EFFECTS OF TWO MONTHS TRAINING ON BLOOD LACTATE LEVELS IN ADOLESCENT SWIMMERS

Accepted for publication 27.06.2008

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ABSTRACT: The aim of this study is to examine the effects of two months swimming training on aerobic and anaerobic capacities with blood lactate. A total of 17 adolescent male swimmers (15.17±0.81 years) were included in the study. The first measurement was conducted 1.5 months after the beginning of the season and this was followed by a second measurement conducted two months after the first measurement. A test protocol of 8x100 m crawl style was applied in the measurements and the subjects swam from slow to fast at five different swimming workloads. Between each training run, blood samples were provided from the earlobes of the subjects in order to measure the amount of blood lactate. Heart rate was measured after five swims. Furthermore, swimming styles and duration were recorded in order to calculate the swimming speed of each subject at each swimming workload. The comparison of blood lactate and speed values of all subjects before and after the training season revealed that lactate acid values had not changed significantly ($p>0.05$) at the lowest swimming workload (75%) and that the speed had significantly increased ($p<0.01$). As for the rest of the swimming workloads, both lactate acid and speed increased significantly ($p<0.05$ and $p<0.01$). Our two month training programme dwelt heavily upon anaerobic training and accordingly aerobic capacity decreased and anaerobic capacity increased at higher speeds. On the other hand, in our study, we found out that anaerobic capacity had not increased only at the 75% workload and that it had decreased at the rest of the workloads.

KEY WORDS: swimming, blood lactate, training

INTRODUCTION

Swimming training varies greatly in content and quality for different age groups. Accordingly, swimming workloads and content are different for each age group. Total energy consumption, blood lactate (BL) and heart rate (HR), all of which constitute the metabolic data of the performance, differ with the swimming distance and workload. The appropriateness of the training to the age group of the swimmers is one of the bases of the field of sports training [17].

The measurement of blood lactate (lactic acid) concentrations has frequently been employed for detecting performance and controlling training. The measurement of blood lactate concentrations is a standard procedure for determining the intensity of physical exertion [11,18,25,26]. Besides the application of the characteristics of the lactate increase, the application value of the lactate concentration is used in certain groups of subjects to objectively estimate the intensity of [14,15,19,26,30] or as a criterion of maximum exhaustion. For more than two decades numerous investigations have dealt with threshold concepts that are based on the BL concentration to evaluate physiological performance capacity [3,6,7,8,33].

Numerous studies have employed the relationship between blood lactate concentrations and swimming speed in order to set the optimal training workload for swimming race and training sessions and to evaluate the adaptation level of the swimmers to the training [17,23,28]. Commencement of BL accumulation and anaerobic threshold are important indicators of performance and exact training workload [1]. The prerequisites for a high level of success in sports are to tolerate high levels of BL and to endure muscle soreness. BL measurement is a proper parameter in detecting the effect of training, calculating the workload and in preventing overtraining [29].

There are many test protocols pertaining to swimming which depend on blood lactate and swimming speed measurements. [20,27,32]. Setting the exact workload required for a training session is one of the most common problems faced by trainers [9]. Trainers use many test protocols to set the training workload and to detect the adaptation level to the training programmes [2,17]. The metabolic demands have been found to differ between the physical loads of varying durations. This causes different values of total energy consumption, blood lactate, and HR between different competitive swimming distances. The differences between test protocols must be known well before training planning. [17].

The purpose of this study was to determine the effects of two months training on blood lactate levels in adolescent swimmers.

MATERIALS AND METHODS

Participants. Seventeen adolescent male swimmers (age, 15.2±0.8 years) volunteered to participate in this study. Subjects were short distance (100 m) swimmers and had been training for 4-6 years. All swimmers were fully informed about the demands and procedures of the study. Prior to testing, written informed consent was obtained from the swimmers and their parents. The study was approved by the university ethics committee.

Test Protocol and Blood Lactate. Test protocol of 8x100 m distance was used in a 25-m pool, because subjects were short distance swimmers. Pre- and posttests were applied to participants before and after the two month training period.

