Arch. Biol. Sci., Belgrade, 66 (3), 1253-1260, 2014 DOI:10.2298/ABS1403253D

EFFECTS OF THREE WEEKS OF OXYGEN SUPPLEMENTATION ON OXYGEN SATURATION AND RECOVERY PARAMETERS OF ELITE WRESTLERS

BILAL DEMIRHAN

Yasar Dogu Faculty of Sport Sciences, Ondokuz Mayıs University, Samsun, Turkey

Corresponding author: bilaldemirhan55@gmail.com

Abstract - The purpose of this study was to investigate the effects of three weeks of oxygen supplementation on oxygen saturation, lactate level, and heart rate (HR) responses of elite wrestlers. The subjects included fourteen elite male wrestlers, mean age of the experimental group was 19.87±0.35; the mean age of the control group was 19.62±0.51. Both groups had similar height, weight and fitness parameters. Before and after training, the heart rates, lactate levels and oxygen saturation values were recorded. Consistent with our hypothesis, the oxygen saturation (SpO_2) values of the experimental group increased significantly ($p<0.05$) while lactate and heart rate values decreased significantly. When the pre-exercise levels of oxygen saturation were compared, the oxygen supplementation group displayed significant differences in the 2nd and 3rd weeks ($P<0.05$). Pre-training HR and lactate levels in the three weeks did not differ significantly. The experiment group had higher measured SpO_2 values immediately after exercise in the 3rd week ($P<0.05$); HR and lactate levels declined after oxygen supplementation ($P<0.05$). Only in the 2nd and 3rd week, the HR values were lower in favor of the experimental group ($P<0.05$). Our findings indicate that oxygen supplementation does not have a chronic effect in increasing oxygen saturation and reducing HR and lactate values; however, oxygen saturation was found to be effective during the short-term recovery periods.

Key words: oxygen saturation; lactate; recovery; heart rate.

INTRODUCTION

Wrestlers prepare for major championships in a month-long process of hard training. Faster recovery of wrestlers positively affects performance in the next training session. Also, wrestlers' rest period between the matches varies from 15 min to 2 h. Wrestlers who recover faster are more successful in the match. Today, a variety of research is devoted to finding out how to help athletes to recover faster. A portion of this research has focused on ergogenic aids. Oxygen (O_2) supplementation is used as an ergogenic aid in several cases. However, only a few studies have investigated the chronic effect of O_2 supplementation on athletes.

Desaturation of hemoglobin is linked to the decline of the amount of oxygen bound to hemoglobin. Some athletes who are able to carry on exercising at very high intensities experience 'desaturation' of their hemoglobin when they work very strenuously under normoxic conditions. Hemoglobin is responsible for transporting O_2 from the lungs to other parts of the body where other cells use the oxygen. Hemoglobin with attached oxygen is called "oxyhemoglobin". O_2 saturation is defined as the ratio of oxyhemoglobin to the total concentration of hemoglobin present in the blood. The normal O_2 saturation level (SpO_2) is 95-100% for an average adult (Booker, 2008). Hyperoxia enhances the level of arterial hemoglobin saturation (SaO_2) as well as the amount of O_2 dissolved in the plasma (Powers et al., 1993; Peltonen et al., 1997). Hyperoxia is attributed to this elevation in O_2 uptake and subsequent aerobic ATP production, in combination with reduced accumulation of lactate in skeletal muscle and blood, which helps to maintain the normal contractile properties of muscles by reducing metabolic acidosis (Linossier et al., 2000). It is clear that increased availability of O_2 decreases pulmonary ventilation (the movement of air in and out of the lungs), and thus reduces the muscular work vital for breathing (Wilson and Welch, 1980), an effect that could lead to a significant improvement in athletic performance (Welch et al., 1977). In theory, these accomplished athletes might benefit from breathing in a high-O_2 gas mixture as they train at very high intensities. Under these conditions, it is less likely that their hemoglobin will become desaturated with O_2. Therefore, O_2 could be supplied at higher rates to working muscles (Powers et al., 1989). Thus, the maximal rate of O_2 consumption can increase by 2-5% when athletes exercise in a hyperoxic environment; their performance can improve up to 40% by breathing pure 100% O_2 instead of the 21% of O_2 normally present in air (Powers and Howley, 1996).

