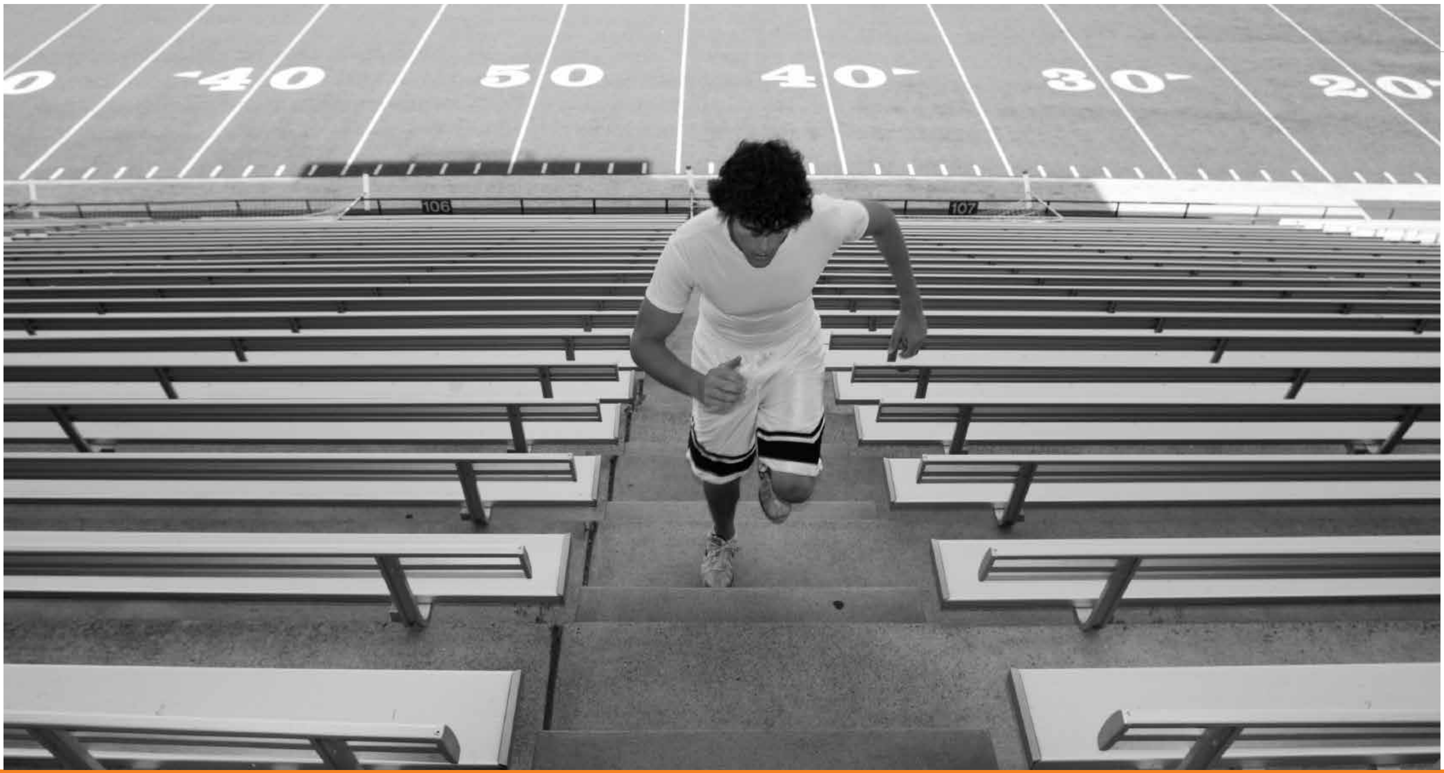

IS LIVE HIGH/TRAIN LOW THE ULTIMATE ENDURANCE TRAINING MODEL?

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PURPOSE

The purpose of this paper is to review literature on the form of altitude training known as "live high/train low." Topics that will be explored include what changes can be expected, what dose is required, and if it preferable to other training models for improving performance in endurance sports such as running, swimming, and cycling.

WHAT IS LIVE HIGH/TRAIN LOW

Live high/train low is a training method in which athletes live at high altitude and train at low altitude, usually with the goal of improving performance at sea level. The main idea is to reap the benefits of high altitude acclimatization while maintaining the intensity of low altitude training. The live high portion of the method is sometimes simulated with the use of altitude tents. The method used for these simulated environments is either oxygen filtration or nitrogen dilution, both of which reduce the concentration of oxygen. The train low portion of the method can be simulated by the use of supplemental oxygen (19).

