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Unseen Colors: Prevalence and Patterns of Color Vision Deficiency Among School Students of Bhairahawa, Nepal

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Abstract

Introduction: Color vision deficiency (CVD), commonly referred to as color blindness, is a disorder of impairment in color perception, often due to an X-linked recessive genetic trait. While its prevalence varies across the globe, limited studies exist in the Nepali population. This study aimed to determine the prevalence of CVD among the school children of grades 6 to 10 in Bhairahawa, Lumbini, Nepal.

Methods: This descriptive cross-sectional study was conducted from September to November, 2024, among 758 students from three secondary schools in Bhairahawa, selected by stratified random sampling. Students were tested using the 38-plate Ishihara chart under well-lit conditions. Parental consent was obtained before testing, and students with severe neurological disorders were excluded.

Results: Among 758 students, 53.95% were males. CVD was detected in 15 students (1.98%), comprising 13 males (3.18%) and 2 females (0.57%). Total color blindness was the most common type (6 cases, 1.47%), followed by protan (5 cases, 0.66%), deutan (2 cases, 0.26%), and combined red-green deficiency (2 cases, 0.26%). The male-to-female ratio was consistent with the expected X-linked inheritance pattern.

Conclusion: In the present study, 1.98% of school-going students of Bhairahawa from grades six to ten had color vision deficiency of different forms, with significantly higher prevalence of males. Total color vision defect was the most common, unlike typical global trends where red-green deficiency is most predominant, highlighting the need for larger epidemiological studies and school-based screening programs.

Keywords: color vision deficiency, Ishihara chart, prevalence, school children, X-linked inheritance

Introduction

Human light perception is an illusion of reality that comes from the interaction of millions of neurons of our brain projecting us into a multicolor Universe[1] with a visible range of wavelengths between 380 and 780 nanometers.[2] Color vision deficiency (CVD), often referred to as color blindness, is a condition affecting the ability to perceive colors accurately.

Most people with CVD can see colors, but they may have difficulty distinguishing between certain shades or specific colors.[3,4] The trichromatic theory explains that the different variety of colors that the brain perceives is the combination of three primary colors including blue, green, and red.[5] Color blindness is a genetic condition commonly caused by an X-linked recessive gene and affecting mostly males.[6]

The prevalence of colorblindness has been seen to vary in different countries across the globe,[7] and the Ishihara color chart is the most commonly used test for screening

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color deficiency.[8] Recent studies in neighboring countries have indicated that the prevalence of CVD in South Asia is comparable to global figures, but detailed studies within Nepal are lacking.[9]

This lack of data is concerning as undiagnosed CVD can affect educational experience and academic performance. This study aims to address the existing gap in knowledge by evaluating the prevalence of CVD among Nepali school students. Utilizing the Ishihara chart, a widely recognized tool for diagnosing color vision deficiencies, this research seeks to provide valuable insight into the frequency of CVD within this demographic, which can be very useful for developing support mechanisms to enhance their educational experiences.

Methods

This descriptive cross-sectional study was conducted on school-going children of three secondary schools of Bhairahawa, Lumbini, Nepal. The study was conducted from September to November, 2024 after obtaining clearance from the Institutional Review Committee of UCMS (UCMS/IRC/088/24). In this study, cluster sampling and simple random sampling techniques were employed to make a genuine representation of school-going children. A total of 758 school students were included in this study. Sample size was calculated using the following formula.

$n = Z^2 \cdot P \cdot (1-P) \cdot r / d^2$

n = required sample size

Z = statistic for a level of confidence (1.96 for 95% confidence level)

P = expected prevalence or proportion (from a similar study)

d = precision (margin of error)

r = design effect

Given:

Z = 1.96 (for 95% confidence level)

P = 9.37% (prevalence from a similar previous study)[10]

d = 0.025 (2.5% margin of error)

r = 1

Using the formula, the final sample size is estimated to be 521 participants. Adding a 10% non-response rate sample, the final calculated sample size obtained was 573. For an increase in precision, we have collected a sample of 758 students.

