Open Access

Original Article

Effect of Physical Training on Oxygen Saturation at Very High Altitude in Young Males

Syed Hassan Raza, Shahzeb Ahmed Satti, Abdur Rehaman Arshad*, Azhar Ali Chaudry, Muhammad Imran, Raheel Iftikhar*****

Department of Pulmonology, Pak Emirates Military Hospital Rawalpindi/National University of Medical Sciences (NUMS) Pakistan, *Department of Nephrology, Pak Emirates Military Hospital Rawalpindi/National University of Medical Sciences (NUMS) Pakistan, **Department of Cardiology, Armed Forces Institute of Cardiology & National Institute of Heart Diseases /National University of Medical Sciences (NUMS) Rawalpindi Pakistan, ***Department of Clinical Hematology, Armed Forces Bone Marrow Transplant Centre /National University of Medical Sciences (NUMS) Rawalpindi Pakistan

ABSTRACT

Objective: To determine the effect of physical training on oxygen saturation at very high altitude in young male individuals.
Study Design: Prospective longitudinal study.
Place and Duration of Study: Department of Pulmonology PEMH Rawalpindi from Jun–Jul 2022.
Methodology: The study was done on 250 young individuals arriving at a height of 11,820 feet for the very first time. All individuals were made to stay at the same height for the study period of 28 days. Individuals were tasked to walk 100 meters daily at a steady pace to ensure physical activity. Oxygen saturation was measured, before and after walking 100 meters at a height of 11,820 feet on day 0, day 7, day 14 and day 28 respectively.
Results: Mean age of the study participants was 28.08±4.82 years. On day 0, post walk average oxygen saturation was 91.53±1.80%. After a stay of 28 days at a height of 11, 820 feet post walk average oxygen saturation increased to 92.24±2.18%.
***Conclusion*:** The oxygen saturation of young individuals improved over a period of 28 days stay after physical training. Human body adapts to physical training at high altitude by undergoing a large number of physiological processes resulting in improved exercising capacity and increase in oxygen saturation over a period of time.

Keywords: High Altitude, Oxygen Saturation, Physical Training, Young Individuals

How to Cite This Article: *Raza Sh, Satti SA, Arshad AR, Chaudry AA, Imran M, Iftikhar R. Effect of Physical Training on Oxygen Saturation at very High Altitude in Young Males. Pak Armed Forces Med J 2024; 74(6): 1624-1627. DOI: https://doi.org/10.51253/pafmj.v74i6.11025*

INTRODUCTION

Across the globe over 150 million people live at high altitudes, most of which are from Asia and South America. Increase in altitude is inversely proportional to the partial pressure of oxygen i.e. higher the altitude lower the partial pressure of oxygen (hypobaric hypoxic environment).[1] According to LandScan 2019 and Multiresolution Terrain almost about 81.6 million people reside at ≥2,500 m, and 14.4 million at ≥3,500 m. Ethiopia has the biggest outright populace at ≥1,500 m and ≥2,500 m, whereas China has the most prominent at ≥3,500 m.[2]

At high altitudes a large number of physiological mechanisms come into play to counter the effect of hypoxic hypobaric environment. The counter protective mechanisms include increased respiratory rate, increased heart rate due to sympathetic overdrive, blood concentration due to diuresis and pulmonary vasoconstriction due to hypoxia.[3] Failure or inadequate adaptation to hypoxic hypobaric environment may result in various pathological processes involving lungs and brain. High Altitude Pulmonary Edema (HAPE) is very common, especially in individuals undergoing rapid ascend without proper acclimatization. The causative factors are multifaceted including both genetic and environmental risk factors.[4]

Variation in pulse rate, blood pressure charting and oxygen saturation could be a red herring to a drastic health catastrophe during ascent. Monitoring the vital signs can be helpful in saving precious lives. Keeping this in mind various devices have been used worldwide to monitor oxygen saturation. These devices, called pulse oximeters use sensors to detect and measure oxygen saturation. Portable and handy devices have largely been used by trekkers, skiers and climbers to monitor physiological responses to high altitude and pre-emptively decide about continuing the ascent.[5] However, on the other side of the picture the interpretation requires experienced personnel.[6]

