JEPonline

Journal of
Exercise Physiologyonline

Official Journal of The American
Society of Exercise Physiologists (ASEP)

ISSN 1097-9751
An International Electronic Journal
Volume 3 Number 2 April 2000

Fitness and Training

The Effect Of Training While Breathing Oxygen-Enriched Air On Time-To-Exhaustion And Aerobic Capacity

W. JEFFREY ARMSTRONG, DEAN E. JACKS, JAMES SOWASH, AND FREDRICK F. ANDRES.

Department of Health Promotion and Human Performance, Exercise Physiology Laboratory, University of Toledo, Toledo, OH 43606

ABSTRACT

W. JEFFREY ARMSTRONG, DEAN E. JACKS, JAMES SOWASH, AND FREDRICK F. ANDRES. **The effect of training while breathing oxygen-enriched air on time-to-exhaustion and aerobic capacity.** JEPonline 3(2):12-20, 2000. Seventeen moderately-trained subjects (21±4 yr; 176.81±12.84 cm; and 74.04±12.31 kg, mean±SD) completed a familiarization trial, a graded cycle ergometer test (VO_2peak), and a time-to-exhaustion cycling test at ~80% VO_2peak (TTE). Subjects were then match paired and randomly assigned (single blind) to train for 40 min, 3 d/wk for 5 wk while breathing room air or ~80% O_2. Each was asked to pedal the cycle ergometer as fast as possible at the resistance estimated to be 60% VO_2peak at 75 rpm and remain between 70-90% of age-predicted HRmax. The workload was increased 0.25 kp at the beginning of weeks 2, 4, and 5. Following training, VO_2peak and TTE were repeated. Doubly MANOVA repeated measures revealed a significant improvement in VO_2peak and TTE (3.20±0.88 L/min to 3.55±0.90 L/min and 899.46±506.49 s to 2925.02±2044.76 s, respectively, (p=0.002) and no significant difference between the treatments across time for VO_2peak and TTE combined (p=0.662). Student's *t*-test for group differences on total work output was not significant (p=0.328). Thus, cycle training with oxygen-enriched air did not significantly enhance endurance performance and muscle function relative to exercise training when breathing room air in moderately-trained subjects at sea level.

Key Words: cycle ergometer, ergogenic aids, exercise, endurance, hyperoxia, performance

INTRODUCTION

The physiological benefits of breathing oxygen-enriched air during an acute bout of exercise are well-documented (3-12,15). Recently, Knight et al. (2) and Moore et al. (3) proposed the use of supplemental oxygen during daily exercise training to improve the physical conditioning of patients with chronic heart failure (CHF). Supplemental oxygen has been hypothesized to enable patients to exercise with reduced symptoms, thereby improving compliance since the activity is no longer intolerable. Furthermore, the oxygen enables the patient to train vigorously and, thereby, improve the metabolic function of skeletal muscles. The improvements in skeletal muscle function require exercising at a higher intensity and for longer duration than would be possible without the use of supplemental oxygen.

Endurance performance may be limited by the ability to maintain a high percentage of oxygen saturation in the blood. In studies of exercise-induced hypoxemia, Babcock et al. (13), Dempsey et al. (14) and Moore et al. (3) found that mild hyperoxia decreased the severity of the hypoxemia. Exercising under conditions of higher than normal inspired oxygen would, thus, be expected to enable the individual to exercise at a higher intensity than usual, providing the potential for enhanced training adaptations and improved exercise performance.

Supplemental oxygen may have potential beneficial effects to athletes training at altitude. Chick and co-workers (16) observed increased maximal cycle time ($p=0.015$) and increased endurance time at 85% maximal workload ($p = 0.012$) following six weeks of hyperoxic (>70% O_2) training in trained subjects at an altitude of 1600 m. Conversely, Favier and co-workers (17) concluded that, in high-altitude natives, increasing oxygen availability to normoxic levels while training at altitude has no advantage over training at sea level.

