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The effect of gradually increasing exercise on oxygen consumption and lactate levels in swimmers

Onder Daglioglu

Gaziantep University, School of Physical Education and Sports, Gaziantep, TURKEY

ABSTRACT

The purpose of this study is to investigate the effect of gradually increasing exercise on oxygen consumption and lactate levels in swimmers. A total of 14 male individuals, 7 elite swimmers and 7 healthy sedentaries as control, between 18-23 years old in the province of Gaziantep were included to the study voluntarily. Ramp protocol was applied to the subjects in cardiopulmonary exercise test with gradually increasing intensity in cycle ergometer. Parameters, such as oxygen consumption and carbon dioxide production, pulse changes, the level of fatigue of the athletes, were also followed with the help of the gas analyzer. Subjects' height, weight, body mass index (BMI), body fat percentage (BF%), systolic blood pressure (SBP), diastolic blood pressure (DBP), maximal work rate (WRmax), maximal minute ventilation (VEmax), resting heart rate (HRrest), maximal heart rate (HRmax), maximal oxygen uptake capacity (VO₂max) were measured. The measurement of lactic acid was performed before, after and 5 minutes after starting to cardiopulmonary exercise test and during the entire test oxygen consumption was measured by ergospirometer. For the difference in dependent variables between the experimental and control groups, independent-samples *t* test (independent two-tailed *t*-test) was used. Two-way (Group/Test) mixed variance analysis (Two-way 2x3 Mixed ANOVA) was used in order to assess lactate (LA) changes of experimental and control groups during the application. All in all, cardiopulmonary exercise test administered to swimmers and sedentary subjects revealed that aerobic endurance, anaerobic endurance and lactate concentration were better in people who exercise regularly.

Key Words: Cardiopulmonary exercise, Oxygen consumption, Lactate profile.

INTRODUCTION

Swimming is one of the important sports all around the world. Healthy effects of swimming on the human body have so far been reported by many scientific reports. Since it is an Olympic sport discipline, it is also one of the well-studied area in sport science [1]. Among the scientific reports focused on the swimming, the performance related investigations are of great importance.

VO₂max is considered to be the best value showing cardiovascular performance and aerobic exercise capacity [2]. During exercise, oxygen consumption (VO₂) increases depending on the workload. Age, gender, exercise habits and cardiac status are the major factors influencing VO₂max [3].

Cardiopulmonary exercise tests are the most widely used test method in determining the exercise performance. In these tests, responses of the body to stress are evaluated by applying a stress gradually on systems along with exercise. Thus, it is possible to determine the athletes' limit of endurance to exercise and whether the processes providing energy to muscle tissue works properly or not.

The energy need of the muscles increases together with rising of exercise intensity and anaerobic mechanisms are gaining importance due to the fact that aerobic metabolism becomes inadequate for energy supply at some point.

This exercise intensity is called anaerobic threshold. Anaerobic threshold helps diagnosis of cardiorespiratory problems relating to the cell metabolism [4].

Increase in anaerobic threshold along with practices is higher than increase in VO_2 max and anaerobic threshold is more correlated with aerobic exercise performance than VO_2 max. Anaerobic threshold is one of the indicators showing the endurance capacity of the individual [5]. Anaerobic threshold is an important criterion in determining the percentage of VO_2 max consistently used and working capacity [6].

Not only high VO_2 max values but also the availability of VO_2 max value before the occurrence of fatigue due to the production of lactic acid have importance for durability performance. The contribution of anaerobic energy pathway would be higher than VO_2 max and the lactic acid production would rise along with increasing exercise intensity. The point at which the lactic acid level in the blood exceeds a certain concentration is defined as anaerobic threshold (AT) [7].

Anaerobic threshold is the effort level at which starting of accumulation of lactic acid in the blood accelerates. However, blood lactate levels in steady-state submaximal exercise may represent muscle lactate metabolism. This level increases linearly with exercise. This level is in concentration of 4-5 mmol/L and means the balance between lactate passing to the blood and lactate removed from the blood [8].

