14 Days of Intermittent Hypoxia Does Not Alter Haematological Parameters Amongst Endurance Trained Athletes

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The aim of this study was to determine the efficacy of intermittent hypoxic therapy on red cell production amongst a group of well trained athletes. Eight rowers underwent preliminary testing and were pair matched for VO_{2max} and performance on a rowing ergometer. In a single blind design, with both groups sitting quietly at rest, the treatment group (TRE) inhaled 12.20% O_2 while the control group (CON) inhaled 20.93% O_2. The groups inhaled gas for 5 min and then room air for 5 min alternately for a total of 90 $min.d^{-1}$ for 14d. The performance test was conducted twice before and twice after 14d of IHT. A venous blood sample was taken at rest before and immediately after IHT.

During IHT there was a decrease in SpO_2 ($p<0.05$) and increase in HR ($p=0.06$) in the TRE compared with the CON. There was no change in resting values for RBC, [Hb], Hct and reticulocytes between pre and post measurements for either the TRE or CON group. During the performance test there were no differences for HR, submaximal VO_2, VO_{2max}, total metres, La and respiratory exchange ratio.

In conclusion, IHT of 90 $min.d^{-1}$ for 14 d had no effect on any haematological parameters which would reflect an increase in total haemoglobin mass and accordingly there was no effect on VO_{2max} or ergometer performance.

Altitude training to enhance sea level performance has been of interest to scientists for more than 30 years. Altitude training is thought to enhance sea level performance as a direct result of increasing red blood cell (RBC) mass and haemoglobin [Hb] concentration (Wolfel et al, 1991). Very few of those that incorporated control groups have shown improved performance and it is recognised that there is a reduction in the ability to train at the appropriate intensity when at altitude. Scientists have been investigating other methods of altitude exposure which potentially offer the physiological benefits of altitude whilst minimising the disturbance to training.

Living at moderate altitude (2200-3000m) but training at sea level (Live High:Train Low) has been reported to increase RBC mass, increase VO_{2max} and improve performance (Levine and Stray-Gundersen, 1997). Because this approach is not always practical methods for simulating altitude have been developed (eg. “altitude houses”). The introduction of simulated altitude houses has enabled more extensive research and rigorous blood analysis. A series of studies at the Australian Institute of Sport which investigated the effect of Live High: Train Low have reported no change in haematological parameters. (Ashenden et al, 1999a, Ashenden et al, 1999b).

Intermittent Hypoxic Training (IHT) is another method of using simulated altitude. IHT was developed in Russia for its use in aviation and clinical medicine but recently has been investigated for possible application to sports performance. IHT involves breathing alternately a hypoxic gas mixture (equivalent to 5000-5500m altitude) and ambient (normoxic) air at rest. Each session consists of 4-6 series of 5-min inhalations of a 10-12% hypoxic mixture with normoxic intervals of the same duration. An IHT course consists of 14-24 sessions with gradually decreasing oxygen concentration. The advantages of such a method include the following: the possibility to control pO_2 in the inhaled hypoxic mixture across a range; the possibility to combine the hypoxic training with sport training at sea level (therefore not compromising training intensity); the absence of organisational and methodical problems connected with the removal to mountains, changes in the usual mode of life, weather and climate. In addition IHT is simple to operate, does not require the expense of building special altitude houses and is portable. IHT allows exposure to quite severe hypoxic conditions without great risk of altitude sickness.

The amount of literature on IHT and sports performance is limited and mostly unavailable in English. There are also very few studies which measured haematological parameters after IHT. A study by Latyshkevich et al. (1993) reported that twenty-four days of IHT decreased submaximal oxygen consumption, ventilation and heartrate during exercise to exhaustion. In addition they reported that athletes were able to produce more work after IHT, but did not indicate how long after the treatment period the subjects were re-tested. More recently Hellemans (1998) reported on the use of IHT for two, one hour periods per day for a duration of eighteen days. He observed an increase in post values for RBC, [Hb], Hct and number of reticulocytes compared with pre values. However, there was no control group making the results difficult to interpret.

The purpose of the following study was to investigate the efficacy of IHT in evoking a change in RBC, [Hb], Hct and reticulocytes amongst a group of well trained athletes.