To date, few studies have been conducted at lower altitudes to determine if supplemental oxygen can be used during exercise training to enhance endurance performance by improving muscle function. Kleiner and Snyder (5) observed an ergogenic affect of hyperoxia that seems to aid only the aerobic aspect of resistance exercise. Moore and co-workers (3) reported improvements in exercise performance and a reduced ventilatory response in patients with chronic heart failure during submaximal exercise while breathing oxygen-enriched air. Significant increases were also reported for oxygen saturation of arterial blood and cardiac output, with significantly reduced minute ventilation. In addition, patients reported less fatigue and feelings of breathlessness. Knight and co-workers (2) observed a trend toward improved maximal oxygen consumption (VO_2max) after 10 wk of exercising three times a week at 70-90% of maximal heart rates for 40 min on a stationary cycle ergometer while breathing 60% O_2. Ploutz-Snyder and associates (4) trained 19 male subjects 5 d/wk for 5 wk on a cycle ergometer at 70% of hyperoxic or normoxic maximal heart rate while breathing 70% oxygen or room air. Throughout the training period, the hyperoxic group was reported to have trained at an intensity approximately 20 W higher than the normoxic group, however, improvements in VO_2max for the hyperoxic group did not differ significantly from the normoxic group. In addition, maximal lactate concentrations, heart rate, stroke volume, and cardiac output were unchanged in both groups. Significant increases in the percentage of type IIa muscle fibers were reported, with no significant differences between groups. The hyperoxic group, however, retained a larger percentage of type IIb fibers. Ploutz-Snyder and co-workers (4) also reported no changes in creatine kinase, phosphofructokinase, and glyceraldehyde phosphate dehydrogenase; increases in cytochrome c-oxidase and citrate synthase for both groups; and 3-hydroxyacyl coenzyme-A dehydrogenase activity increased in the normoxic group, but not in the hyperoxic group. These researchers suggested that there were intramuscular differences between hyperoxic and normoxic training, and that the muscle utilizes additional oxygen, if available.

The effectiveness of breathing enriched air may be dependent upon the oxygen concentration. Yet, there is no consensus as to the optimal oxygen fraction to be used (2,4,5,7,12,18,19,20). One explanation for these discrepancies may be the different exercise intensities used in the studies (12,20). Among the studies of hyperoxic exercise training, Knight and co-workers (2) observed a trend toward increased maximal oxygen consumption using 60% O_2. Ploutz-Snyder and co-workers (4) found no significant difference in improvements in maximum oxygen consumption between training with 70% O_2 and room air. The concentration of O_2 used in these training studies, however, may not have been sufficient to significantly increase the exercise capacity. There are no published studies in which the researcher examined the effect of training while breathing concentrations greater than 70% O_2. In the present study, it was proposed that a concentration of 80%

O_2 would increase the training intensity and be sufficient to observe an effect on maximal oxygen consumption and time-to-exhaustion.

METHODS

Subjects

Eighteen subjects (12 males and 6 females) were recruited from the student population at the University of Toledo and surrounding community by word of mouth and flyers posted on campus. One female subject, however, had to be dropped from the study during the post-training testing due to illness. Subjects were apparently healthy and free of contraindications to exercise as determined from a self-reported medical history. All subjects were regularly active, at least 3 d/wk, in endurance exercise for six months prior to the study. Based on age, gender, height, weight, pre-training data, and self-reported activity level, the subjects were matched and randomly assigned to receive either hyperoxic training (HT, N = 9) or normoxic training (NT, N = 8). Informed consent was obtained before participation and all procedures were approved by the University of Toledo Human Subjects Review Committee.

Exercise Tests

Subjects reported to the exercise physiology laboratory on three separate days for a familiarization trial and preliminary testing. The first day involved a familiarization trial during which each subject was fitted for seat height and completed a 13 to 15 min exercise bout on a cycle ergometer (818E, Monark, Stockholm, Sweden). The familiarization trial was designed to allow the subject to be accustomed to the ergometer and to breathing through a mouthpiece and with a nose clip during graded exercise. On the second day subjects performed a graded exercise test on the cycle ergometer to determine peak oxygen consumption (VO_2peak). During this test, the subject pedaled at 75 rpm and work was progressively increased until no further increase in workload was tolerable. Stages I-III were of 3 min duration at 1, 2, and 3 kp. Stages IV-VI were of 2 min duration and weight dependent. Subjects who weighed more than 70 kg increased in 1 kp increments, and subjects who weighed less than or equal to 70 kg increased in 0.5 kg increments. Expired gases were analyzed for O_2 using a S-3A oxygen analyzer and for CO_2 by a CD-3A carbon dioxide analyzer (Ametek, Thermomax Instruments Division, Pittsburgh, PA). Oxygen consumption measurements were made using an open circuit spirometry system (Rayfield Equipment, VT), and VO_2peak was determined as the average of the highest two 15s data points. On the third day subjects completed a time-to-exhaustion test (TTE). The subject was required to pedal the cycle ergometer at a workload of approximately 80% of VO_2peak until unable to maintain a cadence of ~75 rpm. All testing was performed while breathing room air. Following training, VO_2peak and TTE were repeated under the same conditions as pre-testing.

