 Anthropologist, 20(3): 416-422 (2015)

Some Acute Physiological Responses of Nature Walkers to Different Altitudes

Mergul Colak[1] and Ulviye Bilgin[2]

[1]School of Physical Education and Sports, Erzincan University, 24100 Erzincan, Turkey
E-mail: mergulcolak@hotmail.com
[2]School of Physical Education and Sports, Gazi University, 06100 Ankara, Turkey
E-mail: ulvibilgin@hogmail.com

KEYWORDS Moderate Altitude. Blood Lactate. Heart Rate. Blood Pressure

ABSTRACT The aim of this study was to determine acute physiological responses of nature walkers such as, systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate (HR) and blood lactate (BLA) levels at different altitudes. 25 nature walkers voluntarily participated in the study. SBP, DBP, HR and BLA values of the subjects were measured in Erzincan (1,185 m), at the campsites of Kesis Mountain (2,800 m) and at the summit of Esence (3,549 m). The Bonferroni method, multivariate and test of Within-Subject Effect parametric tests were used in terms of a variance-covariance matrix. No statistically significant difference was found in SBP and DBP values (p>0,05).The summit BLA and HRvalues were found significantly higher (p<0.01) than lactate and HR values at the campsite and in Erzincan, the campsite values were found importantly higher than those in Erzincan (p<0.05, p<0.01 respectively).In conclusion, it was found that acute exposure to different altitudes causes an increase in HR and BLA, but did not make a significant impact on SBP and DBP.

INTRODUCTION

Contamination in human lifehas led to an interest in sportive activities in nature in recent years (Campos 1999; Ardahan 2013*)*.In addition, the progress in transportation technology makes it possible for nature lovers to climb up to altitudes of 3000 meters above sea level with ease (Kanai et al. 2001; Bhagi et al. 2014) and participate in such activities as trekking and/or mountain climbing (Campos 1999).

High altitude, usually 2000 to 3000meters, moderate altitudes and the altitudes over 3000 meters result in physiological stress in the human organism (Bärtsch and Saltin 2008; Willie et al. 2014). A high altitude gives way to proportional decrease in barometric pressure and reduction in atmospheric oxygen pressure, which creates hypobaric hypoxia with different impacts on all body organs, systems and functions (West 2005; West et al. 2013). Among the most important factors of physiological stress caused by high altitudes are hypoxia, high radiation, low temperature, humidity, windy weather, limited food intake and rugged terrain (Pinilla 2014). Physiological stress caused by high altitude in humans due to the abovementioned reasons triggers several adaptation mechanisms. Such adaptation mechanisms and acclimatization vary among the people because of environmental factors, cold weather and exercise. As a result, physiological and pathological responses of human organisms to different altitudes may differ accordingly (Yalcin et al. 2011).

Acute exposure to high altitude is defined as a kind of cardiovascular stress in tachycardia, temporary increase in blood pressure and sudden increase in cardiac output (Naeije 2010; Whayne 2014). The effect of high altitude or hypoxia on human organisms is a complexity that includes cardiovascular, respiratory and cerebrovascular systems and their related autonomic control. As a response to systemic hypoxia, the body raises ventilation to increase arterial oxygen saturation and reorganizes blood flow to carry oxygen to vital organs (Hultgren 1997). Moreover, some studies suggested that acute hypoxia might increase and therefore, cause a rise in blood lactate (Friedmann-Bette 2008; Vogt and Hoppeler 2010). These adaptations and adjustments appear the moment exposure to high altitude occurs, but may continue to exist for some hours, days or months due to interaction of various systems (Hultgren 1997). In a nutshell, it takes a long time to adapt to high altitude (Saito et al. 1995). Indeed, nature walkers climbing at a high altitude with than intent to be away from

Address for correspondence:
Dr. Mergul Colak
School of Physical Education and Sports
Physical Education and Sport Teacher Department
Erzincan University
24100 Erzincan, Turkey
Telephone: +90 446 220 00 24
Fax: +90 446 220 00 25
E-mail: mergulcolak@hotmail.com

the stress of city life and spend their weekend there do not have such a long time to adapt to such altitude. Despite the large number of studies on altitudes (Bärtsch and Swenson 2013; Faulhaber et al. 2014; Liu et al. 2014; Parati et al. 2014) data on the altitude-related physiological changes is somewhat contradictory. For this reason, in this paper, the researchers aimed to reveal some acute physiological responses (SBP, DBP, HR and blood lactate level) of nature walkers to different altitudes.

