The Potential Ergogenic Effects of Training While Breathing Oxygen Enriched Air

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For Super Human Radio

Oxygen enrichment has been around for quite some time. It has been marketed in Oxygen Bars, as a health and wellness aid and to help those with pulmonary disorders. However, until recently, it has not found its greatest utilization. Oxygen enrichment during exercise holds the most benefits for the user.

Oxygen enrichment has not found a true purpose in the general population until recently. It was unclear what role if any hyperoxia played in sports. The following summary is designed to better define an application for oxygen enrichment during exercise performance that the author believes is a potential emerging technology utilizing oxygen enrichment as an ergogenic aid.

Weight Loss / Maintenance

Aerobic exercise is a staple of the exercise regimen for those wishing to lose weight or maintain their existing weight. Reducing fat requires a deficit in caloric intake in combination with added caloric expenditure. Aerobic exercise both burns calories as well as increases Resting Energy Requirements (RER) when done in a moderate to intense fashion. Caloric deficit through reduced caloric intake and low carbohydrate intake, which is the rage right now, tends to reduce the ability to exercise at moderate to intense levels for the required amounts of time. Hyperoxia during moderate to intense aerobic exercise has been shown to reduce perceived exertion[1]. The effects of higher oxygen saturation of the hemoglobin causes the heart[2] and lungs[3] not to work as hard to create the same level of energy output. The reduced perceived exertion allows a person in caloric deficit to work harder without greater stress to their cardio vascular system. The cardio vascular system, and more specifically, the heart, has been shown to be the governor of maximal physical output[4]. This in turn allows that person to burn a greater number of calories than if the same exercise was performed in normoxic conditions.

Hyperoxia has also been shown to increase Leptin production[5]. Leptin, is a hormone known for its hunger-blocking effects.

Increased Strength / Endurance

In the case of increasing ones ability to reach new plateaus of strength and endurance, one must be able to train at a level where you are constantly increasing the output or work being done over a previous session. In the case of aerobic training as of that of a runner, having the body adapt to longer periods of time at higher than normal output levels spurs progress. Hyperoxic conditions have been shown to be a strong ergogenic aid in this area. Runners training under hyperoxic conditions are able to increase VO2 max, and train with greater intensity for longer periods of time. Hyperoxia has been shown to increase the time to exhaustion by as much as 38% and total work output by as much as 15% in one study while maintaining ATP and ADP a resting levels[6]. These effects also mediate the production of lactate which is a contributing factor to the increased time to exhaustion[7, 8].

With strength athletes the effects are similar. These anerobic conditions are greatly affected by oxygen debt and lactate accumulation. Training in Hyperoxic conditions has been shown to reduce oxygen debt and blood lactate levels. This allows an individual to perform those last additional repetitions not possible under normoxic conditions. This in turn allows the recruitment of new muscle fibers which in turn effects both central nervous system adaptation as well as muscular hypertrophy.

Hyperoxic conditions have also been shown to cause a shift in substrate utilization that preserves ATP and ADP and muscle glycogen levels[7]. This in turn allows for faster recovery between bouts of exercise allowing an individual to train with greater intensity for longer periods of time. This is the same premise that exogenous creatine monohydrate supplementation has been built upon. For the bodybuilder/strength athlete there is also an added benefit. It is well know that anaerobic exercise such as heavy weight lifting depends primarily on muscle glycogen. Training under hyperoxic conditions spares muscle glycogen by as much as 30%[9] which equates to a greater level of output, faster recovery and muscle fiber fullness.

Ideal target oxygen enrichment levels for the purpose described above is between 27% to 60%. It is not a good idea to exceed the higher end for long periods of time.