Training Protocol

Following completion of the preliminary testing, subjects were matched according to the pre-training data and randomly assigned to either 5 wk of cycling while breathing room air (NT) or 5 wk of cycling while breathing approximately 80% O_2 (HT). Training was conducted 3 d/wk. Each subject wore a facemask or mouthpiece during administration of the appropriate gas mixture, as described below. Heart rate was monitored continuously during training using telemetry (Polar Electro, Port Washington, NY). The subject was asked to pedal the cycle ergometer at a predetermined workload for 40 min, maintain a cadence that was as fast as possible for the duration, and remain between 70-90% of age-predicted maximum heart rate. During the first week of training, this workload was the resistance estimated to elicit a work output of 60% VO_2peak if pedaling at a cadence of 75 rpm. The workload was increased 0.25 kp at the beginning of weeks 2, 4 and 5. After 20 min of training, the subject was permitted to remove the facemask or mouthpiece for 3 min, and the pedal cadence was reduced while the subject was permitted to drink water. Following this relief period, the facemask or mouthpiece was re-positioned and exercise was resumed for an additional 20 min. Throughout training, the subjects were permitted to watch commercial video recordings or listen to radio. Ergometers were calibrated periodically and samples of the mixed inspired gas were analyzed to maintain a consistent oxygen concentration.

The system used to administer gas to both groups is depicted schematically in Figure 1. The inspired hyperoxic gas was mixed from tanks of compressed 100% O_2 and 100% N_2 by a Air-Oxygen Blender (Bird Products Corporation #03800A) and passed through a nebulizer to humidify the gas and into a series of six 100-200 L Douglas bags. Gas from the reservoir bags was fed by two hoses into PVC pipe regulated by three 3-way valves. These valves permitted gas flow to be switched from room air to hyperoxic air and back without the subjects' knowledge. This also permitted the training of up to three subjects simultaneously. This system permitted hyperoxic gas samples to be taken from the nebulizer or from any available outflow regulator. By periodic analysis of the mixed air, the average gas concentration was found to be 82.49±3.52% O_2.

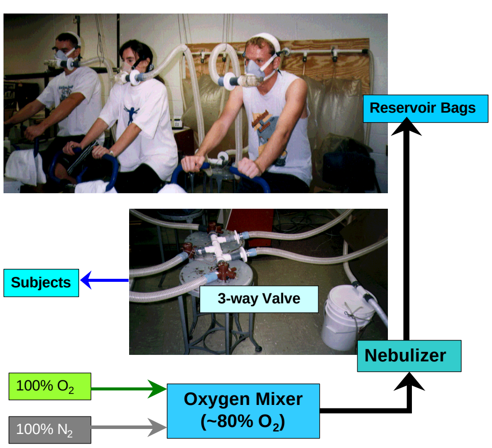

Figure 1. Picture of the system used to administer inspired gas to the exercising subjects.

Data Analysis

The SPSS 7.5 for Windows statistical package was used for all statistical analyses. Doubly MANOVA repeated measures was used to determine whether there were significant effects for time and treatment by time for the linear combination of the dependent variables (VO_2peak and TTE). The data are reported as mean±SD and Student's *t*-tests were used to compare initial group differences for age, height, weight, pre-training VO_2peak and TTE, and group differences for total work output (WO) and average daily work outputs for each training week. In addition, effect size and power were calculated. Significance was accepted at an á-level of 0.05 for all analyses.

RESULTS

Pre-training Data

The age, height, and weight of the participants were 21±4 yr, 176.81±12.84 cm, and 74.04±12.31 kg, respectively. The two treatment groups were successfully matched. Although NT was slightly higher than HT for mean VO_2peak (3.44 L/min v. 2.98 L/min) and TTE (1075.65 s v. 742.84 s), the groups did not differ for age, height, weight, VO_2peak, and TTE at the start of training (p = 0.683, 0.892, 0.837, 0.288, and 0.184, respectively). There were no significant differences between groups in age, height, weight, and the pre-training testing using Student's *t*-tests (Table 1).