TABLE 1. THE PHYSICAL AND PERFORMANCE CHARACTERISTICS OF THE SUBJECTS (N=17)

Parameters	Mean ±SD	Minimum	Maximum
Swimmer Age (years)	15.17 ± 0.81	14.00	16.00
Training Experience (years)	4.79 ± 0.638	4.00	6.00
Height (cm)	161.17 ± 6.68	151.00	176.00
Weight (kg)	50.47 ± 8.02	42.00	73.00
BT resting HR (beats/min)	91.41 ± 9.27	64.00	100.00
AT resting HR (beats/min)	91.52 ± 10.28	60.00	104.00
BT optimum 100 m time (s)	70.00 ± 3.64	63.00	76.00
AT optimum 100 m time (s)	68.23 ± 4.04	60.00	75.00
BT resting BL (Mmol/L)	1.368 ± 0.266	1.10	2.00
AT resting BL (Mmol/L)	1.394 ± 0.194	1.13	1.87

Legend: BT - before training, AT - after training, BL - blood lactate

Two days before testing, the participants performed a 100 m swim at their maximum speed using the front crawl stroke. The training loads were determined by the results of 100 m swimming performance as the participants swam 100 m at 75, 85, 90, 95 and 95% of maximum speed for the distance (as determined previously). Resting blood lactate values were obtained prior to the warm-up of each testing session.

For the first test, subjects performed a swimming session of 100 m, three times at 75% workload with one minute rest intervals. Then, they rested for three minutes after the third set and blood samples were drawn at the 2nd and 3rd minutes of this resting period.

At the second test, subjects performed a swimming session of 100 m, two times at 85% workload with one minute rest intervals. They rested for four minutes after the final set. Blood samples were drawn at the 3rd and 4th minutes of this period.

At the third test, subjects performed a swimming session of 100 m, one time at 90% workload and rested for six minutes. Blood samples were drawn between the 4th and 5th minutes of this resting period.

At the fourth test, subjects performed a swimming session of 100 m, one time at 95% workload, and then rested for 25 minutes. Blood samples were drawn between the 5th and 6th minutes of this period. At the fifth test, subjects performed swimming session, 100 m, one time at 100% workload, then rested for 25 minutes. Blood samples were drawn between the 5th and 6th minutes of this period.

The blood samples were obtained from each participant's earlobe capillary bed. The tips of the earlobes were pierced with Softclix. Blood was collected through a 25 μL capillary tube, transferred to YSI 1500 Sport Lactate Analyzer (Yellow Springs Instrument Inc., Ohio, USA). Analysis of blood lactate (lactic acid) concentration was performed with Lactate Analyzer in Mmol/L.

Heart rates were measured over the carotid artery for 15 seconds at the end of each set of swimming. In addition, swimming speeds were calculated in m/s by recording swimming times.

TABLE 2. THE COMPARISON OF SWIMMING SPEED DATA PROVIDED AT THE END OF 75% WORKLOAD (1st SWIM) BEFORE TRAINING AND AFTER TRAINING

Parameters	Mean ± SD	SE	t	p
BT resting BL (Mmol/L)	1.368 ± 0.266	0.064	-0.745	0.467
AT resting BL (Mmol/L)	1.394 ± 0.194	0.470		
BT BL after 1st swim (Mmol/L)	3.041 ± 0.616	0.149	-1.611	0.127
AT BL after 1st swim (Mmol/L)	3.258 ± 0.625	0.151		
BT resting HR (beats/min)	91.41 ± 9.26	2.247	-0.129	0.899
AT resting HR (beats/min)	91.52 ± 10.28	2.494		
BT HR after 1st swim (beats/min)	142.58 ± 8.82	2.140	-1.705	0.108
AT HR after 1st swim (beats/min)	144.70 ± 10.22	2.479		
BT 1st swim speed (m/s)	1.141 ± 0.060	0.014	-8.868	0.000*
AT 1st swim speed (m/s)	1.174 ± 0.071	0.017		
BT 1st swim duration (s)	87.41 ± 4.56	1.108	12.505	0.000*
AT 1st swim duration (s)	85.00 ± 4.91	1.191		

Legend: SD - Standard Deviation, SE - Standard Error, BT - before training, AT - after training, BL - blood lactate

Training Program. The training programme swimmers completed a 10 weeks was as follows.

Anaerobic capacity developing training (3.5 weeks)

a) Anaerobic threshold training (2-4 Mmol//L) 60%

b) Lactic acid (BL) tolerating training (6-8 Mmol//L) 25%

c) Speed training (over 8 Mmol//L) 15%

Loads at training sessions were applied at speeds that increase blood lactate level up to 4 Mmol/L or higher.

