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ORIGINAL ARTICLE

OXYGEN SATURATION AMONG UNDER-FIVE CHILDREN LIVING AT MODERATE ALTITUDE, ADDIS ABABA, ETHIOPIA

Segen Yohaness, MD[1], Amha Mekasha, MD, Msc[2 *]

ABSTRACT

Introduction: *Acute lower respiratory infections (ALRI) is a major cause of deaths in children worldwide. In ALRI hypoxemia is the most common fatal complication. The WHO definition of hypoxemia does not take altitude into account.*

Objective: *The objective of this study is to determine the oxygen saturation value in apparently healthy under-five children who permanently reside at moderate altitude, Addis Ababa, Ethiopia using pulse oximetry.*

Methods: *The study was a cross sectional design. The location of the study was at 2 health facilities in Addis Ababa. The SpO_2 was measured among apparently healthy under-five year children using Nellcor N-10 self-calibrating pulse oximetry between May and July 2017. A structured questionnaire was used to collect socio-demographic and clinical data. Data were entered and analyzed using SPSS version 20 statistical software.*

Results: *The mean SpO_2 was 93.59% (95% CI 93.06%, 94.11%) with a median of 94.67%. The 2.5^{th} centile threshold of SpO_2 for hypoxemia is 82%. Using suggested formula for hypoxemia threshold for the altitude of Addis Ababa is 90%. A significant difference was observed in SpO_2 between infants and older children, although the difference was not demonstrable when sleeping subjects were excluded. Activities affect SpO_2 whereby sleep and bottle or breast feeding had a lowering effect on SpO_2.*

Conclusions: *This study provided a reference range of SpO_2 values for healthy children under-five years of age. To determine the threshold for hypoxemia needs further clinically relevant cutoff.*

Key words: *Moderate altitude, oxygen saturation, children, under-five-year*

INTRODUCTION

In 2016 acute lower respiratory infections (ALRI) caused over 600,000 deaths among children under five years of age globally (1). Hypoxemia is common among children admitted to a hospital with 11.7% in acute lower respiratory tract infections, 16.5% among neonates (2). In addition studies (3,4) reported association between hypoxemia and death. Ensuring a reliable and efficient system for detecting hypoxemia and supplying oxygen and having clear and simple guidelines for its use are vital to good quality pediatric care. This is particularly so in developing countries given the magnitude of the burden of pneumonia. Such systems are often of poor quality or non-existent where they are most needed, where oxygen administration is often dictated more by availability than by need.

Where pulse oximetry is available, oxygen should be given to all children who have an $SpO_2<90\%$. It was recognized that this threshold may need to be adjusted in settings where oxygen supplies are limited and at higher altitudes where normal values for SpO_2 are lower than at sea-level (5)

In Ethiopia most of the population lives at altitudes between 2400 meter and 3700 meter above sea level. Addis Ababa is located in the foothills of the Entoto Mountains and standing at 2,355 meters above sea level, it is one of highest capitals in the world. Its lowest point is around Bole international airport, at 2326 meters above sea level in southern periphery. However, normal pediatric SpO_2 have not yet been established for different altitudes.

The objective of this study is to determine the reference value and activities that affect the oxygen saturation in apparently healthy under five children who permanently reside in moderate altitude, Addis Ababa, Ethiopia (2326-3000 meters) using pulse oximetry.

METHODS

The location of the study was at 2 sites. One was at Tekle Haymanot health center (THC) in Addis Ababa involving children who come for regular vaccination program. The second was at Zenebework Memorial Hospital (ZMH) in Addis Ababa among children who came for dermatologic disorders.

