BREATHING FREQUENCY PATTERNS DURING SUBMAXIMAL AND MAXIMAL FRONT CRAWL SWIM WITH AND WITHOUT A RESPIRATORY VALVE

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Original scientific paper
UDC 797.212.4:797.22:796.09:612

Abstract:

The purpose of the present study was to ascertain the effect of a respiratory valve (RV) and tubes during three different swimming tests (submaximal and maximal 200m front crawl swim and front crawl swimming to exhaustion) on a breathing frequency, selected biomechanical parameters such as stroke rate and number of breaths, and parameters of blood acid-base status and blood lactate concentration. Twelve former competitive male swimmers performed each swimming test twice: first, with an RV, and second, without an RV. Swimming with an RV induced a slower maximal 200m front crawl swim and shorter front crawl swimming to exhaustion in comparison with swimming without an RV. Furthermore, patterns of the breathing frequency during the submaximal and maximal swimming tests also differed between swimming with an RV and swimming without an RV. Significant differences of [LA^-] after maximal 200m front crawl swimming between swimming with an RV and swimming without an RV ($p \leq 0.05$) were found. Significant differences in [LA^-] and [HCO_3^-] after swimming to exhaustion between swimming with an RV and swimming without an RV ($p \leq 0.01$ and $p \leq 0.05$, respectively) were also found. Therefore, it may be concluded that when an RV is used for measuring respiratory parameters during swimming, a different pattern of breathing (comparing to swimming without an RV) may occur.

Key words: *swimming, breathing, respiratory valve, pH, lactate*

Introduction

Measurements of oxygen uptake and respiratory parameters play an important role in swimming studies. However, the use of measuring equipment (especially a respiratory valve and tubes - RV) may have an effect on the swimming performance and/or physiological response during swimming. To overcome the effects of the assessment procedures on oxygen uptake values, specially designed RV measurements of oxygen uptake and respiratory parameters during swimming were developed (Toussaint et al., 1987).

As compared to swimming without an RV, the respiratory valve developed and tested by Toussaint and associates (1987) was reported to have had no effect on swimming performance and to have had a minimal effect on swimming technique (Kjendlie, Stallman, & Stray-Gundersen, 2003).

An RV modified for breath-by-breath gas analysis via a portable metabolic cart was later tested and validated in laboratory (Keskinen, Rodriguez, & Keskinen, 2003), and swimming pool settings (Rodriguez, Keskinen, & Keskinen, 2001; Rodriguez, Keskinen, Malvela, & Keskinen, 2003).

Respiration during front crawl and other swimming techniques is usually synchronised with the swimming strokes. Compared to swimming without breathing devices, an RV enables breathing frequency (Bf) during swimming, that is, independent of the swimming strokes. It could be questioned whether while swimming with RV swimmers can maintain similar Bf as they have during swimming without an RV due to the increased metabolic demands of maximal swimming.

The purpose of the present study was to test the effect of the use of an RV device during three different swimming tests (submaximal and maximal 200m front crawl swim and front crawl swimming to exhaustion at a fixed, pre-determined velocity) on Bf. A sub-problem was to cross validate previous reports (e.g., Toussaint et al, 1987; Kjendlie et. al., 2003) that swimming with an RV had no effect on swimming performance and a minimal effect on swimming mechanics. In the event that differences between swimming with and without an RV do exist we were also interested to find out the effects of the use of an RV device on selected biomechanical parameters, as well as the parameters of blood acid-base status and blood lactate concentration.

Methods

Subjects

Twelve former competitive male swimmers (age: 24±3 years, height: 181.3±9 cm, weight: 77.4±13 kg) volunteered to participate in this study. On average, the subjects had more than eight years of competitive swimming experience and they had ended their swimming careers at least two years prior to their participation in the present study. The majority of the subjects were former middle-distance specialists (200–400 m) at the national level.

Procedures

Each subject performed one test trial on a given day, in a 25m indoor pool heated at 27 °C. The swimming test was filmed from the longest side of the pool.

