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THE INFLUENCE OF TRAINING WITH REDUCED BREATHING FREQUENCY IN FRONT CRAWL SWIMMING DURING A MAXIMAL 200 METRES FRONT CRAWL PERFORMANCE

VPLIV VADBE Z ZMANJŠANIM ŠTEVILOM VDIHOV MED PLAVANJEM NA SPOSOBNOST PREMAGOVANJA MAKSIMALNIH NAPOROV PRI 200 METROV KRAVL

Abstract

The aim of the study was to ascertain how four weeks of training with reduced breathing frequency during front crawl swimming would influence a maximal 200 metres front crawl performance. Two matched groups of five recreational-level swimmers trained five times per week. During each swimming session breathing frequency was distinguished between the control (the B2 group was taking a breath every second stroke cycle) and an experimental group (the B4 group was taking a breath every fourth stroke cycle). The swimmers performed a maximal 200 metres front crawl swim with an optional breathing pattern before and after the training. Both groups swam the maximal 200 metres front crawl after the training significantly faster than before the training. The improvement was significantly greater in the B4 group than in the B2 group. Group B4 swam a maximal 200 metres front crawl after the training with fewer breaths than before the training. The breathing pattern in the B2 group was unchanged by the training. According to its lower breathing frequency, the B4 group had a significantly higher Pco_2 after the training in comparison with the Pco_2 before the training. Group B4 also had a higher lactate concentration, Pco_2 and a lower pH than the B2 group after the training. It may be concluded that swimmers adapted to swimming with fewer breaths due to training with reduced breathing frequency (taking a breath every fourth stroke cycle) during front crawl swimming.

Key words: swimming, training, reduced breathing frequency, blood acid base status, blood lactate

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Izvleček

Namen raziskave je bil ugotoviti, kakšni so učinki štiri tedenske vadbe z manjšim številom vdihov med plavanjem na plavalčevo sposobnost premagovanja maksimalnih naporov pri 200 metrov kravl. Deset rekreativnih plavalcev je bilo razdeljenih v dve skupini. Plavalci kontrolne skupine (B2) so vadbene intervalne serije kravl plavali z običajnim vdihom ob vsakem drugem zaveslaju, plavalci eksperimentalne skupine (B4) so iste serije plavali z vdihi ob vsakem četrtem zaveslaju. Pred vadbo in po njej so plavalci odplavali 200 metrov kravl maksimalno s poljubnim načinom dihanja. V skladu s pričakovanji sta obe vadbi vplivali na povečanje maksimalne hitrosti plavanja 200 metrov kravl. Večji napredek je dosegla skupina, ki je vadila z manjšim številom vdihov med plavanjem. Skupina B4 je z vadbo zmanjšala število vdihov med 200 metrov kravl, medtem ko je le-to pri skupini B2 z vadbo ostalo nespremenjeno. Skladno z manjšo frekvenco vdihov je imela skupina B4 po vadbi višji Pco_2 kot pred vadbo. Skupina B4 je imela po vadbi višjo koncentracijo laktatov, višji Pco_2 in nižji pH od skupine B2. Večja hitrost ob zmanjšanju števila vdihov med 200 metrov kravl maksimalno skupine B4 po vadbi je bila verjetno posledica prilagoditve na drugačno hidrodinamiko plavanja, ki ima boljše značilnosti.

Ključne besede: plavanje, vadba, manjše število vdihov, acido bazni status krvi, krvni laktat

INTRODUCTION

The swimming specificity, in relation to dry land activities, is strictly technique-dependent breathing (Holmer, Stein, Saltin, Ekblom, & Astrand, 1974). Respiration in swimming is synchronised with swimming strokes. In all swimming techniques except in backstroke, expiration takes place under water and, accordingly, against greater resistance than in air. Furthermore, breathing frequency has to be in accordance with the stroke rate. During breaststroke swimming swimmers should take a breath once during each stroke cycle. Therefore they could only regulate the stroke rate to ensure maintaining needs of increased pulmonary ventilation. In regard to this demand swimmers could also manipulate with different breathing patterns during butterfly and front crawl swimming.