[1] Menelik II Hospital, Department of pediatrics, Addis Ababa.
[2] Tikur Anbessa Specialized hospital, College of Health Sciences, Addis Ababa University.
*Corresponding Author E-mail: amekashaw@yahoo.com, amhamekasha@gmail.com

Study design
The study employed cross-sectional facility-based design. The study was conducted from May to July 2017

Participants
All children who come for vaccination to THC and to ZMH for dermatological disorders were taken as source population. The study included all children under the age of five years. Enrollment was stratified into five age groups: 0–5, 6–11, 12–23, 24–35, and 36–60 months. The study included children who are permanently residing in the Addis Ababa and had no travels out of the city for at least the last one month, absence of bronchospasm or upper respiratory illness during physical exam, no cardiac or pulmonary disease detected during medical evaluation or by clinical history, not having been hospitalized in the last month, no history of blood transfusion within the last six months, no signs and symptoms of anemia or severe acute malnutrition.

Sample size is computed based on the formula: $N = 1+2C\,(s/d)^2$ where C is dependent on the values chosen for significance level (α) and power (1-β). Taking α at 0.05 and 1-β at 0.8 as 7.85.For the same altitude the mean and standard deviation is 2 up to 5 and we took S as 4 and error 1.

$n=1+2(7.85)\,(4/1)^2$
$n=1+(15.7)\,(16)=243$

Data collection
A self-administered questionnaire was used to collect data from the participants. Respiratory rate, heart rate and three oximetry readings were obtained for each child using a Nellcor N-10 self-calibrating pulse oximetry and appropriate sized adhesive transducer placed on the index finger, thumb or large toe of each subject. The average of the three readings, which was measured 10 minutes apart, was taken as the final reading. Measurements were discarded if not consistent with the other readings. Bright lights and excessive motion were avoided during transducer application to minimize artifacts. For the saturation of oxygen to register, the oximeter had to track the peripheral pulse for at least 10 seconds.

The measurements were conducted by trained physician and/or qualified medical interns and socio-demographic data was entered into a study forms. The principal investigator monitored the data collection and did a quality check by counterchecking collected data against information in the charts in randomly selected number of cases.

Statistical Analysis
The data was entered and cleaned using Epi Info version 3.5 and analyzed using Statistical package for social science (SPSS) version 20 statistical software. Central tendencies were calculated and P -value of < 0.05 is taken as significant.

Ethical consideration
The study was approved by the Department of Pediatrics and Child Health Research and publication committee, College of Health Sciences, Addis Ababa University. Caretaker informed verbal consent was obtained prior to the inclusion of infants and children in the study and were told that they have full right of noninvolvement. Names or any personal identifiers were held anonymous. Letters of cooperation were written from the Department of Pediatrics and Child Health to the study health facilities for permission to conduct the study.

RESULTS

A total of 243 children were screened and of this 236 were included in the study seven were excluded because they had conjunctival pallor. Enrollment was stratified into five age groups: 0–5, 6–11, 12–23, 24–35, and 36–60 months. The mean (SD) age was 14.3 (±15.2) months. There were 122 (51.7%) males and 114 (48.3%) were females. Regarding the activities of the subjects 190 children (80.1%) were calm or quiet, 44 (18.6%) were asleep and the remaining two (0.8 %) were breast or bottle feeding (table 1).

All of the children included in the study were born and were residents of Addis Ababa. Most of them were from around Teklehaimanot sub-city in Addis Ababa.

The 2.5^{th} centile of SpO_2 in this study is 82%, 5^{th} centile is 84.7%, 10^{th} centile is 89.6%. However, when we apply the suggested formula by Subhi (6) for the altitude of 2355 meters the threshold for hypoxemia is about 90%. When we use 90% it will be on 14^{th} centile.

Table 1: Frequency distributions of socio-demographic characteristics.

Characteristics	Frequency	Percent
Age group		
1-5 months	80	33.9
6-11 months	55	23.3
12-23 months	53	22.5
24-35 months	19	8.1
36-59 months	29	12.3
Sex		
Male	122	51.7
Female	114	48.3
General activity		
Calm/quiet	190	80.1
Asleep	44	18.6
Breast or bottle feeding	2	0.8

Table 2 shows that the mean(SD) respiratory rate was 43.4 (±8.0) and the mean (SD) pulse rate was 130 (±15.5) for all the subjects. With regard to these vital signs increasing age was significantly associated with a decrease in mean heart rate and mean respiratory rate for each group (p<0.01).