First, the swimmers performed a maximal 200m front crawl swim with the use of an RV. On the second day of testing the swimmers performed a submaximal 200m front crawl swim with an RV. The velocities were set at 90% of velocity reached during 200m front crawl. Finally, on the third day the swimmers performed (even paced) front crawl swimming to exhaustion with and without an RV. The swim to exhaustion trial included a fixed, predetermined velocity that represented 110% of the pace used during the 200m front crawl, first with, and next without the use of an RV. The swim to exhaustion was defined as a drop behind two lights of pre-determined velocity.

An underwater light emitting pacemaker was used to assist the swimmers in keeping to an even speed during the swimming to exhaustion phase. The swimmers made the turns with their head out of the water (like butterfly and breaststroke turns) during all the swimming tests. Each swimming test was performed on a different day in a 25m indoor pool with the water temperature set at 27 °C. The swimming test was filmed from the the pool's longest side.

A digital CASIO stopwatch was used for time keeping. Split times for each 25m intervals were also obtained to calculate velocity (v) for each of the pool lengths. During the swimming tests with an RV, Bf was measured breath-by-breath continuously during the swimming tests using a portable gas exchange system (Metamax 2, Cortex, Germany). The swimmers were breathing through an RV (Toussaint, et al., 1987). During the swimming tests without an RV, a count of the number of breaths was established from videotapes. In addition, Bf was calculated by dividing the number of breaths by the swimming test trial's time. The stroke rate (SR) was established via a videotaped recording of each swimming test trial with a stopwatch, which included a frequency meter (base 3). SR was measured for each 25m and was expressed as the number of complete arm cycles per minute. In order to describe the changes in Bf and SR during the swimming test trials, the data of these parameters were fitted by linear function for each subject. Since SR significantly changed after the first 50m during the 200m front crawl event (replicating the results reported by Sidney, Delhaye, Baillon, & Pelayo, 1999), the linear regression model was used without the inclusion of the data measured during the initial 25 meters of the trial. A change (mean±standard deviation) in each parameter per 100m distance was calculated from the slope of the linear regression line for swimming with and without an RV.

Measures of blood values included lactate concentration ([LA^-]) and parameters of acid-base status (Pco_2), blood partial pressure of oxygen (Po_2), pH and bicarbonate ions concentration ([HCO_3^-])) immediately prior to the swimming trials and between 20 to 40 seconds after the swimming tests (depending on the amount of time it took the swimmers to exit from the water). Capillary blood samples (60–80 μl) were taken by micro puncture from the hyperemic earlob. Blood samples for measuring [LA^-] were diluted in a LKM41 lactate solution (LANGE, Germany) and were analysed using the MINI8 (LANGE, Germany) photometer. Blood samples for measuring Pco_2, Po_2, pH and [HCO_3^-] were collected in heparinised glass capillaries and inserted into the blood gas analyser (ABL5, Radiometer, Denmark).

The values are presented as means±standard deviations (SD). A paired t-test was used to compare the data between front crawl swimming with and without the use of an RV. A 95% level of confidence was accepted as significant for all comparisons. All statistical parameters were calculated using SPSS (Version 10.0) and the graphic representation of the data was prepared with the use of the graphical statistics package Sigma Plot (Jandel, Germany).

Results

Compared to the swimming trials with the use of an RV, the swimmers swam significantly faster (maximal 200m front crawl swim) and longer (front crawl swimming to exhaustion) during the non-RV trials (Table 1).

There were no significant differences in the slopes of the linear regression line of the SR during the swimming tests when comparing the swimming trials with an RV to swimming without an RV (Table 2). However, the slopes of the linear regression line of Bf during the swimming tests were different between the swimming trials with and without an RV ($p \leq 0.01$).

Table 1. Comparisons of v at maximal 200-m front crawl swim (MS) and swimming distance at front crawl swimming to exhaustion (SE) between swimming with an RV and swimming without an RV

	with RV	without RV
v at MS (m/s)	1.28 ± 0.1	1.38 ± 0.1 **
Swimming distance at SE (m)	114 ± 17	129 ± 18 *

** - significant difference between swimming with and without an RV ($p \leq 0.01$); * - significant difference between swimming with and without an RV ($p \leq 0.05$).