Lactate production is present in exercise in all intensities at rest and the difference between the production and removal of lactate identifies the presence of accumulation in blood lactate [9]. Blood lactate concentration at rest was found as 0.4-1.7 mmol/L in non-trained individuals and as 0.3-0.6 mmol/L in the elite distance runners [9]. Anaerobic threshold is the effort level at which accumulation of lactic acid in the blood accelerates [10]. 4 mmol/L of lactate level in the blood is considered as anaerobic threshold [11].

Lactate concentration is 8-12 mmol / L at the maximal oxygen consumption speed. It is not possible to maintain the exercise at this intensity for more than 10-12 min [12]. When 10 mmol/L blood lactate concentration is reached, the mechanism of contraction starts to deteriorate and the athlete cannot maintain his/her velocity at the same rate. It was identified that many athletes could work at 4 mmol/L speed for about 30 min. and 4 mmol/L blood lactate value was determined as anaerobic threshold point by many researchers [13].

Exercise intensity in training is of great importance to ensure optimal load effect [14]. Physiological parameters, such as heart rate (HR), oxygen consumption or blood lactate (LA) concentration, are frequently used in determining the severity of exercise [15]. In exercise tests with gradually increased intensity causing rise in LA concentration, the measurement of LA is accepted as a valid and reliable application in the assessment of endurance performance [16].

The aim of this study in the light of this information is to investigate the effect of gradually increasing exercise on oxygen consumption and lactate levels in swimmers. In this study, determination of the relationship between oxygen consumption, lactic acid, type of exercise, workload of the athletes is important in terms of providing advices in the subjects on loading intensity, adaptation to training and preparation of the training program for sports scientists, coaches and athletes.

MATERIALS AND METHODS

Subjects

14 healthy young male subjects between the ages of 18-23 in the province of Gaziantep participated in the study voluntarily. Of the subjects participating in the study, 7 individuals formed the study group (Swimmer) and rest 7 individuals formed the control group (Sedentary). For this study, the necessary permission was obtained from Gaziantep University Clinical Research Ethics Committee. All subjects were informed about the purpose and plan of the work and written informed consent document showing that the subjects participated in the study voluntarily was taken

Data Collection

Physical Measurements

Anthropometric measurements of the subjects participated in the study were measured before cardiopulmonary exercise test. Body weights and heights were determined using the tool with the brand of N.A.N. During the test, the records of the heart beat numbers of subjects were measured by RS800CX model of Polar ® telemetry heart rate monitor device.

Cardiopulmonary Exercise Test Protocol

Ramp protocol was applied to the subjects in cardiopulmonary exercise test with gradually increasing intensity in electromagnetic cycle ergometer (Ergoline 800, VIASYS Sensormedics). After rest for 3 min and unloaded pedaling for 3 min, the protocol was increased by 5-15 waat (W) a minute. Pedaling rate was kept constant at approximately 60-70 rpm. The work force was increased as computer-controlled. The test was continued to the extent that subjects can not tolerate. At the top point that the subject could reach, work force was decreased to 20 W and then after pedaling for 3 min, test was ended. During exercise, cardiac activities were monitored continuously with ECG. Pulmonary minute ventilation (VE) and gas exchange [oxygen uptake (VO₂) and carbondioxide output (VCO₂)] were measured by the method of breath-by-breath in metabolic measurement system (Vmax Spectra, Sensormedics) [17]. The system was calibrated before each test.

Lactate Measurements

The lactic acid measurement was realized before, after and 5 minutes after starting to cardiopulmonary exercise test. Measurements were made with fingertip blood by lactate analyzer device, Lactate Plus (Nova Biomedical, USA).

Body Composition

Body fat percentages of subjects were measured with Bioelectrical Impedance method (Tanita Body Fat Analyser, Model BC-418MA) [18]. While taking measurements, weight of dress was not included in measurement and conductivity was increased by wiping weighing laid feet with a damp cloth.

SBP and DBP Measurements

Systolic and diastolic blood pressure measurements were done using digital automatic blood pressure monitor (Omron M6 Comfort, Omron Healthcare Co., Ltd. Kyoto, Japan). Two measurements were made with an interval of 1 minute and means of them were recorded.

