Improved Race Performance in Elite Middle-Distance Runners After Cumulative Altitude Exposure

Philo U. Saunders, Richard D. Telford, David B. Pyne, Christopher J. Gore, and Allan G. Hahn

We quantified the effect of an extended live high–train low (LHTL) simulated altitude exposure followed by a series of training camps at natural moderate altitude on competitive performance in seven elite middle-distance runners (VO2max 71.4 ± 3.4 mL·min⁻¹·kg⁻¹, mean ± SD). Runners spent 44 ± 7 nights (mean ± SD) at a simulated altitude of 2846 ± 32 m, and a further 4 × 7- to 10-d training at natural moderate altitude (1700–2200 m) before racing. The combination of simulated LHTL and natural altitude training improved competitive performance by 1.9% (90% confidence limits, 1.3–2.5%). Middle-distance runners can confidently use a combination of simulated and natural altitude to stimulate adaptations responsible for improving performance.

Keywords: running, performance, hypoxia, elite athletes

There has been extensive research into the effects of altitude exposure on physiological capacities on volunteer (moderate- to well-trained) subjects and exercise performance at sea level.¹ However, relatively few studies have monitored elite athletes during a competitive racing season with altitude exposure incorporated into their training.²⁻⁴ This case study followed a group of leading Australian middle-distance runners during a competitive national-level track season (~6 months). We sought to quantify the magnitude of improvement in performance that could be achieved with a structured program involving regular training, simulated altitude exposure, and real altitude training. The altitude regimen included an extended live-high:train-low (LHTL) simulated altitude exposure combined with a series of short training camps to natural moderate altitude. The rationale behind this unique combination of altitude training camps leading into a competitive track season was based on the practical experience of coaches and athletes at the Australian Institute of Sport. Simulated altitude is thought to increase physiological capacities and middle-distance running performance. Ath-

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letes could conceivably undertake the short natural altitude camps at a higher level and the preacclimation of simulated LHTL allows athletes to adapt and train more effectively during short natural altitude camps. The modest level of natural altitude was chosen because it was not too high to compromise training and also provided runners the ready option of going down the mountain for high-quality training on an athletics track.

**Methods**

**Subjects**

Seven elite middle distance runners (6 male; 1 female) voluntarily participated in this study. Subject characteristics were as follows: age 23.0 ± 3.8 y, mean ± SD; body mass 63.1 ± 8.1 kg; VO\textsubscript{2max} 71.0 ± 3.4 mL·min\(^{-1}·kg\(^{-1}\); training volume 114 ± 21 km·wk\(^{-1}\). All runners were competing on the national Australian athletics circuit, and 6 of the 7 runners had been or subsequently were selected to represent Australia at World Junior Championships, World University Championships, World Cross Country Championships, World Championships, Commonwealth Games, or Olympic Games. The subjects were informed of the experimental procedures and possible risks involved with participation before written consent was obtained. The Ethics Committee at the Australian Institute of Sport approved all testing procedures.

**Experimental Protocol**

Initially, the runners completed an extended LHTL simulated altitude protocol, consisting of 44 ± 7 nights (392 ± 67 h) at an altitude of 2846 ± 32 m. During this period, the runners spent 5 nights per wk (9 h/night) in a normobaric hypoxic chamber with N\(_2\) enrichment and 2 nights per week at the ambient altitude of Canberra, Australia (~600 m). All training was performed in normoxia (600 m) and consisted of 10 to 14 running sessions and 2 to 3 gym sessions per week. The details of the LHTL simulated altitude exposure are described elsewhere.\(^5\) Subsequently, the runners participated in 4 × 7- to 10-day training camps at moderate altitude (Charlotte Pass, NSW, Australia) with living and most training at 1700 to 2200 m. Interval training sessions were completed 3 times per week at 1000 m, a live-high:train-high:train-low (LHTHTL) regimen. Figure 1 provides a timeline of all altitude exposures during the study period. It was not logistically possible to obtain a matched control group for this study because these elite runners were undertaking a very specific training/racing schedule. We were unable to perform laboratory tests on these runners because they deemed that such tests might interfere with their busy race schedule. In lieu of laboratory testing, progression in competitive race time was monitored over 3 months, with races conducted 5 to 14 days after each training camp.

**Statistical Analysis**

Measures of centrality and spread are shown as mean ± SD. The precision of estimates was indicated with 90% confidence intervals.
Results

Progression in competitive race performance (800, 1500, and 3000 m) in the elite middle-distance runners (n = 7) that participated in the extended LHTL simulated altitude intervention and the series of 4 training camps at moderate natural altitude are shown in Table 1. There was an improvement in the season best race performance of 1.9% (90% confidence interval 1.3–2.5%) faster after the combination of altitude exposures compared with their personal best times before the intervention. Figure 1 presents all race performances by the 7 subjects during the study period as a percentage of their personal best (PB) time before the altitude training.

Discussion

The combination of LHTL simulated altitude exposure and a series of short training stints at natural moderate altitude elicited a substantial 1.9% improvement in competitive race performance in elite middle-distance runners. Given the unique nature of this study, there was no control group for comparison. The possibility of
The combination of LHTL and LHTHTL altitude exposures was used to increase physiological capacity and prepare athletes for the series of natural altitude training camps and subsequent competitions. The combination was prescribed in consultation with the coaches and runners participating in this study. This regimen should be comparable to the multiple exposures at natural altitude as classically performed in endurance sports and was deemed to be the most logistically relevant for athletes in the current study because they did not have to travel.

Table 1  Progression in Competitive Race Performance of the Runners (n = 7) Who Completed One LHTL Simulated Altitude Block (44 d) and 4 × 7- to 10-Day Training Camps at Natural Altitude

<table>
<thead>
<tr>
<th>Subject</th>
<th>Distance (m)</th>
<th>Pre PB (min:s)</th>
<th>Post PB (min:s)</th>
<th>Difference (s)</th>
<th>Difference (%)</th>
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<td>2.1</td>
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</table>

Mean 1.9
SD 1.3
Lower 90% CI 1.3
Upper 90% CI 2.5

Note. PB = personal best.
overseas, and had access to the simulated altitude house. In addition, the LHTHTL option permitted high-quality training while maintaining a “top-up” hypoxic stimulus.

The natural altitude training camps were based at ~1800 m of altitude, with athletes living and completing easy, moderate, and long runs at altitudes between 1700 to 2200 m. However, all track sessions (3 per week) were performed at a track situated at an altitude of ~1000 m, which was a 30-min drive down the mountain. A lower altitude for high-quality anaerobic running was deemed necessary to maximize the quality of exercise in this precompetition phase of training as recommended in earlier altitude training studies.4 The 1.9% improvement in performance in the current study is similar to the 1.1% improvement in 3000 m time trial performance in a similar group of 14 highly trained middle-distance runners who spent 27 days living at 2500 m and training at 1250 m.4 More importantly, the 1.9% improvement in performance is twofold larger than the smallest worthwhile change in performance (~1.0%) required to have a substantial effect on elite athletes’ chances of winning a medal at major competitions.8 For middle-distance runners, the typical within-subject variation is typically 1% to 2%, and the corresponding smallest worthwhile change ~0.5% to 1% of performance time.

In conclusion, the current study demonstrated that 44 ± 7 days of simulated LHTL altitude exposure of 2850 m, with the addition of short training stints at moderate natural altitude (1700–2200 m), had a positive ~2% impact on competitive race performance in elite middle-distance runners. Middle-distance runners can confidently use a combination of simulated and natural altitude to enhance adaptations responsible for improving performance. These observational findings require further investigation with an appropriate control group.

References