Effect of Twelve-Week hypoxic interval training on lung volumes and records of elite swimmers in 50 and 100 meters breaststroke

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Original Article

Abstract

Introduction: Holding the breath during exercise causes hypoxia. This study set out to investigate the effect of the 12-week hypoxic interval training on lung volume and records of elite swimmers in 50 and 100 meters breaststroke.

Methods: In this quasi-experimental study, 22 male swimmers were randomly divided into the hypoxic interval training group (n: 13; age: 16.61±1.39 years; height: 177.92±1.94 cm; weight 70.17±3.55kg) and normal training group (n: 9; age: 16.67±1.16 years; height: 176.33±5.24cm; weight 67.83±4.24kg). The hypoxic interval training program included 3-8 sets of 25-200 m breaststroke and the butterfly (breathing every 4-6 strokes), six-time per week for 12 weeks. The normal training routine performed without breath-holding (breathing every 2 strokes). The FIVC, FEV1, FVC, and FIV1 parameters, as well as records in 50m and 100m swimming were measured pre- and post-training. The obtained data was analyzed with ANCOVA ($P<0.05$).

Results: Swimmers' records in both 50 m and 100 m swimming scenarios significantly decreased after the application of the hypoxic interval training program. The FIVC, FEV1, FVC, and FIV1 parameters significantly increased only after the hypoxic training ($P<0.05$); in addition, the post-training values of these variables were significantly higher in the experimental group than the control group ($P<0.05$). However, no significant change was observed in the values of these variables in the normal training group (control).

Conclusion: It seems that the 12-week hypoxic interval training program can increase the lung volume and improve the records of the elite swimmers in 50m and 100m breaststroke.

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Introduction:

Athletes and coaches always look for the best training method to improve fitness and athletic performance to win and obtain better results in sport competitions. To this end, the elite international swimmers use different hybrid training techniques (sprint, interval, endurance, etc.). Controlled frequency breathing is a training technique used by swimmers in an effort to simulate high-intensity workloads by limiting oxygen availability to the body and stimulating anaerobic metabolism (1).

Some studies suggest that reducing oxygen availability to muscle tissues during an exercise training course is a suitable technique for improving swimmers' performance (2). In other words, reduced-breathing exercise results in adaptation of muscle tissues to hypoxia and thus the improvement of athletic performance. When hypoxia is applied to swimming, swimmers breathe every 4-6 strokes, instead of every stroke, to reduce oxygen available for delivery to tissues. In this way, swimmer's anaerobic or aerobic performance is improved (3).

Accordingly, hypoxic training is the most frequently used method among the elite international swimmers (4). It seems that such training patterns (e.g. altitude training) can positively affect the speed and record of swimmers. According to the reports, those swimming above sea level (hypobarometric training) have better records than those swimming at the sea level (5). In addition, chemical adaptations made by hypoxic (low oxygen) training may positively affect the performance and records of the swimmers.

On the other hand, optimal athletic performance is connected to efficiency of respiratory system. In other words, the improvement of respiratory performance is an important factor in athletic preparation and success, specifically in swimming. According to the evidence, hypoxic training not only improves the efficacy and performance of respiratory muscles, but also leads to an increased lung capacity. In line with this, previous studies have reported the improvement of the total lung capacity (TLC), viral capacity (VC), and inspiratory reserve volume (IRV), along with the reduction of reserve volume after endurance training (6). It has also been reported that the improvement of respiratory muscles through training increases the tidal volume and decreases respiratory rate, resulting in the reduction of oxygen consumption during physical activity and the improvement of athletic performance in competitions (6,7). Currently, Lavin et al. (2013) have suggested that a 12-session hypoxic training (such as controlled-frequency breath) improves swimming performance and running economy (8).

In addition, Sicharakis et al. (2011) reported that the records of national and international elite swimmers in 25m breaststroke showed a greater improvement under breath-holding than breathing scenarios (9). Accordingly, the question is whether hypoxic training (holding the breath during athletic activity) causes a greater increase in lung volume and improvement of records in 50m and 100m breaststroke in the long-term, as compare to normal training (i.e. without breath-holding).

Methods:

In this quasi-experimental study, 22 young male medalists (in national and league competitions), with 7-10 years history of swimming exercise, were voluntarily and purposively selected from all professional swimmers in Tehran. They were then included into the study after completing demographic questionnaire (personal, medical and athletic information), filling the consent form, and receiving full information about the research procedure. In addition, they were examined by a physician in terms of clinical and physical health before the initiation of the research project. Subjects were randomly divided into the hypoxic interval training group (n: 13; age: 16.61±1.39 years; height: 177.92±1.94 cm; weight 70.17±3.55 kg) and normal training group (n: 9; age: 16.67±1.16 years; height: 176.33±5.24 cm; weight 67.83±4.24kg). They were then homogenized on the basis of characteristics and degree of initial fitness. The hypoxic interval training program included 3-8 sets of 25-200m breaststroke (breathing every 4-6 strokes with resting interval of 2-3 minutes between each set), six-time per week for 12 weeks (details are presented in Table 1).