Lactic acid and speed training (3.5 weeks)

a) MaxBL, speed development trainings (over 8 Mmol//L) 50%

b) Aerobic endurance (2-4 Mmol//L) 20%

c) Explosive power training (over 8 Mmol//L) 30%

At that time, high-speed and multi-set, short distance training was applied.

Preparation phase before competition (2 weeks)

a) BL, speed development, explosive power training (over 4 Mmol/L) 70%

b) Anaerobic threshold training (2-4 Mmol/L) 20%

c) Technical development training (loading up to 2 Mmol/L) 10%

Competition week (peaking phase) (1 week)

a) Mental preparation and technical training 50%

b) Speed training (over 8 Mmol/L) 40%

c) Anaerobic threshold training (2-4 Mmol/L) 10%

At this phase, mental and technical training were at high percentage and short distance repetitive speed trainings was done by the swimmers.

Main BL levels for the training above are given as

1: Technical capacity development workouts and basic endurance workouts (loading up to 2 Mmol/L)

2: Anaerobic threshold training (threshold training between 2-4 Mmol/L)

3: Max VO2 training (loading above 4 Mmol/L and maximum)

4: BL tolerating training (training between 6-8 Mmol/L)

5: Max lactate, speed development training (training above 8 Mmol/L)

Statistical Analysis. Standard statistical methods were used for the calculation of means and standard deviations (SD). Pre- and post training values for all variables were analyzed for significance using paired samples t-tests for each dependent variable. Significance for all analyses was set at $p<0.05$.

RESULTS

The subjects swam at five different workloads which increased progressively throughout the measurements. The workloads were adjusted by the best swimming times for 100 m, which corresponded to 75%, 85%, 90%, 95% and 100% respectively. These workloads are represented as 1st swim, 2nd swim, 3rd swim, 4th swim and 5th swim on the tables and figures (1-2) below.

The age, height, weight, heart rate (HR) at pre-training and post-training, 100 m swimming times and resting BL values are presented in Table 1.

At the 75% workload, subjects produced 3.04±0.61 Mmol/L BL at a speed of 1.14±0.06 m/s before training and 3.25±0.62 Mmol/L

TABLE 3. THE COMPARISON OF SWIMMING SPEED DATA PROVIDED AT THE END OF 85% WORKLOAD (2nd SWIM) BEFORE TRAINING AND AFTER TRAINING

Parameters	Mean ± SD	SE	t	p
BT BL after 2nd swim (Mmol/L)	4.09 ± 0.62	0.151	-2.492	0.024**
AT BL after 2nd swim (Mmol/L)	4.55 ± 1.00	0.243		
BT HR after 2nd swim (beats/min)	155.53 ± 11.12	2.69	-5.892	0.000*
AT HR after 2nd swim (beats/min)	159.29 ± 10.88	2.63		
BT 2nd swim speed (m/s)	1.241 ± 0.064	0.015	-9.350	0.000*
AT 2nd swimming speed (m/s)	1.271 ± 0.072	0.018		
BT 2nd swimming duration (s)	142.58 ± 8.82	2.140	-1.705	0.108
AT 2nd swimming duration (s)	144.70 ± 10.22	2.479		

Legend: SD - Standard Deviation, SE - Standard Error, BT - before training, AT - after training, BL - blood lactate

TABLE 4. THE COMPARISON OF SWIMMING SPEED DATA PROVIDED AT THE END OF 90% WORKLOAD (3rd SWIM) BEFORE TRAINING AND AFTER TRAINING

Parameters	Mean ± SD	SE	t	p
BT BL after 3rd swim (Mmol/L)	5.43 ± 1.11	0.269	-.5.606	0.000*
AT BL after 3rd swim (Mmol/L)	6.21 ± 1.27	0.307		
BT HR after 3rd swim (beats/min)	168.00 ± 8.25	2.000	-4.854	0.000*
AT HR after 3rd swim (beats/min)	172.23 ± 7.93	1.924		
BT 3rd swim speed (m/s)	1.300 ± 0.075	0.018	-6.166	0.000*
AT 3rd swim speed (m/s)	1.330 ± 0.084	0.020		
BT 3rd swim duration (s)	76.90 ± 4.37	1.058	-6.368	0.000*
AT 3rd swim duration (s)	75.05 ± 4.71	1.142		

