VOLUME - 12, ISSUE - 02, FEBRUARY - 2023 • PRINT ISSN No. 2277 - 8160 • DOI : 10.36106/gjra

Original Research Paper

Physiology

CHANGE IN HEMOGLOBIN CONCENTRATION WITH INCREASING ALTITUDE AMONG WOMEN AGED 15-49 YEARS IN INDIA: EVIDENCE FROM NATIONAL FAMILY HEALTH SURVEY (NFHS-4), 2015-16

Muzamil Nazir Assistant Professor, Department of Community Medicine, Government Medical College Baramulla, J&K, India.

Tazeen Khan Lecturer, Department of Physiology, Government Medical College Srinagar, J&K, India.

Zahid Ali Khan* Assistant Professor, Department of Community Medicine, Government Medical College Baramulla, J&K, India. *Corresponding Author

ABSTRACT

Background: High altitude induces a lot of physiological changes in the human body and increase in hemoglobin concentration is one of them. This study aims to determine the effect of altitude on hemoglobin concentration among women aged 15-49 years of India. **Methodology:** This was a cross-sectional survey of 684913 women aged 15-49 years selected from NFHS-4. Association between various variables under study and hemoglobin concentration among study subjects was determined by students' independent t-test and one-way ANOVA and multiple linear regression. **Results:** Mean hemoglobin concentration of women increased significantly ($p<0.001$) with the increase in hemoglobin concentration from 11.7 g/dl at an altitude of up to 1000 meters to 12.8 g/dl at 5000 meters. A statistically significant positive correlation ($r=0.150$, $p<0.001$) was observed between hemoglobin level and altitude of residence of subjects. Multiple linear regression analysis revealed independent association between altitude and hemoglobin concentration among women. **Conclusion:** Hemoglobin concentration among Indian women increases significantly with the altitude of their residence. The increment in hemoglobin concentration was estimated at 0.5 g/dl/1000m altitude which is comparable to the average increment of various populations worldwide.

KEYWORDS : Hemoglobin, Women, Altitude, India, Increase

INTRODUCTION

With increasing altitude, there is a reduction in the barometric pressure which decreases po2 of inspired air. With a rapid increase in altitude, acclimatization to hypoxia occurs through an increase in cardiac output and minute ventilation and redistribution of fluid from circulation to interstitial space. (1)

The plasma volume reduction in early stages resulting in increased hemoglobin concentration is transient and tends to restore to normal levels over time. (2) However, people residing in higher altitudes are adapted to hypoxia and demonstrate persistent higher hemoglobin levels. (3-5)

Gassman et al in a recent meta-analysis of studies from various countries of the world reported an average increment in the hemoglobin concentration of 0.6 g/dl/1000m altitude among different countries like the United States, South American countries, Ethiopia, China, Tibet and other Asian and African countries. (6)

The National Family Health Survey (NFHS-4) or the Indian version of the Demographic and Health Survey (DHS) is based on representative samples from all the districts of the states of India. Hence this study was conducted by analysing NFHS-4 data to determine the effect of altitude on hemoglobin concentration of Indian women at the national level.

2. MATERIAL AND METHODS

This is a secondary data analysis of the National Family Health Survey (NFHS-4), 2015-16 data of 684913 women aged 15-49 years selected for NFHS-4. Data regarding hemoglobin concentration, altitude, age, place of residence, marital status, educational level, wealth index, body mass index (BMI), tobacco smoking and dietary habits of the subjects was taken.

Individuals were categorized according to wealth index into poorest', 'poorer,' 'middle,' 'richer' and 'richest' wealth quintiles based on the standard of living which is obtained from housing conditions, household assets and access to essential services like water, light, fuel, etc. (7)

Body mass index estimated as weight divided by height squared (kg/m^2) was categorised as per the BMI classification for Asian Indians into four categories – 'Underweight' ($BMI<18.0\ kg/m^2$), 'Normal' ($BMI=18.0\text{-}22.9\ kg/m^2$), 'Overweight' ($BMI=23.0\text{-}24.9\ kg/m^2$) and 'Obese' ($BMI\geq25.0\ kg/m^2$). (8)

Statistical analysis:

The data were analysed in version 20 of SPSS statistical software. Mean and standard deviations were obtained and associations were determined through student's independent t-test, one-way ANOVA, Pearson correlation and Multiple linear regression. All p-values less than 0.05 were considered to be statistically significant for the study.

RESULTS

The mean ± SD of hemoglobin concentration among women was 11.75 ± 1.65. Table 1 shows the mean hemoglobin levels increased significantly ($p<0.001$) with increasing altitude. A statistically significant positive correlation ($r=0.150$, $p<0.001$) was observed between hemoglobin level and altitude.

