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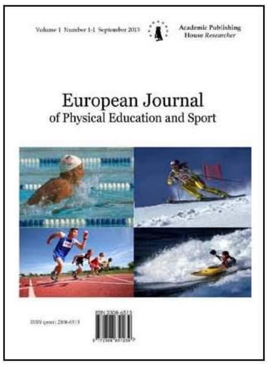

Articles and Statements

Dynamic Apnea in Pubertal Male and Female Swimmers

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Abstract

Blood lactate is an index of maximum anaerobic capacity (Troup et al., 1992). Furthermore, is a biomechanical parameter that presents the most impressive accumulation changes in muscles and blood during exercise, in a way that by measuring it we can obtain important information about maximum swimming efforts (Mougios, 2002).

Lactate accumulation in blood has been observed in several swimming tests. One of those is swimming with apnea that aims at the increase of the athlete's endurance allowing him to swim some meters underwater. However, one of the adaptations of apnea is for sure the improvement of keeping ones breath (Van-Ness, Town, 1989). Apnea remains a popular type of training for elite swimmers maybe because it also provokes other training effects that are not yet recognized (Maglischo, 2003).

The aim of this study is to examine lactate accumulation in blood and heart rate in the test of 4x50m with two different tests: a) freestyle swimming and b) freestyle swimming with dynamic apnea, between male and female swimmers.

12 male and female sprint swimmers of freestyle participated in this research. Firstly, they swam 4x50m freestyle swimming with maximum intensity. Secondly, they swam the same distance with 14-15m underwater movement and for the rest 35m they swam freestyle with maximum intensity. After each effort, blood lactate, heart rate and performance time were recorded.

For the analysis of the results, multivariate analysis of variance was applied (MANOVA). No statistical significant differences for the measured variables between the test of apnea and the test without apnea for the measured variables. Differences were only observed on performance time between male and female.

Keywords: swimming, apnea, blood lactate, heart rate, performance.

1. Introduction

The requirements for adaptive processes in high level athletes show great coaching activation, aimed to disrupt the homeostatic balance of body and force him to go to the operational adaptation necessary for high level achievements.

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Underwater movement of feet that swimmers do at the start of each race distance and each turn is a state of apnea. Apnea in humans' causes bradycardia, decreased cardiac output, peripheral vasoconstriction, systemic hypertension (Andersson et al., 2004; Ferretti et al., 1991; Foster, Sheel, 2005; Gooden, 1994; Kawakami et al., 1967; Schagatay et al., 1999; 2000), redistribution of blood to vital organs and impaired respiratory gas exchange (Kawakami et al., 1967). Until now, studies investigate the apnea under conditions of exercise on cycloergometer (Andersson et al., 2004; Bjertnaes et al., 1984; Lindholm, Linnarsson, 2002).

According to the Geladas (Geladas, 2008), the diving reflex, namely bradycardia and peripheral vasoconstriction as a result of immersion in apnea has proven to be a reflex that serves to save oxygen for the more vital tissues. This reflex is characterized mainly by a large reduction in heart rate, significant increase in blood pressure and intense peripheral vasoconstriction and occurs during both the dynamic and static apnea.

The redistribution of blood flow from the periphery to the brain or central movement is an important indication for the operation of the dive reflex as a protective mechanism for saving oxygen to vital organs.

In recent years, apart from the static and dynamic apnea, the model of repeated apnea is widely investigated. It is observed that repeated apneas may cause transient changes and lead to an increase in the duration of apnea, a phenomenon reported in the literature as a short-term adaptation of apnea (Heath, Irxin, 1968; Schagatay et al., 1999; Schagatay et al., 2001a;2005;2007; Bakovic et al., 2003;2005; Richardson et al., 2005).