Pakistan is a country lying at the confluence of Karakorum and Himalayas. Trekking and climbing expeditions are a common site in Northern Areas of the country especially during summers. The success of any expedition depends upon the pre-climb preparation of which acclimatization is a very basic component. If not executed in true letter and spirit, poor acclimatization could endanger the life of entire expedition. During such tedious climbs portability of

Correspondence: Dr Syed Hassan Raza, Department of Pulmonology, Pak Emirates Military Hospital Rawalpindi Pakistan
Received: 10 Oct 2023; revision received: 22 Jan 2024; accepted: 23 Jan 2024

equipment is a vital component. Amongst all the devices used to measure oxygen saturation, handheld pulse oximeter is used most frequently. In this study, the effect of physical training on oxygen saturation monitored by a pulse oximeter was explored over a span of one month. It helped in understanding the relationship between oxygen saturation, acclimatization and other variables in a reliable manner.

METHODOLOGY

This prospective longitudinal study was carried out at Northern Areas of Pakistan under care of Department of Pulmonology Pak Emirates Military Hopspital (PEMH) Rawalpindi from 1st June to 30th June 2022 with approval by Ethical Review Committee vide certificate No.A/28/EC/548/23. Informed consent was taken from 250 young individuals. All subjects were enrolled in the study using consecutive, non-probability sampling. Mean oxygen saturation of 88.2 was used to calculate sample size using WHO sample size calculator version 2.0.7

Inclusion Criteria: Males in age ranging from 18 to 41 years, Individuals without physical disability and able to walk on their own were included. Individuals from low altitude arriving recently at this new height were preferred. Study included only individuals without significant cardiorespiratory diseases.

Exclusion Criteria: Permanent residents of high altitude, Individuals with physical disability and inability to walk independently. Individuals with cardiorespiratory co-morbids were excluded from the study. Females were excluded due to lack of suitable accommodation at such altitude.

In this study newly arriving young individuals at very high altitude were made to stay at the above mentioned height for a period of four weeks. Parameters including pulse, blood pressure, age, and body mass index (BMI) were noted. Oxygen saturation was measured via digital pulse-oximeter (CERTEZA Pulse Oximeter Model PO-907 – Germany) before and after walking 100 metres at a steady pace on day 0, 7, 14 and 28 days respectively. The pulse oximeter was checked after daily use by comparing the oxygen saturation of random individual at rest and doing the same with an oxygen saturation probe of a bed side cardiac monitor. Throughout the four weeks the oxygen saturation taken by both medical equipment were the same. The study outcomes were measured as improvement in oxygen saturation as monitored by pulse oximeter after undergoing physical exertion over a period of four weeks. The confounding factors like temperature, wind speed, humidity and precipitation were not taken into account.

All the data collection was conducted by the researcher himself to maintain study protocol, data continuity and quality. The data were analyzed in Statistical Package for Social Sciences (SPSS) version 26.0. The continuous variables like age, pulse, body mass index, systolic and diastolic blood pressure were measured as mean, standard deviation were computed. Pre and post walk oxygen saturation was measured and analyzed via Paired sample t test on Day 0, Day 7, Day 14 and Day 28. The p value of ≤ 0.05 was considered significant.

