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Effect of Altitude on some Blood Factors and its Stability after Leaving the Altitude

[1]Yones Hematy, [2]Mahbubeh Setorki, [1]Akram Razavi and [3]Monir Doudi
[1]Department of Physical Education and Science Sport, Izeh Branch, Islamic Azad University, Izeh, Iran
[2]Department of Biology, Izeh Branch, Islamic Azad University, Izeh, Iran
[3]Department of Microbiology, Falavarjan Branch, Islamic Azad University, Isfahan, Iran

Abstract: The underlying mechanisms of altitude training are still a matter of controversial discussion. The aim of this study was to compare the hemoglobin concentration, red blood cell count and volume between normal and high altitude situations and their persistence after returning back from higher altitudes. The study population included male students of Ardal Branch, Islamic Azad University. Twelve apparently healthy individual with high level of physical activity, mean age of 22.6±1.50 years were selected through purposive and available sampling method. In this study, blood samples were collected at different time and altitudes in order to compare the changes of Red Blood Cell (RBC), Mean Cell Hemoglobin (MCH), Mean Corpuscular Hemoglobin Concentration (MCHC) and Mean Cell Volume (MCV). The first blood sampling was conducted at the altitude of 1830 m. The subsequent blood samplings were conducted 48 and 72 h after reaching the altitude of 4000 m and 24, 48 and 72 h after returning back to the altitude of 1830 m. The statistical method used in this study was repeated measurement ANOVA. Red Blood Cell (RBC) changes between onset of climbing to 1830 m and 24, 48 and 2 h after sojourn at 1830 m height (after returning from 4000 m altitude) was significant. Mean Cell Hemoglobin (MCH) showed no significant change in any of the altitudes. MCHC changes between onset of moving toward altitude 1830 meters and 24, 48 and 72 h after sojourn at 1830 m height (after returning from 4000 m altitude) was also significant in addition, MCHC showed a significant difference between 24 h staying at 1830 m altitude with 48 and 72 h staying at 4000 m altitude. Mean Cell Volume (MCV) showed no significant difference between 48 and 72 h staying at 4000 m altitude and also between 24, 48 and 72 h staying at 1830 m altitude; however, there was a significant difference between onset of moving toward 1830 m altitude with 24, 48 and 72 h staying at 1830 m altitude and also 48 and 72 h staying at 4000 m altitude. The results showed that being in altitude has significant effect on RBC and MCHC.

Key words: Altitude, mean cell volume, mean cell hemoglobin

INTRODUCTION

Oxygen pressure is significantly reduced in high altitudes and this causes the reduction of aerobic preparation and implementation of endurance exercises due to aerobic fitness (Fox and Mathews, 1981). Exercising in high altitude can have faster physiological adaptations than exercising at sea level and the reason is oxygen-deficiency condition in higher altitudes which is considered as a pressure that can cause adaptability and acclimatization similar to physical exercising. Therefore, exercising in high altitude can improve the exercise activity at sea level (Fox and Mathews, 1981). Reduction in oxygen pressure causes physiological responses in body. These responses can occur as change in hematologic factors such as hemoglobin, hematocrit, plasma volume, serum Iron and enzymes which happen in body of those who do climbing.

The objective benefits of altitude training are controversial (Levine and Stray-Gundersen, 1995). On one hand, acclimatization to high altitude results in central and peripheral adaptations that improve oxygen delivery and utilization (Banchero, 1975; Brooks *et al.*, 1992; Mairbaurl *et al.*, 1986; Ou and Tenney, 1970; Reynafarje *et al.*, 1975). Moreover, hypoxic exercise may increase the training stimulus, thus magnifying the effects of endurance training (Bigard *et al.*, 1991). Conversely, hypoxia at altitude limits training intensity (Levine and Stray-Gundersen, 1992) which in elite athletes may result in relative deconditioning.

Corresponding Author: Mahbubeh Setorki, Department of Biology, Izeh Branch, Islamic Azad University, Izeh, Iran

Most of climbing of climbers is done in less than 48 h given to the leisure time and it seems that physiological acclimatization of such individuals is low in short time. Thus, assessing the changes in blood serum concentration is an important and basic factor. In the present study, we are looking for a way to reduce the time of presence in high altitude in order to have better economic efficiency and better exercise and training. Most of studies have an incremental trend and length of staying is longer. In this study, changes of selected hematologic factors were evaluated in 48 and 72 h climbing from altitude of 1830 m to 4000 m and 24, 48 and 72 h after returning from high altitude in a mountaineering team in path of Shah-e-Shahidan Zardkouh Camp in Iran.