Statistical Analysis

The statistical analysis of this study was some using SPSS statistical software (SPSS for Windows, version 16.0, 2008, SPSS Inc., and Chicago, Illinois, USA). Statistical results were evaluated in 95% confidence interval and at significance level of $p < 0.05$. For the difference in the dependent variables between the experimental and control groups, independent-samples t test (two-tailed independent t-test) was used. Two-way (Group/Test) mixed variance analysis (Two-way 2x3 Mixed ANOVA) was used in order to assess lactate (LA) changes of experimental and control groups during the application.

RESULTS

Table 1: Comparison of the parameters of the experiment and the control groups after cardiopulmonary exercise test

Dependent Variables	Group	N	M (SD)	t	df	p
Age (years)	Experimental	7	20.71(1.89)	-0.408	12	0.690
	Control	7	21.14(2.04)			
Height (cm)	Experimental	7	179.14(4.60)	1.005	12	0.335
	Control	7	177.00(3.27)			
Weight (kg)	Experimental	7	70.20(6.04)	-1.893	12	0.083
	Control	7	76.43(6.27)			
BMI (kg/m ²)	Experimental	7	21.77(1.52)	-3.147	12	0.008*
	Control	7	24.37(1.56)			
BF (%)	Experimental	7	9.34(4.60)	-1.510	12	0.157
	Control	7	12.41(2.80)			
SBP (mmHg)	Experimental	7	107.14(11.13)	-1.807	12	0.096
	Control	7	117.14(9.51)			
DBP (mmHg)	Experimental	7	70.00(5.77)	-2.274	12	0.042*
	Control	7	76.43(4.76)			
WRmax (W)	Experimental	7	253.57(26.66)	2.467	12	0.030*
	Control	7	228.00(6.43)			
VEmax (l/min)	Experimental	7	132.83(12.73)	1.485	12	0.163
	Control	7	121.34(16.02)			
Hrrest (beats/min)	Experimental	7	72.00(7.64)	-2.092	12	0.058
	Control	7	79.43(5.47)			
Hrmax (beats/min)	Experimental	7	190.14(2.67)	2.002	12	0.068
	Control	7	186.14(4.56)			
VO ₂ max (ml/kg/min)	Experimental	7	45.50(3.94)	2.249	12	0.044*
	Control	7	41.11(3.33)			

* $p < 0.05$

A total of 14 male individuals, 7 experimental group and 7 control group, participated voluntarily in the study realized with the purpose to investigate the effect of gradually increasing exercise on oxygen consumption and lactate levels in swimmers.

Age, height, BMI, BF%, SBP, DBP, WRmax, VEmax, HRrest, HRmax, VO₂max and lactate measurements of the experimental and control groups were compared according to the significance level of 0.05 (Table 1, 2).

In Table 1, the comparison of the measurement results obtained related to parameters after cardiopulmonary exercise test applied to experimental and control groups was given. As a result of the statistical analysis done, any significant change statistically between age, height, body weight, BF%, SBP, VEmax, HRrest, HRmax scores of the experimental and control group was not found ($p > 0.05$).

However, there was a statistically significant difference between BMI, DBP, WRmax and VO₂max scores of the experimental and control group ($p < 0.05$). Accordingly, while BMI and DBP scores of the experimental group was lower than those of the control group, WRmax and VO₂max scores was higher than those of the control group.

Table 2: Changes in Lactate (LA) mmol/L scores in groups throughout the process

GROUP		LArest	LAmox	LA 5min
Experimental n=7	M(SD)	1.57(0.73)	9.23(1.06)	5.17(1.07)
Control n=7	M(SD)	1.91 (0.83)	9.30(1.28)	6.77(1.16)

While LA scores were similar at rest in both groups, they increased significantly during the application and decreased significantly 5 min after the application. These rises and falls were similar in both groups, $F(2,24) = 2.942$ $p = .072$, $\eta^2 = 0.197$, (Figure 1). Also, there was no difference between the groups in terms of general changes, $F(1,12) = 2.864$ $p = .116$, $\eta^2 = 0.193$.