METHODOLOGY

Subjects

The data of this paper was obtained from 13th to 15th July 2012 in the traditional Esence climb. Twenty-five nature walkers (16 men and 9 women) voluntarily participated in the study. The participants were previously informed about the content of the research, and gave their written consent for the study. The average age of men is 32.19±8.76 years, average height is 174.56±4.84 cm and body weight is 72.81±9.57 kg while average age, height and body weight of women is 29.40±3.97 years, 167.40±2.40 cm and 63.60±8.87 kg respectively. The measurements were realized at three different altitudes: in Erzincan (1,185 m), at the campsites of Kesis Mountain ranges (2,800 m), and at the summit of Esence (3,549 m). The subjects went up to 2,500 meters by vehicles. After a short walk, they arrived at the campsite at 2,800meters. After an overnight stay at the campsite, they set out at 5:00 am for the summit and reached the summit after a 5.30-hour walk. The measurements were realized before departure from Erzincan, at the campsite and after 10-minute breaks upon arrival at the summit while the subjects were in a sitting position.

Height (cm) and Weight (kg) Measurements

The height was measured to the nearest 0.1 cm using a stadiometer. Weight was measured to the nearest 0.1 kg on an electronic scale (Seca Corp, Birmingham, United Kingdom). The measurements were performed in Erzincan while the participants wore shorts and t-shirts.

Blood Pressure (mmHg) and Heart Rate (beat/min) Measurements

Blood pressure (Systolic blood pressure (SBP), diastolic blood pressure (DBP)) and heart rate values were measured using the Braun BP 4100 blood pressure monitor.The measurements were realized before departure from Erzincan, at the campsite and after 10-minute breaks upon arrival at the summit while the subjects were in a sitting position. Measurements were performed at two-minute intervals twice and the mean of the results was taken. When the difference between the two measuring values came out to be more than 5 mmHg, the measurements were repeated (Ward and Langton 2007).

Blood Lactic Acid Measurements

Blood lactic acid values were measured using the Accutrend Plus Lactate Analyzer tool (strips used). The measurements were realized before departure from Erzincan, at the campsite and after 10-minute breaks upon arrival at the summit while the subjects were in a sitting position. For a handheld analyzer to be used in the measurement of lactate, test strips from each box, which have a special code, were obtained. Both, the hand held analyzer calibration and the codes on the strips were encoded. The blood taken out of the subject’s finger was put in the special part of the tool. The results on the screen were recorded (Baldari et al. 2009).

Statistical Analyses

For the analysis of the data, the Statistical Package for the Social Sciences (SPSS) software for Windows (version 16.0; SPSS, Inc., Chicago, IL) was used. The data was summarized in the form of average and standard deviations. According to the test of normality, for the data showing normality, the parametric tests, multivariate and Test of Within-Subject effect tests were employed in accordance with the variance-covariance matrix, while Bonferroni tests in multiple comparisons were used to find the source of difference. Error performance was 0.05 in this study.

RESULTS

The average age, height, weight and standard deviations of the participants in the research are given in Table 1. In this paper, the mean ages of female and male participants were found to be 29.40±3.98 and 32.19±8.77 respectively. The mean of body weights was 63.60±8.88 kg and 72.81±9.57kg, respectively. SBP, DBP, HR, BLA averages and standard deviations of the sub-

Table 1: Physical characteristics of the subjects

	Female (n=9)	*Male (n=16)*	*Total (n=25)*
Age (years)	29.40±3.98	32.19±8.77	31.52±7.89
Height (cm)	167.40±2.48	174.56±4.84	172.86±5.34
Weight (kg)	63.60±8.88	72.81±9.57	70.62±10.32

jects were displayed (Table 2). As seen in Table 2, female participants and their total SBP and DBP increased with exposure to different altitudes, but blood pressure values of men remained stable. HR and BLA values of subjects increased as the altitude increased. Table 3 examined, variance-covariance structure. It was found stable (P>0.05).

