training on flowing water. However, a caution that the training stimulus could be lower is necessary. Our results showed that HR kinetics is not concomitant with [LA] kinetics. Although HR_{OBLA} training represents a similar training stimulus as the v_{OBLA} intensity, an appropriate training principle based on HR_{OBLA} should be developed in the future because this is the only adequate way to control target exercise intensity on flowing water.

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RAZLIKE U INTENZITETIMA TRENINGA IZDRŽLJIVOSTI KAJAKAŠA NA DIVLJIM VODAMA KONTROLIRANIMA KONSTANTNOM FREKVENCIJOM SRCA I BRZINOM VESLANJA

Sažetak

Uvod

U treningu izdržljivosti za disciplinu slaloma u kajaku na divljim vodama uglavnom se koristi metoda intervalnog treninga. Priroda intervalnog treninga, međutim, javlja se i u kontinuiranoj metodi veslanja kroz vrata tijekom koje kajakaš mora neprestano izvoditi zavoje u raznim smjerovima pa to zahtijeva stalne promjene brzine veslanja, čak i na mirnim vodama (stajaćicama), a osobito onda kada je smjer veslanja suprotan vodenoj struji tekućice i/ili brzaca. Intenzitet treninga morao bi se za svaku metodu i uvjete rada kontrolirati na različite načine: za veslanje na stajaćici (mirnoj vodi) mogu se koristiti konstantna frekvencija srca (FS) i/ili brzina veslanja (v), tj. zadani vremenski intervali za određene dionice, dok se za kontrolu intenziteta veslanja na tekućicama (i brzacima) može koristiti samo pokazatelj frekvencije srca. Postavlja se, međutim, pitanje izazivaju li trenažni intenziteti kontrolirani pokazateljima FS_{OBLA} ili v_{OBLA} (brzina) istu reakciju organizma te može li ih se smatrati podjednakim trenažnim podražajima (stimulus). Frekvencija se srca obično povećava tijekom kontinuiranoga vježbanja konstantnim intenzitetom (brzinom, snagom). Stoga bi se moglo pretpostaviti da intenzitet treninga kontroliran frekvencijom srca (FS_{OBLA}) utječe drugačije na brzinu stvaranja mliječne kiseline ([LA] *kinetics*) od treninga nadziranoga brzinom rada (v_{OBLA}). Ta hipoteza provjerena je u ovom istraživanju tijekom standardiziranoga intervalnog treninga izdržljivosti na vodi stajaćici.

Materijal i metode

Uzorak ispitanikai (N = 8; dob = 21 ± 3 godine; visina 173 ± 7 cm; tjelesna težina = 63 ± 8 kg) činili su kajakaši - slalomaši na divljim vodama zavidne međunarodne kvalitete, članovi nacionalne slovenske vrste. Svi ispitanici prvo su sudjelovali u standardiziranom progresivnom testu na vodi stajaćici. Test se sastojao od veslanja na pet dionica od 600 m. Svako ponavljanje veslalo se kontroliranom brzinom koja je omogućavala održavanje konstantne FS na 110, 130, 150 i 165 otkucaja u minuti te na razini maksimalne FS. Izračunate su brzine i FS koje su odgovarale razini OBLA. Vrijednosti FS_{OBLA} nakon toga su u prvom eksperimentu korištene kao kriterij za određivanje intenziteta rada u intervalnom treningu koji se sastojao od veslanja 8 x 500m na vodi stajaćici, sa stankom od jedne minute između ponavljanja. Uzorci kapilarne krvi za određenje koncentracije mliječne kiseline u krvi [LA] uzeti su iz ušne resice ispitanika nakon 2., 4., 6., 7. i 8. ponavljanja.

Drugi eksperiment sastojao se od 8 x 500 m intervalnog veslanja na stajaćici (stanka od 1 min između ponavljanja) kroz standardizirano postavljena vrata za slalom. Trenažni intenzitet kontroliran je u tom eksperimentu prolaznim vremenima koja je ispitanik morao postići pri određenim vratima, kao i brzinom za ukupnu dionicu koja je odgovarala v_{OBLA}. Uzorci krvi za određivanje koncentracije mliječne kiseline u krvi uzeti su kao i u prvom eksperimentu (nakon 2., 4., 6., 7. i 8. ponavljanja). Potom je izračunata ΔFS kao razlika između FS određene pomoću razine OBLA i stvarnih vrijednosti FS dostignutih u svakom ponavljanju tijekom treninga. Za svakog ispitanika izračunata je Δt (Δ vrijeme) kao razlika između vremenskih intervala koji odgovaraju za v_{OBLA} i stvarno postignutih vremena u svakom ponavljanju tijekom treninga. Za usporedbu podataka o FS i [LA] dobivenih u raznim ponavljanjima tijekom jednog i drugog eksperimenta korišten je *t*-test za parove. Razlike među vrijednostima FS i [LA] prikupljenima u dva eksperimenta međusobno su uspoređene *t*-testom.