MATERIAL AND METHODS

This quasi-experimental study was conducted in Zardkouh from Zagros Mountains in Iran. The study population included all the male students of Ardal Branch, Islamic Azad University among which 12 students with history of sporting activities were selected through purposive and available sampling method to participate in the study. Furthermore, they were diagnosed healthy during medical examinations. The data about disease history, amount of weekly physical activity, history of mountain climbing and used medications and drugs were collected by a questionnaire. All the subjects gave an informed consent to the blood withdrawal and the local ethical committee approved the study.

During the study, all the subjects had one diet plan and had exercise training twice a day starting with warm-up and 90 minutes recreational volleyball and finishing with recovery (cool down). In terms of estimating the intensity of exercise, it was approximately 50-60% light exercise; MHR (Maximum Heart Rate) VO2 Max. CASIO GPS Altimeter (made in Japan) was used to measure the altitude. In order to implement the tests for the subjects during seven consecutive days, they participated in the study in a certain time with 24, 48 and 72 h time interval at 4000 m altitude and then in 24, 48 and 72 h at the altitude of 1830 m.

After taking the first blood sample at 1830 m, the mountaineering team moved up to 4000 m. After achieving the 4000 m altitude, second and third blood samples were also taken. During 48 and 72 h staying at 4000 m altitude, the subjects freely did their daily activities. There were some limitations in the study such as smoking in the studied variables. After 48 and 72 h staying at 4000 m altitude and taking the second and third blood samples, the subjects started to move down the mountain and the fifth, sixth and seventh blood samples were taken after descending to 1830 m. An indwelling catheter was placed in an arm vein at least 40 min before the submaximal cycle ergometer test. The subjects were in sitting position during the blood withdrawal. Arm position was controlled for all blood draws.

Five cc of blood were slowly placed in two special tubes containing sodium citrate in order to avoid blood clotting. This blood sample was used for CBC tests. Hematological parameters i.e., RBC (red blood cell), MCV (mean cell volume), MCH (mean cell hemoglobin), MCHC (mean corpuscular hemoglobin concentratin) were assessed by using a quantitative, automated hematology analyser (KX21 SYSMEX, Japan).

Statistically method: For analyze of data, statistical method used in this study was Repeated Measurement R.M. ANOVA. When there is a series of test data for a group of people at different times, this analyze is used. We investigated sphericity assumption. After that Least Significant Difference (LSD) has been used for pairwise comparisons. All statistical analysis was conducted by SPSS version 18.

RESULTS

There was a statistically significant effect of time on Rbc, wilk's lambda = 0.183, F (5, 7) = 6.27, p = 0.016. Mauchly's Test of Sphericity indicated that the assumption of sphericity had not been violated, $\chi^2(14) = 7.02$, p = 0.937. Least Significant Difference (LSD) was used to make *post hoc* comparisons between conditions. According to LSD *post hoc* A first paired comparisons indicated that there was a significant difference in the scores for Rbc at climbing time one (height = 1830) with time 4 (p = 0.010), time 5 (p = 0.045) and time 6 (p = 0.010) while these showed height = 1830 after 24, 48 and 72 h standing them at return time. Also there was a significant difference in the scores for RBC at climbing time 2 (height = 4000) after 48 h standing with time 4 (p = 0.008), time 5 (p = 0.021) and time 6 (p = 0.011) while these showed height = 1830 after 24, 48 and 72 h standing them at return time (Fig. 1).

There wasn't statistically significant effect of time on MCH, wilk's lambda = 0.404, F (5,7) = 2.06, p = 0.186. Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, $\chi^2(14) = 24.25$, p = 0.049 and therefore, a Huynh-Feldt correction was used. There wasn't a significant effect of time on MCH, F (4.33,7) = 0.995, p = 0.424 (Fig. 2).

