INFLUENCE OF HIGH ALTITUDE TRAINING ON ATHLETES

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Received May 9, 2006      Accepted October 19, 2006

ABSTRACT

Altitude exposure causes wide-ranging physiological responses. Changes occur in ventilation, heart rate, acid-base regulation, body composition, and substrate metabolism. The environment often increases exercise stress. Low oxygen pressure at high altitude can stress the oxygen transport systems of even the fittest athletes. Cold temperatures can numb the flesh and sometimes suppress cellular metabolism to dangerous levels. Hot temperatures can result in a competition for blood between the skin and muscles that can severely limit physical performance and subject the body to thermal injury. Smoggy air can leave the athlete gasping for air during exercise, while traveling across time zones can fatigue athletes and make them less able to compete. Through this paper, we pay particular attention to effects of those conditions on acute and long term exercise response and to acclimatization.

Key Words : Altitude, Smoggy air, Temperature, Exercise, Physical, Heart rate, Stress.

INTRODUCTION

Humans are exploring new environments, “climbing higher”, “going deeper”, and challenging new frontiers in space. It is important for you to understand the physiological effect of long periods of time in space and upon return to a gravitational environment. This has relevance to extended deconditioning on earth, a used by bed rest, inactivity and aging.

The purpose of this chapter is to provide the knowledge that will allow you to serve as a knowledgeable reference source for those who wish to learn about performance while training at altitude.
When Mexico City (elevation, 7400 feet or 2250 meters) was named as the site for the 1968 Olympic Games, coaches immediately asked: How can we train our athletes to best withstand any effects of altitude on their performance? Should they train only at altitude? If so, at what altitude and for how long? Should they train intermittently at altitude and at sea level? Because the answers to these questions were not available, a great deal of research was initiated.

The longer you remain at altitude, the better your performance becomes, but it never quite reaches the values that are obtained at sea level. As mentioned, the improved performance during a stay at altitude is brought about through acclimatization. The number of weeks to acclimatize depends on the altitude - i.e., for 2700 meters, about 7 to 10 days; for 3600 meters, 15 to 21 days, and for 4600 meters, 21 to 25 days. These are only approximations; a great deal depends on the individual. As a matter of fact, a few people will never acclimatize and will continue to suffer mountain sickness. While at altitude, this happens even with people who were born and raised at altitude. Suddenly, for unknown reasons, they lose their acclimatization and suffer from mountain sickness.

Several studies on the effect of altitude on athletic performance have been conducted involving both high school and college athletes. The results provide important information regarding the effects of training and acclimatization on competitive athletic performances. This section will focus on the effects of altitude on endurance or aerobic activities rather than no sprint or anaerobic events, because, as already mentioned, hypoxia significantly reduces oxygen availability, and thus performance in endurance events.

**MAIN-PART**

From a theoretical viewpoint, training at altitude could produce more rapid and even greater physiological changes that could training at sea level only. The reasons for this is that altitude hypoxia is a stress that produces physiological changes (acclimatization) similar to those caused by physical training. For example, total blood volume, hemoglobin, red blood cell count, mitochondrial concentration, and muscle enzyme changes have all been shown to be enhanced in both types of stress. To a certain extent, this idea has been supported experimentally. For example, in several well controlled studies using nonathletes, greater increases in maximal aerobic power and endurance time were seen when the training session were conducted at altitude (7400 to 11,300 feet) rather than at sea level. In addition, we have shown that some effects of eight weeks of interval training can be maintained for an additional 12 weeks by use to two three hour exposures to a simulated altitude of 15,000 feet perform any exercise, but merely rested. Other studies have shown improved performance at sea level after training at altitude and at simulated altitude. Some of the results are given in the following table.

<table>
<thead>
<tr>
<th>Event</th>
<th>Time at sea level (min:sec)</th>
<th>Time at altitude (min:sec)</th>
<th>Time on return to sea level (min:sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day 3</td>
<td>Day 14</td>
<td>Day 21</td>
</tr>
<tr>
<td>880-yard run</td>
<td>2:41</td>
<td>2:48</td>
<td>2:38</td>
</tr>
<tr>
<td>1-mile run</td>
<td>6:07</td>
<td>6:30</td>
<td>6:15</td>
</tr>
<tr>
<td>2-mile run</td>
<td>13:08</td>
<td>13:45</td>
<td>13:09</td>
</tr>
</tbody>
</table>

*Based on data from Faalkner, Daniels, and Balke.
the conditioning at altitude. In other words, it is possible that their performances would have been improved with further training even at sea level. Figure 1.2 shows that in studies involving highly trained athletes, performance on return from altitude was not much different from prior performance at sea level, if anything, some were

**Fig. 1.1.** Intensity of training workouts for six collegiate runners at various altitudes. Even though their coach was present at all workouts it is clear that altitude greatly reduced their training efforts.

