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Brief Report

Oxygen Saturation in Healthy Children Aged 5 to 16 Years Residing in Huayllay, Peru at 4340 m

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Abstract

Schult, Sandra, and Carlos Canelo-Aybar. Oxygen saturation in healthy children aged 5 to 6 years residing in Huayllay, Peru, at 4340 m. *High Alt. Med. Biol.* 12:89–92, 2011.—Hypoxemia is a major life-threatening complication of childhood pneumonia. The threshold points for hypoxemia vary with altitude. However, few published data describe that normal range of variation. The purpose of this study was to establish reference values of normal mean Sao_2 levels and an approximate cutoff point to define hypoxemia for clinical purposes above 4300 meters above sea level (masl).

Children aged 5 to 16 yr were examined during primary care visits at the Huayllay Health Center. Huayllay is a rural community located at 4340 m in the province of Pasco in the Peruvian Andes. We collected basic sociodemographic data and evaluated three outcomes: arterial oxygen saturation (Sao_2) with a pulse oximeter, heart rate, and respiratory rate. Comparisons of main outcomes among age groups (5–6, 7–8, 9–10, 11–12, 13–14, and 15–16 yr) and sex were performed using linear regression models. The correlation of Sao_2 with heart rate and respiration rate was established by Pearson's correlation test.

We evaluated 583 children, of whom 386 were included in the study. The average age was 10.3 yr; 55.7% were female. The average Sao_2, heart rate, and respiratory rate were 85.7% (95% CI: 85.2–86.2), 80.4/min (95% CI: 79.0–81.9), and 19.9/min (95% CI: 19.6–20.2), respectively. Sao_2 increased with age ($p < 0.001$). No differences by sex were observed. The mean minus two standard deviations of Sao_2 (threshold point for hypoxemia) ranged from 73.8% to 81.8% by age group.

At 4300 m, the reference values for hypoxemia may be 14.2% lower than at sea level. This difference must be considered when diagnosing hypoxemia or deciding oxygen supplementation at high altitude. Other studies are needed to determine whether this reference value is appropriate for clinical use.

Key Words: Oxygen saturation, pulse oximetry; children at high altitude

Introduction

Every year over 150 million episodes of pneumonia occur in developing countries, and over 2 million children die of pneumonia each year (UNICEF/WHO, 2006). In the Americas, it is estimated that 436,000 children die each year, and 60,000 of these deaths are caused by pneumonia (Fuchs et al., 2005). Several factors contribute to mortality by pneumonia: low birth weight, nutritional deficiencies, increased respiratory infections, and hypoxemia (Niermeyer et al., 2009). Peru and Bolivia, where over 20% of the population live at high altitude (Niermeyer et al., 2009), share the highest proportion of deaths in Latin America from childhood pneumonia (15% to 20%) (Fuchs et al., 2005).

The presence of hypoxia is a predictor of radiological findings of pneumonia. It has been observed that about 20% of children with pneumonia have hypoxemia on admission to health services (Graham et al., 2008). Additionally, hypoxemia is an important risk factor for mortality by pneumonia. Pulse oximetry is a simple, fast, and noninvasive way to measure arterial oxygen saturation (Sao_2); hence the World Health Organization has recommended its use to determine the administration of oxygen to patients with hypoxia, and it is one of the suggested measures to reduce

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infant mortality in low- and middle-income countries (Graham et al., 2008).

The diagnosis of hypoxemia in high altitude regions is hampered by the known variation in normal levels of Sao_2 at altitudes greater than 1500 meters above sea level (masl) (Subhi et al., 2009). A previous study performed in Tintaya, Peru (4100 masl), reported a Sao_2 mean value in children over 5 yr of age of 89.6% (Huicho et al., 2001); however, there is not enough information on trends in Sao_2 levels by age group in children at or above 4200 masl. It can be hypothesized that mean Sao_2 values would be even lower than reports at lower altitudes.Therefore, the aim of our study was to determine the values of Sao_2 in a sample of healthy children 5 to 16 yr old residing at 4340 m in order to provide reference values for normal Sao_2 levels and the approximate cutoff point to define hypoxemia for clinical purposes. Additionally, we evaluated whether there is a variation in Sao_2, respiratory rate, and heart rate by age and sex of children.

