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Research article

THE INFLUENCE OF APNEA ON PHYSIOLOGICAL RESPONSES OF FEMALE SWIMMERS

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Georgia Rozi[1], Vassilios Thanopoulos[1], Milivoj Dopsaj[2]

[1]National & Kapodistrian University of Athens, Greece
[2]Faculty of Sport and Physical Education, University of Belgrade, Serbia

Abstract. *The purpose of this study was to investigate the differences in maximum concentration of lactic acid in the blood, heart rate and performance time on the test of 4x50m freestyle swimming on a sample of two protocols: a) one breath every 3 strokes and b) 14-15m of every 50m were swum with underwater movement of the feet without breathing and a rest with one breath every 3 strokes (apnea). The sample consisted of 15 female swimmers of the competitive level aged: 15.0 ± 1.0 years. Their basic style was the freestyle. To determine the maximum blood lactate concentration, capillary blood samples were taken in the 3rd, 5th, 7th minute and analyzed by the automatic analyzer Scout Lactate Germany. We also measured the heart rate immediately after each swimming protocol. The ANOVA showed that there were no statistically significant differences between the two protocols. Maximum lactate concentration in the protocol with apnea was 10.02 ± 3.05mmol / L and without apnea 8.9 ± 3.5mmol / L. Heart rate was 186 ± 6 and 186 ± 7 b/min respectively, and performance time 140.04 ± 8.13 and 138.73 ± 8.01sec in swimmers aged 14-16. Swimming apnea needs to be studied in a larger age sample with more variables to ascertain the effects on sprint swimming.*

Key words: *freestyle swimming 1, apnea 2, physiological responses 3, 14-16 year-old swimmers.*

INTRODUCTION

The level of anaerobic capacity of swimmers can be determined by simple tests (Maglischo, 2003). After analyzing various results, they confirmed that the best test that can assess anaerobic capacity of swimmers is the 4x50m test with maximum intensity and 10’’ stop (Platonov, 1977; Pelayo, 1996).

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Corresponding author: Milivoj Dopsaj
Faculty of Sport and Physical Education, University of Belgrade, St. Blagoja Parovića 156, 11000 Belgrade, Serbia
Phone: +381 11 35 31 000 • E-mail: milivoj.dopsaj@gmail.com

Apnea is a situation where one does not breathe, and it can be static or dynamic. During both static and dynamic apnea (Joulia et al., 2002; 2003; Andersson et al., 2004) an increase in the concentration of blood lactate was observed. Persons with long experience in apnea-related activities (7-10 years) show less or no lactic acidosis after static and dynamic apnea compared with inexperienced people (Joulia et al., 2002).

Apnea causes human bradycardia, decreased cardiac output, peripheral vasoconstriction, systemic hypertension (Gooden, 1994; Schagatay, Van Kampen & Andersson, 1999; Schagatay et al., 2000; Andersson et al., 2004; Foster & Sheel, 2005) redistribution of blood to vital organs and reduced exchange of respiratory gases (Kawakami, Natelson & Dubois, 1967).

A decrease in heart rate was found in studies with people holding their breath on the surface of the water (Manley, 1990; Lin & Hong, 1996; Ferretti, 2001) as well as when they held their breath during exercise (Sundblad & Linnarsson, 1996; Lindholm, Sundblad, & Linnarsson, 1999).

Generally, there is a perception that bradycardia increases with dynamic apnea. In the research of Stromme, Kere & Elsner (1970) it was determined that the rate of bradycardia was more intense during dynamic apnea. According to Geladas (2008), bradycardia and peripheral vasoconstriction as a result of immersion apnea has proven to be a reflex meant to save oxygen for the most vital tissues.

Until now researchers have investigated apnea under conditions of exercise on the ergometer (Bjertnaes et al., 1984; Andersson et al., 2002; Lindholm & Linnarsson, 2002; Andersson et al., 2004; Lemaitre et al., 2007).

Despite all the research in the field of apnea, the role of the adaptability of the human organism to lack of oxygen has not yet been determined.

Underwater movement of feet that swimmers execute after the start of each distance and after each turn is a condition of apnea. Furthermore, as a form of apnea, exercise combined with regular swimming has not been studied from the aspect of physiological responses.

The aim of the present study was to investigate the maximum concentration of lactic acid in the blood, heart rate and performance time in the 4x50m test of freestyle swimming between two different protocols: a) one breath every 3 strokes and b) 14-15m of every 50m were swum with underwater movement of the feet without breathing and a rest with one breath every 3 strokes (apnea).