Table 3: Stability of variance-covariance matrix with regards to the variables

Variables	*Mauchly's W*	*Approx. Chi-square*	*df*	*P*
SBP (mmHg)	0.795	4.354	2	0.113
DBP (mmHg)	0.846	3.172	2	0.205
HR (beat/min.)	0.980	0.393	2	0.822
BLA (mmol/L)	0.845	3.196	2	0.202

As seen in Table 4, according to the results of statistical analysis, no significant difference was found in systolic and diastolic blood pressure (P>0.05) while statistically significant differences was observed in the comparison of heart rate and blood lactate measurements (P<0.01). Because the blood pressure values of men remained stable, the SBP and DBP differences were not meaningful.

Table 5: Multiple comparisons of heart rate measurements

(I) HR	*(J) HR*	*Averages difference (I-J)*	*Std. hata*	*P*
Erzincan	Camp	-7.857	1.970	0.002**
	Summit	-23.190	2.232	0.000**
Camp	Summit	-15.333	2.118	0.000**

**p<0.01

Multiple comparisons of heart rate measurements are examined in Table 5. It can be concluded that the values at the campsite were higher than those measure at Erzincan, while the values with regards to the summit were significantly higher than those taken at Erzincan and the campsite (P<0.01).

Multiple comparisons of blood lactate measurements were given in Table 6. The values from the summit were found to be significantly higher than those concerning Erzincan and the

Table 2: Average values of physiological responses of participants at different altitudes

		Erzincan (1185m)	*Camp (2800m)*	*Summit (3549m)*
SBP (mmHg)	Female	96.80±12.42	110.40±11.80	122.60±11.72
	Male	132.44±15.48	134.88±21.66	134.81±20.40
	Total	123.95±21.27	129.05±22.22	131.90±19.18
DBP (mmHg)	Female	67.20± 8.32	76.80± 8.56	91.80±11.19
	Male	83.81±11.692	83.88± 8.35	84.12± 9.32
	Total	79.86±12.997	82.19± 8.74	85.95±10.07
HR (beat/min)	Female	77.00± 4.123	81.80± 6.80	97.80± 6.97
	Male	77.56±11.927	86.37±11.34	101.50± 7.80
	Total	77.43±10.496	85.29±10.47	100.62± 7.61
BLA (mmol/L)	Female	1.78± 0.59	2.38± 0.84	2.96± 0.66
	Male	1.77± 1.15	2.33± 1.76	3.79± 2.41
	Total	1.77± 1.03	2.34± 1.57	3.60± 2.14

Table 4: Comparison of measurements of participants in the research

		Type III sum of squares	*df*	*Mean square*	*F*	*P*
SBP (mmHg)	Sphericity Assumed	681.556	2	340.778	2.029	0.145
DBP (mmHg)	Sphericity Assumed	397.238	2	198.619	2.369	0.107
HR (beat/min.)	Sphericity Assumed	5842.508	2	2921.254	62.504	0.000**
BLA (mmol/L)	Sphericity Assumed	36.549	2	18.274	24.548	0.000**

**p<0.01

Table 6: Multiple comparisons of blood lactate measurements

(I) BLA	*(J) BLA*	*Averages difference (I-J)*	*Std. hata*	*P*
Erzincan	Camp	-.571	0.207	0.037*
	Summit	-1.824	0.292	0.000**
Camp	Summit	-1.252	0.291	0.001**

*p<0.05 **p<0.01

campsite (p<0.01), while the values with from the campsite were significantly higher than those of Erzincan (P<0.05).

DISCUSSION

In the present paper in which some acute physiological responses of nature walkers at different altitudes were examined, with the increase in altitude, the increase in their acute systolic and diastolic blood pressure was not statistically significant (p>0.05). However, a statistically significant increase was found in the heart rate and blood lactate levels (p<0.01) (Table 4).