Table 2 shows women from urban areas had higher mean hemoglobin concentration compared to those residing in rural areas. There was a significant ($p<0.001$) progressive increase in mean hemoglobin concentration with increasing age, educational level, wealth index, body mass index of women. Mean hemoglobin levels showed a significant ($p<0.001$) association with the marital status

Table 3 shows multiple linear regression revealed an independent association of hemoglobin levels with altitude. After controlling for other confounding factors, an increment of 0.49 gm/dl hemoglobin was observed with an increase in altitude of 1000 meters.

Table 1: Mean hemoglobin concentration of subjects according to the altitude of their residence.

Altitude in meters	N	Haemoglobin (g/dl) Mean ± SD	p-value
Upto 1000	623450	11.67 ± 1.62	<0.001

1001-2000	49987	12.52 ± 1.72	
2001-3000	7222	12.66 ± 1.85	
3001-4000	2098	12.50 ± 2.02	
4001-5000	352	12.50 ± 1.81	
Above 5000	175	12.75 ± 1.88	

Table 2: Mean hemoglobin concentration of subjects as per their baseline characteristics

Characteristics	N	Haemoglobin (g/dl)	p-value
		Mean ± SD	
Age in years			
15-24	241996	11.69 ± 1.63	<0.001
25-34	207828	11.75 ± 1.64	
35-44	163904	11.78 ± 1.69	
45-49	71185	11.82 ± 1.68	
Residence			
Urban	197865	11.83 ± 1.64	<0.001
Rural	487048	11.71 ± 1.66	
Marital status			
Never married	166912	11.84 ± 1.64	<0.001
Currently married	490387	11.71 ± 1.65	
Widowed/divorced/separated	27614	11.70 ± 1.74	
Educational status			
Nil	193227	11.60 ± 1.71	<0.001
Primary	86800	11.70 ± 1.68	
Secondary	327774	11.80 ± 1.63	
Higher	77112	11.94 ± 1.54	
Wealth index			
Poorest	131194	11.49 ± 1.65	<0.001
Poorer	147180	11.71 ± 1.67	
Middle	144554	11.80 ± 1.68	
Richer	135293	11.84 ± 1.66	
Richest	126692	11.88 ± 1.58	
Body mass index			
Underweight	116305	11.47 ± 1.70	<0.001
Normal	354603	11.69 ± 1.65	
Overweight	87345	11.94 ± 1.59	
Obese	125194	12.03 ± 1.60	
Tobacco smoking			
Smokers	8089	12.18 ± 1.83	<0.001
Non-smokers	676824	11.74 ± 1.65	
Dietary habits			
Vegetarian	481554	11.71 ± 1.65	<0.001
Nonvegetarian	203359	11.83 ± 1.66	

Table 3: Multiple linear regression showing association between hemoglobin concentration of subjects and altitude of their residence.

	Unstandardized ficients		Beta	p-value
	B	Std. Error		
(Constant)	10.737	0.016		<0.001
Altitude (in Km)	0.487	0.004	0.142	<0.001
Age (in years)	0.006	0.000	0.034	<0.001
Residence	0.007	0.005	0.002	0.175
Marital status	-0.083	0.003	-0.035	<0.001
Educational level	0.079	0.002	0.048	<0.001
Wealth index	0.033	0.002	0.028	<0.001
Body Mass Index (kg/mt2)	0.025	0.000	0.073	<0.001
Tobacco smoking	0.068	0.007	-0.013	<0.001
Dietary habits	0.055	0.004	0.015	<0.001

DISCUSSION

In our study, we observed an increment of 0.49 g/dl/1000m in Indian women across all the regions. Previous studies suggest that hemoglobin concentration varies across different populations residing at similar altitudes. (6,9) An average 0.6 g/dl/1000m increment in hemoglobin concentration has been reported from the data of various countries and the highest increment of 1 g/dl/1000m has been found in residents of the Andes region. (6)

Genetic factors also play a major role in the differences in hemoglobin concentration as depicted in a comparative study among Bolivian and Tibetan residents by Beale et al. (4) One metanalysis carried out in different countries across the globe has also demonstrated increased hemoglobin concentration in high altitude residents independent of ethnicity and country of residence. (6)

Females show a decline in hemoglobin levels from the early years of the second decade of life to its later part thereafter an increasing trend is seen till they reach their fifties and finally a decline afterwards. (10) Similar pattern was observed in our study. Whereas, the decline in hemoglobin concentration of women in 2nd decade of life corresponds to the onset of menarche, nutritional deficiencies and chronic diseases contribute significantly to declining hemoglobin concentration after menopause. (11,12)

We observed a significant increase in the hemoglobin concentration with increasing body mass index of women supported by many studies. (13-15) This may be attributed to iron-deficient erythropoiesis, iron depletion and reduced iron stores in individuals with low body mass index. (16)

There is well-documented evidence of increased hemoglobin concentration among tobacco smokers in the literature. (17,18) We observed similar findings in our study. This increase is believed to be due to carbon monoxide present in tobacco smoke which binds to hemoglobin to form carboxyhemoglobin with no oxygen-carrying capacity and subsequent increase in hemoglobin concentration as a compensatory method. (17,19)

Although the study provides robust estimates because of the huge sample size, the study also had some limitations as study subjects comprised 15-49 years aged women only. Hence the estimates obtained from this study are not representative of the whole population. Further, the hemoglobin concentration varies with ethnicity the effect of which was not evaluated in the study.