Table 2. Comparisons of the change of SR per 100m distance during the swimming tests (submaximal 200m front crawl swim – SS, maximal 200m front crawl swim – MS, front crawl swimming to exhaustion - SE) between swimming with RV and swimming without RV

	with RV	without RV
change of SR per 100-m distance (min^{-1}) during SS	1.81 ± 1.44	1.76 ± 1.58
change of SR per 100-m distance (min^{-1}) during MS	0.68 ± 2.96	-0.97 ± 2.99
change of SR per 100-m distance (min^{-1}) during SE	6.85 ± 6.67	4.88 ± 6.37

The results of Bf during the swimming test are presented in Figures 1, 2, and 3. In these figures the solid and dashed lines represent linear regression lines fitting data points after the first 50m for swimming with RV and swimming without RV, respectively.

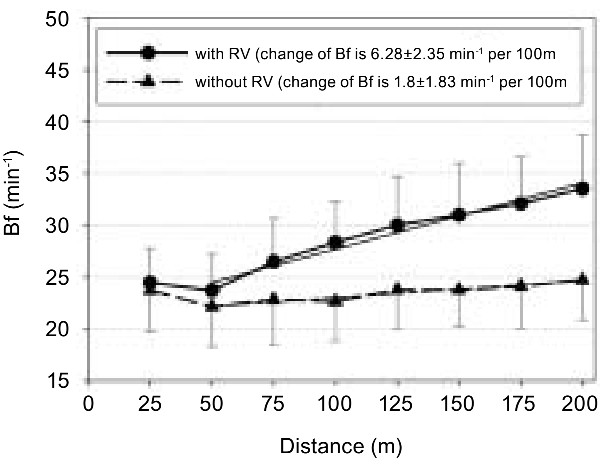

Figure 1. Comparisons of Bf during submaximal 200m front crawl swim between swimming with an RV and swimming without an RV.

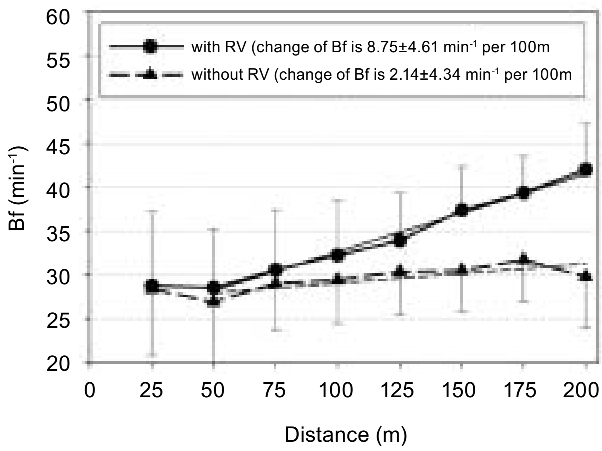

Figure 2. Comparisons of Bf during maximal 200-m front crawl swim between swimming with an RV and swimming without an RV.

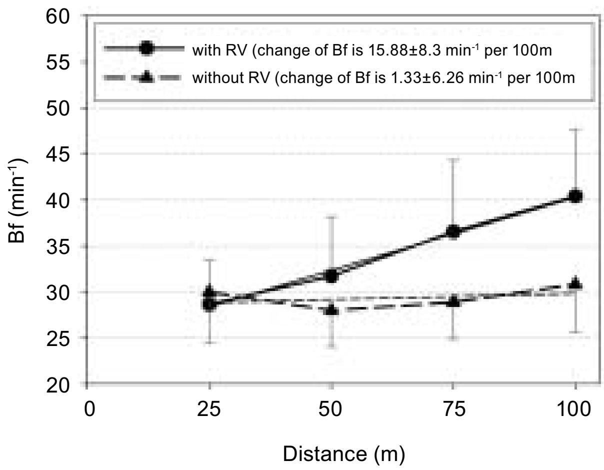

Figure 3. Comparisons of Bf during front crawl swimming to exhaustion between swimming with an RV and swimming without an RV.

During the three non-RV swimming trials, no statistically significant differences were detected between them. While increases of Bf during the swimming tests with an RV were observed, changes in Bf were not statistically significant (changes in Bf were 6.28±2.35 min per 100 m, 8.75±4.61 min per 100 m, and 15.88±8.3 min per 100 m during SS, MS and SE, respectively).