Materials and Methods

The study was carried out in the village of Huayllay in the province of Pasco in the Central Andes of Peru at 4340 m. It is inhabited by a Mestizo population, descendants of Yauro–Aymara ethnic groups. According to the 2007 census, the town has an estimated population of 7140 inhabitants, of whom 1758 are in the 5- to 16-yr range.

Between June 2008 and February 2009, the local health center carried out primary care activities, including free medical care visits for four of the six schools in Huayllay. All appointments took place between 8 AM to 12 noon and included medical and dental care. During these visits, a physician (Sandra Schult) evaluated all the children; as part of this routinary medical evaluation, she collected information regarding medical history, age, sex, Sao_2, heart rate, and respiratory rate. Ten or more minutes before the physical examination, the subject was awake, calm, and rested. Oximetry was recorded with a pulse oximeter, Devon Medical 300C-1 (Devon Medical Inc., King of Prussia, PA, USA), approved by the U.S. Food and Drug Administration for professional medical use that allows reliable reading in dark and severe weather conditions. The pulse oximeter was placed on the index finger of the right hand and recorded a first reading that remained on the output screen for more than 10 sec. The heart rate was taken using the number of beats per minute in the right radial artery, and respiratory rate was recorded by observing the number of chest movements per min. Age was reported as the number of years completed and was verified with the National Identity Document.

From the information gathered, only data from children aged 5 to 16 yr, born in the province of Pasco, permanently residing in the village, and who were healthy at time of examination were included in the analysis. Being healthy was defined as (1) absence of bronchospasm or upper respiratory illness during the physical exam, (2) absence of cardiac or pulmonary disease detected during the medical evaluation or by clinical history, and (3) not having been hospitalized in the last month.

Data Analysis

The three variables of interest were Sao_2, heart rate, and respiratory rate. Simple arithmetic means and standard deviations were estimated. The tentative threshold point for hypoxemia was considered as the mean Sao_2 minus two standard deviations (SD) (Subhi et al., 2009).

The mean Sao_2, heart rate, and respiratory rate were compared among 6 age groups (5–6, 7–8, 9–10, 11–12, 13–14, 15–16) and sex using analysis of variance (ANOVA). The correlation of Sao_2 with heart rate and breathing rate was estimated with Pearson's correlation test. Multiple linear regressions for the three outcomes of interest were calculated, adjusting for age and sex in each. All analyses were performed using Stata v.10 (Stata Corporation, College Station, TX, USA); two-tailed p values < 0.05 were considered significant.

Ethical Issues

All activities included in the health care offered to the community were routinely recorded. The analysis of part of this information was approved by the directors, along with committees of parents in each school. The protocol was reviewed and approved by the ethical committee and the director of the Health Network associated with Social Security in Cerro de Pasco.

Results

We evaluated 583 subjects, of whom 197 were excluded for presenting with respiratory disease (79.0%) or heart murmur (21.0%) at the time of the physical examination. Of the remaining 386 included in the study, 215 (55.7%) were female and average age was 10.3 yr. The distributions of Sao_2, heart rate, and respiratory rate were approximately normal. The mean Sao_2 was 85.7% (Table 1), and the mean minus two standard deviations of Sao_2 was 75.8%.

We found statistically significant differences in the values of oxygen saturation, heart rate, and respiratory rate by age (ANOVA, all $p < 0.01$), although there were no differences by sex (ANOVA, all $p > 0.05$).

In multivariate regression analysis, increases in Sao_2 by each age group were statistically significant from 11 yr to older (Table 2). Heart and respiratory rates also showed significant reductions at older ages; particularly, respiratory frequency showed a reduction in all age groups tested. Based on the data collected, the reference levels for hypoxemia based on the mean minus two standard deviations showed a trend to increase with age, ranging from 73.8% to 81.8% (Table 3).