MATERIALS AND METHODS

Sample

The sample consisted of 15 female swimmers of a competitive level, aged: 15.0 ± 1.0 years, with body height: 165.0 ± 9.0 cm and body weight: 55.0 ± 9.0 kg. Their basic technique was freestyle swimming, and they were all were short and middle-distance swimmers. The swimmers started the measurements in the water. This research was approved by the Internal Ethics Committee of our university.

Procedures

All of the participants were informed about the purpose of the research, the possible risks and the measurement procedures and they gave their written consent, along with the consent of their parents, and we proceeded with the measurements.

The measurements were performed in an open swimming pool of 50m in the afternoon before training, between 17:00 and 19:00. The water temperature was $26^{o} \pm 1$. All measurements were made 10-15 days before the main competition of the summer cycle and completed in random order in 4 different sessions. All of the swimmers participated in daily systematic training two hours a day and at least five days a week.

The athletes swam the 4x50m test with maximum intensity in two protocols on different days, in accordance with the regulations of swimming. Before each protocol they completed a warm-up protocol of 1000m under the guidance of their coach.

In the first set the athletes swam 4x50m freestyle with one breath every 3 strokes with maximum intensity and a 10 sec stop between bouts. In the second set the same athletes swam the same distance with the same intensity and the same interval with the first 14-15m underwater movement of the legs for each 50 meters, and the remaining 35 meters freestyle swimming with one breath every 3 strokes. In order to determine maximum concentration of lactate in the blood, immediately after the end of each test of 4x50m, capillary blood samples were taken from the fingertip of the swimmer after 3, 5, and 7 minutes and analyzed by the automated analyzer Scout Lactate Germany. We also measured the heart rate manually, immediately after each protocol of 4x50m freestyle swimming in 10secs, from the carotid. This method was explained in detail to the participants. All swimmers were familiar with this process because they used this method often in training. Heart rate was reported as beats per minute.

Performance time after the end of each test of 4x50m freestyle swimming was recorded with an electronic watch Seiko Water Resistant 10bar S140.

Statistical analysis

The results were first submitted for descriptive analysis to calculate basic statistical parameters (M = mean, SD = standard deviation). For the statistical analysis of the data, we used the analysis of variance ANOVA. The minimum level of statistical significance was set at $p < 0.05$. Data analysis was done with the statistical program SPSS 19.0.

RESULTS

Mean values and standard deviations of maximum lactate concentration, heart rate and performance time in the of 4x50m freestyle swimming event with underwater movement of the legs and without movement are presented in Table 1.

Table 1 Average values and standard deviations of measured variables

Apnea	Lamax (mmol/L)	HR (beats/min)	Performance (secs)
4×50m freestyle with 15m underwater kick of the legs	10.02±3.0	186±6.0	140.04±8.13
4×50m freestyle	8.9±3.5	186±7.0	138.73±8.01

Table 2 Statistical significances for the protocols with and without apnea.

	Lamax (mmol/L)		HR (beats/min)		Performance (secs)	
	F	Sig.	F	Sig.	F	Sig.
Apnea/ without apnea	.737	.398	.000	1.00	.200	.659

The results of the ANOVA analysis are presented in table 2. The two protocols with and without underwater movement of the legs failed to present statistical significant differences in the measured variables.

Heart rate, which was almost at the same level in the two different protocols, showed no statistically significant differences.

Values are expressed in means and standard deviations. No statistically significant difference in overall performance between the protocols with apnea and without apnea was observed (Table 2).

Discussion

Apnea conditions are usually an integral part of training and competition conditions for many sports or for many specific situations in sport. According to those facts, sports apnea training may be an effective alternative to hypobaric or normobaric hypoxia to increase aerobic and/or anaerobic performance, as a training method in sport (Lemaitre et al., 2010). In swimming, it was found that after 3-month apnea training with a breath-hold program, statistically significant changes were found in the form of the following improvement: the forced expiratory volume in 1 second was higher (4.85 ± 0.78 vs. 4.94 ± 0.81 L, $p < 0.05$), with concomitant increases in $o_2$peak, minimal arterial oxygen saturation, and respiratory compensation point values (W and $W \cdot kg^{-1}$) during the incremental test; the authors found that some aspects of swimming performance had not improved (clean velocity and time on 50 m); but, SR was decreased and SL and IdC were increased; generally, authors stated that these results indicate that apnea training improves effectiveness at both peak exercise and submaximal exercise and can also improve swimming technique by promoting greater propulsive continuity (Lemaitre et al., 2009).

In this investigation, the analysis of the results showed that there were no statistically significant differences between the two protocols of apnea in the maximum production of lactate, heart rate and performance time of 15 female swimmers of the national competition level (Table 2).