Methods

Subjects

Eight rowers (6 females, 2 males) from the ACT Academy of Sport Rowing squad gave written consent to participate in this study which was approved by the Australian Institute of Sport Ethics Committee. The characteristics of the group were age = 21.5± 5.6yr, VO_{2max} = 3.88 ± 0.91L.min^{-1}. Subjects were pair matched based on training history and laboratory indicators of aerobic and anaerobic fitness and their coaches' evaluation of their competitive ability. One group was randomly selected to be the treatment group (TRE, n=4) and the other became the control group (CON, n=4). Each subject kept a daily training log of mode, frequency, intensity and duration. The two males trained together in a pair and the six females all trained in single sculls in the same squad.

Experimental Design

In a single blinded design subjects came into the laboratory for 14 consecutive days. On each occasion they rested in a seated position for 90 minutes and alternated every five minutes between breathing from the room and breathing from a 2000L Douglas bag (Scholle Industries, Elizabeth, South Australia). For the treatment group, the Douglas bag contained 12.2% O_2 (simulated altitude = 5000m) while for the control group it contained 20.93% O_2. The O_2 concentration inside the bag was measured every fifteen minutes with an Ametek (Pittsburgh, Pennsylvania) O_2 gas analyser (model S-3A) which had been calibrated against alpha grade gases (BOC Gases Australia Ltd) that spanned the physiological range. Throughout the 90 minutes, heartrate (HR) and oxyhaemoglobin (SpO_2) were recorded via finger-tip pulse oximetry (Criticare, Waukesha, Wisconsin) every five minutes.

A resting venous blood sample was collected prior to, and immediately after the 14 days of IHT to measure haematological parameters. Each subject underwent a performance test on the rowing ergometer (Concept II) twice before and twice after IHT to ensure reliability.

Haematological Parameters

A venous blood sample was collected via a winged infusion set (21-G, Terumo, Elkton, USA) into a 4ml K3EDTA vacuette tube (Greiner Labortecnik, Kremsmunster). Red blood cell (RBC) count, [Hb] and % reticulocytes were analysed using flow cytometric measurements on a Bayer H*3 Haematology analyser (Bayer Diagnostics, Tarrytown NY, USA). The directly measured percentage of reticulocytes per 20,000 red blood cells and RBC count was used to calculate reticulocyte number.

Absolute reticulocyte count = RBC count x % reticulocytes (x $10^9.L^{-1}$)

Ergometer Testing

The performance test consisted of three 4-minute submaximal workloads, four minutes of rest and a final four minutes, of which the first two minutes was held constant and the final two minutes was an “all out” effort to complete as much work (measured in distance) as possible. The submaximal loads were determined for each rower based on their own personal best time for 2000m ergometer test. This was a modified version of a national test protocol that had been regularly performed by all subjects. A finger tip blood sample was taken after each workload and was analysed for lactate using the Radiometer ABL 625 Analyser (Radiometer, Copenhagen, Denmark). The ABL System 625 was calibrated daily against standards of known lactate concentration.

Oxygen Consumption

During the performance test the metabolic variables of oxygen, carbon dioxide production, minute ventilation and respiratory exchange ratio were measured using an open-circuit indirect calorimetry system every thirty seconds. The O_2 and CO_2 gas analysers were calibrated using three alpha grade gases (BOC Gases Australia Ltd) immediately before each test. Heartrate (HR) was assessed every 5 seconds with a telemetry system (Polar Vantage, Polar Electro OY, Kempele, Finland).

Statistical Analyses
For each dependent variable a delta score was calculated (post treatment minus pre-treatment) at each workload. The delta scores were statistically analysed using non parametric test (Mann-Whitney U) to determine whether IHT produced a physiological response.