Legend: SD - Standard Deviation, SE - Standard Error, BT - before training, AT - after training, BL - blood lactate

TABLE 5. THE COMPARISON OF SWIMMING SPEED DATA PROVIDED AT THE END OF 95% WORKLOAD (4th SWIM) BEFORE TRAINING AND AFTER TRAINING

Parameters	Mean ± SD	SE	t	p
BT BL after 4th swim (Mmol/L)	7.082 ± 1.117	0.270	-3.689	0.002*
AT BL after 4th swim (Mmol/L)	7.776 ± 1.323	0.321		
BT HR after 4th swim (beats/min)	175.76 ± 6.398	1.551	-3.273	0.005*
AT HR after 4th swim (beats/min)	179.29 ± 6.361	1.542		
BT 4th swim speed (m/s)	1.357 ± 0.077	0.018	-10.202	0.000*
AT 4th swim speed (m/s)	1.401 ± 0.087	0.021		
BT 4th swim duration (s)	73.64 ± 4.182	1.014	-11.426	0.000*
AT 4th swim duration (s)	71.23 ± 4.279	1.038		

Legend: SD - Standard Deviation, SE - Standard Error, BT - before training, AT - after training, BL - blood lactate

TABLE 6. THE COMPARISON OF SWIMMING SPEED DATA PROVIDED AT THE END OF 100% WORKLOAD (5th SWIM) BEFORE TRAINING AND AFTER TRAINING

Parameters	Mean ± SD	SE	t	p
BT BL after 5th swim (Mmol/L)	8.223 ± 0.854	0.207	-.4.593	0.000*
AT BL after 5th swim (Mmol/L)	8.776 ± 0.932	0.226		
BT HR after 5th swim (beats/min)	180.70 ± 6.516	1.580	-4.642	0.000*
AT HR after 5th swim (beats/min)	185.17 ± 6.747	1.636		
BT 5th swim speed (m/s)	1.425 ± 0.075	0.018	-9.291	0.000*
AT 5th swim speed (m/s)	1.460 ± 0.087	0.021		
BT 5th swim duration (s)	70.00 ± 3.640	0.882	-10.954	0.000*
AT 5th swim duration (s)	68.23 ± 4.039	0.979		

Legend: SD - Standard Deviation, SE - Standard Error, BT - before training, AT - after training, BL - blood lactate

BL at a speed of 1.17±0.07 m/s after training. The increase in speed was statistically significant ($p<0.01$) but that of BL was not statistically significant ($p>0.05$) (Table 2). At the 85% workload, subjects produced 4.09 Mmol/L BL at a speed of 1.24±0.06 m/s before training and 4.55±1.00 Mmol/L BL at a speed of 1.27±0.07 m/s after training (Table 3). At the 90% workload, subjects produced 5.42±1.11 Mmol/L BL at a speed of 1.30±0.07 m/s before training and 6.20±1.26 Mmol/L BL at a speed of 1.33±0.08 m/s after training (Table 4). At the 95% workload, subjects produced 7.08±1.11 Mmol/L BL at a speed of 1.35±0.07 m/s before training and 7.77±1.32 Mmol/L BL at a speed of 1.40±0.08 m/s after training (Table 5). At the 100% workload, subjects produced 8.22±0.85 Mmol/L BL at a speed of 1.42±0.07 m/s before training and 8.77±0.93 Mmol/L BL at a speed of 1.46±0.08 m/s after training (Table 6). The increases in both speed and BL in all these workloads (Figs. 1-2) were statistically significant ($p<0.01$ and $p<0.05$).

DISCUSSION

Strictly controlled swimming training is a must to examine the relationship between training and performance. An evaluation of the training workload throughout the season requires the classification and recording of each exercise in each training session. This is, of course, a hard task for both the trainer and the researcher. However, the workload of the training can be set with blood lactate (lactic acid) analysis. The absolute value of the lactate concentration is used in certain groups of subjects to objectively estimate the intensity of