Additionally, there was a significant although small negative correlation between Sao_2 and respiratory rate ($r = 0.17$,

Table 1. Demographic and Clinical Characteristics of Subjects Studied

Characteristics	*Value*
Female, frequency (%)	215 (55.7%)
Oxygen saturation, mean (CI 95%)	85.7 (85.2–86.2)
Heart rate/min, mean (CI 95%)	80.4 (79–81.9)
Respiratory rate per/min, mean (CI 95%)	19.9 (19.6–20.2)
Age (yr), mean (CI 95%)	10.3 (9.9–10.6)
Age (yr), frequency (%)	
5–6	78 (20.0)
7–8	43 (11.0%)
9–10	108 (28.0)
11–12	40 (10.0)
13–14	54 (14.0)
15–16	63 (16.0)

Table 2. Multiple Linear Regression of Estimated Change (CI 95%) in Oxygen Saturation, Heart Rate, and Respiratory Rate by Age and Sex

	Oxygen saturation		*Heart rate*		*Respiratory rate*	
Characteristic	*Value (CI 95%)*	*p value*	*Value (CI 95%)*	*p value*	*Value (CI 95%)*	*p value*
Coefficent[a]	**83.6 (82.5; 84.7)**	**<0.01**	**86.4 (81.0; 91.8)**	**<0.01**	**21.6 (21.1; 22.1)**	**<0.01**
Age (yr)						
7–8	0.0 (−1.7; 1.8)	0.96	**−9.2 (−14.5; −4)**	**<0.01**	**−1.1 (−2.3; −1)**	**0.01**
9–10	0.8 (−0.5; 2.2)	0.22	**−6.8 (−10.9; −2.8)**	**<0.01**	**−1.7 (−2.3; −1)**	**<0.01**
11–12	**2.7 (1.0; 4.5)**	**<0.01**	−5.2 (−10.5; 0.1)	0.05	**−2.5 (−3.3; −1.6)**	**<0.01**
13–14	**4.3 (2.7; 5.9)**	**<0.01**	**−5.6 (−10.4; −0.7)**	**0.02**	**−2.8 (−3.6; −2.1)**	**<0.01**
15–16	**4.5 (3.0; 6.1)**	**<0.01**	**−10.9 (−15.5; −6.3)**	**<0.01**	**−3.6 (−4.4; −2.9)**	**<0.01**
Male	0.5 (−0.5; 1.4)	0.31	0.2 (−2.7; 3.1)	0.89	0.3 (−0.2; −0.7)	0.23

[a]Corresponds to females aged 5 to 6 yr.

$p = 0.001$), but no correlation was found between Sao_2 and heart rate ($r = 0.03$, $p = 0.49$).

Discussion

Our study shows a decrease of 12.3% in the levels of mean Sao_2 (85.7% versus 98% at sea level) and 14.2% in the calculated mean cutoff point for hypoxemia (75.8% vs. 90%) at 4340 m compared with sea level. These levels were even lower than those found in other studies at midaltitude (Lozano et al., 1992; Gamponia et al., 1998; Beall, 2000; Graham et al., 2008; Subhi et al., 2009), suggesting a decreasing trend of Sao_2 when altitude increased. The reduction of normal Sao_2 found at this altitude become the reference values used in the coast inappropriate for this population and remarks the importance of determining accurate reference values for children residing at very high altitude.

Low oxygen saturation, as measured by pulse oximetry, predicts the presence of pneumonia more accurately than fast breathing or other physical signs over 2500 m (Reuland et al., 1991). During acute lower respiratory infection, hypoxemia is more frequent in children residing at high altitude and is associated with increased mortality (Niermeyer, 2009). In countries with fewer resources where the public health impact of pneumonia is high, such as Peru and Bolivia (Fuchs et al., 2005), determining the appropriate threshold points for hypoxemia at high altitude is meaningful.