Age (in months)	Age Mean/+ SD	Pulse rate Mean/+ SD	Respiratory rate Mean/+ SD
1-5	2.3/0.8	140.8/14.3	47.9/7.4
6-11	7.6/1.5	131.5/13.2	44.7/7.4
12-23	16.2/3.6	123.8/9.1	40.4/5.3
24-35	26.5/3.7	118.2/8.5	39.9/7.4
36-60	48.3/9.2	116.3/14.0	35.4/6.1
Total	8.9/1.2	130/15.5	43.4/8

Table 2 : Vital signs and anthropometry for different age groups

As shown in table 3 the mean SaO_2 for all subjects was 93.59% (95% CI 93.06 - 94.11) with a median value of 94.7%. No significant difference in SaO_2 was observed by the Kruskal-Wallis test (P=0.098), among age stratified groups.

Although, as a group, children less than one year old had a lower mean SaO_2 93.2% (95% CI 92.3- 93.9); in contrast to the mean SaO_2 of older children was 93.6%; (95% CI 93.5%, 94.7%) (p = 0.05), the difference was not significant when sleeping children were excluded

Table 3: Oxygen saturation and respiratory rate for different age groups.

Age group in months	Number	Oxygen saturation Mean/SD (95% CI)	Oxygen saturation Median	Respiratory rate Mean (95% CI)
1-5	80	92.7/5.4 (91.5-93.9)	94.0	47.9 (46.3-49.6)
6-11	55	93.8/3.3 (92.9-94.6)	94.7	44.7 (42.5-46.6)
12-23	53	94.4 /3.2 (93.5-95.2)	95.0	40.4 (38.8-41.9)
24-35	19	94.1/3.7 (92.4-95.7)	94.0	39.9 (36.4-43.4)
36-60	29	93.7/ 2.6 (92.7-94.6)	94.3	35.4 (32.9-37.6)

Table 4: Oxygen saturation and respiratory rate for age groups excluding sleeping children.

Age group in months	Number	Oxygen saturation Mean/SD (95% CI)	Median	Respiratory rate Mean (95% CI)
1-5	46	93.0/5.1 (91.5-94.4)	94.0	47.9 (45.5-50.1)
6-11	49	93.9/3.5 (92.9-94.9)	94.7	44.7 (42.4 -46.9)
12-23	49	94.4/3.2 (93.5-95.3)	95.0	40.7 (39.0 -42.4)
24-35	19	94.1/3.7 (92.7-95.6)	94.0	47.9 (45.5-50.1)
36-60	29	93.7/2.6 (92.8-94.6)	94.3	44.7 (42.4 -46.9)

P =0.47

Physiological states with corresponding mean values for oxygen saturation, respiratory rate, and heart rate are shown in Table 5. Relatively lower mean values for oxygen saturation were observed in children who were either breast or bottle feeding or asleep, compared with children who were awake and quiet. These differences in SaO_2 were significant (P=0.01).

Table 5: Oxygen saturation and respiratory rate by state of activity.

State of activity	Number	Oxygen saturation Mean/SD (95% CI)	Median	Respiratory rate Mean (95% CI)
Calm/ quite	190	93.9/3.7 (93.3-94.4)	94.7	42.7 (41.5 -43.8)
Asleep	44	92.5/5.2 (90.9-94.1)	94.0	46.3 (43.9-48.6)
Breast or bottle feeding	2	87.7/5.2 (84.0-91.3)	87.7	44.0 (40.0 -48.0)

P=0.01

Comparisons of the sleep state were made with other physiological states only in group (0–5 months old) because it was the only subgroup in which there were adequate numbers of infants sleeping. Sleeping infants tended to have lower SpO_2 mean and median values (Table 6), but this difference did not achieve statistical significance (Mann- Whitney, P=0.58).