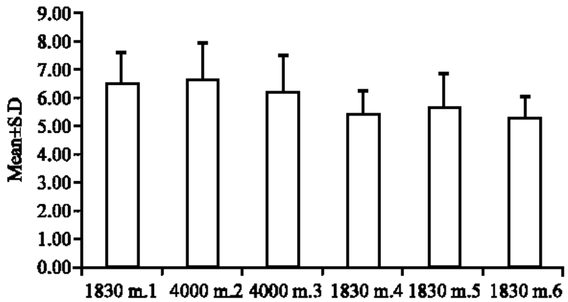

Fig. 1: Changes red blood cell (RBC) factor least significant difference (LSD) was used to make *post hoc* comparisons between conditions. According to LSD *post hoc* a first paired comparisons indicated that there was a significant difference in the scores for RBC at climbing time one (height = 1830) with time 4 (p = 0.010), time 5 (p = 0.045) and time 6 (p = 0.010) while these showed height = 1830 after 24, 48 and 72 h standing them at return time. Also there was a significant difference in the scores for RBC at climbing time 2 (height = 4000) after 48 h standing with time 4 (p = 0.008), time 5 (p = 0.021) and time 6, (p = 0.011) while these showed height = 1830 after 24, 48 and 72 h standing them at return time

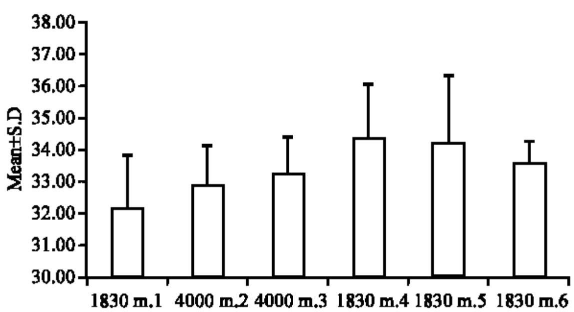

Fig. 2: Changes mean cell hemoglobin (MCH) factor There wasn't statistically significant effect of time on MCH, wilk's lambda = 0.404, F(5, 7) = 2.06, p = 0.186. Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, $\chi^2(14) = 24.25$, p = 0.049 and, therefore, a Huynh-Feldt correction was used. There wasn't a significant effect of time on MCH, F (4.33,7) = 0.995, p = 0.424

There wasn't a statistically significant effect of time on MCHC, wilk's lambda = 0.392, F (5,7) = 2.17, p = 0.171. Mauchly's Test of Sphericity indicated

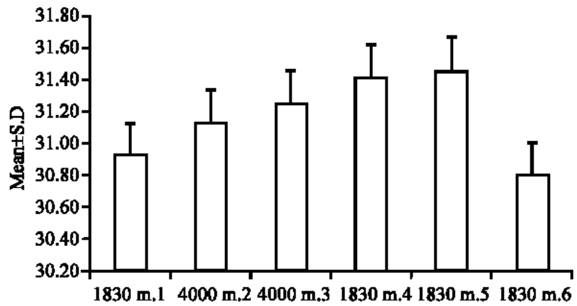

Fig. 3: Changes mean corpuscular hemoglobin concentration (MCHC) factor least significant difference (LSD) was used to make *post hoc* comparisons between conditions. According to LSD *post hoc* A first paired comparisons indicated that there was a significant difference in the scores for MCHC at climbing time1 (height = 1830) with time 4 (p = 0.021), time 5 (p = 0.031) and time 6 (p = 0.033) while these showed height = 1830 after 24, 48 and 72 h standing them at return time. Also there was a significant difference in the scores for MCHC at returning time 4 (height = 1830) after 24 h standing here with time 2 (p = 0.048) and time 3 (p = 0.032) while these showed height = 4000 after 48 and 72 h standing here at climbing time

that the assumption of sphericity had been violated, $\chi^2(14) = 30.76$, p = 0.007 and therefore, a Huynh-Feldt correction was used. There was a significant effect of time on MCHC, F (3.76, 7) = 0.995, p = 0.010. Least Significant Difference (LSD) was used to make *post hoc* comparisons between conditions. According to LSD *post hoc* A first paired comparisons indicated that there was a significant difference in the scores for MCHC at climbing time1 (height = 1830) with time 4 (p = 0.021), time 5 (p = 0.031) and time 6 (p = 0.033) while these showed height = 1830 after 24, 48 and 72 h standing them at return time. Also there was a significant difference in the scores for MCHC at returning time 4 (height = 1830) after 24 h standing here with time 2 (p = 0.048) and time 3 (p = 0.032) while these showed height = 4000 after 48 and 72 h standing here at climbing time (Fig. 3).