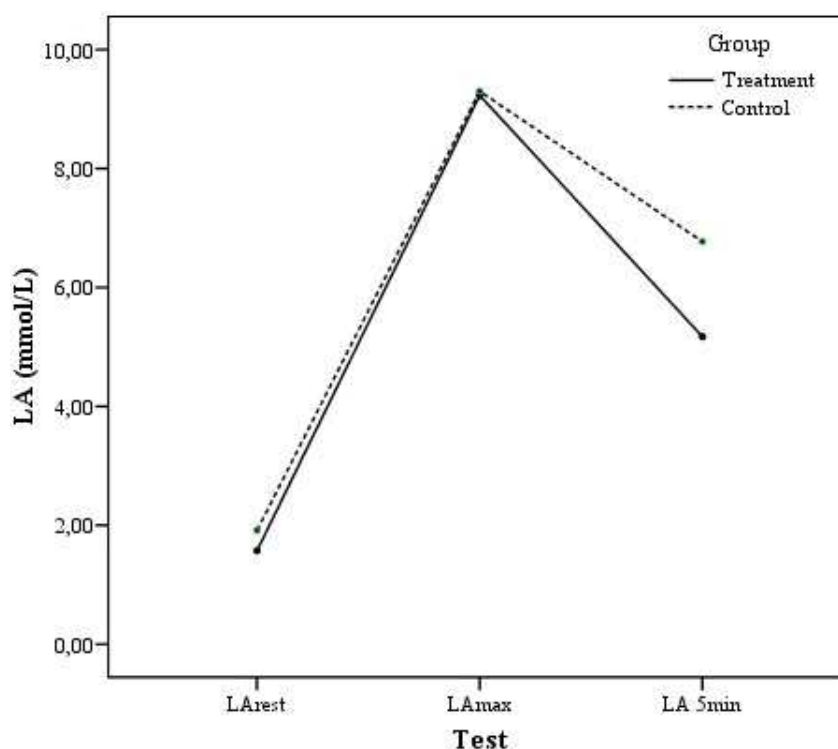


Figure 1. Lactic acid comparison of experimental and control groups

DISCUSSION

Cardiopulmonary system is an important determinant of the aerobic capacity. Exercise tests allow for individual's strength status and the solution of problems according to organism's response to the stress applied to the individuals

in changing workloads. At the same time, they are important in terms of meeting increased energy need and continuing to the exercise during exercise [19]. Exercise test done against load with the intensity increasing regularly contains both aerobic and anaerobic exercise regions [20].

Exercise test done against load increasing regularly is one of the most commonly used exercise protocols in monitoring of responses coming from cardiovascular, respiratory and metabolic systems and determination of the functional status of the systems [19, 21]. During exercise, the detection of changes in metabolism against work force applied is an important issue. In the studies, it was shown that information about metabolic system could be obtained with respiratory pulmonary gas exchange measurements [19, 22].

In this study, the comparison of the measurement results related to parameters taken after cardiopulmonary exercise test applied the experimental and control groups was given. As a result of the statistical analysis done, any significant change statistically between age, height, body weight, BF%, SBP, VEmax, HRrest, HRmax scores of the experimental and control group was not found ($p>0.05$).

However, there was a statistically significant difference between BMI, DBP, WRmax and VO_2 max scores of the experimental and control group ($p<0.05$). Accordingly, while BMI and DBP scores of the experimental group was lower than those of the control group, WRmax and VO_2 max scores was higher than those of the control group.

It is known that VE increases with exercise [23]. However, VE increase is lower in the individuals who exercise regularly than ones living sedentarily at rest and during low intensity exercise.

In this study, the fact that VEmax is high in favor of the experimental group arose from the fact that tidal volume increased more in this group. This suggests that athletes work more economically from point of respiratory aspect.

During the long-term, high-intensity physical activities, VO_2 max has an important place among determining factors moving sporting achievements to upper levels [24]. Aerobics based exercises increase VO_2 max. VO_2 max levels vary from person to person. Average rise in VO_2 max changes between 11-56% together with exercise [25]. In a study on athletes, VO_2 max values were reported as 50,3 ml/kg/min in women and 61,8 ml/kg/min in men [26].

