Visual Function at High Altitude in Nepal

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Abstract

Introduction: Assessment of visual function is important for diagnosing ocular diseases. In the present study we are assessing different components of visual functions like visual acuity, color vision, contrast sensitivity and stereoacuity at high altitude in Nepal.

Methods: A cross- sectional quantitative study was conducted in Bargaun village at an altitude of 3330 meters of Humla district of Western Nepal. Detailed eye examination was carried out for the participants consenting for the study who were from Bargaun and Limatang villages of Humla. Visual acuity, color vision, contrast sensitivity, stereoacuity and oxygen saturation were measured. Convenience sampling was done. Data were entered in excel, converted to a comma separated values format and supplied for regression analysis in Python 3. T-tests were done and a linear regression model was fitted to the data to determine the relationship between independent and dependent variables and obtain coefficients for the relationship.

Results: One hundred and sixty four participants completed the study. Among them, 60.37% were 50 years of age and below. Oxygen saturation was 91 - 100% in 64.63%, 81 - 90% in 33.53% and 70-80% in 1.83% participants. Maximum number of participants had visual acuity of 0.48-1 (6/18-6/6). Contrast sensitivity was 10% in 4.88%, 5% in 23.17%, 2.5% in 40.24% and 1.25% in 31.71%. Stereoacuity was < 30 seconds of arc in 78.5%, 30-60 seconds of arc in 12.80% and 9% of participants had decreased stereoacuity. Color vision was decreased in 4.88%. Increase in age was associated with decrease in oxygen saturation, poorer visual acuity, decrease in color vision and poorer contrast sensitivity (p value = 0.00). Increase in oxygen saturation was associated with better visual acuity, better contrast sensitivity and better stereoacuity which was statistically significant (p value = 0.00).

Conclusions: Oxygen saturation was reduced in 35%, visual acuity was decreased in 2.44%, contrast sensitivity was reduced in 28.05%, stereoacuity was reduced in 9% and color vision was abnormal in 4.88% of the participants residing at high altitude of Nepal.

INTRODUCTION

Visual function at high altitude is of concern to us as Nepal is a mountainous country with people residing at high altitude and many expeditions are carried out round the year in different summits. Northern side of Nepal is bordered by the Himalayan range. Humla district is one of the Himalayan districts, lying in the Western Nepal in Karnali Province. Humla lies at an elevation of 3000 to 5000 meters. Many scattered villages are present in Humla. Bargaun and Limatang villages lie at an elevation of 3300 meters above the sea level.

The functional changes in vision are more common at high altitude due to failure in cerebration.[1] Hypobaric hypoxia has effect on visual performance especially on contrast

sensitivity.[2] Similarly, colors appear less saturated at high altitude.[1]

The visual functions of people residing in the Himalayan regions have not been studied well. Hence, in the present study we are looking for functional changes in the eyes of the people living at high altitude. The visual functions assessed were visual acuity, color vision, contrast sensitivity and stereoacuity and also the oxygen saturation. Visual function measurement and assessment is a fundamental tool for diagnosing ophthalmological disorders.

METHODS

It was a cross-sectional quantitative study conducted in Humla district of Nepal. A screening eye camp was organized in Bargaun village of Humla. All consenting participants who came for eye examination were enrolled. Convenience sampling was done. Participants were from Bargaun and Limatang villages of Humla with a population of 400 and 100 respectively. Visual acuity was examined at 6 meters with Snellen's chart. The chart was kept in the shade. The illumination of the chart was maintained at 70 cd/m. The recorded Snellen's visual acuity was converted into logMAR as per logMAR conversion chart, rounding off to 2 significant figures during analysis. The twenty-five plate Ishihara pseudoisochromatic chart was used to test color vision of participants. Contrast sensitivity was measured with Leas symbol low contrast test 10M chart with illumination of chart being kept at 125 cd/m.[2] The chart was kept vertically straight and tilting was avoided to prevent discrepancy in the testing. Contrast levels of the test lines on the five pages are 20%, 10 %, 5%, 2.5% and 1.2%. Examination was done at a three-meter distance. Similarly, Frisby stereo test was used to examine the threshold of stereoacuity in participants in a two up one down staircase procedure with the correct reading being one where the participant could identify the correct picture three out of four times. The Frisby stereo test utilizes real depth where pictures are printed in three Perspex plates of 1.5, 3.0 and 6.0 mm thickness. Anterior segment was examined with a hand held slit lamp and posterior segment was examined with direct ophthalmoscope. Specially designed proforma was used for data collection. All valid tools were used for the examination of participants. The participants requiring treatment were provided medicines and presbyopic glasses free of cost and those with cataract were referred to the upcoming surgical camp at Simikot of Humla. Altitude, age, sex and oxygen saturation were the independent variables and visual acuity, color vision, contrast sensitivity, stereoacuity were the dependent variables. Ethical clearance was obtained from Nepal Health Research Council and informed consent was taken from the participants for enrollment in the study. Data were entered electronically in excel, converted to a comma separated values format, and supplied for regression analysis in Python 3. T-tests were done and a linear regression model was fitted to the data to determine the relationship between independent and dependent variables and obtain coefficients for the relationship.