While the physiological benefits of inhaling oxygen-enriched air during exercise are well-documented (Moore et al., 1992; Wilson et al., 1980), there are only a few studies about exposure to oxygen-enriched air during recovery. In addition, in many sports, the practical question is whether the breathing of supplemented O_2 during recovery from vigorous exercise hastens recovery or enhances subsequent performance. There are limited studies providing evidence that breathing O_2 during recovery enhances subsequent performance. Wrestling is a combat sport that has short rest intervals between matches and wrestlers need to recover before the upcoming match. In addition, wrestlers must perform efficiently in their training and rest intervals. Therefore, it is important to bring lactate, heart rate and O_2 saturation to normal levels. Thus, the purpose of this study was to investigate the effects of 3 weeks of O_2 supplementation after each wrestling session on O_2 saturation, lactate levels and HR. It was expected that O_2 saturation would positively affect the recovery and performance of wrestlers.

MATERIALS AND METHODS

Subjects

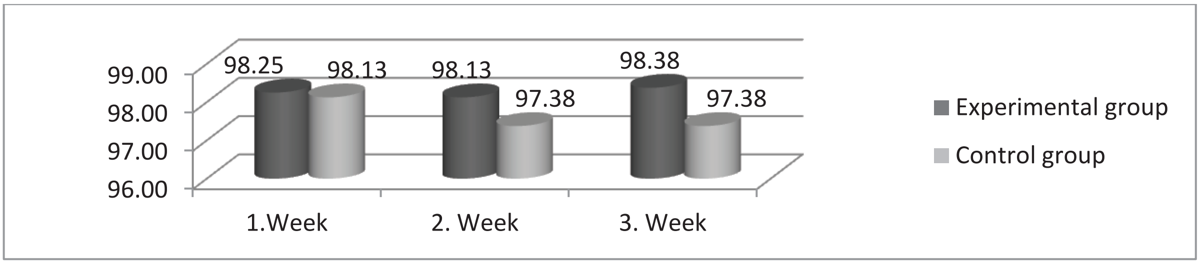
The participants included Greco-Roman Junior National Team members that competed in international tournaments. The mean age of the experimental group (O_2 supplemented) was 19.87 ± 0.35; the mean age of the control group was 19.62 ± 0.51. Sixteen healthy elite male wrestlers voluntarily signed a consent form to participate in the study. Each subject was required to complete a health questionnaire designed to screen out those who were contraindicated for inclusion in the study due to personal or familial health reasons. The purpose and nature of the study was explained to each subject prior to their participation. In addition, each subject read and signed a document that explained in detail the essence of the study. The Ethic Committee approved the study protocol. Two athletes from the same weight class were in the experimental and control groups. The subjects were of similar age, height, weight and fitness parameters.

Experimental protocol

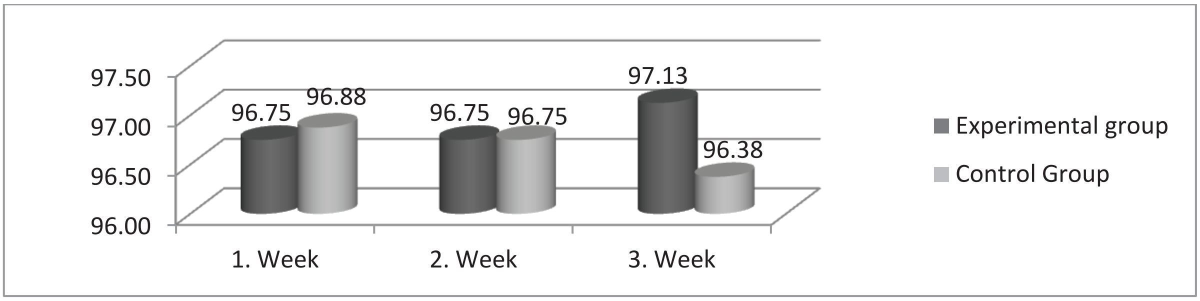
Before the exercise test, physical characteristics of the subjects (height, weight, and body composition) were measured. The participants included wrestlers who were in the Turkish National Team camp and trained for 5 days a week, including two morning and evening training sessions. The experimental group was supplemented with 5 ml/min for 10 min of O_2 while the control group wrestlers did not receive any O_2 treatment. The groups' pre- and post-training HR, lactate levels and O_2 saturation values were recorded. These parameters were measured each week during the 3 weeks.