Hypoxia emerging due to a decrease in ambient pressure and oxygen pressure respired, is a strong environmental stress factor caused by such cardiovascular adaptations as increases in heart rate, respiratory rate, sudden increase in cardiac output, and low systemic blood pressure (Rowell et al. 1989; Halliwill et al. 2003; Naeije 2010). Hypoxia leads to an increase in sympathetic activity or decrease in parasympathetic activity affecting heart rate dynamics and causes signaling peripheral chemoreceptors and rise in local vasodilation (that is, decrease in blood pressure) (Somers et al. 1989; Kara et al. 2003).

Responses of hyperventilation to chemoreceptor signals result in heart rate, cardiac output, increase in catecholamine, and very little difference in blood pressure. Acute hypoxia (Marshall 1994; Reis et al. 1994) sensed by peripheral and medullary chemoreceptors activates strongly sympathetic neural system (Calbet 2003). Depending on the increase in the activation of sympathetic neural system, blood norepinephrine increases and this causes a rise in the heart rate (Hallagan and Pigman 1998).The heart rate and rise in blood pressure resulting from acute exposure to altitude are reported to be related with increasing level of norepinephrine (Wyatt 2014).

Another acute response due to the altitude is an increasein the rest and submaximal cardiac output. In order to catch the low partial oxygen pressure in tissues, increasing cardiac output is primarily provided through increase in heart rate. Blood supply increases with altitude due to arterial desaturation (McArdle et al. 2010).

In most previous studies, it is asserted that acute hypoxia had a trivial impact on systemic blood pressure in humans (Vogel et al. 1967; Vogel and Harris 1967; Kanstrup et al.1999). During a long-lasting hypoxia, systemic blood pressure, specifically average arterial blood pressure and diastolic blood pressure are reported to increase gradually, with increase in norepinephrine in plasma concentration and disposed off through urine (Wolfel et al. 1994; Mazzeo et al. 1998). Some researchers reported an increase in resting blood pressure at over 4000 meters of altitude (Mazzeo et al. 1991; Antezana et al. 1994).

In another paper where responses of women to catecholamine at 4300 meters for 12 days, no significant change was seen in the systolic blood pressure (SBP), and the diastolic blood pressure (DBP) was at peak level during the 3rd and 4th days, and remained stable at this level during the period spent (12 days) at the altitude. In addition, both, at the follicular and luteal phase, a close relation is reported between DBP and urinary norepinephrine secretion (Mazzeo et al. 1998). In another paper, Kanstrup et al. (1999) studied blood pressure and plasma catecholamine for 24 hours and 5 days after climbing up to 4,559 meters. In this study, it was found that on the first day after climbing up to the high altitude, the SBP increased compared to when at sea level and decreased on the 5th day again while DBP increased both on the first and fifth day.

Moreover, Saito et al. (1999) stated that no significant difference was observed between the average blood pressure values at moderate altitude (2700m and 3700m) and at sea level for the trekkers with no training. However, following the exercise, the increase in blood pressure at 3700meters was reported to be significantly higher than that at 2700 meters. Similarly, in other studies conducted earlier, it was seen that hypoxia did not cause any or led to a slight increase in blood pressure. For instance, Somers et al. (1989) argued that average arterial pressure in hypoxia was 3mmHg above normoxia conditions. In most studies (Shave 2004; Houssiere et al. 2006; Snyder et al. 2008; Faulhaber et al. 2010; Wee and Climstein 2015) exposure to acute hypoxia resulted in no change in the SBP and DBP. In this paper, considering acute blood pressure of nature walkers at different altitudes, the findings show a similarity with the relevant literature, (Kontos et al. 1967; Vogel et al. 1967; Vogel and Harris 1967; Somers et al. 1989; Saito et al. 1999; Shave 2004; Houssiere et al. 2006; Snyder et al. 2008; Faulhaber et al. 2010; Wee and Climstein 2015) while no similarity is seen with the results of other studies examined.

Halliwill and Minson (2002) pointed out that various responses of blood pressure to hypoxia result from differences between hypocapnic and isocapnic hypoxia, whether individuals have been subjected to hypoxia or altitude and the degree of hypoxia and different individual responses to hypoxia. Therefore, the results obtained regarding the blood pressure of nature walkers do not show similarity with some studies due to the reasons given by Halliwill and Minson (2002).

