HYPOXIC TRAINING: APPROACHES TO ACLIMATIZATION

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"Hypoxic Training" as a means of adjusting to oxygen lack may be of value in several circumstances:

1. To improve competitive performance
   - At altitude
   - At sea level
2. To improve acclimatization for work or play at altitude by decreasing symptoms of mountain sicknesses
3. To treat various illnesses at sea level

1.To improve competitive performance

In many competitive sports a fraction of a second makes the difference, and various methods for training have been studied ever since the Pan American Games in Mexico City in 1956 demonstrated the effects of competing at altitude. Even earlier a large decompression chamber at Kienbaum (1) was used by the East Germans to train athletes for the Olympics.

Some competitors have lived and trained in a mountain environment; others have lived at altitude but trained closer to sea level. The emerging consensus is that one cannot train at maximum performance above 2,000 m, but that sleeping high and training low may improve performance at sea level. Nevertheless, many competitors believe that for competition in endurance sports at either **low or high altitude** they do benefit by living and training near 2000 m. For very short duration exertions, it makes no difference where the athlete trains.

Levine wrote for the Hypoxia Symposium in 1992 (later paraphrased elsewhere (2):
"... Combining high altitude acclimatization with low altitude interval/intense training in well trained competitive runners results in significant improvement in sea level 5,000 meter times above and beyond those achieved by an equivalent sea level or high altitude control."

In 1999 Fulco (3) wrote:
"Training and/or living at altitude can improve altitude exercise performance in athletic events ... lasting more than about two minutes.... Controlled studies do not support a beneficial effect of altitude training on subsequent sea level performance... Living at altitude but training at a lower altitude permits the theoretical advantage of both acclimatization and training without reducing exercise intensity. This paradigm appears promising but is till open to question since altitude natives training at altitude with oxygen supplementation (in effect "living high, training low") did not improve maximal work capacity more than altitude natives training at altitude without oxygen supplementation."

Training for competitive sports has been extensively discussed elsewhere and will not be covered here. This paper is directed at "training" or "preparation" for a sojurn at high altitude, such as a short trip to moderate elevation or a longer expedition to much higher altitude.

2. To improve acclimatization for work or play at altitude

More and more people are going to the mountains at 2-3,000 m, and much higher in the Himalayas and Andes. Many are in a hurry and believe they cannot take the time needed to adjust and enjoy whatever they go to do. So they look for ways to speed up the acclimatization process which will protect them from mountain sickness. What choices do they have?

First there are medications that might be called artificial acclimatizers such as acetazolamide (Diamox) and dexamethasone. These are effective and relatively free of side effects, but some mountain lovers don't relish the idea "if you can't take time, take Diamox". Some claim, wrongly, that acetazolamide "dangerously masks the symptoms of mountain illnesses".

A better way is to go up in stages - spending a few days at intermediate altitudes before going to a mountain destination, or taking a week or two to walk from a low valley to a Himalayan base camp. Once at base camp, climbing a few hundred feet higher each day, will acclimatize the climber to move further up the mountain. Such "siege" tactics take time but do minimize the risk of altitude sickness. Siege tactics are a form of "hypoxic training".

Other approaches have been tried for almost a hundred years. In 1886, Oertel (4) recommended a program of walks at gradually increasing elevations for the treatment of *"weak heart muscles, poor pulmonary circulation and obesity"*. During WWII some aircraft pilots were sent to mountain resorts to prepare them better for very high altitude combat. Mining is routinely conducted above 18,000 feet, and several living and work protocols have been studied to make workers more effective and less susceptible to mountain sickness (5). Among these are sleeping in oxygen-enriched rooms at the altitude worksite, staging the ascent, or alternating a week at altitude with a week lower down.

Of current interest is whether **brief** periods at simulated altitude will improve performance and minimize mountain sickness during a subsequent visit to **moderate** altitude. Several methods have been advocated and widely advertised to experience altitude without going to the mountains (6).

In 1990 Richalet (7) directed a project called "Everest Turbo", in which five experienced mountaineers were taken for seven days to 4350 m and 4807 m in the mountain environment and then progressively higher for several hours each of the next four days in a decompression chamber. They were then flown from France to Nepal and driven into Tibet, reaching 5200 m on Everest five days later. They immediately started to climb and in four days reached 7800 m but were unable to go higher because of bad weather. Hard data was collected only in France; the experiment was thought a success because the subjects climbed higher faster than an envelope of 305 mountaineers have done on Everest. The study was planned as an "experience" and in no way an attempt to prepare climbers for a high altitude expedition.