The research site was Shahid Shiroudi Sport Complex. The normal training routine was similar to the hypoxic interval training, except that in the latter the swimmer breathed in every 4-6 strokes during breaststroke or the butterfly (Table 1).

The inclusion criteria were: (i) no history of disease, infection, and injury in the preceding month, (ii) following an uninterrupted weekly swimming workout for 7-10 years, (iii) not being on hypoxic training regimen in the preceding year, (iv) participating in the league and national competitions, and (v) being a medalist. In addition, subjects were recommended to avoid any type of performance-enhancing substance such as vitamins and dietary supplements, and drugs, as well as cigarette and alcohol during and 1 week prior to the training course. They were also asked not to participate in any type of heavy swimming activity. All of these exclusion criteria have been mentioned in the research agreement.

The forced vital capacity (CVC), forced expiratory volume in 1sec (FEV1), FEV1/FVC, forced inspiratory vital capacity (FIVC), Forced inspiratory volume in 1sec (FIVC1), and FIV1/FIVC were measured by a pulmonologist in Besat Hospital of Nahaja, using a MIT III spectrometry (made in Italy). In addition, their records in 50m and 100m were measured and recorded at the same pool (Shahid Shiroudi) and the same time of the day (9:00 AM). The mean records in 50m and 100 m were taken as the base records.

The obtained data were analyzed with ANCOVA, using SPSS 19. In addition, $P<0.05$ was considered statistically significant.

Results:

Results of the present study showed that the records in both 50 m and 10 m breaststroke of the elite young swimmers significantly improved after 12-week hypoxic training ($P<0.05$). These improvements was statistically higher in the hypoxic training group than the normal training group ($P<0.05$).

According to Table 2, the normal training group's record in 50 m did not change ($P=0.155$), but this record significantly increased in 100m ($P=0.034$).

Moreover, the FVC, FECV1, FIVC, and FIV1 parameters significantly increased only in the hypoxic training group after the program ($P<0.05$). In comparison, post-training increase in these variables was significantly higher in the test group than the control group ($P<0.05$). However, no significant change was observed in the value of these variables in the normal training group (control). According to Table 3, the FEV1/FVC and FIV1/FIVC values did not significantly change in both groups ($P>0.05$).

Table 1. Pulmonary indices of elite male swimmers before and after 12-week hypoxic and normal training

Type of Training	Daily routine in the first quarter#			The second quarter#			The third auarter#		
	Meter×Set	Rest (minute)	Breathing *	Meter×Set	Rest (minute)	Breathing*	Meter×Set	Rest (minute)	Breathing*
Hypoxic interval n=13	3×200 breasttstroke	3	4 to 1	4×200 breasttstroke	3	5 to 1	6×200 breasttstroke	3	6 to 1
	4×100 breasttstroke	2	4 to 1	5×100 breasttstroke	2	5 to 1	7×100 breasttstroke	2	6 to 1
	6×50 breasttstroke	2.30	4 to 1	7×50 breasttstroke	2.30	5 to 1	8×50 breasttstroke	2.30	6 to 1
	8×25 butterfly	1.30	2 to 1	10×25 butterfly	1.30	3 to 1	12×25 butterfly	1.30	3 to 1
Normal n=19	Similar$		2 to 1 breaststroke 1 to 1 the butterfly	Similar		2 to 1 breaststroke 1 to 1 the butterfly	Similar		2 to 1 breaststroke 1 to 1 the butterfly

* stroke to breathing, # 6 sessions per week, $ similarity with hypoxic interval training in the number of sets and rest periods, except in breathing technique

Table 2. Records of elite male swimmers in 50 and 100 m breaststroke before and after the hypoxic and normal training

Group Record	Test group (n=13; hypoxic training)		Control group (n=9; normal training)		P-value	
	Before	After	Before	After	Before	After
50 m/s	27.19±0.89	26.46±0.8*#	27.37±0.54	27.4±0.53	<0.0001	=0.01
100 m/s	58.50±0.64	57.89±0.57*#	58.53±0.65	58.64±0.65	<0.0001	=0.01 and =0.01

* Significant difference with pre-test, # significant difference with post-test of control group

Table 3. Pulmonary indices of elite male swimmers before and after 12-week hypoxic and normal training

Group / Variable	Test group (n=13; hypoxic training)		Control group (n=9; normal training)		P-value	
	Before	Dimension	Before	Dimension	Intergroup*	Intragroup#
FVC (Liter)	4.93±0.9	5.95±0.97*#	4.65±0.61	4.82±0.48	<0.0001	=0.005
FEV1 (Liter)	4.41±0.97	5.46±0.81*#	4.3±0.46	4.3±0.51	<0.0001	=0.001
FEV1/FVC (%)	88.26±10.38	89.86±8.74	89.57±7.02	90.24±8.91	=0.461	=0.921
FIVC (Liter)	4.69±0.96	5.75±1.01*#	4.51±0.48	4.69±0.46	<0.0001	=0.009
FIV1 (Liter)	4.57±1.12	5.83±0.9*#	4.0±1.17	4.25±1.04	<0.0001	=0.001
FiV1/FiVC (%)	97±77±5.78	98.55±2.83	93.68±8.35	94.97±8.03	=0.643	=0.133