Heart rate

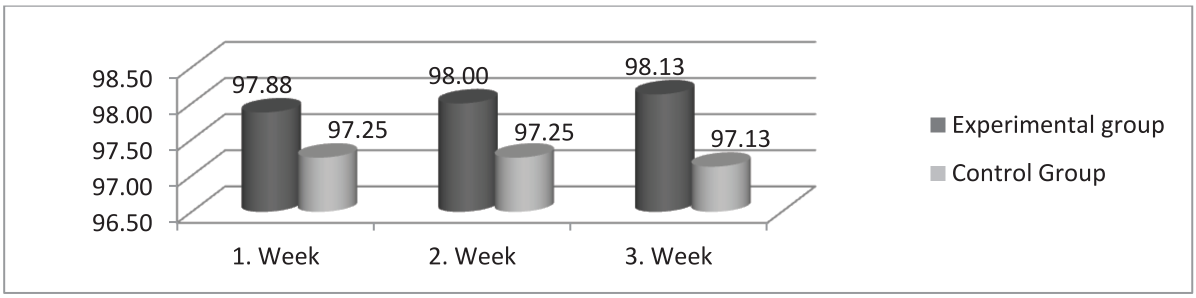
The heart rates of subjects included pre-training, post-training, and after oxygen (O_2) supplementation values that were measured by an oximeter.



A – pre-training values



B – post-exercise values



C – after O_2 supplementation

Fig. 1. SpO_2 values. The experimental group was supplemented with 5 ml/min of O_2 for 10 min. The control group wrestlers did not receive any O_2 treatment. The groups' pre- and post-training O_2 saturation values were recorded during 3 weeks. O_2 saturation measurements were performed with a Contec Plus Pulsoximeter.

Lactate measurement

Lactate values of subjects were measured during pre-training and post-training and after O_2 supplementation in blood taken from the fingertip. Lactate values were measured by a lactate analyzer (Lactate Plus).

O_2 supplementation method

Oxygen supplementation in the experimental group was applied with a cold vapor generating apparatus using a 906 S Nebulizer and a pure O_2 tube (100% oxygen) from the nose and mouth with a mask for 10 min at a rate of 5ml/min. The experimental group received O_2 during the three weeks 21 times.

O_2 saturation measurement

O_2 saturation measurements were performed with a Contec Plus Pulsoximeter. The oximeter probe was

Table 1. Characteristics of participants

Group n=(8+8)	Age (year)	P	Height (cm)	P	Body Weight (kg)	P
Experiment (Oxygen Saturation)	19.87±0.35	0.278	174.37±6..63	0.940	76.50±21.05	0.952
Control	19.62±0.51		174.12±6,49		77.12±19.61	

($p<0.05$) Table 1. There were no significant differences between the groups.

Table 2. Pre-exercise values of participants for each week.

Measurements	Groups n=(8+8)	Beginning of Camp mean±ss	P	Week 1. Resting mean±ss	P	Week 2. Resting mean±ss	P	Week 3. Resting mean±ss	P
O2 Saturation	Experiment	98.25±0.70 a	0.590	98.25±0.70 a	0.717	98.12±0.35 a	0.022*	98.37±0.51 a	0.002*
	Control	98.00±1.06 a		98.12±0.64 a		97.37±0.74 a		97.37±0.51 a	
Heart rate	Experiment	73.00±4.00 a	0.642	72.75±2.37 a	0.701	73.00±1.51 a	0.506	74.25±1.98 a	0.471
	Control	72.00±4.40 a		72.25±2.71 a		73.75±2.71 a		73.50±2.07 a	
Lactate	Experiment	1.7±0.57 a	0.355	1.73±0.40 a	0.621	1.85±0.14 a	0.662	1.5±0.29 a	0.585
	Control	1.5±0.33 a		1.65±0.27 a		1.90±0.28 a		1.62±0.32 a	

a.b.c: letters in the same columns indicate significant differences ($p<0.05$)

cleaned before each measurement. Before the measurements, the subjects were informed about the non-invasiveness of the procedure. Each subject rested comfortably by sitting.

Body weight and height measurement

The subjects' body weights were measured with a Tanita BIA device, and the heights were measured with a sensitive scale.