Swimmers can reduce their breathing frequency during front crawl swimming from the usual taking of a breath on every second stroke cycle to taking a breath every fourth, fifth, sixth or eighth stroke cycles. Swimming training with reduced breathing frequency is often referred to as 'hypoxic training' (Maglischo, 2003). It was thought that, by limiting inspired air, the reduction of the oxygen available for muscular work would result and therefore cause muscle hypoxia similar to that experienced at altitude (Kedrowski, 1979).

In some previous studies swimmers reduced their breathing frequency during tethered flume front crawl swimming (Dicker, Lofthus, Thornton, & Brooks, 1980; Peyrebrune, Robinson, Lakomy, & Nevill, 2002; Town & Vanness, 1990), during front crawl interval sets (Holmer & Gullstrand, 1980), during front crawl swimming at OBLA velocity (Kapus, Ušaj, Kapus, & Štrumbelj, 2002) and during maximal front crawl swimming (Kapus, Ušaj, Kapus, & Štrumbelj, 2003). These studies were unable to demonstrate reduced arterial oxygen saturation, but they did show hypercapnia. However, all of the reported studies investigated the acute effects of reduced breathing frequency during front crawl swimming. Therefore, the purpose of the present study was to ascertain how four weeks of training with reduced breathing frequency during front crawl swimming would influence a maximal 200 metres front crawl performance.

METHOD

Participants

Ten healthy males (age: M = 16.6 yrs, SD = 1.8 yrs; height: M = 180 cm, SD = 7 cm; weight: 70 kg, SD = 7 kg) participated in the study after being informed of the associated risks and giving their written informed consent. The subjects were recreational-level swimmers. They had been training for at least five years. They had never had more than three training sessions per week. Therefore, they were well-skilled swimmers. Their average time of a maximal 200 metres front crawl swim was 157.9 seconds, measured in a pre-training swimming test. They were divided into two groups: control (B2 group) and experimental (B4 group).

Instruments

Measures included lactate concentration ($[LA^-]$) and the parameters of blood acid-base status (Pco_2, Po_2, pH and $[HCO_3^-]$) before and during the first minute after the swimming test. Capillary blood samples were taken via a micro puncture from a hyperemied earlobe. Blood samples (10 μl) for measuring [LA^-] were diluted in a haemolising solution and analysed using the MINI8 (LANGE, Germany) photometer. Blood samples (60 – 80 μl) for measuring Pco_2, Po_2 and pH were collected in heparinised glass capillaries (Radiometer Copenhagen, Denmark) and introduced to a blood-gas analyser (ABL5, Radiometer Copenhagen, Denmark). The blood-gas analyser also automatically calculated [HCO_3^-].

The breathing frequency (Bf) was calculated by dividing the number of breaths by the time, which were both measured during the swimming test.

Procedure

Training

Both groups were given four weeks swimming training five times per week. Nineteen training sessions were undertaken. Each training session consisted of 600 metres of warming up, followed by an interval front crawl set (7 × 100 metres with 3 minutes of recovery or 7 × 125 metres with 3 minutes and 30 seconds of recovery or 5 × 150 metres with 4 minutes of recovery or 4 × 175 metres with 4 minutes and 30 seconds of recovery). The intensity was determined by using the maximal velocity of a 200 metres front crawl swim. During each swim the breathing pattern differed between the B2 group and the B4 group. The B2 group was taking a breath every second stroke cycle, while the B4 group was taking a breath every fourth stroke cycle.

Testing protocol

Swimmers performed a maximal 200 metres front crawl swim with an optional breathing pattern (swimmers chose their own breathing frequencies) before the training (200maxPRE). The breathing pattern during this swimming test was not defined since it is known that swimmers can randomly alternate two or more breathing patterns during competition races.

After the training, swimmers performed a maximal 200 metres front crawl swim again with an optional breathing pattern (200maxPOSTob). Swimmers who changed their optional breathing pattern during this swimming test according to the training characteristics additionally performed a maximal 200 metres front crawl swim with the same breathing pattern they had chosen at 200maxPRE (200maxPOSTeb). 200maxPOSTeb was conducted because changes in breathing frequency during swimming induce changes in blood acid-base parameters (Kapus et al., 2002, 2003) and, therefore, these parameters should only be compared in conditions of similar breathing. Swimmers who had to perform both swimming tests after the training – 200maxPOSTob and 200maxPOSTeb – performed each test on different days.