Table 3 shows significant differences in [LA^-] after maximal 200m front crawl swimming between swimming with an RV and swimming without an RV ($p \leq 0.05$). There were also significant differences in [LA^-] and [HCO_3^-] after forced pace swimming to exhaustion between swimming with an RV and swimming without an RV ($p \leq 0.01$ and $p \leq 0.05$, respectively).

Table 3. Comparisons of values of blood parameters measured prior to the initiation and after the completion of the swimming tests (submaximal 200m front crawl swim – SS, maximal 200m front crawl swim – MS, even swimming to exhaustion - SE) between the swimming with an RV and the swimming without an RV

	with an RV		without an RV	
	before	after	Before	After
$[LA^-]$ (mmol/l) at SS	1.8 ± 0.6	7.4 ± 1.1	2.1 ± 1.0	7.4 ± 1.1
$[LA^-]$ (mmol/l) at MS	2.4 ± 0.8	12.7 ± 2.4	2.5 ± 1.0	14.3 ± 2.1 *
$[LA^-]$ (mmol/l) at SE	1.8 ± 0.5	9.9 ± 1.5	2.1 ± 0.6	12.6 ± 2.8 **
pH at SS	7.42 ± 0.02	7.32 ± 0.04	7.40 ± 0.02 *	7.31 ± 0.03
pH at MS	7.41 ± 0.03	7.24 ± 0.06	7.38 ± 0.06	7.20 ± 0.07
pH at SE	7.43 ± 0.02	7.29 ± 0.04	7.41 ± 0.02 **	7.25 ± 0.06
Pco_2 (kPa) at SS	4.9 ± 0.3	5.2 ± 0.5	5.0 ± 0.4 *	5.2 ± 0.6
Pco_2 (kPa) at MS	5.1 ± 0.4	5.0 ± 0.6	5.1 ± 0.3	5.0 ± 0.5
Pco_2 (kPa) at SE	4.8 ± 0.4	5.1 ± 0.5	4.9 ± 0.4	5.0 ± 0.4
Po_2 (kPa) at SS	12.6 ± 2.1	12.2 ± 1.3	13.1 ± 2.5	13.3 ± 2.1
Po_2 (kPa) at MS	11.8 ± 1.2	13.6 ± 2.1	12.0 ± 1.6	12.8 ± 1.2
Po_2 (kPa) at SE	12.8 ± 1.4	13.4 ± 2.5	13.6 ± 3.0	14.2 ± 2.6
$[HCO_3^-]$ (mmol/l) at SS	24 ± 1	20 ± 2	23 ± 2	19 ± 2
$[HCO_3^-]$ (mmol/l) at MS	24 ± 2	15 ± 2	23 ± 3	14 ± 3
$[HCO_3^-]$ (mmol/l) at SE	24 ± 2	18 ± 2	23 ± 2	16 ± 2 *

** - significant difference between swimming with and without an RV ($p \le 0.01$); * - significant difference between swimming with and without an RV ($p \le 0.05$).

Discussion and conclusion

The main finding of the present study was that swimming with an RV resulted in statistically significant slower maximal 200m front crawl swim as well as a shorter front crawl swimming distance to exhaustion as compared with swimming without an RV (Table 1). Furthermore, patterns of Bf during submaximal and maximal swimming tests were also different between swimming with and swimming without an RV (Figure 1, 2 and 3).

