

Oxygen Saturation of Hemoglobin in Healthy Children of 2-14 Years at High Altitude in Nepal

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INTRODUCTION

High altitude environment is characterized by hypobaric hypoxia and low barometric pressure. At high altitudes normal oxygen levels are lower than at sea levels and hence individuals may have their normal oxygen tension and oxygen saturation of hemoglobin different to those living at lower altitude. Pulse oximetry is one of the commonly used tools for assessing the oxygen saturation of hemoglobin and availability and use of this simple, noninvasive tool is now increasing in the health facilities of developing countries. Pulse oximetry has been suggested as a fifth vital sign in paediatrics as it may result in significant changes in clinical decision making.¹

ABSTRACT

Background

Individuals residing at higher altitude may have oxygen saturation of hemoglobin different to those living at lower altitude.

Objectives

To find out the baseline value of SpO₂ in healthy Nepali children (2-14 years) living permanently at high altitude using pulse oximeter and also to study the relation of SpO₂ with age, sex and ethnicity

Methods

A descriptive observational study was conducted at 4 different altitudes ranging from 2700 to 3800 m in Mustang district. The mean pulse oximetry values at different altitudes were calculated and compared.

Results

One hundred six children were enrolled with the median age of 10 years. The mean SpO₂ value of children permanently residing at altitude 2700m was 95.18%, at 2800m was 94.82%, at 3550m was 94.1% and 3800m was 93.1%.The difference in the SpO₂ values at different altitude was statistically significant. No sex or age wise differences were noted on the mean SpO₂ values in the study group.

Conclusions

The mean SpO₂ values were higher than several other studies done in the altitude above 2500 meters. Enrollment of older children and the different ethnic background could be the contributing factors for the differences.

KEY WORDS

children, high altitude, Nepal, pulse oximetry

There are only a few published studies regarding the pulse oximetry reference values in paediatric populations permanently residing at high altitude. A systematic review to define altitude specific hypoxaemia, published in the Archives of Diseases in Childhood has concluded that the lower values of oxygen saturation can be considered appropriate to indicate the need for supplemental oxygen in children at higher altitude in the setting of limited oxygen supplies at the health facility.² However, hypoxaemia may be a single better predictor of pneumonia in high altitude settings than clinical signs.^{3,4} Oxygen supplementation guided by pulse oximetry findings could be life saving in acute lower respiratory tract infections in children at high altitude and optimal thresholds for initiation and

discontinuation of oxygen supplementation warrants further research.⁵

So far there has been no known/ published study on pulse oximetry reference values for healthy Nepali children living at high altitudes. The objective of the present study is to find the baseline value of oxygen saturation of hemoglobin in healthy Nepali children living permanently at high altitude using pulse oximetry, and to compare these values between different ethnic groups.

METHODS

A descriptive observational study was carried out at four different altitudes in Mustang district of Nepal: Jomsom (2700 m), Kagbeni (2800 m), Jharkot (3550m) and Ranipauwa (3800m). Mustang district lies in the mid western developmental region of Nepal. It has a population of 14,981 and the most common ethnic groups residing in the district are Gurung and Thakali (2001 census).⁶

Healthy Children of either sex, aged two years to 14 years, residing permanently at the given altitudes were enrolled. Children suffering from chronic diseases, congenital heart disease, acute respiratory diseases, cardiovascular compromise and children who have had respiratory tract infections one week prior to the study date were excluded. Children living at the study altitudes but born and lived for more than a month at lower altitudes were also excluded.

For all children fulfilling the inclusion criteria, informed verbal consent was taken from the parents/ guardians and pulse oximetry reading checked and documented for each child by the same individual (Principal Investigator). The pulse oximeter used for the purpose was CMS- 50DL (center for Medicare and Medicaid Services, US)). The pulse oximeter was placed on the index finger or the thumb and several readings were taken until a consistent value was displayed and the pulse rate displayed on the pulse oximeter was consistent with radial pulse simultaneously taken manually on the other hand. Before taking the reading it was made sure that the fingers were warm, and the readings were taken indoors avoiding bright source of light.

The mean pulse oximetry values for different age groups were then calculated and compared. Independent Sample t-test, Analysis of Variance (ANOVA), Spearman's rank correlation and simple regression analysis were used for analyzing the data.