The sampling process involved the following steps:

First of all, a list of all schools of Bhairahawa was compiled. Using a lottery technique, three secondary schools were randomly selected by the cluster sampling method. Students from 6 classes to 10 classes were included in this study. In each class (including all the sections), 30 students were randomly chosen using a lottery method to participate in the study for each class. After selection, the consent form was distributed to the randomly selected students, and they were asked for their parent's signature in the consent form, and data collection was done on the following day.

Ishihara Chart Application Technique[11]

In this study, the Ishihara chart was employed to detect color deficiencies among students. The procedure was carried out as follows:

Test Administration: To ensure optimal visibility of the Ishihara plates, each student was individually tested in a well-lit room. A 38-plate version of the Ishihara chart was used for this technique. It consisted of a series of plates, each displaying a number or shape embedded within a pattern of colored dots.

Testing Procedure: First of all, the students were introduced to the Ishihara chart, and the method of examination was described to them in the local language. The subject was asked to place the chart at a distance of 75 cm and at a right angle with the visual line. The subject was asked to read the numbers in each plate in three seconds, and their answers were recorded. Students who failed to identify certain numbers on the plates were further evaluated to determine the type of color deficiency present. The type of color blindness was identified using the manual of the Ishihara chart.

School-going children from the secondary schools of Bhairahawa from grades 6 to 10 were included, excluding students with serious neurological disorders or students or parents not willing to take part in the study.

Results

In the present study, 758 students from grades six to ten of three secondary schools of Bhairahawa were included. Among 758 students, 409 (53.95%) were male and 349 (46.05%) were female. Among all participants, 15 (1.98%) were found to have color vision deficiency. Among colour vision deficient participants, 1313 (3.18%) were male and 2 (0.57%) were female. Among all color-deficient participants, six had total color blindness, five students had red color deficiency (protan), and two students had green colour deficiency (deutan), while two had both red and green deficiency.

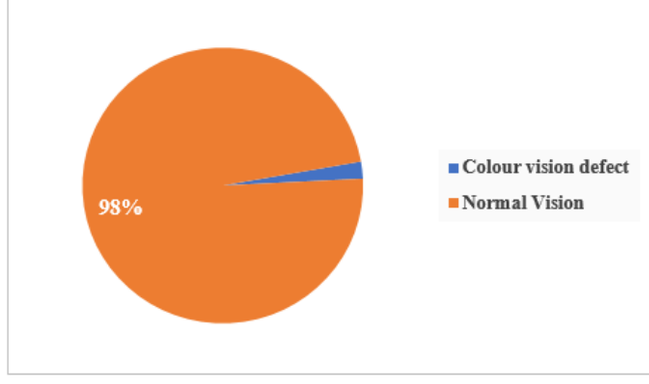

Figure 1: Frequency of color vision deficiency in school students

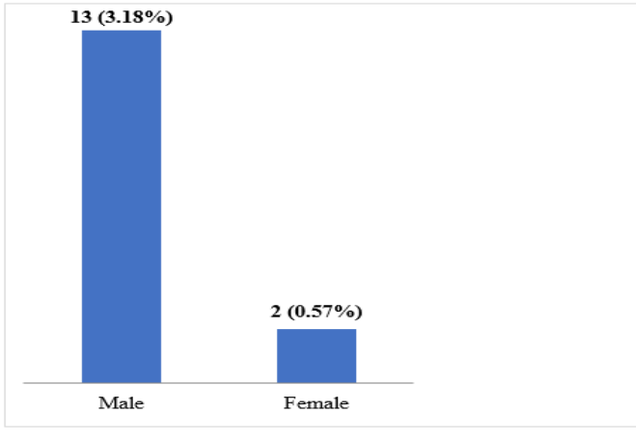

Figure 2: Sex based difference in color vision deficiency in school students

Table 1: Incidence of color vision deficiency among the school students of Bhairahawa

Colour Vision Deficiency	Type	Male	Female	Total
Protan	Mild	3 (0.73%)	1 (0.29%)	4 (0.53%)
	Strong	1 (0.24%)	0 (0.00%)	1 (0.13%)
Deutan	Mild	1 (0.24%)	1 (0.29%)	2 (0.26%)
	Strong	0 (0.00%)	0 (0.00%)	0 (0.00%)
Red-Green color blindness		2 (0.49%)	0 (0.00%)	2 (0.26%)
Total color defect (blindness and weakness)		6 (1.47%)	0 (0.00%)	6 (0.79%)
Total		13 (3.18%)	2 (0.57%)	15 (1.98%)