In the present paper, it was found that heart rate increased with increase in altitude. The value of the heart rate at the peak of 3,549 meters was significantly higher than that at 2,800 meters and 1,185 meters, whereas the heart rate value at 2,800 meters was significantly higher than that at 1,185meters ($p<0.01$) (Table 5).

Exposure to high altitude covers some physiological changes like increase in resting and submaximal KAH and ventilation, rise in blood pressure and catecholamine secretion and decrease in max VO_2. These changes result in increase in oxygen delivery to tissues, increase in alveolar PO_2 accompanied by decrease in H^+ ion and CO_2, increase in lactate production, reduction in work capacity and increase in vascular resistance (Brooks et al. 2000). An increase in the blood norepinephrine level, depending on the rise in the activity of sympathetic nervous system at high altitude regulates heart rate volume and peripheral vascular resistance, and leads to an increase in heart rate (Hallagan and Pigman 1998; Wyatt 2014). In addition, individuals ascending to high altitude also experience a decrease in stroke volume and compensate an increase in heart rate (Buchheit et al. 2012).

Despite the abovementioned physiological changes at high altitude, in some studies, moderate altitudes were reported not to cause any significant change on heart rate (Saito et al. 1995; Faulhaber et al. 2010). However, in most studies conducted at different altitudes, it was reported that high altitude increased significantly the heart rate (Mazzeo et al. 1998; Kanstrup et al. 1999; Halliwill and Minson 2002; Calbet 2003; Heinonen et al. 2012; Parati et al. 2014). In another paper, Kanai et al. (2001) found that heart rate of tourists at 3,700meters was higher than that at sea level and at 2,700 meters.Subudhi et al. (2014) determined that the heart rate after acute and a sixteen-day acclimatization was higher than at sea level.

The results of the study concerning heart rate show similarity with most of the literature while they are not similar with the findings in some studies (Saito et al. 1999; Faulhaber et al. 2010). The studies showed that compared to at sea level, acute exposure to high altitude results in an increase in cardiac output and heart rate in both resting and at a certain level of exercise (Reeves et al. 1987; Ward et al. 1995). In addition, Ward et al. (1995) argued that the higher the altitude is, the higher the heart rate at resting and a certain level of exercise. The discrepancy between the heart rate values of nature walkers and the results of some researches is thought to originate in the degree of altitude where measurement is done, whether the individuals are exposed to high altitude, environmental factors and differences between the responses of individuals to hypoxia.

In the present paper, the blood lactate measurement of nature walkers taken at 3,549 meters and 2,800 meters was found to be higher than that at 1,185 meters while the lactate value measured at 3,549 meters was higher than that at 2,800 meters ($p<0.05$, $p<0.01$) (Table 6).

Heinonen et al. (2012) stated that exposure to acute hypoxia at 3,400 meters of altitude did not have any impact on the blood lactate level. Contrastively, compared to normoxia, blood lactate level is higher in acute hypoxia in case of certain workloads (Adams and Welch 1980; Parolin et al. 2000; Mazzeo 2008). In some studies conducted, exposure to acute hypoxia at 4,300 meters of altitude is reported to increase glycogenolysis, glycolysis and blood lactate production (Friedmann-Bette 2008; Vogt and Hoppeler 2010). Wyatt (2014) stated that catecholamine activity at high altitude regulates heart rate and peripheral vascular resistance and affects the use of energy sources. In the same study, the rise in catecholamine secretion triggers the needed anaerobic glycolysis for energy production and therefore the use of carbohydrates. As a result of partial decomposition of carbohydrates together with anaerobic glycolysis, an augmentation is seen in the amount of lactate accumulated in muscle and blood (Fox et al. 1993). The results obtained in this paper with regards to blood lactate levels demonstrate similarity with most studies. With the increase in altitude, the augmentation in blood lactate levels is thought to result from the increasing use of carbohydrates in acute hypoxia as sources of energy and increasing energy production through anaerobic glycolysis.