Guimard et al., (2017) noticed that in sumbaximal intensity (50m front crawl) with complete apnea resulted in a significantly lower heart rate (peak) and post lactate production in comparison to maximal intensity (50m front crawl), whilst the rate of perceived exertion did not differ between the two conditions.

In another study by Guimard et al., (2014), it was observed that during a 100m freestyle trial separated in repeated efforts of 25m with apnea and maximal speed, performance alteration was correlated with bradycardia (r= .63) and arterial oxygen desaturation (r= -.57). In the same survey apnea did not affect the production of lactic acid.

A decrease in heart rate was found in studies involving people holding their breath on the surface of the water (Manley, 1990; Lin & Hong, 1996; Ferretti, 2001).

Lemaitre et al., (2007) observed a decrease in the production of lactate after repeated attempts at apnea by immersing the face in water during moderate exercise on the ergometer.

According to the results of this research, it was found that underwater movement of the legs (apnea) during maximal swimming effort does not cause different physiological responses in relation to swimming without underwater movement of the legs in female swimmers of a competitive level for a junior sport level age group. Apnea, as a form of exercise in swimming, deserves further study in other techniques of swimming and with different protocols.

One of the possible explanations for the obtained results may be the relatively low performance level of the tested sample in relation to the development of the glycolytic energy system, since the achieved maximum lactate concentration level in both protocols ranged from 8.9 to 10.02 mmol / L, with relatively high levels of maximum heart rate (186 bpm), but at a relatively low performance level achieved on the tests - 138.73 to 140.04, or at swimming speeds of -1.428 to 1.442 (Table 2).

Generally, apnea plays an important role in swimming competitions and needs to be practiced by swimmers. The effects of apnea on physiological responses give information to coaches and researchers on the way swimming programs including apnea should be formed, but further research is needed in order to provide a more integrated view of this field.

CONCLUSION

The apnea condition is usually an integral part of training and competition conditions for many sports or for many specific situations in sport, especially in swimming. The purpose of this study was to investigate the maximum concentration of lactic acid in blood, heart rate and performance time on the 4x50m freestyle swimming between two protocols: a) one breath every 3 strokes and b) 14-15m of every 50m were swum with underwater movement of the feet without breathing and a rest with one breath every 3 strokes (apnea). The sample consisted of 15 female swimmers of the competitive level, aged: 15.0 ± 1.0 years. The results showed that there were no statistically significant differences between the two protocols. Maximum lactate concentration in the protocol with apnea was 10.02 ± 3.05mmol / L and without apnea 8.9 ± 3.5mmol / L. Heart rate was 186 ± 6 and 186 ± 7 b/min respectively, and performance time 140.04 ± 8.13 and 138.73 ± 8.01sec. Generally, apnea plays an important role in swimming training and competition and needs to be practiced by swimmers, and this is the reason why it needs to be studied in a larger age sample, with more variables, to ascertain the effects in sprint swimming.

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UTICAJ APNEE NA FIZIOLOŠKE REAKCIJE PLIVAČICA

Cilj ovog istraživanja bio je da se ispita maksimalna koncentracija mlečne kiseline u krvi, puls i vreme izvršenja na testu 4x50m slobodnim stilom plivanja na primeru dva protokola: a) jedan udisaj svaka 3 zaveslaja i b) 14-15m od svakih 50m preplivani su podvodnim radom nogu bez disanja, a ostatak sa jednom dahom na svaka 3 zaveslaja (apnea). Uzorak je činilo 15 plivačica starosti: 15.0 ± 1.0 godina. Njihov osnovni stil bio je kraul. Da bi se odredile maksimalne koncentracije laktata, kapilarni uzorci krvi uzeti su u 3., 5., 7. minutu i analizirani automatskim analizatorom Scout Lactate, Nemačka. Takođe su mereni otkucaje srca odmah nakon svakog protokola plivanja. ANOVA je pokazala da nije bilo statistički značajne razlike između dva protokola. Maksimalna koncentracija laktata u protokolu sa apneom je 10.02 ± 3.05mmol / L i bez apnee 8,9 ± 3.5mmol / L Puls je 186 ± 6 i 186 ± 7 b / min tim redosledom, i vreme peformanse 140.04 ± 8.13 i 138.73 ± 8.01 sec kod plivača starosti 14-16. Plivanje sa apneom trebalo bi proučavati na uzorku veće starosti, sa više varijabli, kako bi se utvrdio njen efekat na sprint u plivanju.

Ključne reči: *plivanje slobodnim stilom 1, apnea 2, fiziološke reakcije 3, plivači starosti 14-16 godina.*