The results are presented as means and standard deviations (M, SD). The paired T test was used to compare the pre- and post-training data. The training effects of different breathing patterns during front crawl swimming during a maximal 200 metres front crawl swim performance were analysed using ANCOVA.

RESULTS

Despite optional breathing during a maximal 200 metres front crawl in measurements of pre- and post-training conditions swimmers mainly swam the whole distance without changing their breathing patterns. The breathing patterns during a maximal 200 metres front crawl with an optional breathing pattern obtained from individual swimmers before and after the training are shown in Table 1.

Table 1: Breathing patterns during a maximal 200 metres front crawl with an optional breathing pattern obtained from individual swimmers before and after the training

Swimmers		Before the training	After the training
Group B2	1	second	second
	2	second	second
	3	second	second
	4	second	second
	5	second	second
Group B4	6	second and fourth	second and fourth
	7	second	fourth
	8	second	fourth
	9	second	fourth
	10	second	fourth

Legend:
second – swimming by taking a breath every second stroke cycle;
fourth – swimming by taking a breath every fourth stroke cycle.

Most swimmers swam a maximal 200 metres front crawl with an optional breathing pattern by taking a breath every second stroke cycle before the training. Swimmers swam after the training with a similar breathing pattern as they had swum with during the training. The breathing pattern during swimming in the B2 group was unchanged by the training. On the

Table 2: Data on breathing frequency (min^{-1}) during a maximal 200 metres front crawl obtained from individual swimmers before (200maxPRE) and after (200maxPOSTob) the training

Swimmers	*200maxPRE*	*200maxPOSTob*	*200maxPOSTeb*
Group B2			
1	34	34	/
2	29	34	/
3	31	29	/
4	38	36	/
5	42	45	/
M (SD)	35 (5)	36 (6)	/
Group B4			
6	28	31	/
7	40	33	37
8	32	22	33
9	28	20	32
10	32	17	33
M (SD)	32 (5)	25 (7)	34 (2)

contrary, four swimmers in the B4 group changed their breathing pattern with the training. The only exception was swimmer 6. Data on the breathing frequency during a maximal 200 metres front crawl obtained from individual swimmers before and after the training are presented in Table 2.

Four swimmers in the B4 group changed their breathing pattern with the training. They also performed a maximal 200 metres front crawl swim after the training with the same breathing pattern they had chosen at 200maxPRE (200maxPOSTeb).

The breathing frequency during swimming in the B4 group decreased from 32 (SD = 5) to 25 (SD = 7 min^{-1}). Due to the unchanged breathing pattern during swimming in the B2 group (see Table 1) their breathing frequencies were similar in both pre- and post-training conditions.

As shown in Tables 1 and 2 four swimmers in the B4 group performed a maximal 200 metres front crawl swim after the training twice: with a new optional breathing pattern (which was training-specific) and with the same breathing pattern they had chosen as an optional breathing pattern for this swimming test before the training. Therefore, in the following tables the results of measuring data for the B4 group after the training will be presented in the conditions of the optional breathing pattern (200maxPOSTob) and in the conditions of the same breathing pattern they had chosen at 200maxPRE (200maxPOSTeb). Due to the breathing pattern being unchanged by the training, all swimmers in the B2 group and one swimmer in the B4 group performed a maximal 200 metres front crawl swim after the training only once.

Table 3: *Time of a maximal 200 metres front crawl before and after the training in the B2 group (200maxPRE and 200maxPOSTob) and in the B4 group (200maxPRE, 200maxPOSTob and 200maxPOSTeb)*

Parameter	Group	PRE training	POST training	
		200maxPRE M (SD)	200maxPOSTob M (SD)	200maxPOSTeb M (SD)
Time (s)	B2	161.1 (8.2)	157.1 (8.1)** †	
	B4	154.7 (14.6)	148.5 (10.9)*	152.2 (13.4)

Legend:
significant training effect (paired T test): * p < 0.05; ** p < 0.01
significant differences between groups after the training (ANCOVA): † p < 0.05

Both groups swam a maximal 200 metres front crawl with an optional breathing pattern after the training significantly faster than before the training (the B4 group from 154.69 ± 14.63 s to 148.48 ± 10.89 s; the B2 group from 161.12 ± 8.25 s to 157.11 ± 8.13 s) (p<0.05). However, there was no significant difference in time between 200maxPRE and 200maxPOSTeb in the B4 group. The improvement in the time for a maximal 200 metres front crawl was significantly greater in the B4 group than in the B2 group (p<0.05) as regards optional breathing patterns. There were no significant differences in training effects on swimming times between groups concerning the same breathing pattern during a maximal 200 metres front crawl before and after the training.