**Fig. 1.2.** Decreases in running performance at 13,000 feet. The decreases in performance are most pronounced in the longer events where the oxygen system is the predominant energy pathway. Notice that the performance did not exceed their prealtitude values on returning to sea level.
poorer. This would indicate that for the highly trained athlete, training at and acclimatization to altitude does not improve performance. Also, as already pointed out, maximal aerobic power and performance of these athletes do not always improve with altitude acclimatization. One of the major reasons for this might be that the training programs required for these athletes cannot be sustained at altitude at an intensity and duration commensurate with that at sea level. This can be seen from figure 1.1, which gives the intensity of the training workouts for six collegiate runners at various altitudes. Although their coach was present at all workouts, it is clear that altitude greatly reduced their training efforts.

It remains to be seen whether training at altitude significantly improves athletic performance upon returning to sea level. More recently studies have attempted to provide appropriate experimental designs to answer this question. However, even in these studies, methodological problems preclude one from saying that altitude training is beneficial. In addition to answering that basic question, more studies need to address the duration of the activity, timing of return to sea level, and other relevant questions. If you wish to train your athletes at altitude for whatever reason, the following guidelines may prove to be helpful—

1. Adequate training facilities and training atmospheres must be available.
2. The bulk of time spent at altitude should be at moderate altitude (6500-7500 feet).
3. Short exposure to higher altitude should be included regularly during the general training period at moderate elevation.
4. Steady altitude exposure should be limited to periods of two to four weeks, with intermittent sea-level or lower elevation trips scheduled to insure maintenance of muscular power and normal competitive rhythm and intensity of effort.
5. Training at altitude should emphasize maintenance of muscular power yet be geared to include normal or near normal overall amounts of work.
6. Important sea-level efforts should be scheduled about two weeks after leaving altitude.

**Acute Effects of Altitude**

As we ascend above sea level, the barometric pressure (P\textsubscript{B}) decreases as the weight of the atmosphere becomes less. The percentage of oxygen in the air remains 20.93, but the number of oxygen molecules per unit volume decreases. This means that, when at altitude, to receive the same number of molecules in a breath of air that we receive at sea level, we must breathe more air. The main reason for lessened performance at altitude is a consequence of the lowered oxygen partial pressure (P\textsubscript{O\textsubscript{2}}). This lowered P\textsubscript{O\textsubscript{2}} results in hypoxia, which is lack of adequate oxygen. Some of the important physiological adjustments to acute altitude exposure are listed below—

1. Increased pulmonary ventilation (Hyperventilation).
2. Increased resting and submaximal cardiac output.
3. Elevation of pulmonary vascular resistance.

These major physiological changes are immediate and greatly aid in delivering oxygen to the tissues when oxygen is hard to come by atmosphere (i.e. under hypoxic conditions). It is important to point out that some individuals become very sick when they go to altitude. The symptoms of mountain sickness may include pulmonary edema, nausea, vomiting, headache, rapid pulse, and anorexia (loss of appetite).

**CONCLUSION**

It is widely accepted that hypoxia stimulates a number of acclimatization mechanisms, depending on altitude and duration.
of stay. The important physiological changes that take place during acclimatization to altitude include—

1. Increased number of red blood cells and haemoglobin concentration.
2. Elimination of bicarbonate (HCO₃⁻) in the urine.
3. Tissue level changes.

When the person returns from a 3-4 week sojourn at altitude, he or she will lose these changes brought about by acclimatization within a period of about two to four weeks.

The major concepts to be learned from this study are as follows—

- When the pressure on a given volume of gas is increased, the volume decreases (Boyle's law).
- When temperature of given volume of gas is increased, the volume increases (Charle's law).
- The partial pressure of gases in a mixture remain constant and act independently of each other (Dalton's law).
- The amount of gas a fluid will absorb under pressure of the gas (Henry’s law).
- At altitudes over 5000 feet (1524 meters), the ability to perform endurance activities is decreased due to hypoxia i.e. the lowered partial pressure of oxygen in the air.
- Endurance performance at altitude may sometimes be improved with continued stay at altitude due to the acclimatization process.
- Acclimatization to altitude involves:
  1. Increasing pulmonary ventilation,
  2. Increasing red blood cell and haemoglobin concentrations,
  3. Eliminating bicarbonate in the urine, and
  4. Tissue changes.

- Training at altitude might enhance endurance performance at sea level but only in unconditioned, nonathletic individuals.
- For the highly trained athlete, the training intensity required for maintenance of peak performance cannot be achieved at altitude.

REFERENCES