RESULTS

A total of 190 participants fulfilled the inclusion criteria. However, 164 participants completed the study and were analyzed. Females outnumbered males with male: female ratio being 1:1.24.

Table 1: Distribution of Age in Years

Age in years	Frequency	Percentage
< / = 10	3	1.83
11 - 20	11	6.71
21 - 30	26	15.85
31 - 40	1. 23	14.02
50 - 41	36	21.95
60 - 51	32	19.51
70 - 61	27	16.46
80 - 71	5	3.05
90 - 81	1	0.61
Total	164	100.00%

Table 2: Distribution of Oxygen Saturation

Oxygen Saturation	Frequency	Percentage
71 - 80%	3	1.83%
81 - 90%	55	33.54%
100% - 91	106	64.63%
Total	164	100.00%

Table 3: Distribution of Visual Acuity in logMAR

Visual Acuity (logMAR)	Frequency	Percentage
0.48 - 0.0	160	97.56
0.60 - 1.00	4	2.44
> 1	0	0.00
Total	164	100.00%

Congenital color vision defect was seen in two participants who had red green deficiency while acquired color vision defect was seen in four participants. Remaining 96.34% had normal color vision.

Table 4: Distribution of Contrast Sensitivity

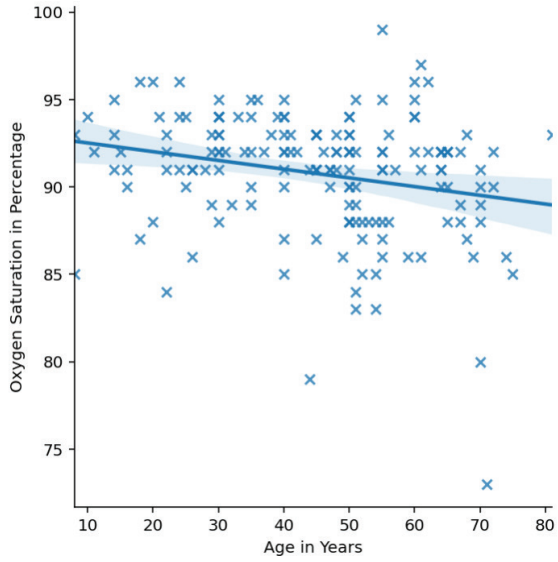
Contrast sensitivity	Frequency	Percentage
25%	0	0
10%	8	4.88
5%	38	23.17
2.5%	66	40.24
1.25%	53	31.71
Total	164	100.00%

Table 5: Distribution of Stereoacuity

Stereoacuity (in seconds of arc)	Frequency	Percentage
600 - 241	6	3.66
240 - 91	2	1.22
90 - 61	7	4.27
60 - 30	21	12.80
< 30	128	78.05
Total	164	100.00%