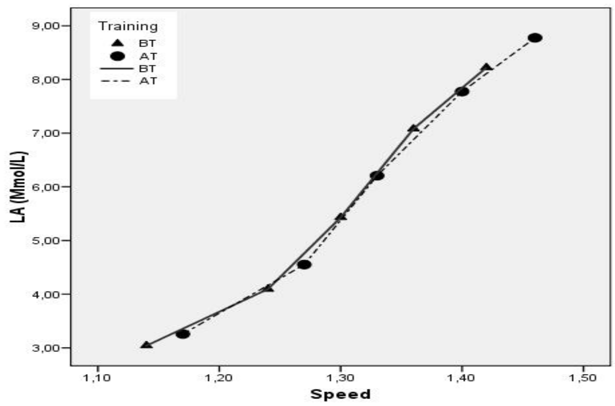

FIG. 1. BEFORE AND AFTER TRAINING MEAN LACTATE ACID -SPEED GRAPH

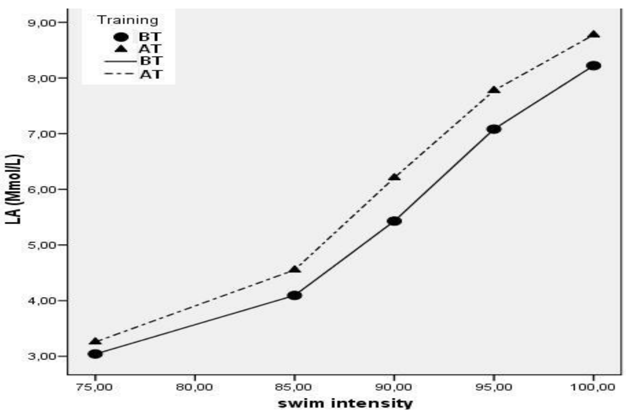

FIG. 2. BEFORE AND AFTER TRAINING MEAN LACTATE ACID -SWIM INTENSITY GRAPH

exercise, or as a criterium of maximum exhaustion [26]. In this study, we conducted BL analyses during swimming sessions, the pace of which increased over time. In the study conducted by Tanaka et al., [31] lactate measurements enabled the researchers to find out running speed at the beginning of the lactate accumulation; thus, the researchers were able to estimate running performance in advance in light of the data provided. In other words, the performance of a person, whether he is a runner or a swimmer, can be found out with lactate measurements.

In our study, the resting BL was 1.368±0.266 Mmol/L before training and 1.394±0.194 Mmol/L after the training. There was not a significant difference between the before training and after training values. Garvin et al. found [13] a 1.14 Mmol/L resting BL value in their study.

Resting HR is a variable which is evaluated in conjunction with the performance of the athlete. If the athlete has a high level of aerobic endurance, then the resting HR is likely to be lower than those of the untrained group. A low HR is closely related with the efficient and economic performance of the athlete's heart. We found a resting HR of 91.411±0.267 beats/min before training and 91.529±10.284 beats/min after training in our study and the difference between these values was not significant. However, our subjects underwent anaerobic training and thus, we did not observe a significant change in resting HR.

In the study conducted by Quirion et al. [24], five female speed skaters trained on bicycle ergometry under different temperatures (0°C, 20°C) for maximal loading. The anaerobic threshold was 4 Mmol/L in this study. The threshold of 4 millimoles of lactic acid indicates that the anaerobic and aerobic systems contributed equally to the resynthesis of ATP [4]. In this study we accepted an anaerobic threshold level of 4 Mmol/L. Thus, at the workloads under anaerobic threshold decrease contribution of anaerobic energy (75% and 85% swimming workloads), over anaerobic threshold increase contribution of anaerobic energy (90%, 95% and 100% swimming workloads).

At the 75% workload, there was no significant difference between the before and after training BL values. Speed, on the other hand, was 1.141±0.060 m/s before training and 1.174±0.071 m/s after training and this difference was significant. The increase in speed, without a significant increase in BL amounts, indicated that there was an improvement in aerobic capacity. At this workload, swimming durations were 87.411±4.569 s before training and 85.000±4.911s after training, which showed that the swimmers produced a similar BL but swam the same distance 2.5 seconds faster. There was a slight increase in HR.

At the 85% workload, both BL and speed values increased significantly. Before the training, anaerobic threshold had corresponded to 85% workload (4.094±0.624 Mmol/L) but after training it corresponded to a lower workload because the BL amount was 4.552±1.001 Mmol/L after swimming at the 85% workload after the training. Namely, subjects reached the anaerobic threshold at a lower speed after the training. This indicated a loss in aerobic capacity at the 85% workload whereas we had observed an improvement in aerobic capacity at the 75% workload and a regression with the increasing speeds at the same workload. This indicated that there was an improvement in the anaerobic capacity. We reached such a result because the two month training programme had been designed to improve the anaerobic capacity. However, in our study we found out that aerobic capacity had increased only at the 75% workload and that it had decreased at the rest of the workloads.