CONCLUSION

With increasing altitude, the hemoglobin concentration of women increases significantly. An increment of 0.5 g/dl/1000 m altitude in hemoglobin concentration was estimated for Indian women which is comparable to the average increment of various populations worldwide.

REFERENCES

1. Windsor JS, Rodway GW. Heights and haematology: the story of haemoglobin at altitude. Postgrad Med J. 2007;83(977):148-51.
2. Pugh L G C E. Blood volume and haemoglobin concentration at altitudes above 18000 feet (5500 m). Physiol. 1964;170(2):344-54.
3. Beall C M, Brittenham G M, Macuaga F, Barragan M. Variation in haemoglobin concentration among samples of high‐altitude natives in the Andes and the Himalayas. Am J Hum Biol 1990;2(6):639-651.
4. Beall CM, Brittenham GM, Strohl KP, Blangero J, Williams-Blangero S, Goldstein MC, Decker MJ, Vargas E, Villena M, Soria R, Alarcon AM, Gonzales C. Hemoglobin concentration of high-altitude Tibetans and Bolivian Aymara. Am J Phys Anthropol. 1998;106(3):385-400.
5. Beall CM, Decker MJ, Brittenham GM, Kushner I, Gebremedhin A, Strohl KP. An Ethiopian pattern of human adaptation to high altitude hypoxia. Proc Natl Acad Sci U S A 2002; 99(26):17215-8.
6. Gassmann M, Mairbäurl H, Livshits L, Seide S, Hackbusch M, Malczyk M. The increase in hemoglobin concentration with altitude varies among human populations. Ann N Y Acad Sci. 2019;1450(1):204-20.
7. International Institute for Population Sciences (IIPS) and ICF. 2017. National Family Health Survey (NFHS–4), 2015–16: India. Mumbai: IIPS. [cited 2021 July 5]. Available at: http://rchiips.org/nfhs/nfhs-4Reports/India.pdf
8. Misra A, Chowbey P, Makkar BM, Vikram NK, Wasir JS, Chadha D, et al. Consensus statement for diagnosis of obesity, abdominal obesity and the metabolic syndrome for Asian Indians and recommendations for physical activity, medical and surgical management. J Assoc Physicians India 2009;57:163–70.
9. Sharma AJ, Addo OY, Mei Z, Suchdev PS. Reexamination of hemoglobin adjustments to define anemia: altitude and smoking. Ann N Y Acad Sci.

2019;1450(1):190–203.
10. Hawkins WW, Speck E, Leonard VG. Variation of the Hemoglobin Level with Age and Sex. Blood 1954; 9 (10): 999–1007.
11. Campbell AJ, Murphy C, Reinken J. Anaemia in old age: A study of prevalence and causes. NZ Med J. 1981;94:209–11.
12. Smith DL. Anemia in elderly. Am Fam Physician. 2000;62:1565–72.
13. Ghadiri-Anari A, Nazemian N, Vahedian-Ardakani HA. Association of body mass index with hemoglobin concentration and iron parameters in Iranian population. ISRN Hematol. 2014;10:525312.
14. Khan T, Khan ZA, Kochhar S, Singh B, Goyal GL, Sharma R. Unfeasible body mass index and its association with low haemoglobin concentration: a correlation study among undergraduate medical students. Int J Res Med Sci 2018;6:4002-7.
15. Akter R, Nessa A, Sarker D, Yesmin M. Effect of Obesity on Hemoglobin Concentration. Mymensingh Med J. 2017;26(2):230-4.
16. Sumarmi S, Puspitasari N, Handajani R, Wirjatmadi B. Underweight as a risk factor for iron depletion and iron-deficient erythropoiesis among young women in rural areas of East Java, Indonesia. Mal J Nutr. 2016;22(2):219-32.
17. Malenica M, Prnjavorac B, Bego T, Dujic T, Semiz S, Skrbo S, Gusic A, Hadzic A, Causevic A. Effect of Cigarette Smoking on Haematological Parameters in Healthy Population. Med Arch. 2017;71(2):132-6.
18. Nordenberg D, Yip R, Binkin NJ. The Effect of Cigarette Smoking on Hemoglobin Levels and Anemia Screening. JAMA. 1990;264(12):1556-9.
19. Aitchison R, Russell N. Smoking - a major cause of polycythaemia. Journal of the Royal Society of Medicine. 1988;81(2):89-91.