Statistical analysis

Statistical analysis was performed with a computer program SPSS 16.0 package, and the average and standard deviations of all parameters were calculated. To determine the homogeneity of the data, the Single Instance Kolmogorov-Smirnov test was applied, and it was determined that the data were not normally distributed. Intergroup Mann-Whitney-U test and group differences were determined with Repeated Measures Analysis of Variance, to determine whether if there is a Minimum Significance Difference; ($P<0.05$) was considered statistically significant.

RESULTS

The age, height and body-weight averages of members of the experimental and control groups that participated in the study were similar ($p<0.05$), (Table 1). The three-week pre-exercise resting parameters in the experimental and control groups were similar. The levels of O_2 saturation one week after measurement time were found to be similar ($p>0.05$). In the 2nd and 3rd weeks, a statistical difference was observed for the value of O_2 saturation in favor of the experimental group ($p<0.05$). There was no statistically significant difference ($p> 0.05$) for the resting HR and lactate parameters during the three-week period (Table 2, Fig. 1A).

Measurement of all groups after 3 weeks of exercise revealed that there was no statistically sig-

Table 3. Post-exercise values for each week

Measurements	Groups n=(8+8)	Week 1. Post-training mean±ss	P	Weeks 2. After training mean±ss	P	Weeks 3. After training mean±ss	P
O2 Saturation	Experiment	96.75±0.46 a	0.554	96.75±0.46 a	1.000	97.12 ±0.64 a	0.049*
	Control	96.87±0.35 a		96.75±0.46 a		96.37 ±0.744 a	
Heart rate	Experiment	169.25 ±4.39 a	0.795	172.37±10.28 a	0.870	177.50 ±11.40 a	0.862
	Control	168.75±3.01 a		173.25±10.68 a		178.37 ±8.07 a	
Lactate	Experiment	11.93±2.51 a	0.567	12.32±2.82 a	0.581	12.27 ±1.83 a	0.239
	Control	11.31±1.67 a		12.95±1.34 a		13.27±1.38 a	

a.b.c: letters in the same columns indicate significant differences ($p<0.05$)

Table 4. Values after 15 min of exercise (with O_2 supplementation).

Measurements	Groups n=(8+8)	Week 1. After O2 supple-mentation mean±ss	P	Weeks 2. After O2 supple-mentation mean±ss	P	Weeks 3. After O2 supple-mentation mean±ss	P
O2 Saturation	Experiment	97.87±0.64 a	0.085	98.00±0.75 a	0.060	98.12±0.35 a	0.002*
	Control	97.25±0.70 a		97.25±0.70 a		97.12± 0.64 a	
Heart rate	Experiment	85.75±3.28 a	0.001*	86.50±5.09 a	0.000*	80.75±4.52 b	0.000*
	Control	93.00±3.20 b		97.50±2.32 a		97.00±5.12 a	
Lactate	Experiment	3.73±0.66 a	0.001*	3.62±0.50 a	0.001*	3.66±0.71 a	0.000*
	Control	4.82±0.37 a		4.62±0.48 a		5.02±0.36 a	

a.b.c: letters in the same columns indicate significant differences ($p<0.05$)

nificant difference in HR and lactate levels ($p>0.05$). The O_2 saturation values after the 1st and 2nd weeks of exercise were found to be similar ($p>0.05$). After the 3rd week of exercise, the values of O_2 saturation of the experimental group were significantly higher ($p<0.05$) (Table 3, Fig. 1B).

The values for the HR and lactate were found to be significantly lower in the experimental group ($p<0.05$) at the end of exercise. There was no significant difference between groups ($p>0.05$) with regard to the O_2 saturation values measured in the 1st week. The O_2 saturation values measured in the 3rd week were significantly higher in the experimental group ($p<0.05$). Although the values of O_2 saturation measured in 2nd week after O_2 supplementation were higher in the experimental group, this value did not reflect a statistically significant difference ($p>0.05$) (Table 4, Fig. 1C).

