

Original Article

## Long term stay at low altitude (1,200 m) promotes better hypoxia adaptation and performance

**Krishan Singh\*, R. K. Gupta, Poonam Soree, Lokesh Rai and G. Himashree**

Defence Institute of Physiology and Allied Sciences,  
Timarpur, Delhi –110 054

### Abstract

Acute exposure to high altitude hypoxia is known to decrease physical performance. The exercise performance increases during moderate altitude training (2000-3000 m) but benefits are overshadowed by adverse effect associated with hypoxia. Therefore, the study was designed to address whether low altitude of 1200 m could increase exercise performance without any adverse effects and a correlation with stay period (stay > 6 month) was optimized. In the present study residents of lower altitude (1200 m altitude) (LA) and sea level (SL) residents were subjected to sub-maximal exercise test and their exercise response in terms of post-exercise heart rate and change in oxygen saturation was compared. Post-exercise peak heart rate ( $129.89 \pm 13.42$  vs  $146.00 \pm 11.81$ ,  $p < 0.05$ ) was significantly lower and arterial oxygen saturation (SpO<sub>2</sub>) after exercise had a significant fall ( $95.3 \pm 2.26\%$  vs  $98 \pm 0\%$   $p < 0.001$ ) in LA residents. The hematological parameters like hemoglobin (Hb) and hematocrit (Hct) taken as markers of physiological adaptation, were also found to be significantly higher in LA as compared to SL residents (Hb  $16.13 \pm 0.70$  vs  $14.2 \pm 0.87$ ,  $p < 0.001$  and Hct  $47.42 \pm 2.08$  vs  $44.05 \pm 0.72$ ,  $p < 0.001$ ). Overall, the study highlights that physiological adaptation at 1200 m results into a better exercise response and hematological benefit compared to sea level residents.

### Introduction

The altitudes have been classically differentiated on the basis of heights above the sea level as Low Altitude (height <1500 m), High Altitude (height 1500-3500 m) and Very High Altitude (height 3500-5500 m) and Extreme Altitude (height 5500-8850 m) (1). When one goes to altitude, there is a depletion of oxygen percentage in air which affects the delivery of oxygen

to tissues. This manifests as decrement in exercise performance of the individual which is well known (2). The mechanism for this performance reduction is related to diffusion limitation in the lung, which is exaggerated in athletes with high pulmonary blood flows (3). Diffusion limitation may not limit exercise at sea level; however, at higher altitudes, impaired oxygen-transport mechanisms may play an important role in the reduced VO<sub>2</sub>max (4, 5).

The effect of moderate altitude acclimatization has been used previously in sports to enhance the VO<sub>2</sub> max of the runners by exposing them to moderate altitude (1800-2200 m) and training at sea level (6). There are various strategies of improving athletic performance like high-high, live high –train low etc.

**\*Corresponding author :**

Dr. Krishan Singh, MD, Defence Institute of Physiology and Allied Sciences, Timarpur, Delhi –110 054, Ph.: 011-23883072, Mob.: 9958364622, Email: krishansingh14@gmail.com  
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Considering the “high-high” method, few studies have addressed the question whether exposure to low (1000–1500 m) or moderate (1800–2500 m) altitude would induce improvements in performance and physiological / haematological variables in highly trained sea level athletes (7-9). Moderate altitude may induce enhancements in hematological variables—for example, an increase in the oxygen carrying transport system. Nevertheless, they are less favoured as they decrease training intensity (6) In contrast, low altitudes are advantageous for maintenance of training intensity, but they do not induce any modification of hematological variables if the duration of stay is less.

The exercise performance during moderate altitude training (2000-3000 m) increases but benefits are overshadowed by adverse effect caused by exposure to hypoxia like headache, lower temperature and increased solar radiation effects, and lower muscular work performing power. Therefore present study was designed to address the issue whether a long term stay of more than 6 months at a low altitude (1200 m) could increase exercise performance without any adverse effects.

## Methods

### Study participants

This was a cross sectional study carried out on 29 healthy, male, soldiers. Out of these, 19 were selected from a unit located at 1200 m with duration of stay of more than 6 months (LA, Low Altitude residents) and 10 participants of same age, weight and height who stayed at sea level for the last 3 months were included in (SL) sea level group. The age, height and weight of the participants of both the groups is given in Table I. The experimental protocol was approved by the Institutional Human Ethics Committee. The participants had no history of any medical illness and did not follow any physical conditioning programme. Baseline recording of physiological parameters as well as post-exercise testing was done in both the groups at their respective locations i.e sea level at 220 m and low altitude at 1200 m.