ALTITUDE ACCLIMATIZATION

The main adaptation from prolonged altitude exposure that is believed to improve performance is the increase in the number of red blood cells, or more specifically, the amount of hemoglobin. An increased red blood cell count increases oxygen carrying capacity and therefore should increase the amount of oxygen delivered to working muscles. With greater oxygen carrying capacity, an increase in VO_2max and an increase in performance would be expected.

Little research has been done to determine what muscular adaptations occur due to altitude exposure (hypoxia). There is evidence to suggest that hypoxia results in greater carbohydrate utilization and dependence, which could be detrimental to endurance performance (4). It is also likely that anaerobic capacity increases due to increase muscle buffering capabilities, which could lead to better performances, even in the absence of VO_2max increases (5). Training in hypoxia, as opposed to simple exposure, may pose additional benefits or problems.

POSSIBLE MECHANISMS OF BENEFITS OR PROBLEMS

Numerous mechanisms have been postulated to explain improved performance in live high/train low athletes. These include improvements in anaerobic capacity, muscle buffering capabilities, oxidative enzyme increases, and erythropoietic pathways (which increases the amount of red blood cells) (10).

Some research suggests that the stress of hypoxia can reduce training stimuli to inadequate levels (i.e., runners training too slow to reap positive benefits) and seems to have a negative effect on immune system function (14). Moreover, the effects of hypoxia in the brain may influence both training intensity and physiological responses during training at altitude (14). Thus, interrupting hypoxic exposure by training in normoxia (i.e., normal levels of oxygen) may be a key factor in avoiding or minimizing the negative effects that are known to occur during chronic hypoxia. Exposure to hypoxia appears to have some positive transfer effects on subsequent training in normoxia during and after live high/train low. The increased oxygen transport capacity of blood allows training at higher intensity during and after the live high/train low method in subsequent normoxia, thereby increasing the potential to improve some neuromuscular and cardiovascular determinants of endurance performance (14).

Other research contends that erythropoietic pathways are responsible for the improved performance (10). According to this research, there are no other effects of altitude acclimatization that can be manipulated independently to improve athletic performance over a sustained period of time. The magnitude of the response at altitude is qualitatively and quantitatively similar to that induced by isolated manipulation of the red cell count (low-dose erythropoietin injection), and the outcome is prevented if the erythropoietic process is impaired by iron deficiency or infection (10).

Opponents to this training method contend that a large amount of error occurs when recording changes in red blood cell count and changes in red blood cell counts do not necessarily correlate with improved performance (7). Furthermore, increases in economy have been recorded in several studies and it seems logical that hypoxia could trigger changes in cardiovascular regulation of muscle blood flow as well as intracellular adaptations (7).

IS LIVE HIGH/TRAIN LOW EFFECTIVE?

To answer this question, we must look at physiological and performance measures while comparing this mode of training to others.

HEMOGLOBIN

Earlier studies (both published in 1999) on the effect of live high/train low showed no change in hemoglobin volume in male or female athletes (1,2). However, these studies might not have allowed for an adequate amount of altitude acclimatization. The subjects in these studies slept in altitude tents for up to 10 hours per night (for 12 or 21 days depending on the group), but spent the rest of the day at an altitude of just 600 meters (1,2). This ratio of altitude exposure to that at sea level may have not induced the desired effects of acclimatization.

Contrary to those earlier studies, a more recent study in 2010 found increased amounts of hemoglobin, and increased 4-mM lactate threshold velocity in swimmers training under the live high/train low method (12). Furthermore, a recent review of this topic suggests that quantities of hemoglobin may be increased by an average of 6.5% with sufficient altitude exposure (15). This review also revealed a 14% gap between altitude natives and other elites, as well as the 35% gap between elites and the general population (15). These numbers help put the training effect in proper perspective. A recent study of elite Swiss orienteers found not only increased amounts of hemoglobin and red blood cells, but also showed improvements in VO_2max which would be expected with greater oxygen carrying capacity (18).

HYPOXIA

A study in 2006 investigated whether exposure to hypoxia in a live high/train low method would impair cardiovascular and autonomic adaptations to endurance training. The researchers determined that exposure to hypoxia did interact with variables such as resting heart rate, diastolic blood pressure, and total peripheral resistance, which were all higher than in the control group, but changes disappeared following a 15-day training protocol at sea level (4).