The amount of blood lactate in muscle serves as a measurement of anaerobic energy production. The concentration of lactate in the blood has been investigated quite a lot in swimming procedures to determine the intensity of energy production (Aujouannet et al., 2006; Barbosa et al., 2006). The level of anaerobic capacity of swimmers can be determined by simple tests. The best test that can assess the anaerobic capacity of swimmers is the test 4x50m freestyle swimming with maximum intensity with 10'' stop which can be used to estimate the maximum lactate production (Platonov, 1977).

During both static and dynamic apnea (Ferretti et al., 1991; Joulia et al., 2002; 2003; Andersson et al., 2004), an increase in concentration of lactic acid in the blood is observed, an indication that we pass from aerobic to anaerobic metabolism due to reduced peripheral oxygen delivery caused by the intense vasoconstriction in the area.

On the other hand, people with long experience in apnea activities (7-10 years) have less or no lactic acidosis after static and dynamic apnea compared with inexperienced persons (Joulia et al., 2002). The application of a training program comprising repetitive dynamic apneas, resulted in limiting the lactic acidosis as determined by the concentration of plasma lactate and pH in both static and dynamic apnea (Joulia et al., 2003). The above change in the concentration of lactate has been linked by researchers with the paradox of lactic acid after acclimatization to severe altitude.

Breathing during free swimming and other types of swimming techniques usually is tuned to the movement of hands (Strumbelj et al., 2007).

A decrease in the percentage of heart rate found in studies of people who held their breath on the water surface (Ferretti, 2001; Lin, Hong, 1996; Manley, 1990). The same was found during the breath-holding exercise (Butler, Woakes,1987; Lindholm et al., 1999; Sundblad, Linnarsson, 1996).

Generally, there is a perception that the bradycardia increases with the dynamic apnea. In their research, Stromme et al., (Stromme et al., 1970) examined bradycardia at rest and during dynamic exercise and found that the level of bradycardia was higher during dynamic apnea. These results agree with the findings of Butler et al., (Butler et al., 1987), Smeland et al., (Smeland et al., 1984) and Finley et al., (Finley et al., 1979) except that the experimental design of Butler et al., (1987) apnea included immersion of the whole body in water with underwater swimming, and of Smeland et al., (Smeland et al., 1984) and Finley et al., (Finley et al., 1979) consisted of static and dynamic apnea with face immersion only.

It should be noted that in the above investigations, the intensity of dynamic exercise was moderate thus we do not know if at a higher exercise intensity diving reflex can occur and to counteract the tachycardia of exercise.

Underwater movement of feet as a form of exercise apnea in conjunction with regular swimming has not been studied in terms of physiological responses.

This study attempts to identify any differences between apnea swimming and free swimming.

After analyzing the various results it was confirmed that the best test that can objectively assess the anaerobic capacity of swimmers is the test of 4x50m freestyle swimming with maximum intensity with a 10'' stop (Platonov, 1977).

The purpose of this study is to investigate physiological responses after the test of 4x50 m freestyle swimming between two different protocols: a) freestyle swimming and b) freestyle swimming with 14-15 m of apnea in male and female swimmers of competitive level.

The comparison will help in assessing useful conclusions for planning and coaching in swimming and it will determine the importance of maximum concentration of blood lactate in maximum-intensity efforts, heart rate and will observe differences between two genders.

2. Methods

Sample

The sample consisted of 12 male and female swimmers of competitive level (male, n:6, age: 16 ± 1,6 years, height: 175 ± 8,8 cm and weight: 70,4 ± 11,8 kg, and female, n:6, age: 15 ± 1,6 years, height: 163,7 ± 9,8 cm and weight: 53,2 ± 8,9 kg). This research has the approval of ethics committee of Athens University.

Procedures

The measurements were made in an open pool of 50m. The water temperature was 26 ± 1degrees. The measurements were made during the afternoon hours of 17:00 until 7:00 p.m. and within 4 days, during the pre-competitive phase of the summer period. To ensure that all subjects are in better physical condition all the measurements were made randomly in 2 sessions. The swimmers participated in regular daily workout lasting two hours, six days per week.