The study was approved by the Institutional Review Committee of Patan Academy of Health Sciences, Nepal. (Ref. No: 2011.105.SS)

RESULTS

A total of 270 children were examined and 106 (47 boys and 59 girls) of age 10 to 14 yrs (median age 10) of them

fulfilling the inclusion criteria were enrolled. Out of 106, 47 were male and 59 female. Most of them were between 10 to 14 years, the median age being 10 years. (Fig 1) The highest number of children studied was from Jomsom. The population of children residing at the altitude of over 3000 was very few reducing the study sample at those altitudes accordingly. (Fig 2) Eighty percent of the study children were born at the same altitude where they were residing and 20 % children were born either at similar or higher altitude than they were presently residing. Children born at lower altitude and now residing at the study altitudes were not enrolled in the study with the exception of a three children whose mother went to the cities at lower altitude (Pokhara or Kathmandu) just for delivery and were back to the study altitudes within the first few days of delivery.

Mean pulse oximetry values and 95% confidence intervals (CI) were calculated. The values were normally distributed with a mean of 94.71% (SD: 1.46) and 95% CI of 94.43% to 94.99%. The mean pulse oximetry value for children at different altitude decreased as the altitude increased. The mean SpO₂ value of children permanently residing at Jomsom (2700m), Kagbeni (2800m), Jharkot (3550m) and Ranipauwa (3800m) was found as 95.18%, 94.82%, 94.11% and 93.11% respectively. The difference in the spo₂ values at different altitude was statistically significant. (Table 1)

Table 1. Mean values (%) for the oxygen saturation of hemoglobin at different altitudes.

Altitude (meter)	N	Mean	Std. Deviation	Median	Minimum	Maximum
2700	56	95.1250	1.32202	95.0000	91.00	98.00
2800	22	94.8182	1.18065	95.0000	93.00	97.00
3550	19	94.8182	1.66315	94.0000	91.00	97.00
3800	9	93.1111	1.16667	93.0000	91.00	95.00
Total	106	94.7075	1.46689	95.0000	91.00	98.00

Anova: F-test = 7.283, p-value = 0.000

Table 2. Mean values (%) for oxygen saturation of hemoglobin in different age group.

Age grp years	N	Mean	Std. Deviation	Std. Error	Minimum	Maximum
2 - 5	14	95.00	1.797	.480	91	97
5 - 10	30	94.27	1.574	.287	91	98
10 - 14	62	94.85	1.304	.166	91	98
Total	106	94.71	1.467	.142	91	98

F=1.982, p-value = 0.143

No sex or age differences were noted on the mean SpO₂ values in the study group. Neither did we observe any difference in the SpO₂ values when compared with the different ethnic groups. The children from the ethnic groups Thakali, Gurung, Lama, Sherpa and Magar who have been residing at high altitude for many generations did not show higher SpO₂ values compared to children of other ethnic groups who had migrated to a higher altitude for

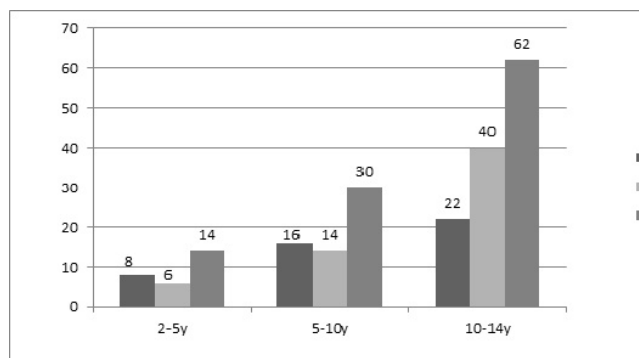


Figure 1. Age wise distribution of the children studied.

the past few generations only. Since one or more variables (age, weight and height) were not normally distributed, non-parametric correlation was used to explore their association with the SpO2. SpO2 was not found to be associated strongly and significantly with the recorded age, height and weight as the correlation coefficient were less than 14% for each one of them and associated p-value were all above 5% using Spearman’s Rank Correlation. (Table 3)

Simple Regression analysis with SpO2 as dependent and altitude as independent variable revealed the statistically different SpO2 values in altitude of every 850 meters. Simple regression analysis also showed that as the altitude increases by one unit (1 meter) the SpO2 decreases with a factor of -0.001. Using this regression equation we can predict the SpO2 values at different altitudes. The predicated data showed that there will be a difference of nearly 6% in SpO2 values among children living at the altitude of 1000 and 5000 meters (Table 4).

This shows the regression equation as:

$$\text{Dependent Variable (SpO2)} = \text{Constant} + \text{Altitude in meter}$$

$$\text{Dependent Variable (SpO2)} = 99.042 + -0.001$$

This negative sign confirms that as the altitude increases by one unit (1 meter) the SpO2 decreases with a factor of -0.001.