There was a statistically significant effect of time on MCV, wilk's lambda = 0.176, F (5, 7) = 6.57, p = 0.014. Mauchly's Test of Sphericity indicated that the assumption of sphericity had not been violated, $\chi2$ (14) = 12.35, p = 0.593. Least Significant Difference (LSD) was used to make *post hoc* comparisons between conditions. According to LSD post hoc we can

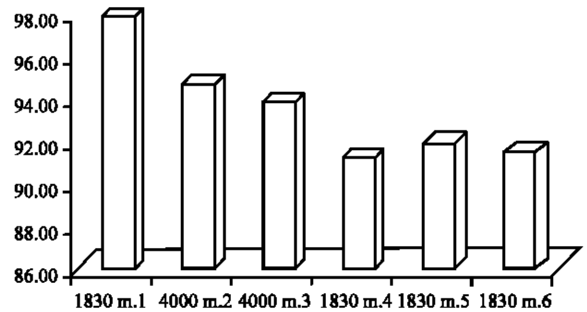

Fig. 4: Changes mean cell volume (MCV) factor least significant difference (LSD) was used to make *post hoc* comparisons between conditions. According to LSD *post hoc* we can claim that between time 2 and time 3 hadn't any statistically significant, also between time 4, time 5 and time 6 there wasn't difference but there were a statistically significant between time1 and them

claim that between time 2 and time 3 hadn't any statistically significant, also between time 4, time 5 and time 6 there wasn't difference but there were a statistically significant between time1 and them (Fig. 4).

DISCUSSION

Upon exposure to lowered PO_2 and subsequent tissue hypoxia, there are many hematological adjustments to allow for increased PaO_2. Hemoglobin (Hb) concentration and hematocrit (Hct) have been shown to increase within 24 h of exposure to altitude. The stimulation of Red Blood Cell (RBC) production occurs as PO_2 sensitive cells within the kidneys stimulate the release of erythropoietin (EPO) (Robergs and Keteyian, 2003). However, with the aforementioned reduction in plasma volume and the lag between EPO secretion and new RBC production, the true initial increases in Hb and Hct actually occur after approximately 3-4 days of exposure. This increase allows for greater PaO_2 and oxygen content per liter of cardiac output (Hahn and Gore, 2001).

The aim of the present study was to compare the hemoglobin concentration, red blood cell count and volume in high altitude and their persistence after returning back. The results showed the following points: Changes of RBC and MCHC were significant between onset of moving toward 1830 m altitude and 24, 48 and 72 h of staying at 1830 m (after returning from 4000 m attitude) and the level of these factors increases at the beginning of climbing to 4000 m and reduced after returning. MCH also showed the same changes; however, they were not significant. The first contact with high altitude (hypoxia) is along with increased Hb concentration resulted from reduction of plasma volume (due to reduction of anti-diuretic hormone) and increased RBC count. Due to increase of Hb concentration, the amount of transported oxygen to the tissues is increased. Increase of hematocrit is associated with reduction and increase of blood viscosity plasma volume; these changes increase blood flow resistance and enhance cardiac performance. These results were in accordance with the studies of (Armstrong, 2000; Pugh, 1964).

After returning back from high altitude, due to high Hb concentration, body is forced to destroy the extra hemoglobin from circulatory system in order for adaptation of the of blood factors concentration. Returning from altitude means no hypoxia conditions and back to more desirable physiologic conditions compared to high altitude and reduction of hemoglobin and RBC counts to the normal level. Hormones and stimulating factors influencing on Hb production in high altitude (e.g., erythropoietin) would lose their effect over time and the body returns to the normal conditions.

In addition, in terms of MCV, there was a significant difference between onset of climbing toward 1830 m with 24, 48 and 72 h staying at 1830 m and also 48 and 72 h staying at 4000 m altitude and amount of this factor showed a reduction at the beginning of climbing (1830 m) compared to clime toward 4000 m and staying in it and return to 1830. The results of this study were not in accordance with the study of Pugh (1964) in which MCV increased after 3 and 18 weeks staying at 5800 m altitude. However, the differences in primary results are related to the difference in altitude and staying duration which the present study is less than 3 days and it was 18 weeks in Pugh's study.

Hemoglobin mass after 21 days of conventional altitude training at 1816 m investigated by Pottgiesser *et al.* (2009) and results showed that no significant difference was found in tHb after the altitude sojourn. Additionally, the analysis of red cell volume, plasma volume and blood volume or haemoglobin concentration (Hb) as well as haematocrit (Hct) did not reveal any significant changes. Several studies have measured tHb prior to and after conventional altitude training and some have reported an increase of tHb by 6-9% (Heinicke *et al.*, 2005; Friedmann *et al.*, 2005) with a wide inter-individual variability while others did not (Friedmann *et al.*, 1999; Gore *et al.*, 1997; Saunders *et al.*, 2004). As the hypoxic dose emerges as a key factor of erythropoietic adaptations, selection of the appropriate altitude and duration of the stay are important factors.

