Oxygen – less is better, more is better??

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Background

Altitude training has been employed as a tool for enhancing performance by athletes since the 1964 Mexico Olympics. The cost and impracticality of going to altitude regularly has led to the development of altitude simulation at sea level by creating low oxygen ('hypoxia') environments. 'Altitude' or 'hypoxic' training facilities are now springing up all around the country.

The evidence supporting altitude as a benefit for health and fitness is now quite substantial. The indications are that either sleeping at altitude, or training at altitude will cause the body to adapt rapidly, resulting in; improvements in the cardiovascular system, oxygen carrying capacity of the blood, exercise tolerance, anaerobic exercise capacity and faster fuel burning. There is even evidence that there may be some kind of protection from heart disease following altitude training (Bailey, Davies and Baker, 2000).

In contrast, there is increasing interest in exactly the opposite type of practice: that of breathing *pure* or increased oxygen ('hyperoxia') for performance enhancement. In this case the individual can take a 'fix' of oxygen, elevating the pressure of oxygen within the lungs. The idea is to assist transfer of oxygen into the blood. Data is limited supporting the efficacy of this approach, however one study has suggested that the use of hyperoxia may assist training in some individuals (Nummela, Hamalainen, and Rusko, 2000).

How then, can both hypoxia and hyperoxia be of benefit to an individual?

Questions are being asked in order to understand just how these type of environments work, and how best to use them to optimise the possible effects. Are they genuinely effective, or are they merely gimmicks?

The Body at Altitude

At altitudes above 1000m, although the composition of the air remains constant, there is a reduction in barometric pressure. This causes the pressure of oxygen within the lungs to be reduced, so there is less drive to force oxygen into the blood. The various mechanisms of the body must quickly respond in order to maintain oxygen delivery to the bodies organs and muscles. At rest, this initially occurs with an immediate increase in breathing depth and frequency. Over time, the cardiovascular system, the blood, and the muscles adapt to cope with this environment. This is called 'acclimatisation'. Humans are capable of adapting to hypoxia due to our ancestry, indeed people live at high altitudes at various locations all over the world. Training rather than just resting in a hypoxic environment accelerates the acclimatisation process, and causes specific muscular adaptations (Benoit et al. 1992; Terrados, 1992).

What's really exciting is that the benefits of training in hypoxia will translate to your other training in normoxia. You may experience a lower level of exertion required for aerobic activity, a lower heart rate, and an improved aerobic and anaerobic performance (Nummela and Rusko, 2000). This may give the edge required to improve a personal best running time, or may just improve your quality of life and general health.

Artificial Altitude

The hypoxic facilities that are now commercially available do not actually take you to altitude. There is not even a reduction in the pressure of the air, however, there is a reduction in the fraction of inspired oxygen in the air, and thus, a reduction of the pressure of oxygen within the lungs. This is technically termed 'normobaric hypoxia'. The effects of this environment on the human body are exactly the same as being at a true altitude yet it's far more convenient. Commercial companies such as Edge 4 (edge4ltd@aol.com) are making available chambers and tents for both training and sleeping.

Normobaric hypoxic facilities usually mimic an altitude of around 2,500m above sea level. This approximately equates to the altitude of some of the ski resorts in the French Alps. The chamber dilutes the oxygen with nitrogen to generate hypoxic conditions, from 20.93% O_2 (in normal air) down to around 15% O_2 in hypoxia. Sleeping in hypoxia and training in hypoxia have been shown to be effective methods of stimulating acclimation to altitude. Breathing hypoxic gas has been shown to stimulate the release of EPO, resulting in increased concentration of red blood cells and ultimately enhancing VO_{2MAX} (Wilber, 2001).

Hypoxia (reduced oxygen)	Hyperoxia (increased oxygen)
• Increased oxygen carrying capacity of the blood, i.e. increased red blood cell mass	• Quicker recovery after high intensity exercise
• Improved aerobic capacity	
• Reduced perceived exertion	
• Improved performance	
• Reduced systolic blood pressure	
• Faster fuel burning	
• Improved oxygen uptake of the muscles	
• Acclimation to altitude (i.e. improved altitud performance and faster acclimatisation)	
• Improved lactate threshold	
• Increased dehydration*	
• Increased sweat rate*	
*Both types of facility offer clean air	

* There may be increased fluid loss through increased sweat rate and increased breathing in hypoxia. Individuals must be sure to drink fluid regularly during and after exercise in hypoxia in order to avoid dehydration.

A large number of elite athletes including football teams in the UK are now using hypoxic training facilities. They lend themselves superbly to the maintenance of fitness while players are injured. The increased cardiovascular stress imposed by hypoxia enables an athlete to train at lower absolute loads whilst maintaining similar relative loads as those employed in the absence of injury. Thus, when the player recovers from injury they return to play faster as a result of their maintained fitness.

The Oxygen Fix

Hyperoxic environments do not occur naturally within the earths atmosphere, unless you go below sea level. Simply pumping oxygen into the air, thus increasing the fraction of inspired oxygen creates artificial hyperoxia. There seems to be little or no evidence that breathing hyperoxic gas will result in long-term improvements in health and fitness. At rest, arterial blood is usually close to 100% saturated with oxygen. Thus, supplying more oxygen to the lungs cannot cause the blood to take up more oxygen. During exercise however, there may be a slight desaturation of arterial blood in some individuals, but this will only be significant at high intensity exercise, and will return to normal with short recovery. According to recent research, taking a few breaths of hyperoxic gas mixture during recovery from short bursts of high intensity exercise may hasten heart rate recovery and delay accumulation of blood lactate. This will only

occur if there is a significant drop in arterial oxygen saturation (Nummela, Hamalainen, and Rusko, 2000). There is also likely to be a detraining effect of using oxygen-enriched air to aid recovery. An individual will not be training themselves to recover quickly in normal air.