Table 3. Rank Correlations among Age, Weight, Height and SpO2.

	Age	Weight	Height	SpO2
Age	1.000	0.927**	0.909**	0.110 ^{NS}
Weight		1.000	0.936 **	0.126 ^{NS}
Height			1.000	0.139 ^{NS}
SpO2				1.000

** Significant P<0.001, NS = Not Significant (P > 0.05)

Table 4. Predicted SpO2 values at different altitude.

Altitude (meters)	SpO2
1000	97.58%
2000	96.12%
3000	94.66%
4000	93.20%
5000	91.74%

DISCUSSION

The baseline reference values for the pulse oximetry

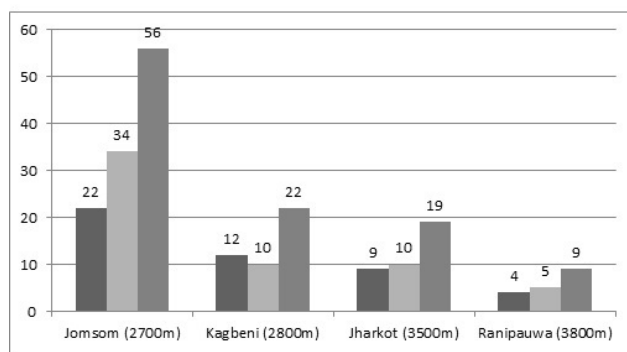


Figure 2. Place wise distribution of the children studied.

readings in children residing at high altitude have been extrapolated based on a few studies done over different parts of the world. There are only a limited number of studies and most studies are done in children under five years of age.

The mean SpO2 values in several other studies done in the altitude above 2500 meters were lower than the values seen in our study. A study done in 189 children aged 5 to 24 days at Bogota (2640 m above sea level), the mean SpO2 was 93.3 % (95% CI of 93.0% to 93.6%).⁷ Another study done at the altitude of 2800 m in 72 children in the age group of 2 days to 22 months in Summit County, USA the mean SpO2 was 91.7% (SD: 2.1).⁸ Two other studies at the altitude above 3000 meters (3750 and 4018 m) in children less than 5 years with sample sizes of 153 and 168 have shown the mean SpO2 of 88.9% and 87.8 % respectively.^{4,9}

One of the important reasons for higher values of SpO2 in our study could be that we studied older children (2-14 years), while all of the above studies included children less than five years. Studies have reported significant differences in SpO2 between infants and older children, and in this study infants were not included. Younger children were also shown to have a lower mean SaO2 than older children living at high altitude, which suggests physiological adaptation to high altitude over time.⁹

Other contributing factors could be differences in the genetic background or ethnicity. A study done in lassa has shown that Tibetan infants had higher arterial oxygen saturation at birth and during the first four months of life compared to Han infants.¹⁰ The majority of the population residing at higher altitude at Mustang district in Nepal are also of Tibetan descent, which could be a contributing factor for our higher values. One another study done in Tibetan population with a big sample size including older children has shown a lower SpO2 compared to our study. Though population in our study area is mostly of Tibetan descent but is of mixed genetic and ethnic background as the different generations of these people are getting married to local people with a different ethnicity and genetic backgrounds.¹¹

Genetic differences among individuals can contribute to individual variation in SaO2. Despite uniform ambient hypoxic stress, Tibetans at given altitude have been found to have wide variation in SpO2.¹² An adult study done in

two groups of people: high-altitude controls and high-altitude monks residing at the same altitude of 3600 m (Ladhak, India) but differing in their daily routines, showed a difference in SaO₂ values measured with a Finger-Pulse Oximeter. The second group (high altitude monks) had 3.08% higher SaO₂ ($P < 0.001$) compared to the first, with mean SaO₂ of $91.8 \pm 6.1\%$ and $89.0 \pm 2.6\%$.¹³ The variation in SaO₂ of normal people at high altitude is an evidence of differences in adaptive response to hypobaric hypoxia.¹⁰ A study done among a small number (9) of healthy 6-13 year old low land children without prior exposure to high altitude coming to trek in Nepal, has shown that the mean SpO₂ values at 3500 meters on day 5 and day 14 were 88.9% and 91.8%.¹⁴ Our study included older children, and only children residing between 2700 to 3000 meters. According to the calculated values from the regression equation from our study SpO₂ at 3500 meters would be between 94.66% and 93.2%, which is higher than that of the lowland western children. This again highlights the physiological adaptation to high altitude and the difference in the genetic background. No difference in the mean SpO₂ was observed between males and females in the present study and so was observed in few other studies.^{15,16} Sex differences in respiratory capacity occur between adolescence and adulthood.¹⁵ In another study it was found that adult males had higher SpO₂ values than adult females but did not find any difference in SpO₂ among teenagers.¹⁶

We tried to study the difference in SpO₂ values in different races/ ethnicity. No difference was noted in children of different ethnic groups. The small sample size for the children belonging to other ethnic groups, who have

migrated to higher altitudes for the past few generations only, could be the reason for not finding the difference in SpO₂ between the children of different ancestry. The number of children enrolled at higher altitudes (>3000m) was very small as the under 14 population in those places were much less. The number of children of non native ethnic groups who have migrated to higher altitudes for the past few generations only was also too small to confidently study any differences.