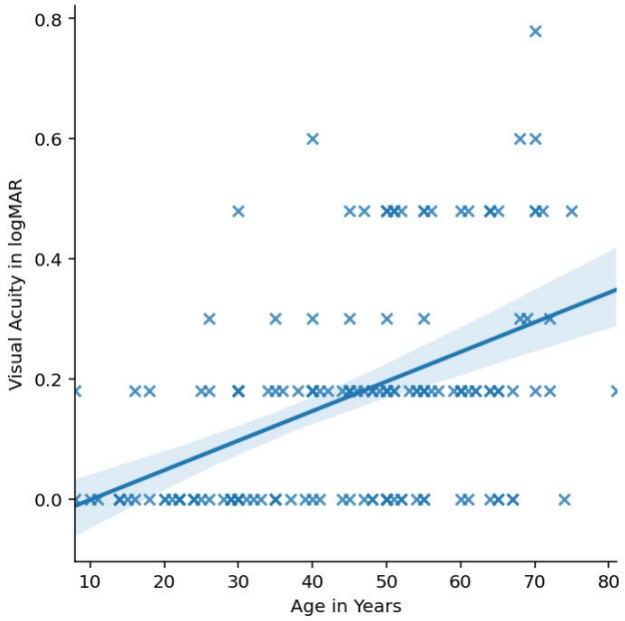
The figures below show a linear relationship between the dependent and independent variables. The crosses indicate data points, the solid blue lines are the regression lines, and the light blue bands around them show the confidence interval.

Fig. 1: Correlation of Age with Oxygen Saturation



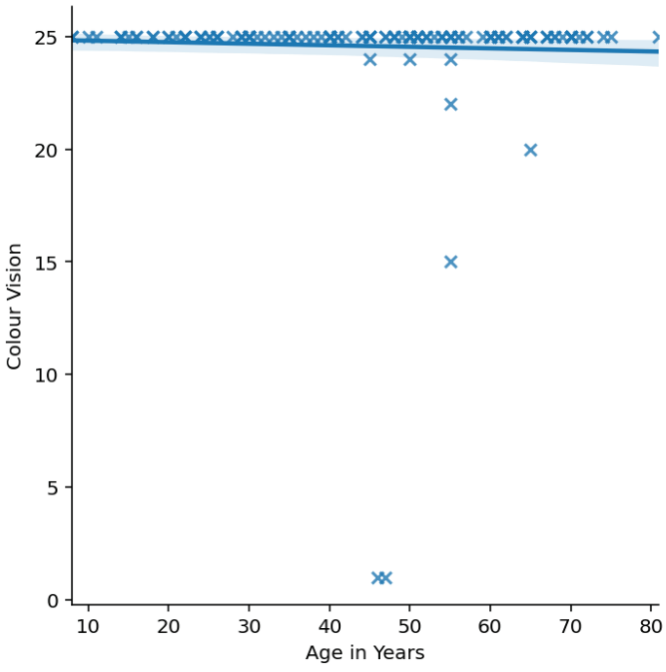
Increase in age is correlated with a decrease in the oxygen saturation. A one-year increase in age is expected to lead to a 0.00177% decrease in the oxygen saturation of a person (*P*=.000).

Fig. 2: Correlation of Age with Visual Acuity



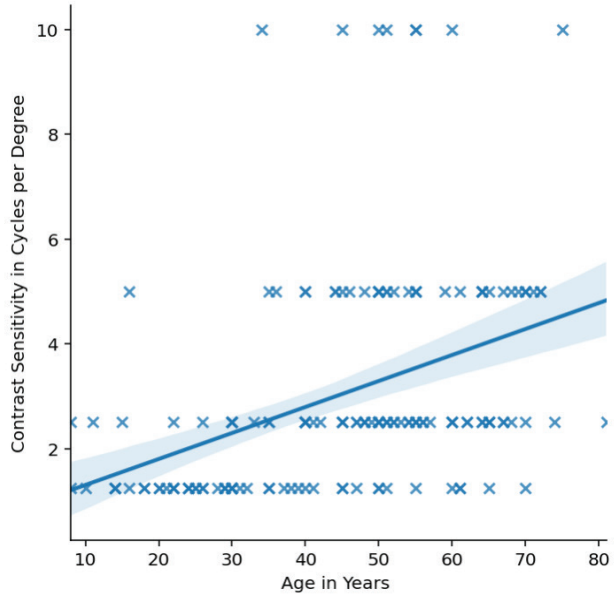
Increase in age is correlated with poorer visual acuity. A one-year increase in age is expected to lead to a 0.00390 unit increase in the log MAR value of visual acuity (P = .000)