Hypoxia may induce greater oxidative stress than normoxic conditions. However, after an 18-day and 13-day live high/train low protocol, investigators of a different study concluded that "repetitions of normoxic exercises at low intensity during endurance training seem to act as a pre-conditioning stimulus for the oxidative stress induced by an acute hypoxic exposure," thereby reducing the deleterious effects (11).

EFFECTS ON PERFORMANCE

When considering what training method will best improve performance, it is important to consider where the performance will take place. Since most athletes that live high, but train low, are trying to improve their sea-level, or normoxic, performance, this is where the bulk of studies take place.

As stated above, live high/train low training method is intended to provide the benefits of altitude acclimatization, combined with the neuromuscular benefits of intense sea-level training. In support of this concept, a study of collegiate runners revealed that live high/train low runners improved their 5,000-m run performance while live high/train high runners did not (19). It should be noted that both groups improved red blood cell counts and VO_2max to similar degrees. In the same study, the live low/train low group did not see improvements for any parameters (19).

A study of 39 competitive runners revealed that 5,000-m time trial performance was improved by an average of 13 s after a 4-week live high/train low protocol (9). All runners were trained together for six weeks before dividing into sub-groups of live high/train low, live high/train high, and a no altitude control group. Both altitude groups improved physiological measures but only the live high/train low group improved time trial performance (9). Similarly, the study of Swiss orienteers showed an average improvement of about 18 s in 5,000-m run times after following the live high/train low method (18).

Research is often criticized for not using ultra elite athletes, or in the case of the orienteers, while their run time did improve the significance of a running time trial for orienteers is a limitation due to its lack of specificity to orienteering.

A study of sub-elite runners and triathletes utilized altitude tents to induce live high/train low conditions. Each athlete completed normal training in normoxia for about 25 days, and then performed 2-, 4-, and 8-min treadmill runs to exhaustion. Performance increased by about 1% when training was augmented by sleeping at simulated high altitude (8). Based on this data, the authors concluded that live high/train low is an effective method for middle distance runners (8).

Another question to ask is whether alternative forms of this training method produce different outcomes on performance.

LIVE HIGH/TRAIN HIGH

A review of several different training methods states that training in hypoxic conditions, specifically live high/train high, seems to limit the intensity of workouts and the authors site several studies backing this claim along with data showing the time trial decrease (19). In another study, the authors thoroughly reviewed the performance outcomes of live high/train high and found a split in the literature, with slightly more studies finding no performance improvement (5). They concluded by acknowledging the challenges of overtraining, detraining, and the effect of individual variability on the effective use of this method.

As mentioned in the study of 39 competitive runners, VO_2max improved and red blood cell counts increased in both live high/train high and live high/train low groups but only the live high/train low group improved 5,000-m time. These findings support the idea that intermittent breaks from hypoxia, as well as maintenance of training intensity, could make live high/train low superior to live high/train high for improving sea-level performance.

LIVE LOW/TRAIN HIGH

Live low/train high or intermittent hypoxic training involves living at a normal altitude while training in hypoxia via oxygen filtration or nitrogen dilution. Purported benefits of this method include increases in erythrocyte volume, muscle mitochondrial density, capillary-to-fiber ratio, and fiber cross-sectional area (19).

However, reviews of the literature reveal little evidence that live low/train high protocols increase the amount of hemoglobin, improve VO_2max, or improve performance (17,19). The results are summed up in the following statement: “Collectively, live low/train high studies have failed to yield a clear picture of this training concept’s effects on VO_2max, peak power output during incremental testing, or time trial performance,” (17).

Based on the evidence, it seems that the short duration of hypoxic exposure (far less than the minimally recommended 12 hours per day), along with the intensity of training (or overtraining), hampers performance improvements for athletes using this type of method.

LIVE LOW/TRAIN LOW

It is suspected that prolonged hypoxic exposure, combined with exercise, can harm immune system function (5). This idea has been supported by two studies of athletes living at 3,500 meters (5,19). One study found a decreased leukocyte count, and the other found depletion of secretory immunoglobulin A (5,19).

Some studies of elite runners have found large portions of that population to be non-responders to live high/train low (3). Specifically, runners that improved 5,000- or 3,000-m time trial performance more than the average time were considered high responders, while runners that did not improve at all were considered non-responders. Between the two studies, 20 of the 61 runners were considered non-responders (3).

Given the large number of runners that don’t respond to training, along with possible immune system dysfunction, high cost, time consumption, and possibility of acute altitude sickness, live high/train low represents a more risky activity than normal sea-level training (live low/train low).