Training Work Output

A plot of the group means for the average daily training power output for each week of the training is provided in Figure 2. Although mean average daily power output for NT was slightly higher than that for HT, except for Week 2, there was no significant difference between groups for each week.

VO_2peak and TTE

The pre- and post-training VO_2peak and TTE data for both groups are shown in Figures 3 and 4. Despite the short duration, the training period was sufficient to elicit a significant improvement in VO_2peak and TTE (p = 0.002). VO_2peak increased 7.3% and 14.6% for NT and HT, respectively, and TTE increased 156.4% and 313.8% for NT and HT, respectively. However, these increases for each of VO_2peak and TTE were not significantly different.

Table 1. Physical characteristics of subjects (mean±SD)

Group	Height (cm)	Weight (kg)	Age (yr)
NT (N=8)	177.28 ± 11.20	74.73 ± 13.08	21.75 ± 4.95
HT (N=9)	176.39 ± 14.82	73.44 ± 12.35	21.00 ± 2.12

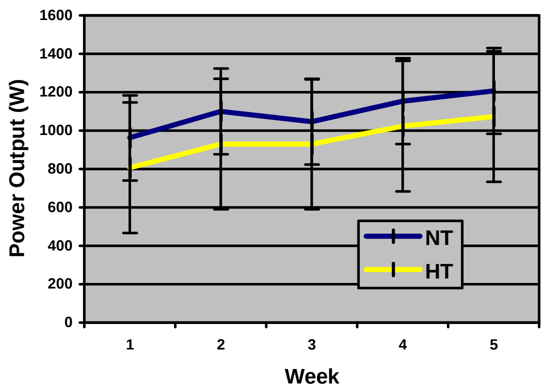

Figure 2. Plot of group means for average daily work output during 5 wk of exercise training while breathing room air (NT) or a hyperoxic gas mixture (HT); * *p* < 0.05.

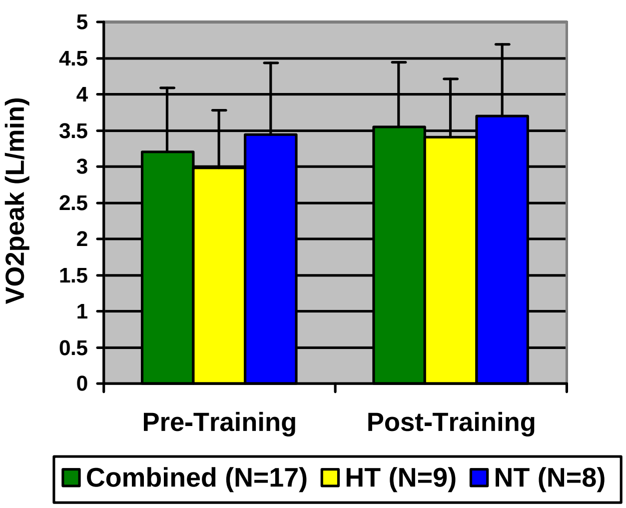

Figure 3. VO_2peak data (mean±SD) pre-to post-testing.

Statistical Power

Effect size for the treatment and time-by-treatment effects (0.054 and 0.057, respectively) were very small, and consequently observed power for the present study was quite low (0.10 and 0.11, for VO_2peak and TTE, respectively). For an acceptable power of 0.8, we would have only been able to detect a mean difference of 1.29 L/min and 1306 s for VO_2peak and TTE, respectively. For more physiologically meaningful differences of 250 mL/min and 250 s for VO_2peak and TTE, respectively, the number of subjects required would have been greater than 200 per group. Clearly, the small improvements seen with hyperoxic training compared to normoxic training, using our methodology, requires a large number of subjects to attain potential significance. This is an unrealistic requirement in human subjects research. Nevertheless, based on poor statistical power our non-significant findings need to be interpreted with caution.