### Baseline recording

Prior instruction was given to wear light clothing and sport shoes for step test, have a light breakfast 2–3 hours before the test and refrained from any physical activity for that period. The subjects were rested for at least 5 mins before the measurement of the resting physiological parameters. Resting heart rate, systolic blood pressure and diastolic blood pressure were measured by electronic BP measuring device HR-100C Omron device (Omron, Health Care Inc, Bethesda, MD, USA) in the right arm of each participant while seated and after a 5-min rest. Oxygen saturation was measured using a pulse oximeter (Fingertip pulse oximeter Ver 3.0 Choicemmed, Europe). The mean of the two measurements separated by a 2-min interval was taken as the valid determination for blood pressure, heart rate and oxygen saturation.

### Haematological variables

Blood samples at rest were obtained by venepuncture before starting the exercise. Samples were analysed, following standard procedures immediately. Hemoglobin and hematocrit were mainly used to compare the hematological response.

### Exercise protocol

The sub maximal exercise i.e Queens College Test was done in both the groups to get the peak post-exercise heart rate for comparison between the two groups.

Queens College Test was performed on a stool of 16.25 inches (41.3 cm) height for a total duration of 3 min at the rate of 24 cycles per minute set by a metronome. Post-exercise recording of carotid pulse was measured from 5–20 seconds of the recovery period in sitting position (10). This 15 second pulse rate was then converted into beats per minute and taken as the peak heart rate. Both the peak heart rate and SpO<sub>2</sub> was noted within 5-20 sec of recovery period.

### Statistical analysis

The results of low altitude and sea level groups were

analysed as mean±SD. The intragroup comparison before and after exercise was done by using paired students 't' test. Intergroup comparison of pre-exercise and post-exercise values was done by student 't' test. The statistical significance was considered as p value < 0.05.

## Results

The age, height and weight of the subjects from both sea level and low altitude groups were measured and compared to avoid the effect of anthropometric variables in the study. The data obtained from both the groups is presented in Table I. There was no significant difference in the any anthropometric variables of both groups' studies and were comparable to each other.

The resting physiological parameters of sea level and low altitude subjects were done to compare if any difference is there before exercise. These parameters have been shown in the Table II. There was no significant difference observed in resting heart rate, systolic blood pressure, diastolic blood pressure and mean arterial pressure between two groups.

Queens College Step test was performed to check the post-exercise heart rate response on giving equal

TABLE I : Anthropometric data of sea level and low altitude residents.

	Sea level (n=10)	Low altitude (n=19)
Age (yr)	28.7±4.5	29.6±4.8
Height (cm)	169.6±3.8	166.09±4.7
Weight (kgs)	67.5±5.6	65.91±8.2

Values are presented as mean±SD.

TABLE II : Comparison of resting physiological parameters of SL and LA residents.

	Sea level	Low altitude (1200 m)
HR (Bpm)	72.70±9.66	71.95±9.85
SBP (mmHg)	130.20±5.57	125.58±7.10
DBP (mmHg)	72.60±6.50	72.68±8.72
MAP (mmHg)	91.61±4.50	90.14±7.27

HR - Heart Rate, SBP - Systolic Blood Pressure, DBP - Diastolic Blood Pressure, MAP - Mean Arterial Pressure values are presented as mean±SD.

work load and also to check the fall of the oxygen saturation. The peak exercise heart rate was determined by taking the carotid pulse for 15 sec immediately after 3 min of step test. Then this heart rate was multiplied by 4 to get the maximum heart rate per min. Low altitude residents showed about 11% less heart rate rise during exercise than sea level and the results were statistically significantly (129.89±13.42 vs 146.00±11.81, p<0.05). The results of comparison have been summarized in Fig. 1 along with resting heart rate.

*Effect on SpO2:* Fall in the oxygen saturation was taken as the minimum drop of SpO2 within 15 sec of the termination of step test. There was a drop of about 2.5% SpO2 in the low altitude residents compared to sea level. This difference was also statistically significant in the 1200m subjects (95.5% vs 98% p<0.001) shown in the Fig. 2.

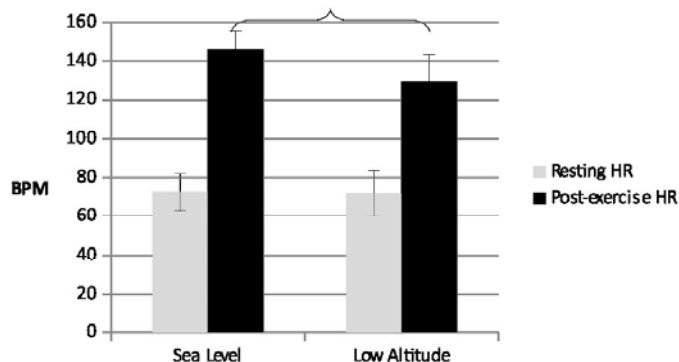


Fig. 1 : Effect of exercise on the heart rate in sea level and low altitude group. \*Indicates p<0.05 between post-exercise heart rate of sea level and low altitude (1200 m). Exercise was done at sea level and low altitude (1200 m) respectively; Low altitude is showing 11% less rise of post-exercise heart rate.