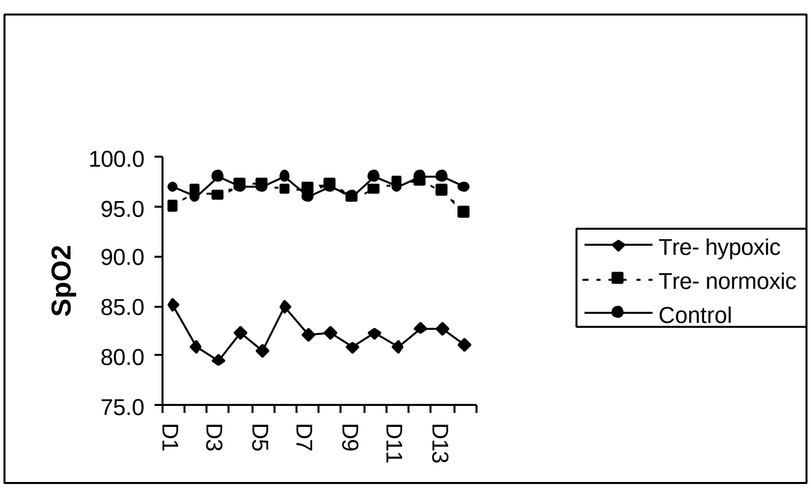
Results

As expected in the time periods where hypoxic gas was breathed there was a decrease in SpO_2 ($p<0.05$, Figure 1) and an increase in HR ($p=0.06$, Figure 2) in the TRE group compared with the CON. There was no change in resting values for RBC, [Hb], Hct and reticulocytes between pre and post measurements for either the TRE or CON group (Table 1).
During the performance test no differences were observed between the groups for HR, submaximal VO_2, VO_{2max}, total metres, La and respiratory exchange ratio (Fig 3 a-e).

TABLE 1. Haematological parameters pre and post 14 days of IHT amongst TRE and CON groups. Values are mean ± SD

	T-PRE	T-POST	C-PRE	C-POST
RBC	4.94±0.61	4.91±0.6	4.83±0.65	4.80±0.75
Hb	14±1.5	13.8±1.4	13.6±1.2	13.5±1.4
Hct	0.42±0.04	0.42±0.04	0.41±0.04	0.41±0.04
# Retics	42±18.2	35.8±15.0	41.5±20.2	46.0±12.5
% Retics	0.85±0.34	0.75±0.35	0.85±0.37	0.95±0.24

Figure 1. Oxygen saturation (SpO_2) during the 14 days of IHT comparing TRE to CON groups.



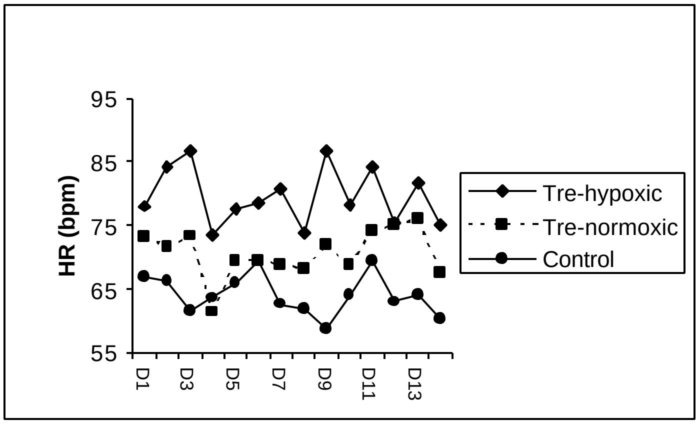


Figure 2. Heartrate response during 14 days of IHT comparing TRE and CON groups.