In other study Savourey *et al.* (2004) investigated control of erythropoiesis after high altitude acclimatization. In this research erythropoiesis was studied in 11 subjects submitted to a 4 h Hypoxia (HH) in a hypobaric chamber (4,500 m, barometric pressure 58.9 kPa) both before and after a 3-week sojourn in the Andes. On return to sea level, increased red blood cells, haemoglobin at the end of HH ($p<0.05$) attested high altitude acclimatization. Reticulocytes increased during HH after the sojourn only ($p<0.01$) indicating a probable higher reticulocyte release and/or production despite decreased serum erythropoietin (EPO) concentrations.

Exposure to acute hypoxia is associated with changes Plasma Volume (PV) investigated by Poulsen *et al.* (1998). In this study PV and hemoglobin in ten normal subjects at sea level and again 24 h after rapid passive ascent to high altitude (4,350 m) measured. The results showed little changes in Hb and significant reduction in plasma volume (Poulsen *et al.*, 1998).

The studies have shown that permanent exposure to altitude for a few days reduces the amount of erythropoietin to the previous amount before climbing; although, alveolar oxygen pressure and hemoglobin saturation decreased, the amount of Hb and Hematocrit did not change (Siri *et al.*, 1966).

Stimulation of erythropoiesis is simply not done in all the hypoxic levels. Hb concentration increases linearly at 4000 m altitude and higher than this point up to 6000 m, it is a non-linear increase and it will be a reduction process (Milledge and Cotes, 1985).

Increase of oxygen transfer in high altitude includes a slow stage and requires long duration for adaptability of the body; however, stimulation of erythropoiesis has no important role for tissues in short periods of staying in high altitude. Some changes in hematocrit increase is due to plasma volume reduction because of an increase in blood viscosity, it probably has a negative effect on tissues oxygenation (Ward *et al.*, 1989).

Blood factors are also changed in high altitudes. Plasma level is reduced by staying in high altitude (Boning *et al.*, 1997).

Faura *et al.* (1969) announced that one week staying at 4530 m can cause few increases in hematocrit and significant increase in RBC count (Faura *et al.*, 1969). Hematocrit was increase in those staying at 4300 m altitude from 12 days to 4 weeks; however, it had no change in those staying at this altitude for a short time (Wolski *et al.*, 1996).

CONCLUSION

The present study is different from previous studies and no study has ever been done in such conditions. Most of studies has either been done in a long duration at altitude 1800-3000 m or has been conducted in extremely hard situation and time such as at Everest Mountains which both are to some extent hard and not cost-effective; because going to mountains is expensive and the more the time of the study is, there is a more possibility for sample loss. However, if we are looking for efficiency from altitude and hypoxic conditions, we have to reduce the time period so that more people can be in attitude. Changes in blood factors at altitude depend upon duration of staying, intensity of activity and other influencing factors.

REFERENCES

Armstrong, L.E., 2000. Performing in Extreme Environments. Human Kinetics, Canada, ISBN-13: 9780880118378, Pages: 333.

Banchero, N., 1975. Capillary density of skeletal muscle in dogs exposed to simulated altitude. Proc. Soc. Exp. Biol. Med., 148: 435-439.

Bigard, A.X., A. Brunet, C.Y. Guezennec and H. Monod, 1991. Skeletal muscle changes after endurance training at high altitude. J. Applied Physiol., 71: 2114-2121.

Boning, D., N. Maassen, F. Jochum, J. Steinacker and A. Haider *et al.*, 1997. After-effects of a high altitude expedition on blood. Int. J. Sports Med., 18: 179-185.

Brooks, G.A., E.E. Wolfel, B.M. Groves, P.R. Bender and G.E. Butterfield *et al.*, 1992. Muscle accounts for glucose disposal but not blood lactate appearance during exercise after acclimatization.to 4,300 m. J. Appl. Physiol., 72: 2435-2445.

Faura, J., J. Ramos, C. Reynafarje, E. English, P. Finne and C.A. Finch, 1969. Effect of altitude on erythropoiesis. Blood, 33: 668-676.

Fox, E.L. and D.K. Mathews, 1981. The Physiological Basis of Physical Education and Athletics. 3rd Edn., Saunders College Publishing, USA., ISBN-13: 9780030576768, Pages: 677.

Friedmann, B., J. Jost, E. Weller, E. Werle, K.U. Eckardt, P. Bartsch and H. Mairbaurl, 1999. Effects of iron supplementation on total body hemoglobin during endurance training at moderate altitude. Int. J. Sports Med., 20: 78-85.