Acclimatization by exposure to gradually increasing hypoxia has the following effects: increased red blood cell production by release of EPO, increased minute volume of ventilation, temporarily increased cardiac output, decreased sympatho-adrenergic stimulation, decreased exercise capacity, and, depending on the degree of hypoxia, slowed cognitive responses (8).

These responses fit into the General Adaptation Syndrome, or Stress Response described by Selye (9) many years ago. Selye hypothesized that a stressor provoked an "alarm reaction" consisting of physiological changes to mitigate the stress. After some period, dependent on duration and intensity of stress, the organism either adapted by sustaining some of the responses, or deteriorated, ultimately dying. Applying Selye's theory to high altitude, we find that up to a certain point (roughly 5500m), these responses are protective and we call them acclimatization, but after longer exposure to severe hypoxia they are counterproductive and lethal.

Finding other methods of acclimatizing has stimulated several techniques for "hypoxic training" at sea level in low oxygen rooms or tents or in decompression chambers. Some approaches call for an hour or two once or twice a day, others for twenty minutes several times a day, still others for sleeping in the simulated altitude environment. Many Scandinavian hotels have special low oxygen rooms, and in this country several athletic clubs offer either low oxygen rooms or low pressure chambers (10). Different models for home use are on the market. This has become a popular method for getting ready for a visit to a moderate altitude.

Unfortunately little hard data has been collected to indicate whether these various procedures have any beneficial effect. They are expensive and, as is true of many costly products, some of those who use one of the techniques are enthusiastic.

3. For treatment of various illnesses

During the last ten years the Moscow Hypoxia Medical Academyhas collected data during Interval Hypoxic Training (IHT) to treat a variety of medical problems (11). IHT consists of 'courses ' of cyclic repetition of brief normobaric hypoxic episodes and subsequent re-oxygenation. The intensity and duration is customized for specific diseases and individuals. The hypoxic mixture is administered through a mask, from a calibrated machine using a membrane oxygen generator. A variety of illnesses are treated in different 'courses' of varying length.

Researchers at HMA hypothesize (12) why repeated courses of IHT are effective:

"IHT effectively decreased the response of pulmonary ventilation and heart rate to a physical load (the effect similar to that observed in altitude exposure)... At a load of 150 Watts the double product (heart rate multiplied by systolic blood pressure), an indirect measure of myocardial oxygen consumption, was significantly lower (P<0.04) in the group of volunteers (sport students) after the IHT course as compared with placebo group. Similar results were obtained in patients with coronary heart disease (stable angina of effort). At a load of 50 Watts the decrease of

the double product was accompanied by the increase of physical load tolerance (P<0.05)". [When the load was further increased, the benefit attributed to IHT was increased (P<0.01)]. *"The above results suggest the outlook for the therapeutic use of IHT.*

(In preparation for a mountain ascent) *"The placebo controlled study was carried out ... on young healthy volunteers... at the altitude of 3000 m (10,000 feet) in the decompression chamber...* [The course of IHT] *was shown to retain significantly higher arterial blood oxygen saturation (P<0.05) than placebo controls. ...* [There was] *a statistically significant 1.7 fold increase in erythropoietin level in blood ... from the fourth IHT session, with the level remaining high during the IHT course".*

To evaluate the therapeutic benefits of interval hypoxic training in the variety of illnesses described by the Moscow group requires further large and carefully controlled studies by other investigators. However, one can say with confidence that the hypotheses and basic physiology on which the treatment rests are sound and the observations so far published are encouraging.

SUMMARY
From the information available today, both anecdotal and hard data, the following conclusions seem reasonably well established

1. Training to compete at any altitude is best accomplished by sleeping high and training low. There may be a break point around 1500 m, above which this precept weakens.
2. Acclimatization for ascent to very high altitude is best accomplished by exposure to gradually higher altitudes (i.e. to gradually decreasing ambient oxygen pressure).
3. Preventing or minimizing mountain sickness at moderate altitude (2500-3000 m) may be accomplished by medication or by staged ascent. The effect of intermittent exposure to hypoxia in preventing mountain sickness has not been proven.
4. The beneficial effects of intermittent exposure to normobaric hypoxia in accelerating acclimatization are suggestive but require further rigorously controlled study.
5. The beneficial effects of Interval Hypoxic Training in treatment of various illnesses are suggestive but require more well controlled clinical studies.
6. The complex processes of acclimatization include many inter-related changes which are in accord with Hans Selye's General Adaptation (Stress) Syndrome.

Charles S Houston MD
Burlington, Vermont
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