However, live high/train low has been shown to improve physiological measures and, more importantly, time trial performance over sea-level training (3). Live high/train low might also have training benefits that go beyond an immediate time trial performance as researchers have noted “increased oxygen transport capacity of blood allows training at higher intensity during and after training in subsequent normoxia, thereby increasing the potential to improve some neuromuscular and cardiovascular determinants of endurance performance,” (14).

Athletes must balance the risks involved with the possible benefits of live high/train low versus the live low/train low method, but if the resources exist, it is clear that the risk could be well rewarded.

CAN LIVE HIGH/TRAIN LOW BE IMPROVED?

Owing to impaired aerobic capacity in hypoxia, exercise intensity has to be reduced during training at moderate altitude to reach a similar intensity compared to sea-level training. Therefore, training at altitude might be used for an increase in exercise intensity, which might be more difficult to achieve during sea-level training. In some studies, where athletes exercised with higher intensity during altitude compared with sea-level training (although such an increase was not intended) sea-level performance improved after return to sea level (5).

Training in hypoxia is also associated “with beneficial changes in skeletal muscle mitochondrial density, capillary-to-fiber ratio, and fiber cross-sectional area,” (19). Combining these adaptations with a possible increase in intensity mentioned above and it becomes clear that there might be some benefit to a live high/train low + train high model.

A recent study of live high/train low + train high found subjects improved VO_2max and increased amount of hemoglobin after training, but only a 1.1% improvement over a 3,000-m time trial. This percent improvement does not distinguish itself from improvement in live high/train low methods. Investigators concluded that a combined approach of live high/train low + train high results in an enhancement in the physiological capacities that facilitate successful competitive performance compared with live high/train low or train high alone (13). However, there was a lack of direct transfer of these physiological adaptations to improved time trial performance (13). With 46% of the training being hypoxic in this study, it is possible that a smaller, or even a larger, portion of hypoxic training could have a positive impact.

Another possible way to improve upon the live high/train low model would be reducing the prevalence on non-responders. This could be achieved "by screening the erythropoietic and training velocity response to acute altitude, either shortly after arrival at altitude or in a laboratory setting," (3). This type of screening could help identify athletes that could benefit from train high/live high as well as those better off staying at sea level. It could also help identify optimal training or sleeping altitudes for individual athletes (3).

HOW MUCH ALTITUDE EXPOSURE IS NEEDED?

It is unknown what dose of altitude exposure or training is needed to induce the necessary adaptations for improved performance. However, after years of research, a general recommendation is becoming clear. A recommendation from a review paper stated 3 to 4 weeks at an altitude of more than 2,000 meters for using the live high/train high method (5). Interestingly, earlier investigators offered a similar recommendation, "the minimum dose to attain a hematological acclimatization effect is greater than 12 hours a day for at least 3 weeks at an altitude, or simulated altitude, of 2,100 – 2,500 meters," (14). It is possible that live high/train low sessions require higher altitude than classical sessions of the same duration due to the reduced time of exposure.

The authors of the most thorough review on this particular topic recommend at least 4 weeks of at least 22 hours per day of living at 2,000 – 2,500 meters. If using simulated altitude, the authors recommend at least 4 weeks and 12 – 16 hours per day of living at 2,500 – 3,000 meters (20). Living at higher altitudes than those suggested could have debilitating consequences.

CONCLUSION

Evidence suggests that live high/train low can enhance physiological and sea-level performance to a greater extent than training methods using live high/train high, live low/train high, and live low/train low. However, before an athlete commits to such a training regimen, the costs and risks should be considered. Typically, 1% improvements can be gained after 3 – 4 weeks, but this is not always the case.

Once individual response variability is understood to a greater degree, screenings may become more common and reliable, and live high/train low or live high/train low + train high could be optimally utilized. Responders have shown as much as a 4% improvement, while non-responders have shown as much as a 1% decrement following live high/train low regimens, making individual variability possibly the most important issue remaining to be understood (20).

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Jamie Ness first discovered an interest in altitude training in a college course in which he took part in a live high/train low plus train high training for a short period in Colorado before his upcoming track season. Since that time, Ness has coached cross country and track and field for seven years, including four at the collegiate level. He is currently teaching in Eastern Kentucky University’s Exercise and Sports Science program. Ness holds a Master of Science degree in Kinesiology and Health Promotion from the University of Kentucky and the Certified Strength and Conditioning Specialist® (CSCS®) certification from the National Strength and Conditioning Association (NSCA).