“Live High - Train Low”
Altitude Training for Endurance Performance

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Introduction

Coaches and athletes alike are constantly striving for training strategies to provide an advantage over their competitors. Altitude training is an integral part of many endurance athlete’s preparation for competition and a common approach to this conditioning strategy is ‘live high train low’ (LHTL) where as the description implies athletes live at altitude to stimulate physiological adaptation but train at sea level so exercise intensity can be maintained and de-conditioning avoided. LHTL can be achieved naturally or artificially which can be grouped into three distinct categories (Figure 1) [1] the artificial long continuous approach includes studies in which participants are exposed to simulated moderate altitude (generally defined as 1,500 m-2,500 m) for 8 to 18 hours per day. The artificial short continuous approach includes studies in which participants are exposed to simulated moderate-high altitude (generally defined as 2,500 m-5,300 m) for 1.5 to 5 hours per day. The artificial brief intermittent approach includes studies in which participants are exposed to simulated high altitude (generally defined as 5,300 m-8,848 m) for less than 1.5 hours per day. The aim of this editorial is to combine information from a recent meta-analysis and an associated editorial to provide guidance in terms of simulated height of altitude exposure, both daily exposure and intermittent brief and continuous brief training is an integral part of many endurance athlete’s preparation for competition and a common approach to this conditioning strategy is ‘live high train low’ (LHTL) where as the description implies athletes live at altitude to stimulate physiological adaptation but train at sea level so exercise intensity can be maintained and de-conditioning avoided. LHTL can be achieved naturally or artificially which can be grouped into three distinct categories (Figure 1) [1] the artificial long continuous approach includes studies in which participants are exposed to simulated moderate altitude (generally defined as 1,500 m-2,500 m) for 8 to 18 hours per day. The artificial short continuous approach includes studies in which participants are exposed to simulated moderate-high altitude (generally defined as 2,500 m-5,300 m) for 1.5 to 5 hours per day. The artificial brief intermittent approach includes studies in which participants are exposed to simulated high altitude (generally defined as 5,300 m-8,848 m) for less than 1.5 hours per day. The aim of this editorial is to combine information from a recent meta-analysis and an associated editorial to provide guidance in terms of simulated height of altitude exposure, both daily exposure and intermittent brief and continuous brief

Published LHTL studies

A recent meta-analysis of 11 studies [1] showed athletes exposed to (LHTL) hypoxia had higher maximal oxygen consumption compared to those undertaking normoxic training, Weighted Mean Difference (WMD) 1.51 ml.kg⁻¹.min⁻¹ [0.44, 2.58, p=0.006]. Haemoglobin was also higher in those undertaking LHTL hypoxic training (WMD) 0.57 mg/dl⁻¹ [0.38, 0.75, p=0.00001] and maximum heart rate was lower (WMD) -1.77 beats.minute⁻¹ [-3.03, -0.50, p=0.006], as was peak exercise blood lactate (WMD) -3.03 mmol.L⁻¹ [-4.57, -1.49, p=0.0001]. This analysis showed studies utilizing hypoxic exposure using altitudes between 2500 to 3500 m for a minimum 9.5 hours daily showed a significantly greater weighted mean difference in maximal oxygen consumption WMD 3.45 ml.kg⁻¹.min⁻¹[0.30, 6.60] p=0.03, in the hypoxic subjects. This work concluded that protocols using a minimum of 9.5 hours daily for at least 2 weeks elicited greatest performance effects.

Training camp versus hypoxic effects

In their recent editorial related to the meta-analysis by Lancaster and Smart [1], Duke et al. [2] allude to fact that training venues differ in many ways from the normal daily lives of athletes. At a training venue, athletes can focus solely on training, so one would expect athletes to improve their endurance (track) performance and markers of this (maximal oxygen consumption). Only one study to date, Levine and Strat-Gundersen [3], utilized a sea level training camp to control for the relative training camp/group training effects versus effects solely due to hypoxia. For future regime design, quantification of training of the subjects prior to the intervention of altitude or hypoxic exposure would assist in separating training camp versus LHTL effects.

Effects of baseline iron storage

Serum ferritin reflects total body iron storage, a high percentage of endurance athletes display clinically low levels of iron stored as ferritin [4]. Baseline serum ferritin levels prior to an altitude training camp have demonstrated a positive correlation with changes in both red cell mass and VO₂max after four weeks of Live high - Train low altitude training [4], therefore future regime design would be enhanced by baseline measurements of iron storage differences prior to hypoxic exposure and training.

Hypoxic dose required for erythropoiesis

Duke et al. suggest that erythropoietic effects of hypoxic acclimatization are the primary mediator of improved athletic performance [2]. Studies to date have utilized a varied dose-response in terms of simulated height of altitude exposure, both daily exposure duration and number of days. The meta-analysis of Lancaster et al. suggest a minimum exposure of 9.5 hours daily, at 2,500-3,500 m for 14 days [1], although Duke et al. suggest a slightly lower altitude (2000 – 2500 m) for > 20 hours daily, for a period of no less than 28 days [2]. While the latter suggestion is almost certainly adequate enough to produce significant and substantial changes in red cell/haemoglobin mass, the former may not. Nevertheless it may be difficult to find venues where athletes can spend 20 hours daily above 2,000 m and still have time to travel to and from a sea level training venue so and also complete a sufficient volume of endurance training. Even if a suitable venue is acquired it would be tiring to the athletes, coaches and auxiliary staff to complete this regime on a daily basis.

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Figure 1: Methods of Live-high Train low altitude training (with permission).
The basis for Duke et al.’s recommendation [2] is based on the following observations. Three hours per day exposure to a simulated altitude of 5500 m for 4 weeks produced no change in red cell mass or volume [5], despite transient increases in erythropoietin after hypoxic exposure. Absent erythropoiesis after intermittent hypoxia appears to be a function more of the duration of the normoxic exposure, rather than the duration of hypoxic exposure [2]. For this reason Duke et al. advocate for at least 20 hours per day exposure to hypoxia [2]. Levine and Stray-Gundersen [3], advocate that exposure<2 weeks to hypoxic conditions fails to significantly increase red cell mass and that 4 weeks is required to elicit optimal changes in red cell mass.

Natural (hypobaric) versus artificial (normobaric) LHTL

The combined effects of hypobarics and hypoxia may be superior to normobaric hypoxia, while both result in improved exercise performance at high altitude [6]; 7 days of intermittent normobaric hypoxia exposure did not enhanced high altitude exercise performance [7]. These data may indicate that LHTL is better delivered naturally rather than artificially.

Summary

LHTL training regimes and evaluation of hypoxic effects should consider the following:

- Measure and compare training volumes before and during LHTL training camps so training camp versus LHTL effects can be separated.
- Measure baseline iron storage capacity of each athlete who will undertake LHTL.
- Take into consideration the logistics of maximizing hypoxic exposure and daily travelling to and from a sea level training venue when deciding on the variables related to LHTL exposure dose.

Conclusions

Previous work may have not correctly attributed endurance performance changes to hypoxic effects, several measures can be taken to isolate LHTL effects. Special attention should be paid to dose-response parameters and type (natural versus artificial) of altitude exposure required to elicit desired adaptations.

References


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