Altitude Training for Improvements in Sea Level Performance
Is There Scientific Evidence of Benefit?

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Summary
Altitude training invokes physiological changes that are very similar to those caused by endurance training. As a result, it has been incorporated in the training regimes of elite athletes in an effort to improve sea level performance. Several training strategies, such as constant altitude exposure, intermittent altitude exposure or ‘live high train low’, have been used in an effort to incur an advantage in sea level performance over just sea level training alone. In spite of the accumulating scientific evidence that altitude training affords no advantage over sea level training, many coaches and athletes believe that it can enhance sea level performance for any athlete, whether endurance or power is the focus in their particular sport. However, altitude training may not be suitable for some athletes depending on their age, fitness level, health, iron status and the energy and technical requirements of their sport. The issue of whether altitude training enhances sea level performance remains a controversial topic.
Altitude training and acclimatisation for athletic performance at altitude and at sea level has been an area of interest and controversy over the past several decades. Knowledge of the physiological effects of altitude is largely based on research done at high altitude. However, it is the moderate altitude elevations (1400 to 3000m) at which most athletes train or compete. This is because the higher altitudes tend to increase the frequency of symptoms of high altitude illnesses and limit the absolute intensity at which the athlete can train. The impact of the moderate altitude range on physiological and performance variables requires further investigation.

In the different studies conducted, the altitude of ascent, duration of exposure, the fitness level of the participants as well as the type of training done while at altitude has varied substantially. As a result, altitude training research has produced confusing information. Anecdotal evidence suggests that altitude training may provide an ergogenic effect on sea level performance, but most scientific evidence has been unable to support these claims. This review summarises the purpose and underlying physiology of altitude training for sea level performance, the types of training strategies currently being researched in the field, and the effect of altitude training on the physiology and performance of different types of athletes.

1. The Purpose of Altitude Training

Altitude training invokes physiological changes that are very similar to those caused by endurance training such as an increase in myoglobin, haemoglobin level, haematocrit and aerobic enzymes in the muscle. Elite athletes, in pursuit of these changes, have incorporated altitude into their training regimen in an effort to improve sea level performance. The theory states that the stress of hypoxic exposure, in addition to training stress, will compound the training adaptations the athletes experience which, in turn, will lead to greater improvements in performance. However, the value of training at altitude for sea level performance is controversial. Some studies have shown improvements in sea level endurance performance after altitude training while others have shown that altitude training has no effect, or a detrimental effect, on sea level performance. In order to resolve the possible causes of these conflicting results, an understanding of the physiology of altitude acclimatisation and the extent to which acclimatisation might benefit or detract from exercise performance is essential.

2. Physiological Changes Invoked by Short Term Altitude Exposure

As altitude increases, barometric pressure decreases resulting in a decrease in the partial pressure of oxygen (PO2) which causes the alveolar oxygen tension and arterial oxygen saturation to fall. This results in less oxygen transfer from the environment to the blood as the diffusion of oxygen across the alveoli is directly dependent on the PO2 gradient between the alveoli and the arterial blood. Thus, as arterial oxygen pressure (PaO2) decreases at altitude, less oxygen will be delivered to the tissues of the body. In response to this, physiological changes occur within the first 4 hours of exposure to hypoxia and will continue for many months if the exposure persists. The initial stage of altitude acclimatisation is characterised by a variety of functional changes that collectively facilitate oxygen transport to maintain tissue PO2 and oxygen consumption (VO2).

2.1 Ventilatory and Acid/Base Changes

An increase in ventilation with hypoxic exposure has been observed by several researchers and is considered to be one of the fundamental changes that characterises the initial stages of acute acclimatisation. When ventilation increases upon ascent to altitude, the partial pressure of carbon dioxide (PCO2) of the blood decreases, resulting in a decrease in hydrogen ion level and a corresponding increase in pH. This initial respiratory alkalosis causes the kidneys to increase renal bicarbonate excretion. Blood bicarbonate is the primary buffer of lactic acid, thus during initial acute exposure to hypoxia, the efflux of muscle lactate...