HR can not be used in order to find the anaerobic threshold; however, it can adjust the intensity of the activity below or above the threshold but this requires individual information on HR-anaerobic threshold relationship. Namely, the workload of the training can be controlled with HR [10]. In this study, we observed that BL and HR had increased simultaneously at the anaerobic threshold intensity workload. HR was 155.529±11.125 beats/min before the training but it increased to reach a mean level of 159.294±10.884 beats/min after the training. However, Hurley et al. applied 12 weeks training on sedentary subjects and observed that VO2 maximum, which corresponded to 2 Mmol/L BL (aerobic threshold), increased significantly (39%) while the heart rates decreased without any significance (2.4%) [16]. Saltin et al. [27] applied 8-10 weeks training on sedentary middle-aged and elderly males and reported that strength, which corresponded to 4.0 Mmol/L (anaerobic threshold), increased (13%) while HR had an insignificant decrease (3.8%) [12]. In this way, intensive training sessions could be responsible for increasing the endurance performance of subjects. But subjects in our study had more anaerobic-type training.

Reilly and Secher reported that energy requirement in certain sports such as wrestling, boxing, judo, taekwondo and synchronized swimming depends on anaerobic energy up to 70% [24]. In our study, 90%, 95%, 100% workloads experienced an increase in anaerobic capacity. At all these workloads, both speed ($p<0.01$) and BL value increased significantly ($p<0.01$). In our study, the subjects swam 100 m at maximum speed with a mean duration of 70.000±3.640 s before training and with 68.235±4.039 s after training. Maximum speed was 1.425±0.075 m/s before training and 1.460±0.087 m/s after training. There was a significant difference at duration and speed between the two periods.

The study conducted by Bonifazi et al. [5] (age; 15-26 years) revealed that swimming speed (freestyle) was 2.139±0.043 m/s and BL was 10.40±2.59 Mmol/L in males and that swimming speed was 1.718 m/s and BL was 9.95±1.68 Mmol/s in females. Olbrecht et al. applied a 2x200 m free style testing protocol on 59 male swimmers of the German National Team and found a lactate value of 5 Mmol/L at 1.25m/s-1.30m/s. speeds. These researchers reported that there was a lactate accumulation of 13 Mmol/L at 1.45 m/s-1.50 m/s speeds after the second 200 m [22].

We detected a maximum BL of 8.223±0.854 Mmol/L before training and 8.776±0.932 Mmol/L after training. There was a significant difference between the two values. In the study of

Garvin et al. [13] maximum LA was 8.22 Mmol/L 3-5 minutes after training. Avlonitou et al. [2] had 10 male swimmers (age 15.3±3.4) in their study and measured the highest BL concentration as 8.0±1.8 Mmol/L. The results of the above studies support our findings.

Sharp et al. (1984) found the maximal BL value of the college swimmers as 11.76±0.87 Mmol/L with the 2x200 m protocol. This LA value is higher than that of this study. However, LA increases as the distance decreases [2]. The maximal BL concentration in our study was lower than those of some studies. This difference can be explained by the fact that the mean ages in these studies were higher than that of our study or by the nature of the training. Of all the studies on this subject, the highest BL value (25.7 mol/L) was found by Sawka et al. [28], who acquired this value after 200 m swimming of mixed style.

We measured the maximum HR as 180.705±6.516 beat/min before training and 185.176±6.747 beat/min. after training. HR significantly increased after training. In our study, both HR and LA increased as the speed increased at all swimming workloads, except for the 75% workload. There was no significant increase in HR and BL values during the first two workloads examined in the study by Arabas et al as well. This confirms the occurrence of oxygen transfer and usage during swimming sessions with a workload of less than 80% [1].

Medbo and Burgers applied a two minute exercise at the 116% of VO_2max or a 30 second exercise at the 165% of VO2max for six weeks and eventually found a 10% increase in anaerobic capacity an also reported that supramaximal training improved anaerobic metabolism [21]. The results of different studies have suggested the inclusion of high intensity anaerobic training into the training programmes of short distance swimmers.

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