Rodriguez et al. (2001) reported that during an incremental test with increasing speed every 50meter, swimming with a respiratory snorkel and valve system did not prevent swimmers from reaching their maximal speed. Similar results were also reported by Kjendlie et al. (2003), who assessed the impact of an RV during interval a front crawl set (6×25meters). The swimming test used in the present study differed from the testing protocol used in the above mentioned studies. Two different varieties of a maximal test were used in the present study: (1) a test which "simulates" a competition-like event and is comprised of a maximal 200m front crawl swim, and (2) an "open-ended" constant load-like test (forced pace) front crawl swimming to exhaustion. Therefore, durations of maximal swimming (200 meters and 114 meters as was the average swimming distance for the front crawl swimming to exhaustion trials with an RV) were longer in the present study in comparison to the previously mentioned studies (it may be assumed that in the Rodriguez et al. (2001) study, swimmers swam only the last 50meters at maximal speed). However, the question why swimmers swam faster and longer without an RV in the present study, still needs to be answered. In previously reported studies, the use of an RV did not increase active drag during swimming (Toussaint et al., 1987). Also, it is possible that the presence of an RV introduces no biomechanical limitations since a swimmer does not need to turn his/her head for inhalation. To not have to turn one's head could result in increased swimming efficiency (Chatard, Collomb, Maglischo, & Maglischo, 1990) and reduced hydrodynamic resistance (Kolmogorov & Duplisheva, 1992). This effect, however, was not observed in the present study. On the contrary, the use of an RV device resulted in a significantly poorer swimming performance.

The values of $[LA^-]$ measured after the maximal 200m front crawl swim and after the front crawl swimming to exhaustion (Table 3), indicate the maximum range of the swimming exercise. These results were compatible with the results reported by Bonifazi and associates (1993) who measured $[LA^-]$ after a competition. However, swimming with an RV induced significantly lower values of $[LA^-]$ after both swimming tests compared to swimming without an RV. It may be presumed that $[LA^-]$ was lower during swimming with an RV because of the slower maximal 200m front crawl swim and shorter front crawl swimming to exhaustion. There were no significant differences in Po_2 and Pco_2 between swimming with an RV and swimming without an RV. When swimming with an RV, swimmers increased their Bf according to their increased metabolic demands for more frequent breaths imposed by the high intensity (maximal or near maximal) swimming, however, increased Bf did not result in increased CO_2 elimination (no significant differences were found in Pco_2 after swimming with and without an RV).

The pulmonary ventilation during front crawl swimming is synchronised with the strokes. Therefore, the breathing phases (exhalation, inhalation, apnea associated with Bf) should be in accordance with the stroke parameters (stroke rate and stroke length). In the present study there were no significant differences in the stroke rate during the swimming tests between swimming with an RV and swimming without an RV (Table 2). However, significant differences in patterns of Bf between swimming with an RV and swimming without an RV were found. (Figures 1, 2 and 3). When swimming with an RV, swimmers increased their Bf in accordance with their increased metabolic demands for more frequent breaths imposed by the high intensity (maximal or near maximal) swimming. On the contrary, swimming without an RV induced almost unvaried Bf during the swimming tests. The present results showed that swimmers took advantage of free breathing while swimming with an RV. It seems that the previously mentioned synchronised pulmonary ventilation during swimming without an RV did not trigger an adaptation to increased metabolic demands as was the case during free breathing swimming.

The finding that when compared to free swimming, the use of an RV alters the breathing pattern and this indicates that in order to minimise the differences between RV and free swim trials it may be suggested that the subjects should be instructed to keep a Bf rate that is similar to the Bf rate that during free swimming. It is also suggested that when swimming with an RV subjects should be instructed to inhale during the recovery of the breathing arm. It was also found that the swimming with an RV induced significantly lower values of $[LA^-]$ after both swimming test comparing to the swimming without an RV, probably because of the slower maximal 20m front crawl swim and the shorter front crawl swimming to exhaustion with an RV.

References

Bonifazi, M., Martelli, G., Marugo, L., Sardella, F., & Carli, G. (1993). Blood lactate accumulation in top level swimmers following competition. *Journal of Sports Medicine and Physical Fitness, 33*(1),13-18.

Chatard, J.C., Collomb, C., Maglischo, E., & Maglischo, C. (1990). Swimming skill and stroking characteristics of front crawl swimmers. *International Journal of Sports Medicine, 11*(2), 156-161.

Keskinen, K.L., Rodriguez, F.A., & Keskinen, O.P. (2003). Respiratory snorkel and valve system for breath-by-breath gas analysis in swimming. *Scandinavian Journal of Medicine and Science in Sports, 13*(5), 322-329.

Kjendlie, P.L., Stallman, R., & Stray-Gundersen, J. (2003). Influences of a breathing valve on swimming technique. In J.C. Chatard (Ed.), *Biomechanics and medicine in swimming. Saint-Etienne 9* (pp. 69-73). France: Laboratoire de Physiologie and Service de Exploration Fonctionnelle Cardio-respiratorie et de Medecine du Sport.