CONCLUSION

The mean SpO₂ values in the present study were higher than several other studies done in the altitude above 2500 meters. Enrollment of older children and the different ethnic background could be the contributing factors for the differences.

However, as this is a very small study with small sample size further research in children with different ethnic groups and different genetic backgrounds, residing permanently at similar altitudes are needed to clarify the issues. This is a preliminary pilot study; the predicted SpO₂ values using the regression equation can be verified in a larger study including children from other altitudes.

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REFERENCES

- Mower WR, Sachs C, Nicklin EL, Baraff LJ. Pulse oximetry as a fifth Pediatric sign. *Pediatrics*. 1997;99:681-86.
- Subhi R, Smith K, Duke T. When should oxygen be given to children at high altitude? A systematic review to define altitude-specific hypoxaemia. *Arch. Dis. Child*. 2009;94: 6-10.
- Lozano JM, Steinhoff M, Ruiz JG, Meza ML, Martinez N, Dussan B. Clinical predictors of acute radiological pneumonia and hypoxaemia at high altitude. *Arch Dis Child*. 1994;71:323-27.
- Reuland DS, Steinhoff MC, Gilman RH, Bara M, Olivares EG, Jabra A et al. Prevalence and prediction of hypoxaemia in children with respiratory infections in the Peruvian Andes. *J Pediatr* 1991; 119(6):900-06.
- Niemeyer S, Mollinedo PA, Huicho L. Child health and living at high altitude. *Arch Dis Child*. 2009;94:806-11.
- Statistical Year Book of Nepal 2009, Central Bureau of Statistics, Government of Nepal.
- Lozano JM, Duque OR, Buitrago T, Behaine S. Pulse oximetry reference values at high altitude. *Arch Dis Child*. 1992; 67(3): 299-301.
- Nicholas R, Yaron M, Reeves J. Oxygen saturation in children living at moderate altitude. *J Am Board Fam Pract*. 1993;6:452-6.
- Gamponia M J, Babaali F, Yugar F, Gilman RH. Reference value for pulse oxymetry at high altitude. *Arch Dis Child*. 1998;78:461.
- Niemeyer S, Yang P, Shanmina, Drolkar, Zhuang J, et al. Arterial oxygen saturation in Tibetan and Han infants born in Lhasa, Tibet. *N Engl J Med* 1995; 333 (19):1248-52.
- Beall CM. Oxygen saturation increases during childhood and decreases during adulthood among high altitude native Tibetans residing at 3800-4200 m. *High Altitude Medicine Biology* 2000;1(1):25-32.
- Beall CM, Song K, Elston RC, Goldstein MC. Higher offspring survival among Tibetan women with high oxygen saturation genotypes residing at 4000 m. *PNAS* 2004;101(39):14300-304.
- Qadar Pasha M A, Kocherlakota K S, Khan A P, Norboo T, Grover S K, Baig M A, et al. Arterial oxygen saturation under hypoxic environment of high-altitude associates with routine physical activities of natives. *Current Science*. 2003;85(4):502-6.
- Scrase E, Laverty A, Gavlak J CD, Sonnappa S, Denny ZH, Levet D ZH et al. The young Everest study: Effects of hypoxia at high altitude on cardiorespiratory function and general well being in healthy children. *Arch. Dis. Child*. published online 23 Apr 2009; doi:10.1136/adc.2008.150516.
- Huicho L, Pawson IG, Lon-velarede F, Rivera-Ch M, Pacheco A, Muro M et al. Oxygen saturation and heart rate in Healthy school children and adolescents living at high altitude. *Am j Human Biology* 2001;13:761-70.
- Beall CM, Almasy LA, Blangero J, Williams-Nlangero S, Brittenham GM, Strohl KP et al. Percent of oxygen saturation of arterial hemoglobin among Bolivian Aymara at 3,900 m-4000 m. *Am J Phys Anthropol*. 1999; 108:41-51.