RESULTS

Total of 250 individuals were included in this study group. All individuals belonged to the male gender (100%). The age of individuals ranged from 18 to 41 years with a mean age of 28.07±4.87 years. Most of the individuals ie., 52(20.8%) belonged to age group between 27 to 29 years. BMI of all individuals ranged from 17 to 32 kg/m² with a mean BMI of 23.14±2.79 kg/m². Mean pulse rate, systolic blood pressure and diastolic blood pressure were 83.71±8.82 beats/min, 111±8.76 mm of Hg and 70.72±5.47 mm of Hg respectively (Table-I). Pre-exercise oxygen saturation on Day 0 was 90.64±1.80 while that on Day 28 was 91.67±2.08 (Table-II). Similarly post-exercise saturation was 91.53±2.34 on Day O and 92.24±2.19 on Day 28 respectively (Table-III). Post exercise oxygen saturation decreased on Day 7 (p-value 0.185) making it statistically insignificant, however it increased by Day 28 (p-value <0.001).

Table-I: Descriptive and Clinical Profile of the Study Participants (n=250)

Variables	Mean±SD
Age (Years)	28.07±4.82
Body Mass Index (Kg/m²)	23.14±2.79
Pulse (Beats/min)	83.71±8.82
Systolic Blood Pressure (mmHg)	111.0±8.76
Diastolic Blood Pressure (mmHg)	70.72±5.47

Table-II: Comparative change in SpO2 Pre/ Post exercise, at four different points in time (n=250)

Days	Pre- exercise Oxygen Saturation(%) Mean±SD	Post- exercise Oxygen Saturation(%) Mean±SD	p-value
0	90.64±1.80	91.53±2.34	<0.001
7	90.82±2.09	91.02±2.25	0.185
14	91.17±1.63	92.12±2.02	<0.001
28	91.67±2.08	92.24±2.19	<0.001

Table-III: Comparative Changes in Pre/Post Exercise SpO2 Over 28 days (n=250)

Days	Pre-Exercise Oxygen Saturation (%) Mean±SD	Post- Exercise Oxygen saturation (%) Mean±SD	*p*-value
0	90.64±1.80	91.53±2.34	<0.001
28	91.67±2.08	92.24±2.19	<0.001

DISCUSSION

The oxygen saturation of young individuals improved over a period of 28 days stay after physical training, However, the role of physiological bodily mechanisms resulting in acclimatization could not be ruled out. Most climbers train themselves both physically and mentally to cope up with the increasing hardships being faced by individuals at high altitude. Rapid ascent by lowlanders to high altitudes can have deleterious health effects including Acute Mountain Sickness (AMS), High Altitude Pulmonary Edema (HAPE) and High Altitude Cerebral Edema (HACE)[8]. Previously used live low train high (LTHT) strategy was employed for acclimatization by athletes, however in recent times repeated sprint training has gained significant importance.[9]

In a study on a Pakistani expedition by Tannheimer *et al*., recommended the use of a pulse oximeter device with memory function, monitoring oxygen saturation in continuous mode and training of individual noting the oxygen saturation.[10] In our study we use a simple pulse oximeter without memory function though the readings were noted by a trained staff throughout the period of study. In an Indian study for assessment of cardiopulmonary status of 600 individuals at high altitude, the age bracket ranged from 17 to 55 years.[11] The age bracket differed from out study as the most aged person in our study was in his early forties.

This study measured effect of oxygen saturation post physical exertion without any diurnal variation. On the other hand, in an observational study on a mountaineering expedition in Peru, Tannheimer and colleagues noticed improvement in oxygen saturation at a height of 3050 meters on twenty first night which increased from 88.3% to 90.1%.[12] Other factors including poor acclimatization and extreme altitude effected the pattern of oxygen saturation in the same study group.

Depending on the type of exercise literature search revealed that singing, which is a rehabilitative therapy in chronic lung diseases helped in improving oxygen saturation in simulated high altitude environment.[13] Though in our study the same was observed with regular physical exertion at high altitude.