Clean Air

Both types training involve altering the composition of the air. The added benefit is that the air is cleaned in the process, offering a reduced chance of bacterial infection.

Conclusion

The benefits of training in hypoxia seem to outweigh the benefits of training in hyperoxia. Of the two, hyperoxia wins the gimmick prize, whereas the hypoxia seems to offer long term beneficial effects to both health and fitness. Those adaptations associated with hypoxic training are strikingly similar to those associated with endurance training. If you have contraindications to exercise, ensure that you consult your doctor before using hypoxic or hyperoxic training facilities.

References

1. Benoit, H., Germain, M., Barthelemy, J. C., Denis, C., Castells, J., Dormois, D., Lacour, J. R., & Geyssant, A. 1992, "Pre-acclimatization to high altitude using exercise with normobaric hypoxic gas mixtures", *International Journal of Sports Medicine*, vol. 13 Suppl 1, p. S213-S216.
2. Fehrenbach, E. and Northoff, H. (2001) Free radicals, exercise, apoptosis, and heat shock proteins. *Exerc Immunol Rev*. 7, pp. 66 - 89
3. Graham, T.E., Petersen, P.K., Saltin, B. (1987) Muscle and blood ammonia and lactate responses to prolonged exercise with hyperoxia. *Journal of Applied Physiology*, 63, pp. 1457 – 62
4. Nummela, A.T., Hamalainen, I.T. and Rusko, H.K. (2000) Effect of hyperoxia on SaO_2, blood pH and heart rate recovery during intermittent exercise. *Medicine and Science in Sports and Exercise* 32(5), S358
5. Nummela, A.T. and Rusko, H. (2000) Acclimatisation to altitude and normoxic training improve 400m running performance at sea level. *Journal of Sports Sciences,* 18, pp. 411 – 419
6. Terrados, N. (1992) Altitude training and muscular metabolism. *International Journal of Sports Medicine*. 13(S1), pp. S206 – S209
7. Wilber, R.L. (2001) Current trends in altitude training. *Sports Medicine*, 31(4), pp. 249 – 265

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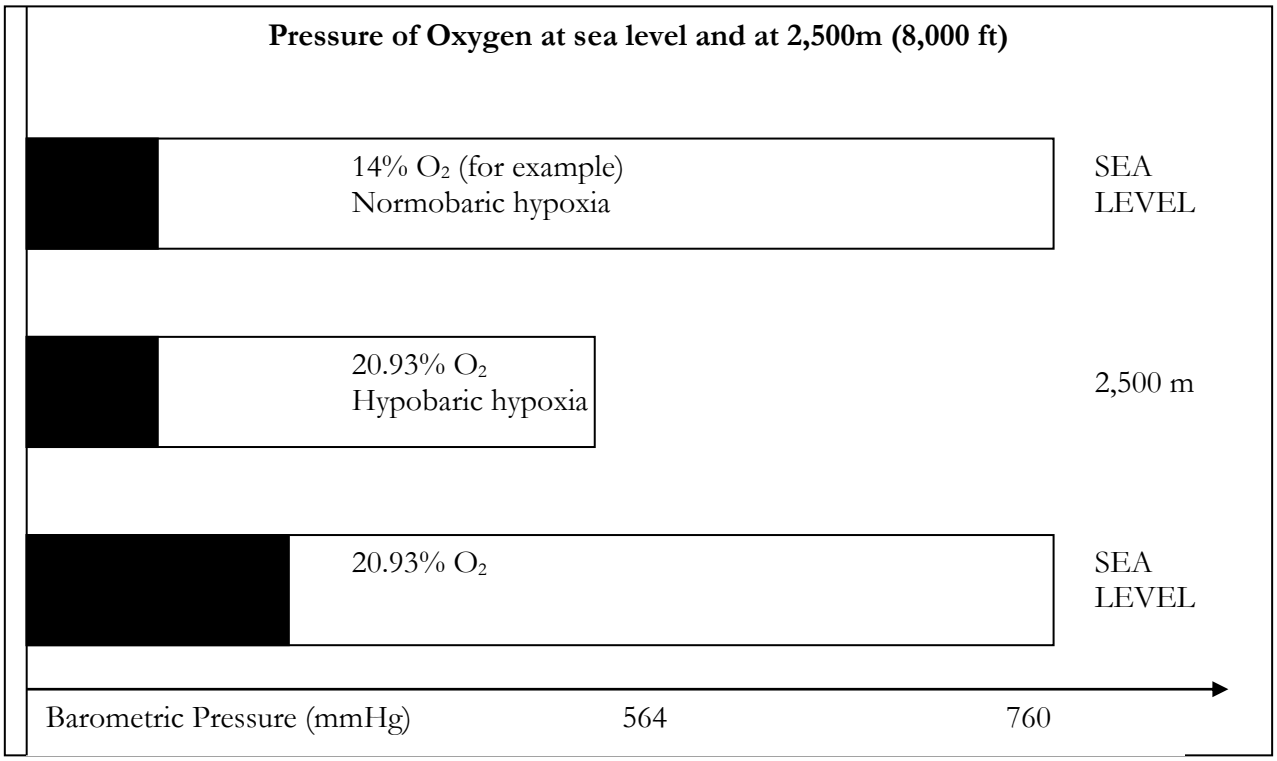
Pressure of Oxygen at sea level and at 2,500m (8,000 ft)
14% O2 (for example)
Normobaric hypoxia
SEA LEVEL
20.93% O2
Hypobaric hypoxia
2,500 m
20.93% O2
SEA LEVEL
Barometric Pressure (mmHg)
564
760