In Latin America, in Bogota, Colombia (2640 masl), Lozano and colleagues (1992) found values of mean Sao_2 of 93% among children aged 1 month to 2 yr, and in El Alto, Bolivia (4018 m), Gamponia and colleagues (1998) found a mean saturation of 87.3% in children 1 to 5 yr old. In Tibet, a decreasing trend of Sao_2 with higher altitude was found; the average Sao_2 in the 0- to 9-yr age range was 89.3% at 3800 m and 85.5% at 4200 m, and in the 10- to 19-yr age range the average Sao_2 was 90.9% at 3800 m and 88.7% at 4200 m (Beall, 2000). A systematic review of 14 studies of Sao_2 in 1- 5-yr-old healthy children living at high altitude found a threshold point for hypoxemia of 90% at 2500 m, which decreased to 85% at 3200 m (Subhi et al., 2009).

In Tintaya, Peru, in the only study in the region of children older than 5 yr (6 to 18 yr) living at 4018 m, a mean Sao_2 of 89.6% and a threshold point for hypoxemia of 83.4% were found (Huicho et al., 2001). Our results showed lower values than those of the Tintaya study, which may in part be explained by the distinct methodological protocols for obtaining Sao_2 values and because our study was conducted at an approximately 320-m higher altitude.

We observed that the mean minus two standard deviations of Sao_2 increases with age from 73.8% to 81.8%, showing a significant increase from 11 to 14 yr. This increase differs from that described in the Tibetan population, who typically experience a marked rise in Sao_2 levels during the first decade of life and then remaining stable after 11 yr (Beall, 2000). In other reports, Huicho and colleagues (2001) found a weak positive association between saturation and age from 4 to 18 yr. This difference in Sao_2 suggests that infants at very high altitude have not yet compensated for the ambient hypoxia to the same degree as older children.

Although sex differences for Sao_2 have been reported, they seem to develop in adulthood, as described in another study between Aymara and Bolivian populations (Reuland et al., 1991). This is consistent with our data, which did not show differences in values of Sao_2 by sex among children aged 5 to 16 yr.

There are number of limitations in the study design we used. A larger number of subjects would be needed to arrive at a more accurate description of Sao_2 and the change in Sao_2

Table 3. Comparison of Mean and Mean Minus Two Standard Deviations (sd) for Oxygen Saturation, Heart Rate, and Respiratory Rate by Age

	Oxygen saturation		*Heart rate*		*Respiratory rate*	
Age	*Mean (SD)*	*Mean-2 (SD)*	*Mean (SD)*	*Mean-2 (SD)*	*Mean (SD)*	*Mean-2 (SD)*
5–6	83.8 (5.0)	73.8	86.5 (13.4)	59.7	21.7 (2.0)	17.7
7–8	83.7 (4.2)	75.3	77.2 (11.4)	54.4	20.6 (2.2)	16.2
9–10	84.7 (2.7)	79.3	79.7 (15.6)	48.5	20.1 (1.9)	16.3
11–12	86.5 (4.3)	77.9	81.3 (12.8)	55.7	19.2 (2.0)	15.2
13–14	88.1 (3.5)	81.1	80.9 (14.3)	52.3	18.9 (2.7)	13.5
15-16	88.4 (3.3)	81.8	75.6 (12.8)	50.0	18.2 (2.5)	13.2
Total	85.7 (5.0)	75.7	80.5 (14.2)	52.1	19.9 (2.5)	14.9

Statistically significant differences were found in the mean and mean-2SD of oxygen saturation, heart rate, and respiratory rate by age (p value < 0.01). All comparison was done by ANOVA.

with age and hypoxemia. The Sao_2 values could be influenced by weather conditions. From a biological perspective, studies of children with lower respiratory infection and Sao_2 are needed to assess the most appropriate threshold point for hypoxemia, instead of the statistical criteria commonly used (e.g., the mean minus two standard deviations).

In summary, the study suggests that at 4300 m the reference values for hypoxemia should be 14.2% lower than at sea level. If these values are confirmed by other large studies at similar altitude, they should be considered when diagnosing pneumonia or deciding whether to give oxygen supplementation at high altitude.

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Disclosures

The authors have no conflicting interests or financial ties to disclose.

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