Once informed of the purpose of the research and measurement procedures, the athletes gave their written consent. All subjects made a warming up of 800m under the guidance of the coach. After warming up, they rested out of the water for 15 minutes and were preparing to start the measurement.

For the purpose of the study, the athletes swam with a maximum intensity the distance of 4x50m freestyle swimming with two different ways on different days, taking into account the regulations of swimming.

The first way was to swim 4x50 meters freestyle at maximum intensity and 10'' stop between 50m with start from the water and breathing as they normally do in training and competitions, every 2 to 3 strokes. In the next session, the second way involved 4x50m freestyle swimming with the first 14-15m underwater movement of the legs and the remaining 35 meters freestyle swimming with maximum intensity and 10'' stop between 50m.

Anthropometrics

From the anthropometric data measured body height (cm) with precision scale to the nearest 0,5 cm and body weight (kg) was measured to the nearest 1/100kg with electronic precision scale 100gr with the athletes wearing their swimsuits.

Instruments

In order to determine the concentration of blood lactate immediately after each effort, capillary blood samples were taken at 3, 5 and 7 minute of recovery, and analyzed by automatic analyzer LACTATE SCOUT GERMANY.

We also recorded heart rate in the first 10'' immediately after exercise with Polar Finland 610I.

Performance time in each 50m and total time of 4x50m were recorder manually with electronic timer SEIKO WATER RESISTANT 10BAR S140.

Statistical analysis

The statistical analysis of data from blood lactate, heart rate and swimming performance at maximum repeated attempts was made by using multivariate analysis of variance MANOVA. For the investigation of individual differences among male and female swimmers and the two conditions, with and without apnea, ANOVA analysis was applied.

Values are expressed as average values and standard deviations of (M ± SD). The minimum level of statistical significance was set for all parameters at $p < 0.05$. The data analysis was done with the statistical program SPSS 22.0.

3. Results

All data went through descriptive statistics and normality tests (Table 1).

The results of multivariate analysis MANOVA showed a significant effect of the variable 'gender' to the linear combination of the dependent variables. The multivariable index Wilk's L was equal to 0.423, corresponding to F (3,18) = 8,185, Sig. .001, p <.05. The index η^2 is equal to 0.57, ie 57% of the distribution of the linear combination of the dependent variable was explained by the statistical effect of the independent variable 'gender'. This finding is obvious as male have generally better performance times in comparison to female.

There was no significant effect of the independent variable 'apnea' to the linear combination of the dependent variables. The multivariate index Wilk's L was equal to 0.784, corresponding to F (3,18) = 1,649, p <.05.

Finally, no statistically significant interaction occurred between the variables 'condition' and 'gender' to the linear combination of the dependent variables. The multivariable index Wilk's L was equal to 0.927, corresponding to F (3,18) = 0,47,

p < .05.

In individual level, statistical significant difference was observed only between male and female swimmers in performance time, with male presenting lower values in comparison to female.

Table 1. Average values and standard deviations of measured variables

Apnea condition	**gender**	**Lamax (mmol/l)**	**HR (beats/ min)**	**Performance (secs)**
4χ50μ freestyle with 15m underwater kick of legs	male	9,8±3,2	187±12,8	130,4±5,5
	female	11,1±2,8	186±7,5	136,8±5,6
4χ50m freestyle without 15m underwater kick of legs	male	10,7±2,4	193±15,8	125±3,64
	female	10,4±3,4	184±7,2	134,5±5,4

Table 2. Statistical significances for the protocols of apnea and without apnea (Anova)

	Lamax		**HR**		**performance**	
	F	Sig.	F	Sig.	F	Sig.
Apnea	.005	.945	.183	.674	3.403	.080
Gender	.169	.685	1.142	.298	14.044	.001*
Apnea* Gender	.428	.520	.731	.403	.538	.472

*statistical significant difference

Maximum blood lactate levels did not differ statistically between the two conditions of apnea or the two genders. Blood lactate varied at both protocols between 10,5 ± 2,8 mmol/l.