Discussion

Color vision deficiency (CVD) is a common condition that can impair educational outcomes, daily activities, and even the career goals of school children. Despite these challenges, very few studies have explored the prevalence and patterns of CVD in school-going children of Nepal. This study was prompted by the lack of data on CVD in this demographic, aiming to fill this huge gap by determining the prevalence of color vision deficiencies (CVD) among school-going children of grades six to ten in Bhairahawa, Lumbini, Nepal. Out of 758 participants, 15 students (1.98%) were found to have some form of CVD, with a significantly greater frequency in males (13 out of 15) compared to females, aligning with the X-linked pattern of color blindness.

Similar studies conducted in Nepal have demonstrated different results in different variety of populations. For instance, a study conducted by Jha et al.[12] in undergraduate students of the Kavre district revealed that 5% of the participants had some form of color deficiency. In another study conducted on school children of Pokhara, Nepal, the prevalence of color blindness was found to be 3.8%.[13] Likewise, in another survey of a tertiary care center in the western part of Nepal, it was observed that 9.31% of the participants were color blind.[9] In another study done in Kathmandu Nepal the prevalence of color-blindness was found to have 5.24%.[14] In the present study, the overall prevalence of color blindness present was 1.98%, representing a diverse demographic configuration of the study population, including the children from both rural and urban settings. The differences in percentage of color deficiency among participants in different studies may be due to differences in ethnic and genetic backgrounds of study participants. The variation in the number of study participants and the method of sample selection can also affect the overall results.

Many other studies conducted in different countries across the globe have also demonstrated that the prevalence of color blindness varies in different geographical areas and differs from race to race.[15] A study conducted by Xie et al.[16] in Southern California has found the prevalence of color blindness to be only 1.6% . Similarly, in Andhra Pradesh of India, the prevalence of color-blindness was 1.9%, which is very near to the prevalence of the present study.[17] In Kuala Lumpur, Malaysia,[18] it was observed to be 2.7%, whereas in Northeast Ethiopia it was 4.3%.[15] Similarly, in another study Harrington et al.[19] found the prevalence of color-blindness to be 5.4% in Ireland, Europe. So this variation again highlights the role of genetics and ethnicity in the determination of the prevalence of color-blindness. Sample size variation and gender distribution could also be the reasons behind these differences, as males are more likely to be color-blind due to the X-linked inheritance of this disorder. Different diagnostic tools used for the diagnosis of color deficiency, including the Ishihara chart, digital color vision tests, or anomaloscopes, may produce varying results due to differences in sensitivity and specificity.

In the present study, total color defect was found to have the highest percentage (40%) among all types of color vision deficiencies. This finding is notable as it is highly inconsistent with the commonly reported global pattern,[15-19] where total color defect is a relatively rare phenomenon, whereas red-green color blindness exhibits the highest prevalence. The high frequency of total color defect in our study population suggests an existence of unique predisposing factors. Genetic background, including the families with high consanguinity and inherited retinal disorder, may be the reason behind this. Similar studies conducted in isolated populations have demonstrated this type of pattern.[20,21] In order to investigate the root reasons of these unique patterns, more thorough epidemiological and genetic studies are required.

This study was confined to only three schools, which may not be the true representation of the broader population. In the future, studies with large sample sizes, including many schools in large geographic areas could improve generalizability. In regards to detection of color vision deficiency, the Ishihara chart may not be sufficient; combining it with advanced tools is recommended

Conclusion

The present study found that 1.98% of school-going students of Bhairahawa from grades six to ten had color vision deficiency of different forms, with a significantly higher prevalence of males. Total color vision defect was

the most common, followed by protan type deficiency and red-green and deutan types of deficiency. These findings differ with global data, emphasizing the need for exploring a detailed study in this regard. The implementation of school-based screening medical camps for vision defects could help in diagnosis and management, decreasing the potential academic and career-related challenges for color vision-deficient students.

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