DISCUSSION

The present study was initiated to ascertain whether the acute effects of exercise while breathing oxygen-enriched air (~80%) would enable one to train at a higher intensity and, thereby, enhance post-training performance. If intensity of training is the most important factor in improving performance, as Mujika and co-workers (1) have indicated, then one could hypothesize that training while breathing oxygen-enriched air will improve performance. These data fail to support any beneficial effect of hyperoxic training at sea level. Nevertheless, the subjects who trained while breathing a hyperoxic gas mixture did show a trend for greater mean improvements in VO_2peak and TTE (14.6% v. 7.3% and 313.81% v. 156.4%, respectively).

Although the subjects who participated were regularly active, they were not highly-trained. This may have dampened the ability to see the added results from hyperoxic training. For example, had the subjects been highly-trained, a larger difference in the training effects may have been expected as the availability of oxygen might then have been a potential limiting factor to further training improvements.

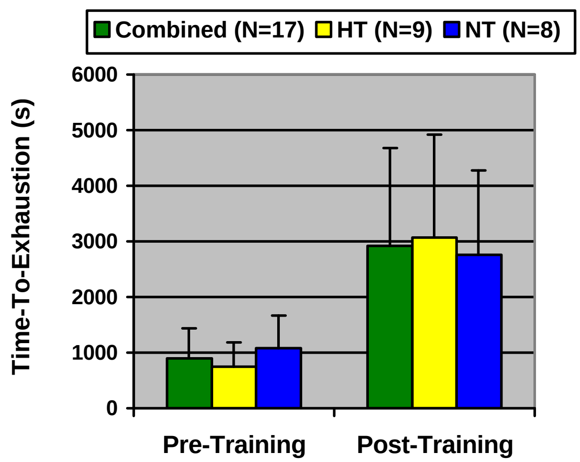

Figure 4. TTE (meanSD) pre- to post-training.

In a recent study by Ploutz-Snyder et al. (4), subjects breathing a 70% O_2 gas mixture were able to train at an intensity of 20 W higher than subjects breathing room air. This was not the case in the present study. Subjects breathing ~82.5% O_2 produced a mean accumulated power output of 101061.1±24253.1 W compared to 116568.3±38224.0 W for the normoxic group. Although NT trained at a slightly higher intensity than HT, this may be attributable to the slightly higher average fitness level rather than an effect of breathing oxygen-enriched air. The groups were matched as closely as possible, however, the loss of one subject from this group resulted in a positive shift in the mean. The difference in pre VO_2peak was insignificant (Figure 3), and statistically, there was no difference in mean total power output between groups. Thus, the hypothesized increase in power output for the subjects breathing hyperoxic gas was not observed.

During training, the resistance on the cycle ergometer was set at a level that was estimated to elicit an oxygen consumption of 60% VO_2peak if pedaling at 75 rpm. Subjects were asked to pedal as fast as they could at this resistance, when considering the exercise duration, while maintaining a heart rate of 70-90% age-predicted maximum heart rate. While other training protocols may have been selected, the authors anticipated that the hyperoxic gas mixture (~80%) would permit an increased maximal rate of work rate during exercise (4, 5, 9). Thus, if two subjects were matched and asked to exercise with the same resistance setting on the cycle ergometer, a subject breathing a hyperoxic gas mixture would pedal at a higher cadence and average power output than his/her normoxic counterpart. This, however, was not the case. One consideration that was omitted, though, was motivation. It is certainly possible that some subjects would be more driven to push themselves than others. This would, nonetheless, only be possible within the permitted heart rate range, and random assignment was intended to minimize group differences for which there were no controls. No distinct disparity in motivation was observed, but any difference, albeit slight, may have affected the power output.

Figure 2 contains a comparison of average daily power outputs. From week 2 to 3, NT declined slightly, while HT maintained a steady power output. Resistance was increased for all subjects during weeks 2, 4 and 5. During week 3, power output might have been expected to increase, if pedal cadence increased, or stay the same, if pedal cadence was maintained. That pedal cadence was maintained by HT may indicate that the subjects found a more or less comfortable cadence that they maintained throughout the training despite increases in resistance. Interestingly, the decline in work output for NT between week 2 and week 3 may be attributable to the fact that television and video entertainment was introduced for most of the subjects at this time. This is, however, speculative since there were no steps taken to quantify the effect of such entertainment on the subjects' attention to the exercise activity at hand. It may be that the introduction of the videos initially distracted the subjects, but after a brief time progression resumed. However, this interpretation is not supported in the literature (21, 22). Brownley et al. (23), suggested that listening to upbeat music may be beneficial for untrained runners, but counterproductive for runners who are trained. It may also be that NT had a heightened enthusiasm during the first two weeks of training that motivated them to train harder during the early weeks and waned after a time.