Shah *et al*., tried to check the effect of apnea training and its effect on symptoms of acute mountain sickness. According to them apnea training at high altitude led to a significant increase in the mean longest breath-hold times from baseline (80.42 ± 32.49 [median 87.00] seconds) to (107.02 ± 43.65 [113.00] seconds) by the end of 6 weeks, however there was no significant difference in oxygen saturation, heart rate, or blood pressure among the apnea versus control groups, respectively.[14] On the other hand, Netzer and colleagues found that when mountain hike was performed at altitude between 2,800 to 4,200 meters, stark differences in oxygen saturation as well as heart rate were noted compared to a simulated hike in a normobaric hypoxia chamber.[15] Thus, indicating that real time measurements of oxygen saturation can differ from simulated environments.

Oxygen saturation at high altitude is dependent and at the same time independent of various factors. One such is limitations of pulse oximeter. These include skin pigmentation of individual whose oxygen saturation is being measured, application of nail polish/artificial nails and cold peripheries.[16] While measuring oxygen saturation with pulse oximeters these factors should be catered for especially, cold peripheries at high altitude. Peripheries should be warmed and then oxygen saturation be monitored for accurate readings. This aspect was catered for in our study to avoid erroneous readings.

In a study Williams *et al*., found that supplemental oxygen did not have any effect on self-selected work rate at moderate altitude.[17] As opposed to this study another study conducted in Chile demonstrated mobile module oxygen delivery system improved arterial oxygenation and neuropsychological performance in workers at 5050 meters.[18] It is not only difficult to face the hardships of high altitude, but it can have deleterious effects on the cardiovascular system as prolonged stay at high altitude predisposes to myocardial infarctions as well.[19]

This study showed that in early days of study oxygen saturation did not improve, however improvement was recorded at the end of four weeks. On the other hand, pre-exercise oxygen increased likewise post oxygen saturation. It is a little difficult to comment on what brought the improvement in oxygen saturation both pre and post exercise. Physical exertion can be one of the factors, however the natural height induced physiological processes do come into play on high altitudes which cannot be denied at all in this study. This study is the first of its kind on newly arriving lowlanders at high altitude in Pakistan. It does have its limitations; more studies can be conducted with sophisticated equipment at hand to explore the multifactorial effects of high altitude and physical exertion on oxygen saturation.

ACKNOLEDGMENT

The authors thank all participants who took their time and effort.

CONCLUSION

The oxygen saturation of young individuals improved over a period of 28 days stay after physical training, However, the role of physiological bodily mechanisms resulting in acclimatization could not be ruled out.

Conflict of Interest: None.

Funding Source: None.

Authors' Contribution

The following authors have made substantial contributions to the manuscript as under:

SHR & SAS: Study design, data interpretation, drafting the manuscript, critical review, approval of the final version to be published.

ARA & AAC: Conception, data analysis, drafting the manuscript, approval of the final version to be published.

MI & RI: Data acquisition, critical review, approval of the final version to be published.

