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

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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

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. 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. However, hypoxaemia may be a single better predictor of pneumonia in high altitude settings than clinical signs. 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 had 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: 2011.105.55)

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.

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

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

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

<table>
<thead>
<tr>
<th>Age grp</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 - 5</td>
<td>14</td>
<td>95.00</td>
<td>1.797</td>
<td>.480</td>
<td>91</td>
<td>97</td>
</tr>
<tr>
<td>5 - 10</td>
<td>30</td>
<td>94.27</td>
<td>1.574</td>
<td>.287</td>
<td>91</td>
<td>98</td>
</tr>
<tr>
<td>10 - 14</td>
<td>62</td>
<td>94.85</td>
<td>1.304</td>
<td>.166</td>
<td>91</td>
<td>98</td>
</tr>
<tr>
<td>Total</td>
<td>106</td>
<td>94.71</td>
<td>1.467</td>
<td>.142</td>
<td>91</td>
<td>98</td>
</tr>
</tbody>
</table>

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
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 predicted 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:

Dependent Variable (SpO2) = Constant + Altitude in meter
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.

<table>
<thead>
<tr>
<th>Age</th>
<th>Age</th>
<th>Weight</th>
<th>Weight</th>
<th>Height</th>
<th>Height</th>
<th>SpO2</th>
<th>SpO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.000</td>
<td>0.927**</td>
<td>0.909**</td>
<td>0.110^ns</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.000</td>
<td>0.936**</td>
<td>0.126</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.000</td>
<td>0.139^ns</td>
<td>0.139^ns</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

Table 4. Predicted SpO2 values at different altitude.

<table>
<thead>
<tr>
<th>Altitude (meters)</th>
<th>SpO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>97.58%</td>
</tr>
<tr>
<td>2000</td>
<td>96.12%</td>
</tr>
<tr>
<td>3000</td>
<td>94.66%</td>
</tr>
<tr>
<td>4000</td>
<td>93.20%</td>
</tr>
<tr>
<td>5000</td>
<td>91.74%</td>
</tr>
</tbody>
</table>

DISCUSSION

The baseline reference values for the pulse oximetry 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%).

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). 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.

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.

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. 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

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. An adult study done in

Figure 1. Age wise distribution of the children studied.

Figure 2. Place wise distribution of the children studied.
two groups of people: high-altitude controls and high-altitude monks residing at the same altitude of 3600 m (Ladakh, 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 values than adult females but did not find any difference in SpO2 among teenagers.

In another study, it was found that adult males had higher SaO2 values than adult females but did not find any difference in SpO2 among teenagers.

CONCLUSION

The mean SaO2 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