Practical Importance of Hyperoxic Exercise

With the small effect sizes we reported for the variables VO_2peak and TTE, it was a practical impossibility to study a sufficient number of subjects to attain statistical significance. One must consider the time, cost and convenience of training individuals under hyperoxic conditions. Given that only small training improvements are important to the performance of elite level athletes, the within and between subjects variability in the physiological responses to hyperoxic training may cause experimental research to never be able to document a statistically significant benefit of hyperoxic training. In this case, physiological significance becomes a secondary, but important assessment of this procedure.

Hyperoxic exercise training has previously been found to be beneficial in patients with CHF (2) and trained individuals at moderate altitude (16). The ergogenic effects of such training may be limited to conditions of impairment, and the small effect of such training for healthy individuals training at sea level may be of little practical benefit. CHF patients generally have impaired exercise capacity because of muscle fatigue or other symptoms, including dyspnea (3). Moore et al. (3) indicated that improved skeletal muscle conditioning may play a role in increasing aerobic capacity in CHF. Knight et al. (2) found only a non-significant trend toward improved VO_2peak for CHF patients after 10 weeks of hyperoxic exercise training, and this benefit was not long-lasting. This may indicate a skeletal muscle adaptation that produces a short-term performance enhancement in poorly-conditioned individuals.

The research done at altitude is interesting. It appears that hyperoxic exercise training at altitude permits athletes to train at higher intensities despite the effects of lowered oxygen pressures (16). Thus, it may be possible that athletes *living high* may simulate *training low* without leaving altitude. It appears, however, that this notion does not carry over to the prospect of *living low/training lower*, as was tested in the present study.

Ploutz-Snyder et al. (4) also concluded that there was no significant effect of hyperoxic exercise in healthy young adults at sea level. Thus, hyperoxic exercise training may be most beneficial when performance is impaired rather than in situations where it is desirable to push normal exercise performance to a higher level. However, it may be concluded that cycle training while breathing oxygen-enriched air (82.5% O_2) did not enhance endurance performance and muscle function of moderately-trained subjects living at sea level.

Suggestions for Future Research

This study and that of Ploutz-Snyder et al. (4) were of a short duration (five weeks). Knight et al. (2) trained CHF patients for 10 weeks. A longer training study with non-diseased subjects may be warranted. A comparison of the response of high fitness subjects and low fitness subjects to exercise training while breathing oxygen-enriched air also merits consideration. It would also be worthwhile to consider the ergogenic benefit of hyperoxic exercise training at altitude.

The exercise intensity for TTE may have been too low to elicit a significant difference between HT and NT. Ideally, the intensity should be such that the subjects fatigue between 5 and 10 min in the pre-training trial. In addition, it would be interesting to examine whether breathing oxygen-enriched air affects work output, controlling for motivational factors. This could be accomplished using a 2x2 factorial design (gas concentration x work output) in which subjects are matched and randomly assigned to one of four treatments: hyperoxic-high, normoxic-high, hyperoxic-low, and normoxic-low. Hyperoxic-high and normoxic low would train as described in the present study. Normoxic-high would then be matched to the work output of hyperoxic-high and hyperoxic-low to that of normoxic-low. Such a design might control the effects of motivation and examine whether it is the gas mixture or work output that facilitated any improvement in training adaptations.