Friedmann, B., F. Frese, E. Menold, F. Kauper, J. Jost and P. Bartsch, 2005. Individual variation in the erythropoietic response to altitude training in elite junior swimmers. Br. J. Sports Med., 39: 148-153.

Gore, C.J., A.G. Hahn, C.M. Burge and R.D. Telford, 1997. VO_2max and haemoglobin mass of trained athletes during high intensity training. Int. J. Sports Med., 28: 477-482.

Hahn, A.G. and C.J. Gore, 2001. The effect of altitude on cycling performance: A challenge to traditional concepts. Sports Med., 31: 533-557.

Heinicke, K., I. Heinicke, W. Schmidt and B. Wolfarth, 2005. A three-week traditional altitude training increases hemoglobin mass and red cell volume in elite biathlon athletes. Int. J. Sports Med., 26: 350-355.

Levine, B.D. and J. Stray-Gundersen, 1992. A practical approach to altitude training: Where to live and train for optimal performance enhancement. Int. J. Sports Med., 13: S209-S212.

Levine, B.D. and J. Stray-Gundersen, 1995. Exercise at High Altitudes. In: Current Therapy in Sports Medicine, Torg, J.S. and R.J. Shepard (Eds.). 3rd Edn., Mosby-Year Book, St. Louis, MO., USA., pp: 588-593.

Mairbaurl, H., W. Schobersberger, E. Humpeler, W. Hasibeder, W. Fischer and E. Raas, 1986. Beneficial effects of exercising at moderate altitude on red cell oxygen transport and on exercise performance. Pflugers Archiv, 406: 594-599.

Milledge, J.S. and P.M. Cotes, 1985. Serum erythropoietin in humans at high altitude and its relation to plasma renin. J. Applied Physiol., 59: 360-364.

Ou, L.C. and S.M. Tenney, 1970. Properties of mitochondria from hearts of cattle acclimatized to high altitude. Respir. Physiol., 8: 151-159.

Pottgiesser, T., C. Ahlgrim, S. Ruthardt, H.H. Dickhuth and Y.O. Schumacher, 2009. Hemoglobin mass after 21 days of conventional altitude training at 1816 m. J. Sci. Med. Sport, 12: 673-675.

Poulsen, T.D., T. Klausen, J.P. Richalet, I.L. Kanstrup, N. Fogh-Andersen and N.V. Olsen, 1998. Plasma volume in acute hypoxia: Comparison of a carbon monoxide rebreathing method and dye dilution with Evans blue. Eur. J. Applied Physiol. Occup. Physiol., 77: 457-461.

Pugh, L.G.C.E., 1964. Blood volume and haemoglobin concentration at altitudes above 18,000 ft.(5500 m). J. Physiol., 170: 344-354.

Reynafarje, C., J. Faura, D. Villavicencio, A. Curaca and B. Reynafarje *et al*., 1975. Oxygen transport of hemoglobin in high-altitude animals (Camelidae). J. Applied Physiol., 38: 806-810.

Robergs, R.A. and S.J. Keteyian, 2003. Fundamentals of Exercise Physiology: For Fitness, Performance and Health. 2nd Edn., McGraw-Hill Collage, New York, ISBN-13: 9780072552447, Pages: 512.

Saunders, P.U., R.D. Telford, D.B. Pyne, R.B. Cunningham, C.J. Gore, A.G. Hahn and J.A. Hawley, 2004. Improved running economy in elite r unners after 20 days of simulated moderate-altitude exposure. J. Applied Physiol., 96: 931-937.

Savourey, G., J.C. Launay, Y. Besnard, A. Guinet and C. Bourrilhon *et al*., 2004. Control of erythropoiesis after high altitude acclimatization. Eur. J. Applied Physiol., 93: 47-56.

Siri, W.E., D.C. Van Dyke, H.S. Winchell, M. Pollycove, H.G. Parker and A.S. Cleveland, 1966. Early erythropoietin, blood and physiological responses to severe hypoxia in man. J. Applied Physiol., 21: 73-80.

Ward, M.P., J.S. Milledge and J.B. West, 1989. High Altitude Medicine and Physiology. Chapman and Hall Medical, London, UK., Pages: 148.

Wolski, L.A., D.C. McKenzie and H.A. Wenger, 1996. Altitude training for improvements in sea level performance. Is the scientific evidence of benefit? Sports Med., 22: 251-263.