Table 4: Comparisons of pH, $[LA^-]$, $[HCO_3^-]$, Pco_2 and Po_2 values before (rest) and after a (test) maximal 200 metres front crawl between before and after the training in the B2 group (200maxPRE and 200maxPOSTob) and in the B4 group (200maxPRE, 200maxPOSTob and 200maxPOSTeb)

Parameter		Group	PRE training	POST training	
			200maxPRE	*200maxPOSTob*	*200maxPOSTeb*
pH	rest	B2	7.42 (0.03)	7.42 (0.03)	
		B4	7.41 (0.03)	7.43 (0.01)	7.40 (0.04)
	test	B2	7.23 (0.03)	7.24 (0.03) †	
		B4	7.16 (0.07)	7.14 (0.04)	7.17 (0.03)
$[LA^-]$ (mmol/l)	rest	B2	2.8 (0.7)	2.7 (1.8)	
		B4	2.8 (0.9)	2.4 (1.4)	2.4 (1.2)
	test	B2	12.1 (1.2)	10.3 (1.6) †	
		B4	13.9 (1.7)	13.9 (1.1)	13.5 (1.9)
$[HCO_3^-]$ (mmol/l)	rest	B2	23 (0.5)	23 (1.6)	
		B4	22 (2.9)	24 (2.9)	23 (2.5)
	test	B2	15 (1.3)	16 (0.5) ††	
		B4	14 (1.8)	14 (1.6)	14 (0.05)
Pco_2 (kPa)	rest	B2	4.7 (0.3)	4.9 (0.1)	
		B4	4.7 (0.4)	5.0 (0.2)	5.1 (0.2)
	test	B2	5.1 (0.5)	5.0 (0.5)* ††	
		B4	5.3 (0.5)	5.6 (0.5)	5.3 (0.3)
Po_2 (kPa)	rest	B2	10.8 (1.2)	10.9 (1.3)	
		B4	11.2 (1.5)	10.6 (1.3)	10.8 (0.9)
	test	B2	10.8 (0.7)	12.0 (0.9	
		B4	11.4 (1.2)	11.6 (1.0)	11.6 (0.9)

Legend:
significant training effect (paired T test): * $p < 0.05$
significant differences between groups after the training (ANCOVA): † $p < 0.05$, †† $p < 0.01$

According to the lower breathing frequency during 200maxPOSTob the B4 group showed a significantly higher Pco_2 after the training (M = 5.6kPa, SD = 0.5 kPa) in comparison to the Pco_2 before the training (M = 5.3 kPa, SD = 0.5 kPa). There were no significant differences in other measuring data between 200maxPRE and 200maxPOSTob in both groups. Comparing 200maxPRE and 200maxPOSTeb conditions the parameters in blood did not change significantly with the training in the B4 group. As regards 200maxPOSTob conditions, the B4 group had a higher $[LA^-]$ (M = 13.9 mmol/l, SD = 1.1 mmol/l and M = 10.3 mmol/l, SD = 1.6 mmol/l), Pco_2 (M = 5.6 kPa, SD = 0.5 kPa and M = 5.0 kPa, SD = 0.5 kPa) and a lower pH (M = 7.14, SD = 0.04 and M = 7.24, SD = 0.03) than the B2 group. Comparing measuring data concerning the same breathing pattern during a maximal 200 metres front crawl before and after the training there was only one significant difference between the groups. The B4 group had only lower $[HCO_3^-]$ (M = 14 mmol/l, SD = 0.4 mmol/l and M = 16 mmol/l, SD = 0.5 mmol/l) than the B2 group after 200maxPOSTeb.