Kolmogorov, S.V., & Duplisheva, A. (1992). Active drag, useful mechanical power output and hydrodynamic force coefficient in different genders and performance levels. *Journal of Biomechanics, 25*(3), 311-318.

Nelson, R.C., & Goldfuss, R.A. (1971). A temporal force analysis of tethered swimming. In I. Lewillie & J.P. Clarys (Eds.), *First International Symposium on Biomechanics in Swimming* (pp. 129-142). Brussels: Universite Libre de Bruxelles.

Rodriguez, F., Keskinen, K., & Keskinen, O. (2001). Aerobic cost of crawl swimming during an incremental pool test measured by breath-by-breath gas analysis. In J. Mester, G. King, H. Strüder, E. Tsolakidis & A. Osterburg (Eds.), *6th ECSS Annual Congress* (p. 532). Cologne: German Society of Sport Science.

Rodriguez, F., Keskinen, K., Malvela, M., & Keskinen, O. (2003). Oxygen uptake kinetics during free swimming: A pilot study. In J.C. Chatard (Ed.), *Biomechanics and medicine in swimming. Saint-Etienne 9* (pp. 379-384). France: Laboratoire de Physiologie and Service de Exploration Fonctionnelle Cardio-respiratorie et de Medecine du Sport.

Sidney, M., Delhaye, B., Baillon, M., & Pelayo, P. (1999). Stroke frequency evolution during 100-m and 200-m events front crawl swimming. In K.L. Keskinen, P.V. Komi & A.P. Hollander (Eds.), *Biomechanics and medicine in swimming VIII, Jyväskylä* (pp. 71-75). Finland: University of Jyväskylä, Gummerus Printing.

Toussaint, H.M., Meulemans, A., de Groot, G., Hollander, A.P., Schreurs, A.W., & Vervoorn, K. (1987). Respiratory valve for oxygen uptake measurements during swimming. *European Journal of Applied Physiology, 56*(3), 363-366.

Research was supported by the grant from ARRS No. 5 – 6570.

OBRASCI FREKVENCIJE DISANJA TIJEKOM SUBMAKSIMALNOG I MAKSIMALNOG PLIVANJA KRAULOM S VENTILOM ZA DISANJE I BEZ NJEGA

Sažetak

Uvod

Precizna mjerenja primitka kisika i respiratornih parametara tijekom plivanja vrhunac su istraživanja uspješnosti u plivanju. U cilju poboljšanja valjanosti testiranja, Toussaint i suradnici (1987) razvili su respiratorni ventil i cijevi (RV), specifično oblikovan za mjerenje primitka kisika i respiratornih parametara tijekom plivanja. Ipak, utvrđivanje stupnja odgovarajuće valjanosti mjerenja disanja tijekom plivanja s korištenjem ventila u usporedbi s normalnim disanjem tijekom plivanja zahtijeva daljnja istraživanja. Disanje tijekom plivanja kraulom, prsnog plivanja i delfinom sinkronizirano je sa zaveslajima. Štoviše, frekvencija disanja (Bf) mora odgovarati frekvenciji zaveslaja. Upotreba ventila omogućuje plivaču da diše slobodno i bez prekida, tj. plivač ne mora pribjegavati posebnoj mehanici disanja koja se inače mora primijeniti pri specifičnom plivačkom zaveslaju i frekvenciji zaveslaja. Stoga je cilj ovog istraživanja bio utvrditi učinak korištenja respiratornog ventila na frekvenciju disanja, odabrane biomehaničke parametre, kao što su frekvencija zaveslaja i broj udisaja, parametre acidobaznog statusa krvi te koncentraciju laktata u krvi tijekom tri različita plivačka testa (submaksimalnog i maksimalnog pčivanja kraulom na 200 metara te testa plivanja kraulom do iscrpljenja pri zadanoj, prethodno utvrđenoj brzini).