Also, as oxidative stress increases with the higher amounts of oxygen consumed it is prudent to increase antioxidant intake to help quench the additional free radicals that will be released into the system

Summary of Benefits

- Increased output with reduced perceived exertion
- Burn more calories for same time spent exercising
- Conserve muscle glycogen
- Reduce effects of lactate buildup
- Reduced heart rate while exercising
- Increased Leptin production
- Increased VO2 max
- Increase oxygen delivered to organs and tissue
- Train at higher levels of output than possible in normoxic room air
- Feel refreshed after exercise
- Recover faster from intense exercise

1. The effects of hyperoxia on performance during simulated firefighting work
Author/s Petersen, S. R., Dreger, R. W., Williams, B. E., McGarvey, W. J.
Source ERGONOMICS , 43(2):210-222 2000

2. The effect of normobaric hyperoxia on cardiac index in healthy awake volunteers.
Harten JM, Anderson KJ, Angerson WJ, Booth MG, Kinsella J.
University of Glasgow Department of Anaesthesia, Glasgow Royal Infirmary

3. Hyperoxia improves maximal exercise with the self-contained breathing apparatus (SCBA)
Author/s Eves, Neil D., Petersen, Stewart R., Jones, Richard L.
Source ERGONOMICS , 45(12):829-839 2002

4. Evidence that a central governor regulates exercise performance during acute hypoxia and hyperoxia
Author/s Noakes, T. D., Peltonen, J. E., Rusko, H. K.
Source JOURNAL OF EXPERIMENTAL BIOLOGY , 204(18):3225-3234 2001

5. Hyperoxia increases leptin production: a mechanism mediated through endogenous elevation of corticosterone
Author/s C BarazzoneArgiroffo, P Muzzin, Y R Donati, C D Kan, M L Aubert, P F Piguet
Source American Journal of Physiology - Lung Cellular and Molecular Physiology , 281(5):L1150-6 2001

6. Effect of hyperoxia on aerobic and anaerobic performances and muscle metabolism during maximal cycling exercise
Author/s Linossier, M. T., Dormois, D., Arsac, L., Denis, C., Gay, J. P., Geyssant, A., Lacour, J. R.
Source ACTA PHYSIOLOGICA SCANDINAVICA , 168(3):403-412 2000

7. EFFECTS OF HYPEROXIA ON SKELETAL MUSCLE CARBOHYDRATE METABOLISM DURING TRANSIENT AND STEADY STATE EXERCISE.
Stellingwerff T, Glazier LR, Watt MJ, LeBlanc PJ, Heigenhauser GJ, Spriet LL.
Department of Human Biology and Nutritional Sciences, University of Guelph, Guelph, ON., Canada.

8. Gas exchanges during exercise in normoxia and hyperoxia
Author/s H Gautier, D Maillard, D Zaoui
Source RESPIRATION PHYSIOLOGY , 33(2):199-211 1978

9. Oxygen administration enhances memory formation in healthy young adults
Author/s Moss, M. C., Scholey, A. B., Moss_M_C, Scholey_A_B
Source PSYCHOPHARMACOLOGY (BERLIN) , 124(3):255-260 1996

The effects of hyperoxia on performance during simulated firefighting work
Author/s Petersen, S. R., Dreger, R. W., Williams, B. E., McGarvey, W. J.
Source ERGONOMICS , 43(2):210-222 2000

Abstract This study evaluated the effects of hyperoxia (inspired oxygen fraction = 40%) on performance during a simulated firefighting work circuit (SFWC) consisting of five events. On separate days, 17 subjects completed at least three orientation trials followed by two experimental trials while breathing either normoxic (NOX) and hyperoxic (HOX) gas mixtures that were randomly assigned in double-blind, cross-over design. Previously, ventilatory threshold (Tvent) and VO2max had been determined during graded exercise (GXT) on a cycle ergometer. Lactate concentration in venous blood was assessed at exactly 5 min after both the experimental trials and after the GXT. Total time to complete the SFWC was decreased by 4% ($p < 0.05$) with HOX. No differences were observed in individual event times early in the circuit, however HOX resulted in a 12% improvement ($p < 0.05$) on the final event. A significantly decreased rating of perceived exertion (RPE) was also recorded immediately prior to the final event. No differences were observed in mean heart rate or post-exercise blood lactate when comparing NOX to HOX. Heart rates during the SFWC (both conditions) were higher than HR at Tvent, but lower than HR at VO2max ($p < 0.05$). Post-SFWC lactate values were higher ($p < 0.05$) than post-VO2max. These results demonstrate that hyperoxia provided a small but significant increase in performance during short duration, high intensity simulated firefighting work.
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The effect of normobaric hyperoxia on cardiac index in healthy awake volunteers.