DISCUSSION

Blood hemoglobin concentration is increased with oxygen supplementation. Evidence suggests that intensive exercise causes a fall in the percentage of O_2 bound to hemoglobin (%SaO_2) by more than or equal to 5% below the resting values in some well-trained endurance athletes (Powers et al., 1993). High-intensity training may be hard to maintain due to restrictions in systemic O_2 transport, especially at high altitudes (Chick et al., 1993). Exercising under conditions of higher than normal inspired O_2 would be expected to enable the individual to exercise at a higher intensity than usual, providing the potential for enhanced training adaptation and improved exercise performance.

The physiological outcomes of inhaling O_2-enriched air during exercise are well-documented (Moore et al., 1992; Wilson et al., 1980). A high-intensity training protocol using hyperoxic gas inhalation in athletes training at an altitude of 1 600 m was observed to increase work capacity after maximal training at moderate altitude (Chick et al., 1993; Favier et al., 1995; Kleiner and Snyder, 1995). Kleiner et al., (1995) described an ergogenic influence of hyperoxia that helped in aerobic resistance exercise. Several researchers (Knight et al., 1989; Moore, 1992; Mayron et al., 2012) have reported improvements in exercise performance and a reduced ventilatory response in patients with chronic heart failure during submaximal exercise while breathing O_2-enriched air. Significant increases were also reported for O_2 saturation of arterial blood and cardiac output, with significantly reduced minute ventilation. Hyperoxic aerobic high-intensity interval training in COPD patients with hypoxemia at peak exercise increases VO_2 peak, peak workload, work economy and quality of life (Helgerud et al., 2009). Supplemented O_2 has been hypothesized to enable patients to exercise with reduced symptoms, thereby improving compliance since the activity is no longer intolerable. Furthermore, the O_2 enables the patient to train vigorously and thereby improve the metabolic function of skeletal muscles. The effectiveness of breathing enriched air may be dependent upon O_2 concentration. For example, in studies of exercise-induced hypoxemia (Moore et al., 1992; Babcock et al., 1995; Dempsey et al., 1984), it was found that mild hyperoxia decreased the severity of the hypoxemia, while the VO_2max, running time and peak blood lactate were not altered in another study after HbO_2 treatment (Hodges et al., 2003). However, there is no consensus as to the optimal O_2 fraction used (Chick et al., 1993; Nummela et al., 2002). One explanation for these discrepancies may be the different exercise intensities used in the studies (Welch et al.,: 1982; Nummela et al., 2002).

While the physiological benefits of inhaling oxygen-enriched air during exercise are well known (Chick et al., 1993; Favier et al., 1995), there are only a few studies about long-term exposure to oxygen-enriched air during recovery periods. In our study, 5 ml/min of oxygen supplementation during 10 min were found to be beneficial for athletes to recover faster than the group that did not have such a treatment. According to measurements after 15 min of training, the O_2 saturation levels after O_2 supplementation showed significant differences in favor of the experimental group. In a similar study (Nummela et al., 2002), the experimental group had high hemoglobin saturation values after O_2 supplementation when compared to the control group. In another study, Peltonen et al. (2001) found that O_2 saturation levels increased after the supplementation. Similarly, Nummela et al. (2002) in his study revealed that athletes who received O_2 supplementation after high-intensity exercise had higher O_2 saturation levels as compared to athletes that did not receive such treatment during the study. In addition to these studies, it was shown that the peak power of elite swimmers performing high-intensity intervals could be improved by exposure to O_2-enriched air during recovery (Sperlich et al., 2011). In another study, it was noted that athletes who inhaled O_2 following a vigorous work bout appeared to recover faster than would normally be expected (Hill and Flack, 1909). These results support our findings of increased O_2 saturation levels after O_2 supplementation during short recovery periods. However, according to the Bjorgum et al. (2003), subjects that inhaled 100% O_2 subsequent to running on a treadmill, did not display significant differences when compared to the control. This can be explained by the fact that in our study, subjects that participated in short-term vigorous wrestling practices produced an O_2 “debt”. Also, in our study, to determine the chronic effects of O_2 loading, pre-exercise oxygen saturation measurements were taken once a week. We measured similar O_2 saturation values in the experimental and control groups. It can be concluded that oxygen loading did not have a positive effect on athletes’ oxygen saturation.