DISCUSSION

This study is the first to our knowledge that has examined the influence of training with reduced breathing frequency during front crawl swimming on a maximal 200 metres front crawl performance. As expected, training with both breathing patterns (taking a breath every second stroke cycle and taking a breath every fourth stroke cycle) during front crawl swimming brought about an improvement in swimming speed. Both groups of swimmers swam a maximal 200 metres front crawl with an optional breathing pattern after the training significantly faster than before the training. But this improvement was significantly greater in the B4 group than the B2 group (see Table 3). Further, during the swimming test after the training the B4 group changed its optional breathing pattern in comparison to the pre-training choice of breathing pattern.

Four swimmers in the B4 group swam a maximal 200 metres front crawl with an optional breathing pattern (swimmers chose their own breathing frequencies) after the training with fewer breaths than before the training (see Table 2). The breathing pattern during the swimming test in the B2 group was unchanged by the training (see Table 1). Swimmers can generally swim faster when they do not turn their heads to breathe (Maglischo, 2003). Lerda, Cardelli and Chollet (2001) analysed the interactions of breathing and arm actions in the front crawl. They found that breathing while swimming increased the discontinuity in the propulsive action of the arms. This enhanced continuity, in addition to the improved gliding position of the body obtained in a front crawl without breathing, could result in greater swimming efficiency by reducing energy cost (Chatard, Collomb, Maglischo, & Maglischo, 1990) and hydrodynamic resistance (Kolmogorov & Duplisheva, 1992) and by increasing propulsive force (Nelson & Goldfuss, 1971). Considering the insignificant difference in time between 200maxPRE and 200maxPOSTeb in the B4 group it seems that the fewer breaths during the swimming test in the B4 group after the training enabled more mechanically efficient and therefore faster swimming in comparison with the more frequent breaths taken during the swimming test before the training. This could also be the reason for the greater training improvement in times of a maximal 200 metres front crawl in the B4 group than in the B2 group.

Fewer breaths during the swimming test caused a higher Pco_2 in the B4 group after the training comparing to their Pco_2 before training and to the Pco_2 in the B2 group after the training (see Table 4). Group B4 also had a higher $[LA^-]$ and a lower pH than the B2 group in the post-training conditions (see Table 4). These changes were similar to the acute effect on reduced breathing frequency during swimming obtained in previous studies (Dicker et al., 1980; Holmer & Gulstrand, 1980; Kapus et al., 2002, 2003; Town & Vanness, 1990). However, when four swimmers in the B4 group repeated a maximal 200 metres front crawl with the same breathing pattern they had chosen at 200maxPRE, there were no differences between pre- and post-training conditions in the B4 group and between groups in post-training in these blood parameters. According to these results, it could be concluded that training with reduced breathing frequency during front crawl swimming adapted the B4 group to hypercapnia and respiratory acidosis, which produced a strong drive to breathe. Despite the usual discomfort suffered by swimmers in these conditions, the four swimmers in the B4 group who reduced their breathing frequency during the swimming test with the training did not report such feelings after the training. Instead, they felt their breathing during swimming was too frequent when they repeated a maximal 200 metres front crawl with the same breathing pattern they had chosen at 200maxPRE. This is in accordance with a previous study concerning the acute effects of reduced breathing frequency during swimming, which presumed that an improved tolerance to high alveolar CO_2 contents might be a specific physiological adaptation of training with reduced breathing frequency during swimming (Dicker et al., 1980; Peyrebrune et al., 2002). However, the data of Holmer and Gullstrand (1980) suggest that competitive and experienced swimmers also tolerate high alveolar Pco_2 levels with training with usual breathing frequency during swimming. This phenomenon could be the result of generally restricted conditions and the swimmers' tendency to hypoventilate (Holmer & Gullstrand, 1980). Considering that the question arose why the B2 group did not decrease its breathing frequency with the training, it seemed that more complex adaptation (biomechanical, physiological and psychological) could also be the reason for fewer breaths being taken during swimming in the B4 group after the training.

It may be concluded that swimmers adapted to swimming with fewer breaths due to training with reduced breathing frequency (taking a breath every fourth stroke cycle) during front crawl swimming. Adaptation to hypercapnia and respiratory acidosis could also be the result of such training. All of this resulted in a larger decrease of the time for swimming a maximal 200 metres front crawl in comparison with training with the usual breathing frequency (taking a breath every second stroke cycle) during front crawl swimming.

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