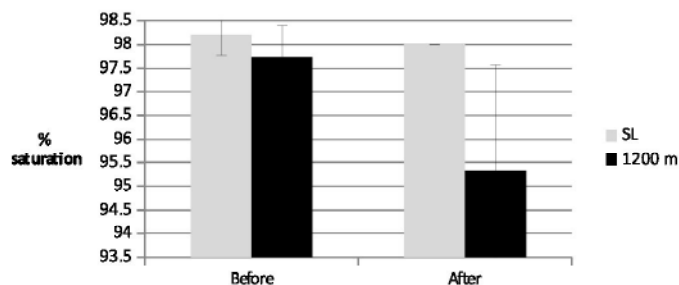


Fig. 2 : Effect of exercise on SpO2 between sea level and low altitude groups. \*Indicates p<0.001 in the fall of SpO2 after exercise between sea level and low altitude (1200 m). Low altitude residents are showing a definite fall in SpO2 after exercise meaning presence of hypoxia and adaptive changes.

**Haematological parameters**

Low altitude subjects had a significantly higher values for both hemoglobin and hematocrit compared to sea level. (Hb 16.13±0.70 vs 14.2±0.87, p<0.001 & Hct 47.42±2.08 vs 44.05±0.72, p<0.001). Hemoglobin showed a 11.9% increase whereas hematocrit showed a 7.1% increase in the low altitude residents. The results have been shown in the Table III.

TABLE III: Comparison of Hematological parameters of SL and LA residents.

	<i>Sea level</i>	<i>Low altitude</i>
Hemoglobin (gm/dl)	14.2±0.87	16.13±0.70#
Hematocrit (%)	47.42±2.08	44.05±0.72#

SL - Sea Level residents, LA - Low Altitude Residents (1200 m), Values indicate mean±SD, SL, # - p<0.001.

**Discussion**

The present study has shown for the first time that long term stay and training at lower altitude of 1200 m can increase the physical performance along with hematological advantage.

The physical fitness of an individual can be compared by three variables like VO2 max, HR and Rating of Perceived Exertion (RPE). Here we compared the maximum heart rate achieved after step test as index of fitness. When the Low Altitude residents performed step test, they achieved significantly lower post exercise heart rate as compared to Sea Level. A person with a relatively high aerobic power can accomplish more exercise and achieves higher oxygen uptake before reaching their peak HR than a less fit person. The person with the lowest heart rate increase tends to have the highest exercise capacity and largest VO2 max (11). The person exhibiting more exercise capacity also shows the superiority in cardiorespiratory fitness. Post exercise (recovery) HR decreases with improved cardiorespiratory fitness (12). It is clear from the findings of this study that these people were living in a definite hypoxic condition as there was a significant fall in post-exercise SpO2. This hypoxia must have induced acclimatization changes leading to higher physical fitness in the form of lower rise of post

exercise heart rate. This was illustrated even at an altitude of 1200 m which has not been shown by any other previous study to best of our knowledge. The cause of this less post exercise heart rate in low altitude residents can be explained by minimal hypoxia prevailing in the environment. This may have caused peripheral systemic vasodilation but was not sufficient enough to cause pulmonary vasoconstriction. The resulting arteriolar vasodilation caused greater blood flow to capillaries and increased venous return increasing end-diastolic volume. Since end-diastolic volume is proportional to the stroke volume therefore this basal increase of stroke volume in the residents of low altitude must have been the cause of lower rise of post-exercise heart rate.

The low altitude residents showed lower resting arterial oxygen saturation and after exercise had significantly lower values than sea level. This means that the low altitude residents are living in an area of definite hypoxia, no doubt of lesser intensity. When they perform exercise, it leads to diffusion limitation and more fall of oxygen saturation (13, 14). This hypoxia improves physiological adaptation of the body like increase in the oxygen transport (more hemoglobin and hematocrit). Arterial O2 desaturation occurs more readily during exercise at altitudes above 3,000 m (15, 16) however, arterial O2 desaturation has also been reported in persons exercising at altitudes between 1,520 m and 1,850 m (17, 18).

There was an appreciable increase in the oxygen transport system in the form of hemoglobin and hematocrit in low altitude residents. A review of many research studies suggest that the appropriate training altitude is 2000–3000 m for benefiting the athlete in terms of both performance and hematological response (19) and still other study shows that no doubt performance increases at 1200 m but hematological response is delayed when the residence period is 13 days (20). The present study clearly shows that, even at 1200 m if the residence is prolonged for 6 months, the performance is increased with a significant increase of hemoglobin and hematocrit and no adverse effects.

**Conclusion**

It may be concluded that physiological adaptation

in response to mild hypoxia at 1200 m results in better exercise performance. This knowledge can help us to develop strategy in improving athletic performance by locating their training areas in such altitude.

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