CONCLUSION

It can be concluded that acute exposure to different altitudes increases heart rate and blood lactate levels of nature walkers but no significant effect is observed on systolic and diastolic blood pressure.

RECOMMENDATIONS

In the light of this study, since acute exposure to medium altitude does not lead to any serious physiological changes in terms of health, people are advised to go up to medium altitudes on the weekends.

ACKNOWLEDGEMENTS

I acknowledge my deepest gratefulness to all nature walkers who participated in the study.

REFERENCES

Adams R, Welch HG 1980.Oxygen uptake, acid-base status, and performance with varied inspired oxygen fractions. *J Appl Physiol,* 49: 863-868.

Antezana AM, Kacimi R, Le Trong JL, Marchal M, Abousahl I et al. 1994. Adrenergic status of humans during prolonged exposure to the altitude of 6,542m. *J Appl Physiol,* 76: 1055-1059.

Ardahan F, Mert M 2013.The validity and reliability of motivational factors scale and the benefits scale of participating in trekking activities for Turkish population. *International Journal of Human Sciences,* 10(2): 338-355.

Baldari C, Bonavolonta V, Emerenziani GP, Gallotta MC, Silva AJ, Guidetti L 2009. Accuracy, reliability, linearity of Accutrend and Lactate Pro versus EBIO plus analyzer. *European Journal of Applied Physiology,* 107(1): 105-111.

Bärtsch P, Saltin B 2008. General introduction to altitude adaptation and mountain sickness. *Scand J Med Sci Sports,* 18(1): 1-10.

Bärtsch P, Swenson ER 2013. Clinical practice: Acute high-altitude illnesses. *N Engl J Med,* 368: 2294-2302.

Bhagi S, Srivastava S, Singh SB 2014. High-altitude pulmonary edema: Review. *J Occup Health,* 56: 235-243.

Brooks GA, Fahey TD, White TP, Baldwin KM 2000. *Exercise Physiology: Human Bioenergetics and Its Applications.* 3rd Edition. Mountain View, CA: Mayfield Publishing Company.

Buchheit M, Kuitunen S, Voss SC, Williams BK, Mendez- Villanueva A et al. 2012. Physiological strain associated with high – intensity hypoxic intervals in highly trained young runners. *The Journal of Strength and Conditioning Research,* 26(1): 94-105.

Calbet JAL 2003. Chronic hypoxia increases blood pressure and noradrenaline spilover in healtthy humans. *J Physiol,* 55(1): 379-386.

Campos AL, Costa RVC 1999. Physical activity at moderate and high altitudes: Cardiovascular and respiratory morbidit. *Arq Bras Cardiol,* 73(1): 121-128.

Faulhaber M, Gatterer H, Haider T, Patterson C, Burtscher M 2010. Intermittent hypoxia does not affect endurance performance at moderate altitude in well-trained athletes. *Journal of Sports Sciences,* 28(5): 513-519.

Faulhaber M, Wille M, Gatterer H, Heinrich D, Burtscher M 2014. Resting arterial oxygen saturation and breathing frequency as predictors for acute mountain sickness development: A prospective cohort study. *Sleep Breath,* 18: 669-674.

Fox EL, Bowers RW, Foss ML 1993. *The Physiologycal Basis for Exercise and Sport.* 5thEdition. Madison, WI : WCB Brown and Benchmark.

Friedmann-Bette B 2008. Classical altitude training. *Scand J Med Sci Sports,* 18(S1): 11-20.

Halliwill JR, Minson CT 2002. Effect of hypoxia on arterial baroreflex control of heart rate and muscle sympathenic nerve activity in humans. *J Appl Physiol,* 93: 857-864.

Halliwill JR, Morgan BJ, Charkoudian N 2003. Peripheral chemoreflex and baroreflex interactions in cardiovascular regulation in humans. *J Physiol,* 552: 295-302.

Hallagan LF, Pigman EC 1998. Altitude: Acclimatization to Intenmediate Altitudes. Encyclopedia of Sports Medicine and Science. From <http://www. sportscie. org> (Retrieved on 14 January 2015).