HR depends on the intensity of exercise. The increase in HR increases tissue O_2 consumption for metabolic needs. HR varies with the type and intensity of exercise. In dynamic exercise, the HR increases more than in static exercises. In addition, HR is directly proportional to the intensity of exercise. The duration of exercise affects the HR (Gunay and Cicioglu, 2001). Our study showed that the experimental and control groups had significantly different HRs when compared before and after matches (P<0.05). The HR after the exercise is considered a natural reflection of heavy exercise, and this is supported by many studies. According to measurements obtained after 15-min training, the HR after O_2 supplementation showed significant differences in favor of the experimental group. Similarly, Elbel et al. (1961) reported that when 100% O_2 was administered after a submaximal treadmill exercise, the pulse rate was depressed when compared with the control group, as was similarly reported in the study of Numell et al. (2002) where sprinters received O_2 supplementation during recovery periods of 3x3x300 running exercise. The O_2-supplemented group exhibited a faster recovery of HR when compared to the group that did not receive O_2 supplementation. These results support our findings of HR values. The lower HR after the treatment could be attributed to the increase in O_2 saturation that had a positive impact on the reduction of HR due to the activation of parasympathetic activity.

In our study, the experimental group had lower lactate levels in three weeks after each of 15 O_2 supplements. Similarly, Partice et al. (1995) found that individuals who were supplemented with O_2 for 10 min after maximal exercise had decreased lactate concentrations as compared to the group that did not have any O_2 supplementation. The reduction in lactate levels after the supplementation could be due to increased O_2 saturation that can help lactate clearance from muscle cells.

CONCLUSION

Three weeks of O_2 supplementation does not have any positive effects on wrestlers' performance. However, during 15-min recovery periods, O_2 supplementation produced beneficial effects on the heart rate, lactate levels and O_2 saturations of wrestlers. This implies that O_2 supplementation had positive effects on the wrestlers' performance during recovery.

REFERENCES

Babcock, M.A., Johnson, B.D., Pegelow, D.F., Suman, O.E., Griffin, D. and *J.A. Dempsey* (1995). Hyperoxic effects on exercise-induced diaphragmatic fatigue in normal healthy humans. *J. Appl. Physiol.* **87**(1), 82-92.

Booker, R. (2008). Pulse oximetry. *Nursing Standard,* **22**(30), 39-41.

Briggs, H. (1920). Physical exertion, fitness and breathing. *J Physiol,* **54**(4), 292-318.

Chick, T.W., Stark, D.M. and *G.H. Murata* (1993). Hyperoxic training increases work capacity after maximal training at moderate altitude. *Chest,* 104(6), 1759-62.

Dempsey, J.A., Hanson, P.G. and *K.S. Henderson* (1984). Exercise-induced arterial hypoxaemia in healthy human subjects at sea level. *J. Physiol,* **355**, 161-75.

Elbel, E.R., Ormond, D. and *D. Close* (1961). Some effects of breathing oxygen before and after exercise. *J. Appl. Physiol.* **16**, 48-52.

Favier, R., Spielvogel, H., Desplances, D., Ferretti, G., Kayser, B., Grünenfelder, A., Leuenberger, M., Tüscher, L., Caceres, E. and *H. Hoppeler (1995).* Training in hypoxia v. training in normoxia in high-altitude natives. *J. Appl. Physiol.* **78**(6), 2286-93.

Gunay, M. and *İ. Cicioğlu* (**2001).** Sports Physiology. *Gazi Publications, Ankara,* 307-313.

Helgerud, J., Bjørgen, S., Karlsen, T., Husby V.S., Steinshamn, S., Richardson, R.S. and *J. Hoff* (2009). Hyperoxic interval training in chronic obstructive pulmonary disease patients with oxygen desaturation at peak exercise. *Scand. J. Med. Sci. Sports.* 10.1111/j.1600-0838.2009.00937.

Hill, L. and *M. Flack* (1909). The influence of oxygen on athletes. *J. Physiol. (Proceedings)* **38**, 23-28.

Hodges, A.N.H., Delaney, S., Lecomte, .J.M., Lacroix, V.J. and *D.L. Montgomery* (2003). Effect of hyperbaric oxygen on oxygen uptake and measurements in the blood and tissues in a normobaric environment. *Br. J. Sports. Med.* **37**, 516-520

Kleiner, D.M. and R.C. Snyder (1995). The effectiveness of acute hyperoxia as an ergogenic aid in resistance training. *J. Strength and Cond Res.* **9**(4), 228-31.