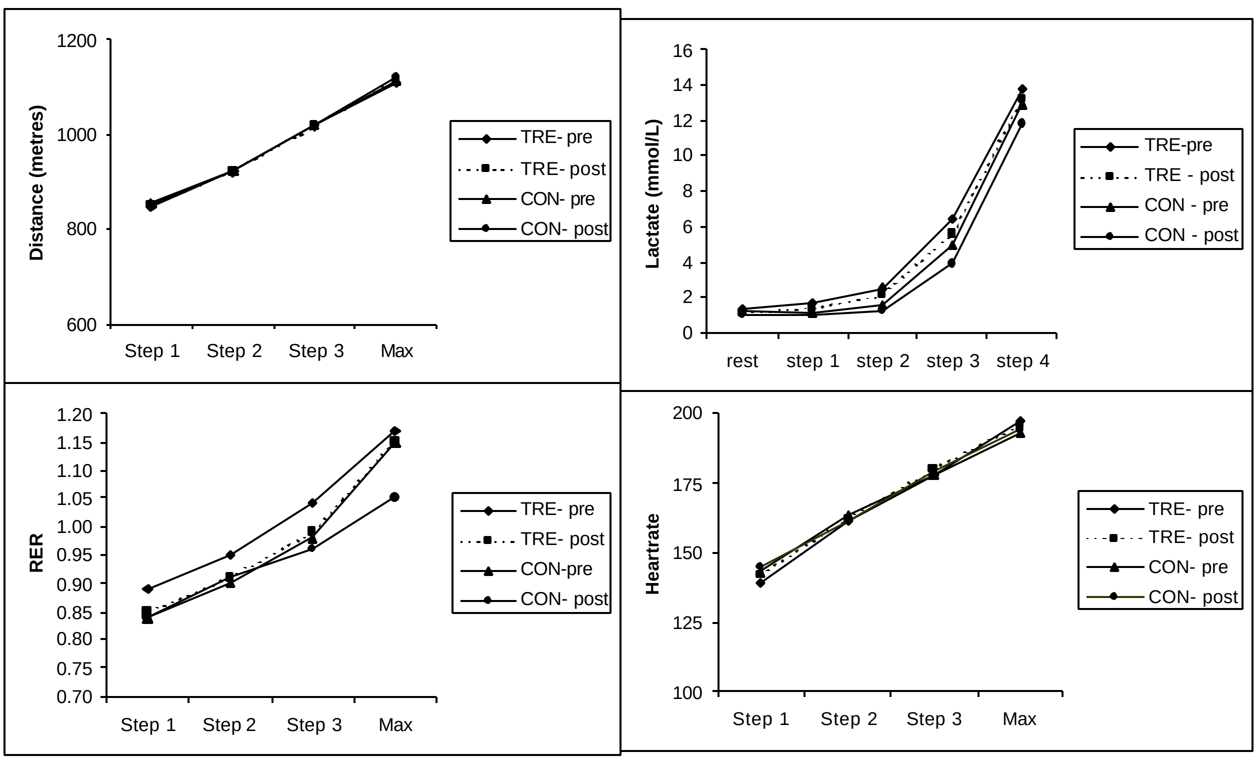


Figure 3 (a-e) Change in (a) distance (m), (b) heartrate (HR), (c) oxygen uptake (VO2), (d) Lactate and (e) respiratory exchange ratio (RER) during exercise after 14 days of IHT, comparing TRE and CON groups.

Discussion

This study did not find any increase in RBC, [Hb], Hct and total number of reticulocytes after 14 days of IHT. Our results differ from others (Hellemans 1998, Radezievsky et al, 1993, and Rodriguez et al 1999), however the present study was the only one to use a control group. It is unlikely that the difference between our results an those of the other researchers can be explained by the total amount of hypoxic exposure to which the athletes were subject. While both the daily duration (45 min vs 60 minutes) and the number of days (14 vs 18) was less than that of Hellemans (1998), he reported the greatest change in the haematological profile and physical performance occurred in a subject who reduced IHT to one session per day. This would be less than the daily exposure in the current study. Furthermore, Radzievsky et al. (1993) used a protocol of hypoxic exposure (15 days, one session per day) similar to ours and yet reported an increased [Hb].

Rodriguez et al. (1999) reported a significant increase in RBC and [Hb] after nine days of hypobaric hypoxia. The subjects in this study were not exposed to classic IHT but to a continuous hypoxic stimulus (equivalent to 4000-5500m altitude) for 3-5 hours per day. Mean RBC increased from 5.16 to $5.79 \times 10^{12} L^{-1}$ and [Hb] from 14.2 to $16.7 g.dL^{-1}$. It seems unlikely that these changes could have resulted from an increase in red blood cell production, since even daily administration of $50 U.kg^{-1}$ recombiant erythropietin does not produce changes of such a magnitude within ten days (Audran et al, 1999). In addition the subjects of Rodriguez et al. (1999) showed no increase in VO_{2max}. An increase would have been expected if red blood cell numbers were augmented (Audran et al, 1999.

There is a substantial day to day variation in [Hb] (Martin et al, 1997) and reticulocytes (Schmidt et al, 1988), and changes also occur across the training cycle. Schmidt et al. (1988) reported that a single bout of exercise doubled the number of reticulocytes one to two days later. An examination of blood reticulocyte number across a group of rowers showed that the values increased on average by 22% as the rowers moved from an endurance phase to an intensive phase of training (Parisotto, personal communication). This fast response of reticulocytes points to a washout effect releasing premature reticulocytes from the bone marrow rather than a stimulation of RBC Mairbaurl, (1994). It is possible that the reported changes observed by others may reflect a temporary effect of training and not a real increase in RBC production.

Conclusion

It is well recognised that living at high altitude (4000m or higher) is a strong stimulus for an increase in RBC mass (Wolfel et al, 1991). Using the method of IHT in the present study does expose the athlete to high levels of hypoxia however the interval approach and the short duration of exposure was not enough to evoke a change in haematological parameters and accordingly there was no effect on VO_{2max} or ergometer performance.

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