Heinonen I, Kemppainen J, Kaskinoro K, Peltonen JE, Spilä HT et al. 2012. Effects of adenosine, exercise, and moderate acute hypoxia on energy substrate utilization of human skeletale muscle. *Am J Physiol Regul Integr Comp Physiol,* 302: R385-R390.

Houssiere A, Najem B, Pathak A, Xhaet O, Naeije R et al. 2006. Chemoreflex and metaboreflex responses to static hypoxic exercise in aging humans. *Med Sci Sports Exerc,* 38(2): 305-312.

Hultgren HN 1997. *High Altitude Medicine.* Stanford, CA: Hultgren.

Liu Y, Zhang JH, Gao XB, Wu XJ, Yu J et al. 2014. Correlation between blood pressure changes and AMS, sleeping quality and exercise upon high-altitude exposure in young Chinese men. *Military Medical Research,* 1: 1-9.

Kanai M, Nishihara F, Shiga T, Shimada H, Saito S 2001. Alterations in autonomic nervous control of heart rate among tourists at 2700 and 3700m above sea level. *Wilderness and Environmental Medicine,* 12: 8-12.

Kara T, Narkiewicz K, Somers VK 2003. Chemoreflexes-physiology and clinical implications. *Acta Physiol Scand,* 177: 377-384.

Kanstrup IL, Paulsen TD, Hansen JM, Andersen LJ, Bestle MH et al. 1999. Blood pressure and plazma catecholamine in acute and prolonged hypoxia: Effects of local hypothermia. *J Appl Physiol,* 87(6): 2053-2058.

Kontos HA, Levasseur JE, Richardson DW, Mauck HPJ, Patterson JLJ 1967. Comparative circulatory responses to systemic hypoxia in man and in unanesthetized dog. *J Appl Physiol*, 23: 381–386.

Marshall, JM 1994. Peripheral chemoreceptors and cardiovascular regulation. *Physiol Rev,* 7: 543-594.

Mazzeo RS, Bender PR, Brooks GA, Butterfield GE, Groves BM et al. 1991. Arterial catecholamine responses during exercise with acute and chronic high-altitude exposure. *Am J Physiol*, 261: E419-424.

Mazzeo RS, Child A, Butterûeld GE, Mawson JT, Zamudio S et al. 1998.Catecholamine response during 12 days of high-altitude exposure (4,300 m) in women. *J Appl Physiol*, 84: 1151–1157.

Mazzeo RS2008. Physiological responses to exercise at altitude: An update. *Sports Med,* 38(1): 1-8.

McArdle WD, Katch FI, Katch VL 2001. *Exercise Physiology: Energy, Nutrition and Human Performance.* 5th Edition. Balmitore, MD: Lippincott Wilkins Publishers.

Naeije R 2010. Physiological adaptation of the cardiovascular system to high altitude. *Prog Cardiovasc Dis*, 52: 456-466.

Parati G, Bilo G, Faini A, Bilo B, Revera M et al. 2014. Changes in 24h ambulatory blood pressure and effects of angiotensin II receptor blockade during acute and prolonged high-altitude exposure: A randomized clinical trial. *European Heart Journal,* doi: 10.1093/eurheartj/ehu275, 2-10.

Parolin M, Spriet LL, Hultman E, Hollidge-Horvat M, Jones NI et al. 2000. Regulation of glycogen phosphorylase and PDH during exercise in human skeletal muscle during hypoxia. *J Appl Physiol,* 278: E522-534.

Pinilla OCV 2014. Exercise and training at altitudes: Physiological effects and protocols. *Rev Cienc Salud,* 12(1): 111-130.

Reeves JT, Groves BM, Sutton JR, Wagner PD, Cymerman A, et al. 1987. Operation Everest II: Preservation of cardiac function at extreme altitude. *J Appl Physiol,* 63(2): 531-539.

Reis DJ, Golanov EV, Ruggiero DA, Sun MK 1994. Sympatho-excitatory nerous of the rostral ventrolateral medulla are oxygen sensor and essential elements in the tonic and reflex central of the systemic and cerebral circulations. *J Hypertens Suppl,* 12: S159-180.

