Running Science

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Altitude Training - Part Two

Written by Philo Saunders

Michael Shelley and Philo Saunders training at altitude.

As a continuation from the article in the previous issue of R4YL, which introduced altitude training for distance runners and the potential to improve running economy and performance, this article will present findings of recent scientific research into the benefits that can be gained from altitude training for highly trained and elite distance runners.

To determine the effect of living at altitude on running economy, a study using untrained subjects was undertaken at sea level to compare the running economy of residents living at high altitude to that of residents living at sea level. Running economy was significantly better in the highlanders indicating that high-altitude residents are more economical runners compared to their sea level counterparts (2). While this study used untrained subjects, further studies have demonstrated that various forms of altitude training can also improve running economy in highly trained distance runners.
Katayama and colleagues have demonstrated on two separate occasions that intermittent hypoxic exposure improves running economy in well-trained runners. The first study reported that simulated hypoxic exposure (equivalent to an altitude of 4500 m) of three hours per day for 14 consecutive days improved running economy (2.6-3.3%) at 14 and 16 km/h and also improved 3000m running performance (1%). The improvement in running economy accounted for 37% of the improvement observed in the 3000m time trial performance (3). These results were confirmed in a second study using a simulated altitude of 4800m.
Improvements in running economy were similar to the first study and were accompanied by a decreased heart rate (3.3% and 3.9% at 14 and 16 km/h, respectively) and an improved 3000m run time (1.3%) (4).
Our research group at the Australian Institute of Sport (AIS) have also reported improvements in running economy and performance in elite distance runners after exposure to altitude. An initial study investigated the effects generated by 20 days of different altitude exposures on running economy and running performance. The three experimental groups were:
Live high - train low (LHTL): simulated altitude exposure equivalent to an altitude of 2500-3100m.
Live moderate – train moderate (LMTM): natural altitude training camp of 1500 m at Falls Creek, Australia.
Control group: lived and trained at normal altitude in Canberra, Australia (600 m).
It was demonstrated that 20 days of sleeping at 2500-3100m simulated altitude while training at 600m altitude (LHTL) improved running economy in elite distance runners when compared with a control group who lived and trained at 600m (Graph 1) (7). Running economy was improved by 3.3% over a range of running speeds (14, 16 and 18 km/h). A second important finding of this study was that the LMTM group training at Falls Creek did not improve running economy. Of note is that all of the runners who competed (n = 7) ran personal or season best times over distances ranging from 1500 to 10000m within one month of the LHTL intervention. In comparison, only 3 of the 13 control subjects ran personal or season best times within one month of the control intervention. These results suggest that 20 days is sufficient time to acquire benefits from altitude acclimatisation, although the elevation must be greater than 2000 m to provide sufficient stimulus to improve running economy and performance.

Key terms

Hypoxia: Low levels of oxygen in the air. At sea level, 22% of the air is made up of oxygen; this is reduced to 17.5% at an altitude of 2000m.

Running economy: The amount of oxygen required to run at a given running speed. Lower oxygen consumption indicates better running economy. There is a strong link between running economy and running performance in distance runners.

VO2max: The maximal amount of oxygen that can be delivered to the working muscles. High VO_{2max} values are associated with superior endurance performance.

Highly trained distance runners: VO_{2max} generally between 60-70 ml/min/kg and can run 35 min or better for 10 km.
Elite distance runners: Generally VO_{2max} 70 ml/min/kg or greater and can run 30 min or better for 10 km.

Altitude training is traditionally thought to improve performance in endurance athletes by increasing the number of red blood cells in the body. This is a response to cope with the lower levels of oxygen in the air. On return to sea level, increases in the total number of red blood cells allow the body to transport more oxygen to the working muscles thereby improving maximal oxygen uptake (VO_{2max}) and, ultimately, running performance. In our 20-day study mentioned previously, there was no change in red blood cells in any of the three experimental groups. Therefore, we conducted a second study at the AIS to determine whether an extended duration (50 days) of LHTL simulated altitude exposure of 9 hours per day substantially increases red blood cells, VO_{2max}, and running economy in elite middle distance runners, and whether this improvement is greater than that previously documented after 20 days of LHTL altitude exposure (8). It was demonstrated that 50 days of simulated LHTL altitude exposure at an equivalent altitude of 2900m substantially improved running economy (3%), decreased sub-maximal heart rate (3%) and increased the number of red blood cells (5%) in elite middle distance runners (Graph 2). The increase in red blood cells is in contrast to that of earlier studies from our laboratory with LHTL exposures ranging from 12-23 days that failed to elicit a substantial increase in red blood cells. However, we did not observe an increase in VO_{2max}, which suggests the involvement of unknown regulatory mechanisms. We speculate that the mechanism could be related to a decrease in cardiac output (reduced blood flow from the heart) and/or a decrease in maximal heart rate that are inhibiting VO_{2max} from increasing immediately after exposure to moderate simulated altitude despite an increase in total red blood cells. This study demonstrates that longer or more frequent altitude training camps are required to stimulate red blood cell production.