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Fifteen healthy volunteers were exposed to a stepwise increase in FIO2 between 0.21 and 1.0, and their haemodynamic responses were measured with a non-invasive transthoracic bio-impedance monitor. There was mean reduction in cardiac index from 3.44 to 3.08 l.min-1.m-2 (10.7%, $p < 0.001$). The mean reduction in heart rate was from 77.3 to 69.1 beats.min-1 (10.5%, $p < 0.001$) and the mean systemic vascular index increased from 2062 to 2221 dyne.s-1.cm-5.m-2 (7.7%, $p < 0.025$). There were no significant changes in stroke index or mean arterial pressure. These changes are similar quantitatively and qualitatively to those previously reported by dye dilution techniques.

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Hyperoxia improves maximal exercise with the self-contained breathing apparatus (SCBA)
Author/s Eves, Neil D., Petersen, Stewart R., Jones, Richard L.
Source ERGONOMICS , 45(12):829-839 2002

Abstract The effects of hyperoxia on maximal exercise while breathing from a self-contained breathing apparatus (SCBA) were studied in 25 males. Each participant completed three graded exercise tests (GXT) for the assessment of maximal oxygen uptake (VO 2max): two with 20.95 ± 0.28% O 2 and the third (GXT 40) while breathing hyperoxia (40.64 ± 1.29% O 2). No significant differences were found between the two normoxic tests, except for a 16W increase in maximal power output (PO max) in the second trial (GXT 21). Compared to GXT 21 , hyperoxia significantly increased VO 2max and PO max by 10.0 ± 3.8% and 10.2 ± 7.1%, respectively. This was likely due to an increase in O 2 delivery as suggested by the significantly higher oxyhemoglobin saturation. The increase in VO 2max with hyperoxia was similar to the increase in carbon dioxide production (9.3 ± 6.5%). No other significant differences were found at maximal exercise. However, at the intensity that elicited VO 2max in GXT 21 , pulmonary ventilation and SCBA mask pressure were significantly lower during GXT 40 , suggesting a decrease in the work of breathing. These findings could have significant implications for occupations that involve heavy work with SCBA.
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Evidence that a central governor regulates exercise performance during acute hypoxia and hyperoxia
Author/s Noakes, T. D., Peltonen, J. E., Rusko, H. K.
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Abstract An enduring hypothesis in exercise physiology holds that a limiting cardiorespiratory function determines maximal exercise performance as a result of specific metabolic changes in the exercising skeletal muscle, so-called peripheral fatigue. The origins of this classical hypothesis can be traced to work undertaken by Nobel Laureate A. V. Hill and his colleagues in London between 1923 and 1925. According to their classical model, peripheral fatigue occurs only after the onset of heart fatigue or failure. Thus, correctly interpreted, the Hill hypothesis predicts that it is the heart, not the skeletal muscle, that is at risk of anaerobiosis or ischaemia during maximal exercise. To prevent myocardial damage during maximal exercise, Hill proposed the existence of a 'governor' in either the heart or brain to limit heart work when myocardial ischaemia developed. Cardiorespiratory function during maximal exercise at different altitudes or at different oxygen fractions of inspired air provides a definitive test for the presence of a governor and its function. If skeletal muscle anaerobiosis is the protected variable then, under conditions in which arterial oxygen content is reduced, maximal exercise should terminate with peak cardiovascular function to ensure maximum delivery of oxygen to the active muscle. In contrast, if the function of the heart or some other oxygen-sensitive organ is to be protected, then peak cardiovascular function will be higher during hyperoxia and reduced during hypoxia compared with normoxia. This paper reviews the evidence that peak cardiovascular function is reduced during maximal exercise in both acute and chronic hypoxia with no evidence for any primary alterations in myocardial function. Since peak skeletal muscle electromyographic activity is also reduced during hypoxia, these data support a model in which a central, neural governor constrains the cardiac output by regulating the mass of skeletal muscle that can be activated during maximal exercise in both acute and chronic hypoxia.
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Hyperoxia increases leptin production: a mechanism mediated through endogenous elevation of corticosterone