REFERENCES

1. Mujika I, Chatard J-C, Busso T, Geyssant A, Barale F, Lacoste L. Effects of training on performance in competition swimming. **Can J Appl Physiol** 1995;20(4):395-406.
2. Knight PE, Kleiner DM, Bates SH, D'Angelo SF. Hyperoxia training and effects on de-training: A preliminary study (Abstract). **J Cardiopulm Rehab** 1989;IX(10):398.
3. Moore DP, Weston AR, Hughes JMB, Oakley CM, Cleland JFG. Effects of increased inspired oxygen concentrations on exercise performance in chronic heart failure. **Lancet** 1992;339:850-3.
4. Ploutz-Snyder LL, Simonaeu J-A, Gilders RM, Staron RS, Hagerman FC. Cardiorespiratory and metabolic adaptations to hyperoxic training. **Eur J Appl Physiol** 1996;73:38-48.
5. Hughson RL, Kowalchuk JM. Kinetics of oxygen uptake for submaximal exercise in hyperoxia, normoxia, and hypoxia. **Can J Appl Physiol** 1995;20(2):198-210.
6. Plet J, Pedersen PK, Bensen FJ, Hansen JK. Increased working capacity with hyperoxia in humans. **Eur J Appl Physiol** 1992;65:171-7.
7. Wilson GD, Welch HG. Effects of hyperoxic gas mixtures on exercise tolerance in humans. **Med Sci Sports Exerc** 1975;7(1):48-52.
8. Hagerman FC, Bowers RW, Fox EL, Ersing WW. The effects of breathing 100 percent oxygen during rest, heavy work, and recovery. **Res Quart** 1967;39(4):965-74.
9. Hughes RL, Clode M, Edwards RHT, Goodwin TJ, Jones N. Effect of inspired O_2 on cardiopulmonary and metabolic responses to exercise in man. **J Appl Physiol** 1968;24(3):336-47.
10. Aaron EA, Seow KC, Johnson BD, Dempsey JA. Oxygen cost of exercise hypernea: Implications for performance. **J Appl Physiol** 1992;72(5):1818-25.
11. Allen PD, Pandolf KB. Perceived exercise association with breathing hyperoxic mixtures during submaximal work. **Med Sci Sports Exerc** 1977;9(2):122-7.
12. Welch HG. Hyperoxia and human performance: a brief review. **Med Sci Sports Exerc** 1982;14(4):253-63.
13. Babcock MA, Johnson BD, Pegelow DF, Suman O E, Griffin D, Dempsey JA. Hyperoxic effects on exercise-induced diaphragmatic fatigue in normal healthy humans. **J Appl Physiol** 1995;87(1):82-92.
14. Dempsey JA, Hanson PG, Henderson KS. Exercise-induced arterial hypoaemia in healthy human subjects at sea level. **J Physiol** 1984;355:161-75.
15. Wilson GD and Welch HG. Effects of varying concentrations of N_2/O_2 and He_2/O_2 on exercise tolerance in man. **Med Sci Sports Exerc** 1980;12(5):380-4.
16. Chick, TW, Stark DM, Murata GH. Hyperoxic training increases work capacity after maximal training at moderate altitude. **Chest** 1993;104(6):1759-62.
17. Favier R, Spielvogel H, Desplances D, Ferretti G, Kayser B, Grünenfelder A, Leuenberger M, Tüscher L, Caceres E, Hoppeler H. Training in hypoxia v. training in normoxia in high-altitude natives. **J Appl Physiol** 1995;78(6):2286-93.
18. Bannister RG, Cunningham DJC. The effects on respiration and performance during exercise of adding oxygen to the inspired air. **J Physiol** 1954;125:118-37.
19. Briggs H. Physical exertion, fitness, and breathing. **J Physiol** 1920;54:292-318.
20. Kleiner DM, Snyder RC. The effectiveness of acute hyperoxia as an ergogenic aid in resistance training. **J Strength and Cond Res** 1995;9(4):228-31.
21. Abadie BR, Chance MK, O'Nan D, Lay C. Viewing music videotapes during exercise and ratings of perceived exertion. **Percep and Motor Skills** 1996;83(1):226.
22. Thornby MA, Haas F, Axen K. Effect of distractive auditory stimuli on exercise tolerance in patients with COPD. **Chest** 1995;107(5):1213-17.
23. Browning KA, McMurray RG, Hackney AC. Effects of music on physiological and effective responses to graded treadmill exercise in trained and untrained runners. **Int J Psychophysiol**

1995;19(3):193-201.
24. Hinkle DE, Wiersma W, Jurs SG. **Applied Statistics for the Behavioral Sciences (3rd Ed.)** Boston, MA: Houghton Mifflin Co., 1994, p. 638.
25. Stevens J. **Applied Multivariate Statistics for the Social Sciences (3rd Ed.)** Mahwah, NJ: Lawrence Erlbaum Associates, 1996, pp. 172-176.

Address for Correspondence: Dr. W. Jeffrey Armstrong, Department of HPERD, Eastern Michigan University, Ypsilanti, MI 48197. E-mail: Jeff.Armstrong@emich.edu.