Heart rate was recorded immediately after each test at 10''. Heart rate varied at both protocols between 187,5 ± 11,2 beats per minute. The heart rate showed no statistically significant differences between the protocol of apnea and the protocol without apnea. The average values and standard deviations of heart rate for each protocol are presented in Table 1.

Performance time, that varied between 131,7± 6,6 at the overall sample, was statistically significant different between the two genders but no difference was observed between the two apnea protocols. However, a tendency was observed for performance time with apnea, with both male and female swimmers having lower values of performance time when executing the test with apnea (underwater movement of legs).

4. Discussion

In this investigation, the analysis of results showed no statistical significant differences between the two protocols of apnea in the measured variables in maximum production of blood lactate, heart rate and time of performance.

When an athlete performs an attempt to swim with high intensity, blood lactate is a good indicator of intensity of swimming and can be used as an indicator of adaptation of the swimming training (Costill, 1992). Thompson & Cooper (Thompson, Cooper, 2003) found a strong relationship between submaximal swimming velocity and lactate concentrations. Avlonitou (Avlonitou, 1996) in her research reported that rates of lactic acid after competition were between 12.0 and 13.1 mmol / L for adult men and 10.5 and 12.6 mmol / L for adult women.

According to the results, the maximum production of blood lactate showed no differences between the two protocols. Similar results were observed in other sports using different protocols apnea.

The reduced acidosis in divers as endurance athletes as a result of the apnea training program can mean either reduced production of lactate from the exercising muscles or increase from other tissues (Geladas, 2008). Also, Joulia et al., (Joulia et al., 2003), examined the effects of dynamic apnea training on metabolic acidosis. The increased concentration of blood lactate in plasma disappeared during static apnea, whereas the concentration of blood lactate in the blood decreased significantly in dynamic apnea.

Heart rate showed no statistically significant differences between the protocol with and without apnea.

In contrast to the results of this research, a decrease in the percentage of heart rate was found in studies of people who held their breath on the water surface (Ferretti, 2001; Lin, Hong, 1996; Manley, 1990).

The results of this investigation are in contrast to the findings of the following investigations. Sanchez & Sebert (Sanchez, Sebert, 1983) examined in 12 subjects (6 men and 6 women) the effect of apnea on heart response to different intensities of dynamic (30 and 50 % of VO2max) and isometric exercise. The subjects in each condition had two apneas in the 30 second and 4th minute of exercise. The duration of dynamic exercise was set at 6 minutes and the static was to exhaustion. The level of bradycardia was stronger in men than women only during the second apnea in both the dynamic and the isometric exercise.

In their research Stromme et al., (Stromme et al., 1970) examined the bradycardia of apnea at rest and during dynamic exercise and found that the level of bradycardia was higher during dynamic apnea.

These results agree with the results of Butler et al., (Butler et al., 1987), Smeland et al., (Smeland et al., 1984) and Finley et al., (Finley et al., 1979). In 2002, Andersson et al., (Andersson et al., 2002) examined 8 men in cyclo-ergometer for 50min in 100W and every 5 minutes the subjects were holding their breath for 30". They found that the diving reflex managed to overcome the tachycardia of exercise.

5. Conclusion

According to the results of this research, apnea during maximal effort in swimming does not cause different physiological responses in relation to swimming without apnea in swimmers of competitive level.

Performance time was statistically significant different between the two genders but no difference was observed between the two apnea protocols.

This type of apnea needs further investigation with larger sample but even though there were no differences between the protocols with and without apnea, we would suggest to competitive swimmers and coaches to include to their training program the adaptation in apnea and the underwater movement of legs for the first 15m of each 50m in training and competition as it is an integral part of swimmers performance.

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