Knight, P., Kleiner, D.M., Bates, S.H. and *S.F.D. Angelo* (1989). Hyperoxia training and effects on de-training: A preliminary study (Abstract). *J. Cardiopulm Rehab.* **9**(10), 398.

Linossier, M.T., Dormois, D., Arsac, L., Denis, C., Gay J.P., Geyssant, A. and *J.R. Lacour* (2000). Effect of hyperoxia on aerobic and anaerobic performances and muscle metabolism during maximal cycling exercise. *Acta. Physiol. Scand.* **168**(3), 403-411.

Moore, D.P., Weston, A.R., Hughes, J.M.B., Oakley, C.M. and *J.F.G. Cleland* (1992). Effects of increased inspired oxygen concentrations on exercise performance in chronic heart failure. *Lancet,* **339**, 850-3.

Nummela, A., Hamalainen, I. and *H. Rusko* (2002). Effect of hyperoxia on metabolic responses and recovery in intermittent exercise. *Scand. J. Med. Sci. Sports.* **12**(5), 309-315.

Oliveira, M.F., Rodrigues, M.K., Treptow, E., Cunha, T.M., Ferreira, E.M. and *J.A. Neder* (2012). Effects of oxygen supplementation on cerebral oxygenation during exercise in chronic obstructive pulmonary disease patients not entitled to long-term oxygen therapy. *Clin Physiol Funct Imaging.* **32**, 52-58.

Peltonen, J.E., Rusko, H.K., Rantamaki, J., Sweins, K., Niittymaki, S. and *J.T. Viitasalo* (1997). Effects of oxygen fraction in inspired air on force production and electromyogram activity during ergometer rowing. *Eur. J. Appl. Physiol. Occup. Physiol.* **76**(6), 495-503.

Peltonen, J.E., Tikkanen, H.O., Ritola, J.J., Ahotupa, M. and *H.K. Rusko* (2001). Oxygen uptake response during maximal cycling in hyperoxia, normoxia and hypoxia *Aviat Space Environ Med.* **72**(10), 904-11.

Powers, S.K., Martin, D.,and S., Dodd, (1993). Exercise induced hypoxaemia in elite endurance athletes. Incidence, causes and impact on VO2max. *Sports Med.* **16**(1), 14-22.

Powers, S., Lawler, K.J., Dempsey, J.A., Dodd, S. and *G. Landry* (1989). Effects of incomplete pulmonary gas exchange on VO2max. *Journal of Applied Physiology.* **66**, 2491-2495.

Powers, S.K. and *E.T. Howley* (1996). Exercise physiology: theory and application to fitness and performance. *3rd ed. Boston, Massachusetts: McGraw-Hill.*

Powers, S.K., Lawler J., Dempsey J. A., Dodd S. and *G. Landry* (1989). Effects of incomplete pulmonary gas exchange on VO_2 max. *J. Appl. Physiol.* **66**, 2491-2495.

Sperlich, B., Zinner, C., Krueger, M., Wegrzyk, J. and *J. Mester* (2011). Ergogenic effect of hyperoxic recovery in elite swimmers performing high-intensity intervals. *Scand. J. Med. Sci. Sports.* **21**, 421-429 doi: 10.1111/j.1600-0838.2011.01349.

Partice, T., Dieudonne, W., Emmanuel, B., Jean, R.L. and *G. David* (1995). Hyperoxia during recovery from consecutive anaerobic exercises in the sickle cell trait. *European Journal of Applied Physiology,* **71**(2-3), 253-258.

Welch, H.G. (1982). Hyperoxia and human performance: a brief review. *Med Sci Sports. Exerc.* **14** (4), 253-63.

Welch, H.G., Bonde-Petersen, F., Graham,T., Klausen, K. and *N. Secher* (1977). Effects of hyperoxia on leg blood flow and metabolism during exercise. *Journal of Applied Physiology.* **42**, 385-390.

Wilson, G.D. and *H.G. Welch* (1975). Effects of hyperoxic gas mixtures on exercise tolerance in humans. *Med. Sci. Sports Exerc.* **7**(1), 48-52.

Wilson, G.D. and *H.G. Welch* (1980). Effects of varying concentrations of N2/O2 and He2/O2 on exercise tolerance in man. *Med. Sci. Sports Exerc.* **1**(5), 380-4.