Fig. 3 Correlation of Age with Color Vision



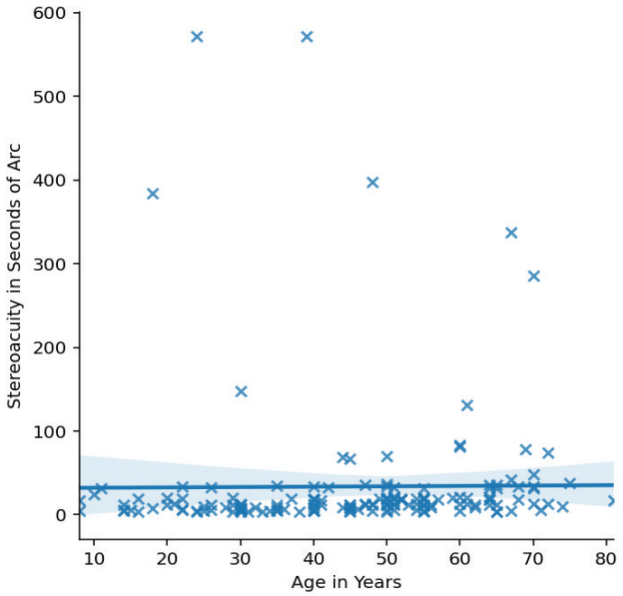
Increase in age is correlated with poorer color vision. A one-year increase in age is expected to lead to a .0480 plate decrease in color vision (*P* = .000).

Fig. 4 Correlation of Age with Contrast Sensitivity



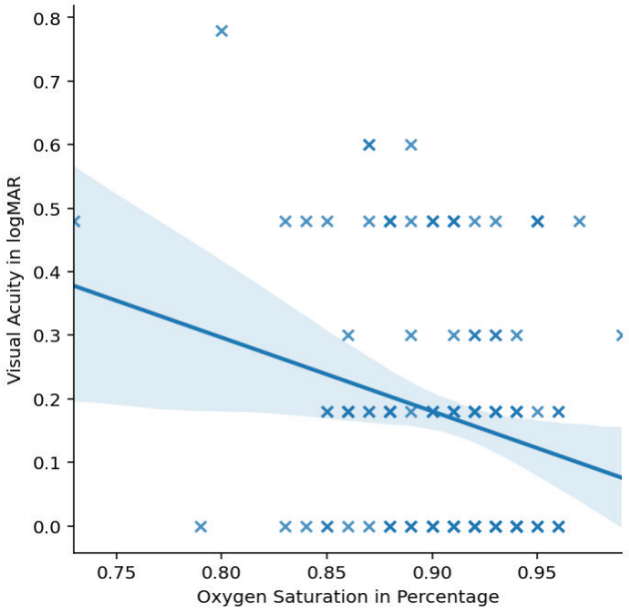
Increase in age is correlated with poorer contrast sensitivity. A one-year increase in age is expected to lead to a 0.0654 unit increase in contrast sensitivity (*P* = .000) indicating worse contrast sensitivity.

Fig. 5 Correlation of Age with Stereoacuity



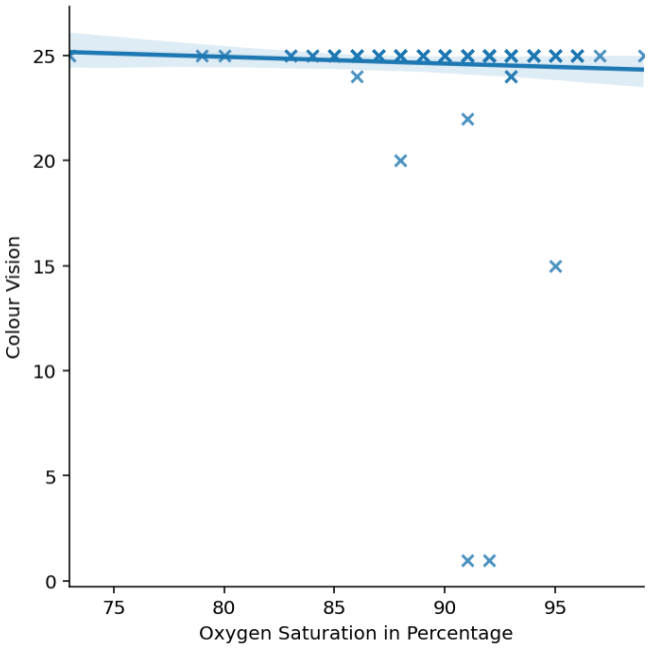
Increase in age is correlated with poorer stereoacuity. A one-year increase in age is expected to lead to a 0.665 unit increase in the stereoacuity value (*P*=.000), indicating poorer stereoacuity.