* Significant difference with pre-test, # significant difference with post-test of control group

Conclusion:

According to the results, the elite swimmers' records in 50 m and 100 m decreased by 73 ms and 61 ms after the 12-week hypoxic training program; whereas, the normal training program did not improve the swimmers' record in 50m, but did in 100m by 11 ms. It seems that in long term, the hypoxic and breath-holding trainings can result in such adaptations as an increase in the energy stored as creatine phosphate, adenosine triphosphate, and lycogen (that is, anaerobic metabolism) in the muscles, as well as buffer capacity of them (10).

Another finding of the present study was an increase in FVC, FEV1, FIVC, and FIV1 values following the 12-week hypoxic training; whereas, these values did not significantly change after normal (non-hypoxic) training. In addition, post-training values of FEV1/FVC and FIV1/FIVC did not change in both groups. With respect to the hypoxic training, this stability may be due to relatively equal changes in the numerators and denominators of these ratios. The FEV1/FVC ratio, also known as Tiffeneau index, refers to the volume exhaled during the first second (of a forced expiratory maneuver). The FEV1/FVC ratio <80% indicates that there exists an obstructive defect. Several studies have shown that swimming and respiratory muscle training increase lung volume and capacity (11,12). The underlying reason behind why the normal (without breath-holding) training failed in increasing these lung indices in the swimmers may lie in previous maximal adaptations of these swimmers to such workouts. Subjects in both groups were professional and elite swimmers who were on normal training routines for several years: however, they did not undergo hypoxic or breath-holding training in the preceding year. In line with this finding, a study (2009) reported that a 3-month breath-holding training program for swimming increased the FVC and FEV1 ratios in male swimmers; in addition, breath-holding training for swimming significantly improved the maximal and submaximal swimming techniques (13).

In general, as compared to normal training (without breath-holding), hypoxic interval training (breath-holding) for swimming leads to an increase in FVC, FEV1, FIVC, and FIV1 values in elite swimmers through the improvement of the respiratory muscles strength and endurance. This, along with some hypoxic training-induced biochemical adaptations (e.g. buffering capacity improvement, oxygen-carrying capacity increase, carbon dioxide sensitivity reduction, acidosis decline, and oxidative stress alleviation) and positive changes in swimming techniques (performing less head, chest, and cervical rotations) improves the swimmers' records in 50 m and 100 m breaststroke.

References:

1. Aspenes S, Kjendlie PL, Hoff J, Helgerud J. Combined strength and endurance training in competitive swimmers. J Sports Sci Med. 2009;1;8(3):357-365.
2. Aspenes ST, Karlsen T. Exercise-training intervention studies in competitive swimming. Sports Med. 2012;42(6):527-543.
3. Altose M, Cherniack N, Fishman AP. Respiratory sensations and dyspnea. J Appl Physiol. 1985;58(4):1051-1054.
4. Truijens MJ, Rodríguez FA. Altitude and hypoxic training in swimming. New York: Nova Science Press; 2010: 393-408.
5. Vallier JM, Chateau P, Guezennec CY. Effects of physical training in a hypobaric chamber on the physical performance of competitive triathletes. Eur J Appl Physiol Occup Physiol. 1996;73(5):471-478.
6. Kippelen P, Caillaud C, Robert E, Connes P, Godard P, Prefaut C. Effect of endurance training on lung function: a one year study. Br J Sports Med. 2005;39(9):617-621.
7. Lucía A, Hoyos J, Pardo J, Chicharro JL. Effects of endurance training on the breathing pattern of professional cyclists. Jpn J Physiol. 2001;51(2):133-141.
8. Lavin KM, Guenette JA, Smoliga JM, Zavorsky GS. Controlled-frequency breath swimming improves swimming performance and running economy. Scand J Med Sci Sports. 2015;25(1):16-24.
9. Psycharakis SG, McCabe C. Shoulder and hip roll differences between breathing and non-breathing conditions in front crawl swimming. J Biomech. 2011;3;44(9):1752-1756.
10. Hoppeler H, Vogt M. Muscle tissue adaptations to hypoxia. J Exp Biol. 2001;204(18):3133-3139.
11. Enright SJ, Unnithan VB, Heward C, Withnall L, Davies DH. Effect of high-intensity inspiratory muscle training on lung volumes, diaphragm thickness, and exercise capacity in subjects who are healthy. Phys Ther. 2006;86(3):345-354.
12. Mickleborough TD, Stager JM, Chatham K, Lindley MR, Ionescu AA. Pulmonary adaptations to swim and inspiratory muscle training. Eur J Appl Physiol. 2008;103(6):635-646.
13. Lemaître F, Seifert L, Polin D, Juge J, Tourny-Chollet C, Chollet D. Apnea training effects on swimming coordination. J Strength Cond Res. 2009;23(6):1909-1914.