Rowell LB, Johnson DG, Chase PB, Comess KA, Seals DR 1989. Hypoxemia raises muscle sympathetic activity but not norepinephrine in resting humans. *J Appl Physiol,* 66:1736-1743.

Saito S, Shimada H, Imai T, Futamata Y, Yamamori K 1995. Estimation of the degree of acclimatization to high altitude by a rapid and simple physiological examination. *Int Arch Occup Environ Health,* 67: 347-351.

Saito S, Nishihara F, Takazawa T, Kanai M, Aso C et al. 1999. Exercise-induced cerebral deoxygenation among untrained trekkers at moderate altitudes. *Archives of Enviromental Health,* 54(4): 271-276.

Shave RE 2004. Effect of prolonged exercise in a hypoxicenvironment on cardiac function and cardiac troponin T. *Br J Sports Med,* 38(1): 86-88.

Snyder EM, Carr RD, Deacon CF, Johnson BD 2008. Overnight hypoxic exposure and glucagon-like peptide-1 and leptin levels in humans. *Appl Physiol Nutr Metab,* 33(5): 929-935.

Somers VK, Mark Al, Zovala DC, Abbound FM 1989. Influence of ventilation and hypocapni on sympathenic nerve responses to hypoxia in normal humans. *J Appl Physiol,* 67: 2095-2100.

Subudhi AW, Fan JL, Evero O, Bourdillon N, Kayser B et al. 2014. Altitude Omics: Effect of ascent and acclimatization to 5260 m on regional cerebral oxygen delivery. *Exp Physiol,* 99(5): 772-781.

Vogel JA, Hansen JE, Harris CW 1967. Cardiovascular responses in man during exhaustive work at sea level and high altitude. *J Appl Physiol,* 23: 531–539.

Vogel JA, Harris CW 1967. Cardiopulmonary responses of resting man during early exposure to high altitude. *J Appl Physiol,* 22: 1124–1128.

Vogt M, Hoppeler H 2010. Is hypoxia training good for muscles and exercise performance? *Prog Cardiovasc Dis,* 52(6): 525-533.

Yalcin M, Kardesoglu E, Isilak Z 2011. High altitude and heart. *TAF Prev Med Bull. (Periodical of Gulhane Medical Faculty Dpt of Public Health),*10(2): 211-222.

Ward MP, Milledge JS, West JB 1995. *High Altitude Medicine and Physiology.* 2nd Edition. London, UK: Chapman and Hall Medical.

Ward M, Langton JA 2007. Blood pressure measurement. *Continuing in Anaesthesia, Critical Care and Pain,* 7(4): 122-126.

Wee J, Climstein M 2015. Hypoxic training: Clinical benefits on cardiometabolic risk factors. *Journal of Science and Medicine in Sport,* 18: 56-61.

West JB 2005. The atmosphere. In: TF Horbein, RB Schoene (Eds.): *High Altitude: An Exploration of Human Adaptation. Lung Biology in Health and Disease,* 161: 30-35.

West JB, Schoene RB, Luks AM, Milledge JS 2013. *High Altitude Medicine and Physiology.* 5th Chapter "Sleep" Boca Raton, FL: CRC Press, pp. 202-215.

Whayne TF 2014. Cardiovascular medicine at high altitude. *Angiology,* 65(6): 459-472.

Willie CK, Smith KJ, Day TA, Ray LA, Lewis NCS et al. 2014. Regional cerebral blood flow in humans at high altitude: Gradual ascent and 2 wk at 5,050m. *J Appl Physiol,* 116: 905-910.

Willie CK, Smith KJ, Day TA, Ray LA, Lewis NCS et al. 2014. Regional cerebral blood flow in humans at high altitude: Gradual ascent and 2 wk at 5,050 m. *J Appl Physiol,* 116: 905-910.

Wolfel EE, Selland MA, Mazzeo RS, Reeves JT 1994. Systemic hypertension at 4,300 m is related to sympathoadrenal activity. *J Appl Physiol,* 76: 1643–1650.

Wyatt FB 2014. Physiological responses to altitude: A brief review. *Journal of Exercise Physiology,* 17(1): 90-96.