Fig. 6: Correlation of Oxygen Saturation with Visual Acuity



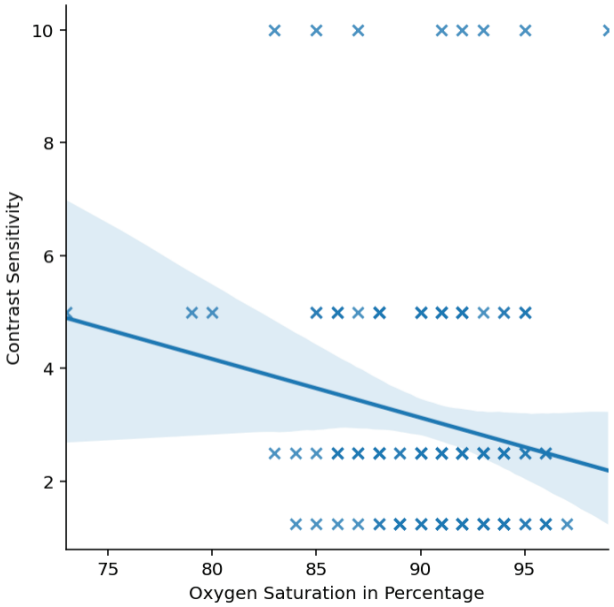
Increase in oxygen concentration is correlated with increased or better visual acuity. A one percent increase in oxygen concentration is expected to lead to a 0.1870 unit decrease in the logMAR value of visual acuity (P = .000).

Fig. 7: Correlation of Oxygen Saturation with Color Vision



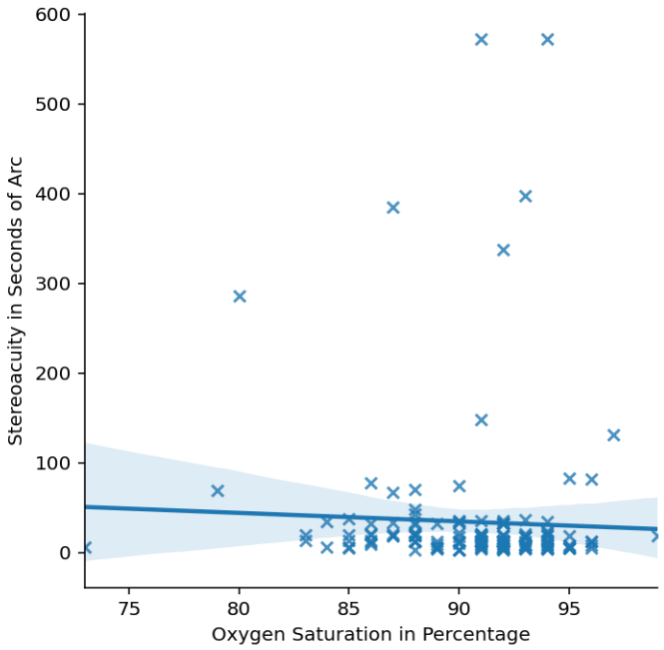
There appears to be no correlation between color vision and oxygen saturation. The regression run on this variation showed the relationship to be insignificant.

Fig. 8 Correlation of Oxygen Saturation with Contrast Sensitivity



Increase in oxygen concentration is correlated with better contrast sensitivity. One percent increase in oxygen concentration is expected to lead to a 3.34 unit decrease in the value of contrast sensitivity (P = .000) indicating better contrast sensitivity.

Fig. 9:Correlation of Oxygen Saturation with Stereoacuity



Increase in oxygen concentration is correlated with better stereoacuity. One percent increase in oxygen concentration is expected to lead to a 37.0 unit decrease in stereoacuity (P=.000) indicating better stereoacuity.

DISCUSSION

Mountain medicine recognizes an altitude of 1500-3500 meters as high altitude with decreased oxygen level in the atmosphere.[3] The reduction in oxygen supply to the brain results in visual field narrowing, decrease in central vision, altered perception and impaired contrast sensitivity[2].

Scano et al cited in Duke-Elder S found a decrease of visual acuity by 6% at 12,000 ft. (3658 meters) and by 12% above this and becomes normal with adequate oxygen supply within 10 minutes.[4] Visual acuity is better than 0.48-0 in 97.56% in the present study and the altitude at which the study was conducted was 3330 meters only among the residents of that altitude. And the present study also showed that with the increase in oxygen saturation, visual acuity was better.