Author/s C BarazzoneArgiroffo, P Muzzin, Y R Donati, C D Kan, M L Aubert, P F Piguet

Source American Journal of Physiology - Lung Cellular and Molecular Physiology , 281(5):L1150-6 2001

Abstract Leptin, a cytokine involved in the regulation of food intake, has been reported to be decreased in lung diseases such as chronic obstructive pulmonary disease and cystic fibrosis and increased in critically ill patients with sepsis. We investigated the role of leptin during hyperoxia in mice, which results in alveolar edema, severe weight loss, and death within 3-4 days. In oxygen-breathing mice, serum leptin was increased six- to sevenfold and its mRNA was upregulated in white adipose tissue. Leptin elevation could not be attributed to changes in circulating tumor necrosis factor-alpha but was completely dependent on endogenous corticosterone elevation because adrenalectomized mice did not exhibit any increase in leptin levels. Using leptin-deficient mice and wild-type mice treated with anti-leptin antibody, we demonstrate that weight loss was leptin independent. Lung damage was moderately attenuated in leptin-deficient mice but was not modified by anti-leptin antibody or leptin administration, suggesting that leptin does not play an essential role in the direct and short-term effects of oxygen-induced injury.

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Effect of hyperoxia on aerobic and anaerobic performances and muscle metabolism during maximal cycling exercise

Author/s Linossier, M. T., Dormois, D., Arsac, L., Denis, C., Gay, J. P., Geyssant, A., Lacour, J. R.

Source ACTA PHYSIOLOGICA SCANDINAVICA , 168(3):403-412 2000

Abstract The hyperoxia-improved tolerance to maximal aerobic performance was studied in relation to exercising muscle metabolic state. Five students were submitted to four different tests on a cycle ergometer, each being conducted under normoxia and hyperoxia (60% Fio2) on separate days: Test 1, a progressive exercise until exhaustion to determine the maximal work load (Wmax) which was unchanged by hyperoxia; Test 2, an exercise at Wmax (287 +- 12 W) until exhaustion to determine the performance time (texh) which was elevated by 38% under hyperoxia but exhaustion occurred at the same arterial proton and lactate concentrations; Test3 (S-Exercise test) consisted of cycling at Wmax for 90% normoxic-texh (4.8 +- 0.5 min under both O2 conditions) then followed by a 10-s sprint bout during which the total work output (Wtot) was determined; Wtot was elevated by 15% when exercising under hyperoxia; Test 4 (M-Exercise test) consisted also of cycling at Wmax for 4.8 +- 0.5 min with blood and muscle samples taken at rest and at the end of the exercise to compare the level of different metabolites. During hyperoxic M-Exercise test, glycogen was twice more depleted whereas glucose-6-phosphate and lactate were less accumulated when compared with normoxia. No significant differences were observed for pyruvate, phosphocreatine and muscle/blood lactate ratio between the two conditions. Conversely to normoxia, levels of ATP, ADP and total NADH were maintained at their resting level under 60% Fio2. These data lead us to suppose a higher oxidation rate for pyruvate and NADH in mitochondria, thereby lowering the metabolic acidosis and allowing a better functioning of the glycolytic and contractile processes to delay the time to exhaustion.

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EFFECTS OF HYPEROXIA ON SKELETAL MUSCLE CARBOHYDRATE METABOLISM DURING TRANSIENT AND STEADY STATE EXERCISE.

Stellingwerff T, Glazier LR, Watt MJ, LeBlanc PJ, Heigenhauser GJ, Spriet LL.
Department of Human Biology and Nutritional Sciences, University of Guelph, Guelph, ON., Canada.