Table 6: Oxygen saturation and respiratory rate for sleeping children (age <6 months) compared with other activity states.

State of activity	Number	Oxygen saturation mean/SD (95% CI)	Median	Respiratory rate mean (95% CI)
Asleep	34	92.4/5.8 (90.2-94.2)	94.0	47.8 (45.3-50.4)
Other state	46	93.0/5.1 (91.4-94.4)	94.0	47.9 (45.7-50.4)

P-value = 0.58

DISCUSSIONS

This study has shown the normal value of oxygen saturation in children under five years of age at a moderate altitude of 2355 meters above sea level. In a systematic review by Subhi [6] showed that the threshold for hypoxemia decreases with increase in altitude. Subhi (6) found hypoxaemia threshold at an altitude of approximately 2500 m above sea level, the 2.5th centile of the distribution of SpO2 in normal, healthy children is 90%. This decreases to 85% at approximately 3200 m above sea level. Taking the mean SpO_2 of our study subjects they are all above the threshold level for the estimated altitude of Addis Ababa.

In adaptation to high altitude hypoxia it has been demonstrated that higher hemoglobin concentration and percent of oxygen saturation of hemoglobin among Ethiopian highlanders do not differ from sea-level in these two traits (7). It has been shown that genetic adaptations may permit adequate oxygenation [8]. However, earlier studies have shown mean lower oxygen saturations in children living at high altitudes (6,9-11). The study also observed a difference in the SpO_2 of children based on their state of activity. Those who were awake and quiet had mean saturation of 93.9% (95% CI 93.3-94.4) which are higher than the SpO_2 of children who were asleep 92.5% (95 % CI 90.9-94.1). The mean SpO_2 for the breast or bottle

Others also have shown similar trends of SpO2 at different activities (8,9,12,13). Sleeping children had lower saturation due to the hypoxic state that we expect and we speculate that because recumbency occurs with sleep, it is usually associated with mildly decreased functional residual capacity, owing to pulmonary atelectasis, which results in the child taking more frequent and shallower breaths. Thus, the activity state of the child should be considered when measuring SpO_2.

In addition, we found a significant difference in oxygen saturation between infants and older children living at moderate altitudes. The mean saturation for <12 months was 93.2 (95% CI 92.3-93.9) and for >12 months was 93.6 (95 % CI 93.5-94.7) with a P-value of 0.05. The trend is similar to an observation by Reuland *et al.* (10] that, in general, younger children have lower mean SpO_2 values—a relation seen only at altitudes above 3000 m. Though in previous study there was no clinically important differences in the oxygen saturation of haemoglobin in the range of ages included (9). We expect infants to have a lower mean SpO_2 than older children because during infancy many of the physiological compensations stimulated by low oxygen tension may not yet be developed; infants have comparatively less functional residual capacity than older children; and their smaller airways generate a higher airway resistance.

Other similar researches support the finding of this study. A research conducted by Lozano *et al* in Bogota, Columbia provided reference values for children 5 days to 24 months of age at an altitude of 2640 m found mean (SD) value of 93.3(2.05)% with 95 % CI of 93.0-93.6% (9).

In line with results of this study, we found low mean and median saturation levels at high attitude. In Bolivia, which is situated above 4018m above sea level, has a mean saturation of 86.9 (95% CI 85.4%-88.4%) and median of 87.0% (12). Our study has higher saturation mean 93.59% (95% confidence intervals (CI) 93.06%, 94.11%) with a median value of 94.67% may be due to low elevation of Addis Ababa compared to Bolivia.

Conclusions

This study provides normal SpO_2 in healthy under-five year children living at high altitude (2300-3000m). Younger children have lower mean SpO_2 than older children living at high altitude. Sleep had a lowering effect on SpO_2, the clinical importance of this effect remains undetermined.

In addition this research could be used as a reference value for places with similar altitude to use for oxygen administration.

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Competing Interest

The authors declare that this manuscript was approved by all authors in its current form and that no competing interest exists.

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