In a study by Davies AJ et al, there was no change in color vision on exposure to an altitude of 3300 meters in mesopic condition which the authors stated may be below the threshold altitude for cone dysfunction.[5] However, it has been suggested that tritan vision axis (blue cones) is more susceptible to hypoxic insult than protan axis (red cones).[6]Vingrys and Garner had found that there was a loss of discrimination with Farnsnell Munsen 100- Hue tool in combination with anomaloscope at an altitude of 12,0000 feet.[7] Lesser number of participants with decreased color vision was found in the present study which may be due to the younger age group of the participants and the altitude of residence was 3330 meters and color vision was tested with Ishihara isochromatic color vision charts which may not have been the ideal. Apart from that the correlation between oxygen saturation and color vision was insignificant in the present study.

Contrast sensitivity was significantly decreased at high altitude as compared with baseline and decreased contrast sensitivity was correlated with oxygen saturation which occurred irrespective of acute mountain sickness in a study by Katrin Gekeler et al. However, visual acuity had remained unchanged.[8] In a study by Willam Z. Bridges and Hansjoerg Kolder done on seven test subjects, the contrast sensitivity began to decrease shortly after transition to 10% oxygen and decreased markedly during the post hypoxia period also.[9] Hypoxia increased mesopic contrast acuity thresholds by approximately 4%, decreased mesopic dynamic contrast sensitivity by approximately 2db and extended mean ellipse axis by approximately 1 CAD unit at mesopic luminance.[10]Adjustments of corneal thickness in hypobaric hypoxia contributes to changes in contrast sensitivity at high altitude[6]. Increase in lactic acid and carbon dioxide levels in various corneal structures results in corneal oedema responsible for decrease in contrast sensitivity.[11,12,13]In the present study, contrast sensitivity was decreased in 28.05% participants although visual acuity was 0.48-1 in 97.56% and an increase in oxygen

concentration is correlated with better contrast sensitivity.

Poorly understood visual association areas in the central nervous system are responsible for higher level visual tasks like stereopsis, identification of faces and are sensitive to damage leading to severe functional impairment despite relatively normal visual acuity at high altitude.[14]Stereoacuity which is the measure of depth perception may be diminished at high altitudes[2]. According to RC Sharma, at high altitude stereoscopic vision is depressed or may be abolished.[1] However, in our study the values of stereoacuity are better as we have measured the threshold of stereoacuity and we have more younger participants as stereoacuity is decreased in only 9.15%.The present study also showed that an increase in oxygen concentration is correlated with better stereoacuity.

A moderate but steady decline in visual acuity was observed as a person ages 60 and on to the age of 80.[15]Increase in age is correlated with poorer visual acuity in the present study.

Abnormal color increases significantly with aging affecting one half or more of people in oldest age groups.[16] According to Randy Dotinga, color vision tends to fade with age. People lose their ability to distinguish certain colors clearly with aging especially starting around seventy years of age and worsening over time.[17] Increase in age is correlated with poorer color vision in the present study also.

Contrast sensitivity also declines with age[18] and is more sensitive to the effects of normal aging or diseases than high contrast visual acuity.[19,20] In our study also an increase in age is correlated with poorer contrast sensitivity.

The overall stereoacuity measured by all stereotests showed a mild decline with age in a study by Garnhamet al.[21] Similarly, an increase in age is correlated with poorer stereoacuity in the present study.

Further study should be done using charts with greater accuracy such as Pelli-Robson chart for contrast sensitivity, log MAR chart for visual acuity and D-100 panel for color vision assessment which also shows hues and also deficiencies in the tritan axis.

Limitation of the study was that only those participants coming for the eye examination in the camp were enrolled.

CONCLUSIONS

Oxygen saturation was reduced in 35% of the study participants in Bargaun village of Humla district of Nepal. Visual acuity was decreased in 2.44%, contrast sensitivity was reduced in 28.05%, stereoacuity was reduced in 9% and vision was abnormal in 4.88%. This can be due to 60% of the participants being 50 years and below. Increase in age was associated with decrease in oxygen saturation, poorer visual acuity, decrease in vision and poorer contrast sensitivity. Similarly, an increase in oxygen saturation was associated with better visual acuity, better contrast sensitivity and better stereoacuity.

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