Metode

Dvanaest nekadašnjih natjecatelja plivača (dob: 24 ± 3 godine, visina: 181,3 ± 9 cm, masa: 77,4 ± 13 kg) dobrovoljno je pristalo sudjelovati u istraživanju. Na početku su ispitanici dvaput otplivali 200 metara kraul maksimalnom brzinom, najprije s respiratornim ventilom, a u drugom pokušaju bez ventila. Zatim su plivači otplivali 200 metara kraul s ventilom i bez njega. Brzine su prethodno zadane na razinu od 90% maksimalne brzine postignute u testu 200 metara kraul, zasebno s respiratornim ventilom i bez njega. Konačno, plivači su otplivali (čak uz određivanje tempa) kraul do iscrpljenja, sa i bez ventila. Test plivanja do iscrpljenja uključivao je zadanu, prethodno određenu brzinu koja je predstavljala 110% tempa korištenog u testu 200 metara kraul, najprije s respiratornim ventilom, a zatim bez njega. Tijekom plivačkih testova s respiratornim ventilom, frekvencija disanja mjerena je kontinuirano (*breath by breath*), korištenjem prijenosnog sustava izmjene plinova (Metamax 2, Cortex, Germany). Tijekom plivačkih testova bez respiratornog ventila, broj udisaja tijekom preplivane dionice od 25 metara određen je uz pomoć snimljenih videovrpca. Izmjereni krvni parametri uključivali su koncentraciju laktata ($[LA^-]$) i parametre acidobaznog statusa - Pco_2, parcijalni tlak kisika u krvi (Po_2), pH i koncentraciju bikarbonatnih iona ($[HCO_3^-]$) prije početka svakog testa i tijekom prvih 30 do 45 sekunda nakon plivačkih testova.

Rezultati, rasprava i zaključak

Plivanje s ventilom uzrokovalo je nižu brzinu u maksimalnom testu 200 metara kraul (1,28 ± 0,1 m/s) u odnosu na veću brzinu (1,38 ± 0,1 m/s; $p<0,01$) u plivanju bez ventila. Isto tako, korištenje ventila rezultiralo je kraćom dionicom (114 ± 17 m; $p<0,05$) plivanja kraulom do iscrpljenja u odnosu na veću udaljenost prijeđenu u plivanju bez ventila (129 ± 18 m; $p<0,05$). Nadalje, obrasci frekvencije disanja tijekom submaksimalnih i maksimalnih plivačkih testova također su se razlikovali između plivanja s respiratornim ventilom i bez njega. U plivanju s respiratornim ventilom, ispitanici su povećavali frekvenciju disanja u skladu s povećanim metaboličkim zahtjevima za učestalijim udisajima nametnutim visokim intenzitetom plivanja (maksimalni ili blizu maksimalnog). Nasuprot tome, plivanje bez ventila uzrokovalo je gotovo nepromijenjenu frekvenciju disanja tijekom plivačkih testova. Na temelju rezultata ovog istraživanja može se zaključiti da se pri korištenju ventila za mjerenje respiratornih parametara tijekom plivanja može pojaviti drugačiji obrazac disanja (u usporedbi s plivanjem bez ventila). Sljedeći krvni testovi ($[LA^-]$, $[HCO_3^-]$, pH, Po_2 i Pco_2) su primijenjeni da bi se utvrdilo jesu li različiti obrasci disanja (ukoliko su nađeni) rezultirali također i razlikom u odabranim fiziološkim parametrima. Nađene su značajne razlike $[LA^-]$ nakon maksimalnog testa 200 metara kraul između plivanja s ventilom (12,7 ± 2,4 mmol/l) i plivanja bez ventila (14,3 ± 2,1 mmol/l; $p\leq0.05$), kao i razlike u $[LA^-]$ i $[HCO_3^-]$ nakon plivanja do iscrpljenja između plivanja s ventilom ($[LA^-]$ = 9,9 ± 1,5 mmol/l; $[HCO_3^-]$ = 18 ± 2 mmol/l) i plivanja bez ventila ($[LA^-]$ = 12,6 ± 2,8 mmol/l; $[HCO_3^-]$ = 16 ± 2 mmol/l) ($p\leq0,01$ i $p\leq0,.05$, prema redoslijedu).

Submitted: January 24, 2007
Accepted: December 28, 2007

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