Other research groups have also demonstrated increases in red blood cells after a period of altitude training. Heinicke et al. (1) demonstrated a 9% increase in red blood cells after three weeks living and training at a moderate natural altitude of 2050m in elite biathletes. Similarly, Levine and Stray-Gundersen (5) reported a 7% increase in red blood cells after a 4 week live high (2500m) train moderate (1250m) altitude training camp in well trained distance runners. It has been suggested that the inability of studies to elicit an increase in red blood cells after altitude exposure may be due to inadequate duration or severity of the hypoxia (6). The recommendations of Rusko and colleagues (6) for effective LHTL exposure are at least 12 hours per day, for more than 3 weeks, at altitudes between 2100-2500m or higher. Our research suggests that the total accumulation/duration of exposure at regular intervals over an extended period is probably the primary consideration for the prescription of altitude exposure rather than specific durations per night and per training camp.
In summary, research has demonstrated that improved running economy and an increase in red blood cells are two mechanisms by which altitude training can improve running performance in distance runners. The next issue of R4YL will focus on the practical applications of using altitude training within a season to maximise the effects and the timing of exposure to gain best performances at major competitions.

References

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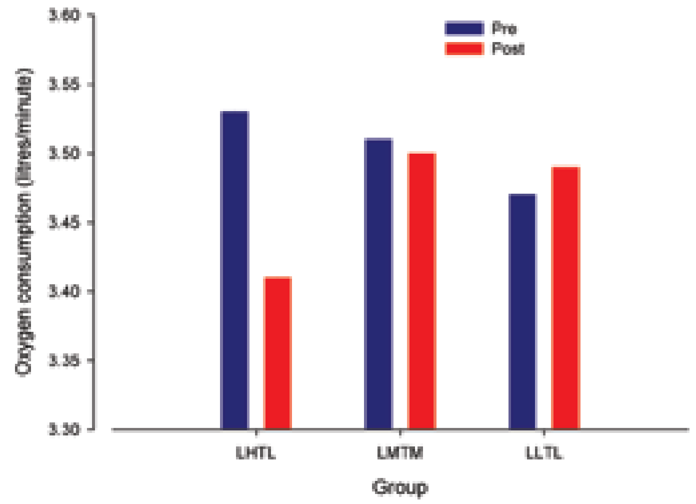
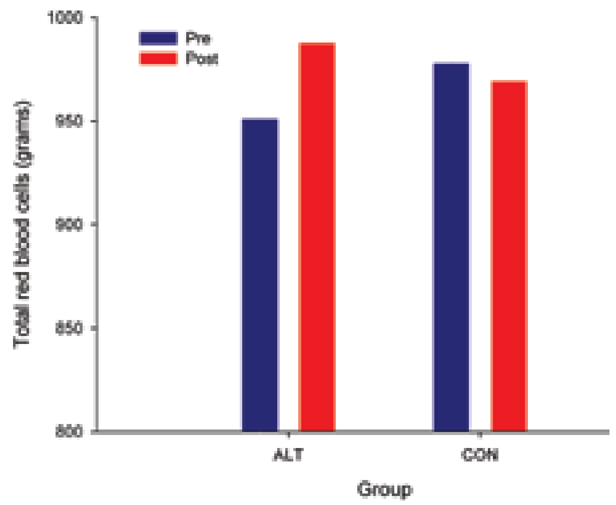


Graph 1 shows a significant reduction in oxygen consumption in the LHTL group, indicating improved running economy after 20 days of simulated altitude exposure.



Graph 2 demonstrates an increase in total red blood cells (haemoglobin) after 50 nights of LHTL simulated altitude exposure.