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

REFERENCES

1. Bebic Z, Brooks PM, Polaner DM. Respiratory physiology at high altitude and considerations for pediatric patients. Paediatr Anaesth 2022; 32(2): 118-125. https://doi.org/10.1111/pan.14380
2. Tremblay JC, Ainslie PN. Global and country-level estimates of human population at high altitude. Proc Natl Acad Sci U S A 2021; 4: 118(18). https://doi.org/10.1073/pnas.2102463118
3. Mallet RT, Burtscher J, Pialoux V, Pasha Q, Ahmad Y, Millet GP, et al. Molecular Mechanisms of High-Altitude Acclimatization. Int J Mol Sci 2023 15; 24(2): 1698. https://doi.org/10.3390/ijms24021698
4. Bhagi S, Srivastava S, Singh SB. High-altitude pulmonary edema: review. J Occup Health 2014; 56(4): 235-243. https://doi.org/10.1539/joh.13-0256-ra
5. Dünnwald T, Kienast R, Niederseer D, Burtscher M. The Use of Pulse Oximetry in the Assessment of Acclimatization to High Altitude. Sensors 2021 10; 21(4): 1263. https://doi.org/10.3390/s21041263
6. Furian M, Tannheimer M, Burtscher M. Effects of Acute Exposure and Acclimatization to High-Altitude on Oxygen Saturation and Related Cardiorespiratory Fitness in Health and Disease. J Clin Med 2022 12; 11(22): 6699. https://doi.org/10.3390/jcm11226699
7. Syed VS, Sharma S, Singh RP. Determinants of Acclimatisation in High Altitude. Med J Armed Forces India 2010; 66(3): 261-265. https://doi.org/10.1016/S0377-1237(10)80052-8
8. Sharma P, Mohanty S, Ahmad Y. A study of survival strategies for improving acclimatization of lowlanders at high-altitude. Heliyon 2023; 28; 9(4): e14929. https://doi.org/10.1016/j.heliyon.2023.e14929
9. Millet GP, Roels B, Schmitt L, Woorons X, Richalet JP. Combining hypoxic methods for peak performance. Sports Med 2010; 40: 1–25. http://doi.org/10.2165/11317920-000000000-00000
10. Tannheimer M, Lechner R. The correct measurement of oxygen saturation at high altitude. Sleep Breath 2019 ; 23(4): 1101-1106. https://link.springer.com/article/10.1007/s11325-019-01784-9
11. Singh G, Mukherjee S, Trivedi S, Joshi A, Kaur A, Sahoo S. Observational study to compare the effect of altitude on cardiopulmonary reserves of different individuals staying more than 6 weeks at 10,000 ft and 15,000 ft. Med J Armed Forces India 2021 77(4): 419-425. https://doi.org/10.1016/j.mjafi.2021.07.002
12. Tannheimer M, van der Spek R, Brenner F, Lechner R, Steinacker JM, Treff G. Oxygen saturation increases over the course of the night in mountaineers at high altitude (3050-6354 m). J Travel Med 2017 1; 24(5). https://doi.org/10.1093/jtm/tax041
13. Idrose AM, Juliana N, Azmani S, Yazit NAA, Muslim MSA, Ismail M, et al. Singing Improves Oxygen Saturation in Simulated High-Altitude Environment. J Voice 2022; 36(3): 316-321. https://doi.org/10.1016/j.jvoice.2020.06.031
14. Shah N, Bye K, Marshall A, Woods DR, O'Hara J, Barlow M, et al. The Effects of Apnea Training, Using Voluntary Breath Holds, on High Altitude Acclimation: Breathe-High Altitude Study. High Alt Med Biol 2020 ; 21(2): 152-159. https://doi.org/10.1089/ham.2019.0087
15. Netzer NC, Rausch L, Eliasson AH, Gatterer H, Friess M, Burtscher M, et al. SpO2 and Heart Rate During a Real Hike at Altitude Are Significantly Different than at Its Simulation in Normobaric Hypoxia. Front Physiol 2017 13; 8: 81. https://doi.org/10.3389/fphys.2017.00081
16. Torp KD, Modi P, Simon LV. Pulse Oximetry.In: StatPearls Treasure Island (FL): StatPearls Publishing; 2023.
17. Williams KA, Bell K, Jacobs RA, Subudhi AW. Supplemental Oxygen Does Not Influence Self-selected Work Rate at Moderate Altitude. Med Sci Sports Exerc 2019; 51(3): 575-581. https://doi.org/10.1249/mss.0000000000001801
18. Moraga FA, López I, Morales A, Soza D, Noack J. The Effect of Oxygen Enrichment on Cardiorespiratory and Neuropsychological Responses in Workers With Chronic Intermittent Exposure to High Altitude (ALMA, 5,050 m). Front Physiol 2018 23; 9: 187. https://doi.org/10.3389/fphys.2018.00187
19. Yogesh Kumar YS, Sud S, Bhardwaj S, Pareek TK. Acute coronary syndrome in young males after a prolonged stay at high altitude. Med J Armed Forces India 2021; 77(4): 490-493. https://doi.org/10.1016/j.mjafi.2020.09.007

....