This study compared the effects of inspiring either a hyperoxic (60% O2) or normoxic gas (21% O2) while cycling at 70% V02peak on; 1) the ATP derived from substrate phosphorylation during the initial minute of exercise, as estimated from phosphocreatine degradation and lactate accumulation and, 2) the reliance on carbohydrate utilization and oxidation during steady state cycling, as estimated from net muscle glycogen use and the activity of pyruvate dehydrogenase in the active form (PDHa), respectively. We hypothesized that 60% O2 would decrease substrate phosphorylation at the onset of exercise and that it would not affect steady state exercise PDH activity and therefore muscle carbohydrate oxidation would be unaltered. Ten active male subjects cycled for 15 min on two occasions while inspiring 21% or 60% O2, balance N2. Blood was obtained throughout and skeletal muscle biopsies were sampled at rest and 1 and 15 min of exercise in each trial. The ATP derived from substrate level phosphorylation during the initial min of exercise was unaffected by hyperoxia (21%: 52.2 +/- 11.1; 60%: 54.0 +/- 9.5 mmol ATP (.) kg(-1) dw). Net glycogen breakdown during 15 min of cycling was reduced during the 60% O2 trial vs. 21% O2 (192.7 +/- 25.3 vs.138.6 +/- 16.8 mmol glycosyl units (.) kg(-1) dw). Hyperoxia had no effect on PDHa, as it was similar to the 21% O2 trial at rest and during exercise (21%: 2.20 +/- 0.26; 60%: 2.25 +/- 0.30 mmol (.) kg(-1) ww (.) min(-1)). Blood lactate was lower (6.4 +/- 1.0 vs. 8.9 +/- 1.0 mM) at 15 min of exercise and net muscle lactate accumulation was reduced from 1 to 15 min of exercise in the 60% O2 trial compared to 21% (8.6 +/- 5.1 vs. 27.3 +/- 5.8 mmol (.) kg(-1) dw). We concluded that O2 availability did not limit oxidative phosphorylation in the initial minute of the normoxic trial, as substrate phosphorylation was unaffected by hyperoxia. Muscle glycogenolysis was reduced by hyperoxia during steady state exercise, but carbohydrate oxidation (PDHa) was unaffected. This closer match between pyruvate production and oxidation during hyperoxia resulted in decreased muscle and blood lactate accumulation. The mechanism responsible for the decreased muscle glycogenolysis during hyperoxia in the present study is not clear.

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Gas exchanges during exercise in normoxia and hyperoxia

Author/s H Gautier, D Maillard, D Zaoui

Source RESPIRATION PHYSIOLOGY , 33(2):199-211 1978

Abstract Exercises of constant workload (90 watt) have been carried out during normoxia or hyperoxia FIO2 = 0.45). It has been shown that, in spite of a significant dispersion in the values of O2 deficit and O2 debt calculated, these values are related to the increased blood lactate level which contributes to the marked acidosis observed in both conditions of oxygenation. Hyperoxia reduces lactate level as well as the O2 debt. In addition to the significant increase in arterial [H+] and PCO2, exercise provokes a slight decrease in PO2. It is suggested that the significant variations of these humoral factors might contribute to the control of ventilation during exercise in both conditions of oxygenation.

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Oxygen administration enhances memory formation in healthy young adults

Author/s Moss, M. C., Scholey, A. B., Moss_M_C, Scholey_A_B

Source PSYCHOPHARMACOLOGY (BERLIN) , 124(3):255-260 1996

Abstract Despite numerous studies indicating that transient cerebral oxygen depletion has a detrimental effect on cognition, surprisingly little research has examined the possibility of cognitive enhancement following elevated oxygen levels in healthy adults. Here, we present evidence demonstrating that oxygen administration improves memory formation. Inhalation of oxygen immediately prior to learning a word list resulted in a significant increase in mean number of words recalled 10 min later, compared to subjects who inhaled oxygen immediately prior to recall or to controls who underwent no intervention. In a second experiment, the learning-test interval was increased to 24 h and, again, only pre-learning (but not pre-test) oxygen administration resulted in significant memory facilitation. In experiment 3, inhalation of oxygen prior to learning was compared to inhalation of compressed air, oxygen (but not compressed air) resulted in a significant increase in word recall 24 h later. In no experiment did oxygen have a significant effect on any mood item measured. We interpret these data as indicating that increased availability of cerebral oxygen facilitates cognition, including memory consolidation. The implications for the psychopharmacology of cognitive enhancement are considered in the context of cholinergic systems and neural metabolism.

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