In this study, experimental group maintained cardiopulmonary exercise test for a longer time and reached a greater workload and higher VO_2 max level than sedentary group. At the level of anaerobic threshold, the experimental group reached anaerobic threshold point later. In other words, it could be said that aerobic capacity of the experimental group developed more than the control group.

It is stated that increase in lactate is associated with decrease in the strength [27]. The increasing level of lactic acid in the blood causes a decrease in pH of the intracellular and extracellular environment and thus causes fatigue. It is reported that muscle lactate concentration increases 14-fold in high-density exercises than the state of relaxation and 1/3 of that is released into the blood. While blood lactate values change between 9-12 mmol/L in untrained individuals, these values can increase up to 12-22 mmol/L in trained individuals [28]. It is reported that the concentration of lactate in plasma increases as a response increasing exercise [29].

Franchini et al [30] express that there is a significant decrease in blood lactate in 15-minute active rest after judo match. Medbo et al [31] specify that 48% of muscle lactate passes into the blood and 52% of it is eliminated in the muscle and converted into glycogen in relaxation period after intense exercise.

In the literature, while there are sources specifying that there are no change in lactate carrying capacity after exercises [32], there are also sources identifying increase in that [33, 34].

In this study, LA scores, which are similar at rest in both groups, increased significantly at the end of cardiopulmonary exercise test and decreased significantly 5 min after the application. These rises and falls were similar in both groups, $F(2.24) = 2.942$ $p = .072$, $\eta^2 = 0.197$, (Figure 1). Also, there was no difference between the groups in terms of general changes, $F(1.12) = 2.864$ $p = .116$, $\eta^2 = 0.193$.

It was detected that blood lactate value was higher than previous lactate value in experimental and control group together with increasing exercise intensity after cardiopulmonary exercise test. Decrease was observed in both groups 5-min after exercise. This result can be accepted a finding showing that resting accelerates passage of intramuscular lactate into the blood and lactate is eliminated in other tissues. Results are similar in both groups. The fact that the experimental group can maintain more workload and test than control group despite increased lactate level can be considered as a reflection of compliance to regular training.

Measurement of body composition plays a role in making important decisions related to health in clinical sciences [35]. Some studies have found decreases in BF% and BMI values as a result of the exercise [36, 37]. In this study, it is seen that swimmers have lower BF% and BMI values than sedentaries. It is thought that this situation is resulted by the regular training and exercise.

In the study applied on athletes, a significant result was obtained with decrease from 71.56 ± 2.67 beats/min to 69.42 ± 2.87 beats/min in terms of HR_{rest} values as a result of aerobic training program for 6 weeks [38]. In the subjects subjected to 12-week aerobic training program, significant differences between pre-test and post-test were obtained in DBP values [39]. In another study, it was reported that regular exercise had the positive effects on SBP and DBP values [40].

As a result of statistical analysis of this study, while there was no significant difference in SBP values of the experimental and control group $p > 0.05$, a significant difference was found in DBP values $p < 0.05$. Lower SBP and DBP values in the experimental group than control group is thought to be resulted from increase in pressure riding the blood vessels as result of regular exercise. No significant difference was found between HR_{rest} and HR_{max} values of the experimental and control groups ($p > 0.05$). However, it was found that HR_{rest} was lower and HR_{max} is higher in the experimental group than the control group. This situation is thought to be due to hypertrophy occurring in left ventricle of the heart as a result of regular exercise. The results of the study results are in line with the literature.

CONCLUSION

In this study, it is concluded that aerobic endurance, anaerobic endurance and lactate concentration were better in people who exercise regularly according to the results of cardiopulmonary exercise test applied to swimmers and sedentaries. It can be said that physiological parameters measured during the exercise test provide support to sports scientists dealing with swimming, coaches and athletes on the subjects of preparation of the training program, adaptation to training, workload, type and duration of exercise. Regular aerobic exercises can be recommended for sedentary individuals for quality of life and health.

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