Rezultati

U prvom eksperimentu FS_{OBLA} bio je ciljani pokazatelj intenziteta intervalnoga treninga (veslanje 8 x 500m). Relativne prosječne vrijednosti grupe, dobivene iz razlike između FS_{OBLA} i vrijednosti izmjerenih tijekom treninga (ΔFS), pokazale su da su veslači relativno točno postizali ciljanu FS_{OBLA}. Usprkos tome što je prosječna vrijednost koncentracije mliječne kiseline u krvi [LA] (4.4 ± 1.1mmol/l) bila različita od referentnih 4.0 mmol/l, pojavile su se druge dvije karakteristike koje su upućivale na to da je [LA] odgovor bio drugačiji od očekivanoga. Prvo obilježje bila je velika standardna devijacija (± 1.1mmol/l), a druga je pokazivala neprekidno smanjivanje koncentracije [LA] tijekom treninga – od 4.3 ± 1.2mmol/l, zabilježene tijekom drugog ponavljanja, preko 3.4 ± 1.4mmol/l ($p<0.01$) do vrijednosti od 3 ± 1.1mmol/l, zabilježene u

mjerenju nakon posljednjeg veslanja dionice od 500m. Dakle, maksimalna razina trenažnog intenziteta, gdje je vrijednost koncentracije laktata [LA] trebala biti konstantna, uopće nije dosegnuta.

U drugom eksperimentu v_{OBLA} je bio ciljani pokazatelj intenziteta intervalnoga treninga (veslanje 8 x 500m). Ispitanici su postizali ciljano individualno vrijeme točnošću od ± 5 s. Relativna FS dobivena je kao razlika između i vrijednosti zabilježenih tijekom svakog ponavljanja (Δ FS). U prvom veslanju dionice od 500m zabilježene su vrijednosti slične vrijednostima FS_{OBLA} (2 ± 5 otk./min), ali je nakon toga FS kontinuirano rasla. Vrijednosti Δ FS dosegnule su statistički značajno ($p<0.05$) više vrijednosti u četvrtom ponavljanju (8 ± 6 otk./min) i nastavile su rasti sve do 15 ± 9 otk./min. Prosječne vrijednosti koncentracije mliječne kiseline u krvi [LA] bile su konstantne, ali su bile više od 4.4 mmol/l. Dakle, v_{OBLA} ili ekvivalentni vremenski interval nisu odrazile laktatni odgovor organizma na očekivani način (4.4 mmol/l).

Zaključci

U literaturi nisu nađeni podaci o tome da bi se intenzitet treninga izdržljivosti za kajakaše - slalomaše na divljim vodama istraživao kriterijem OBLA, usprkos uvjerenju autora da se taj kriterij uobičajeno rabi u sportskoj praksi. Naši rezultati, u eksperimentu u kojemu je FS_{OBLA} bio kriterij za određenje intenziteta treninga, pokazuju da vrijednosti [LA] inicijalno rastu do određene razine, a onda u gotovo svih ispitanika počinju polagano opadati tijekom treninga, premda su vrijednosti FS čitavo vrijeme prilično stabilne. Dakle, FS_{OBLA} može predstavljati niži intenzitet veslanja od onoga u kojemu je koncentracija laktata fluktuirala oko sličnih vrijednosti između ponavljanja. Kada se brzina veslanja v_{OBLA} koristila kao kriterij za određenje intenziteta intervalnog treninga izdržljivosti, u većine ispitanika zabilježena je stabilna fluktuacija [LA] između ponavljanja, usprkos povišenim vrijednostima (>4.4 mmol/l). Dakle, postignute su takve specifične stabilne vrijednosti [LA] usprkos tomu što nije moguće potvrditi da su to bili i maksimalni intenziteti, tijekom kojih se inače koncentracija [LA] ne povećava. Može se zaključiti da su vrijednosti FS_{OBLA} odgovarale nižem, a vrijednosti v_{OBLA} višem trenažnom podražaju kada se kao referentna mjera uzela u obzir kinetika [LA]. Rezultati govore u prilog kontrolnog principa v_{OBLA} koji bi bilo preporučljivo koristiti u treningu izdržljivosti za kajakaše na divljim vodama, disciplina slalom, zato što on osigurava puno intenzivniji trenažni podražaj. Budući da se određivanje intenziteta treninga pomoću v_{OBLA} može koristiti samo za trening na stajaćim vodama, za određivanje intenziteta treninga na tekućim i divljim vodama morat će se koristiti kriterij FS_{OBLA}, ali pri tome je potreban oprez, zato što tako određen trenažni podražaj (stimulus) može biti niži od potrebnoga. Naši rezultati pokazuju da FS nije sukladna s kinetikom koncentracije mliječne kiseline u krvi.