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Prevalence and Frequency of Color Vision Defects among Injibara University Students in Injibara, Ethiopia

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Abstract

***Purpose:** The objective of this study was to determine the prevalence and frequency of color vision defects among Injibara University regular undergraduate students in Injibara, Ethiopia.

Method: A descriptive cross-sectional design was used to determine the prevalence and frequency of color vision deficits among Injibara University students. The study participants were Ethiopian students, above 18 years old, with normal eyesight, who gave their consent for the study. A total of 2130 students were included, 1112 of whom were female and 1018 of whom were male. A color vision test was used with seventeen Ishihara plates, and participants were asked to sit in a room with sufficient light and read the plates from a computer screen placed 75 cm away from the student.

Result: There was a significant association at the 95% significance level between sex and the status of color vision of students (4, N = 2130), $\chi 2$ = 11.998, p = 0.017. The relation between ethnic group and color vision defect status variables was highly significant (3, N = 2130, $\chi 2$ = 14.434, p = 0.002 at 95% CI). The prevalence among 2130 students tested was that 50 (2.34%) had color vision defects, and of these 32 males (1.5%) and 18 (0.84%) were females. The frequency of red-green colorblindness in males was higher than in females by 2.2%. In males, the protan dominant normal allele (L) had a frequency of P = 0.986 and the recessive (l) frequency of q = 0.014, whereas the dominant allelic frequency of females was 0.998 for (L) and 0.004 for (l).

Conclusion: The prevalence of color blindness was observed to be higher in males than in females, and there were higher protan types of color vision defects than in other color vision defects at the university. Early screening for CVD should be encouraged among university students to guide their choice of future profession and help mitigate work hazards resulting from being color deficient.

Keywords: Allelic frequency, color vision deficiency, color blind defect prevalence, genotypic frequency, Ishihara test plates, phenotypic frequency

Introduction

Color blindness is considered a disease in which a person has little or no ability to distinguish and recognize the colors in normal light[1]. Color vision-deficient (CVD) people have difficulties recognizing certain spectral hues[2]. Color-deficient individuals characteristically confuse colors that normal people can distinguish. Pseudo-isochromatic color plates are patterns of colored and gray dots that reveal one pattern to the normal and another to the color-deficient plates of the Ishihara test, which are read differently by affected and unaffected people [3].

Color vision deficiency (CVD) describes the failure of an individual to see traditionally, resulting from the failure of the retinal cones to discriminate between different wavelength stimuli [4]. Congenital Color Vision Disorder is most commonly a sex- or X-linked genetic disorder with the defective gene located on the X chromosome within the Xq28 band, while the blue pigment gene resides on the 7th chromosome. It could also be autosomal dominant, especially with tritan disorders, and rarely autosomal recessive [5].

The prevalence of color vision deficiency is expected to increase globally with the growing population and varies among different races and geographical areas. **Across the world, there are significant differences in the prevalence of colorblindness.** The incidence of congenital color blindness is different in various regions of the globe. For instance, 8% of adult males and 0.4% of adult females are color blind in western states. The prevalence of CVD is 4–6.5% in Japan and China, 4% in African countries, 7.3% in Turkey, and 2.9–11% in Saudi Arabia. Still, the prevalence of acquired color blindness varies according to occupation, sex, and age, and has been reported to be 5–20% in different studies[6]. Although statistics vary across different groups and geographical locations, the incidence CVD is less than 2% in Native Americans and Australians, whereas it is 4% in Africans, 5% in Asian populations and about 8% in Caucasians The study of color blindness in Ethiopian population is scarce with only two published studies. According to these studies, the prevalence of congenital color blindness among Ethiopians was reported to be 4.2% among males and 0.2% among females[7].

It can affect access to education, exam grades and career choices. Color blind people are limited in a few areas of industry, transport services and the armed forces. It is accepted that color blindness could potentially cause problems and it is recognized that there are certain job types in which the color blind people are not suited to, mostly for safety reasons. Also, color blindness may pose occupational handicaps in certain areas of medical practice and the health sciences as color perception is important in histology, histochemistry, biochemical tests and other color based assessments[8].

A color vision issue has an impact on an individual's life. Learning and reading may become more difficult, and the person may not be able to pursue certain jobs like driving because they have trouble telling the difference between a red and green traffic light. In order to raise awareness about the existence of color vision problems among university students generally and draw attention to the impact of colorblindness on the learning and teaching process, this study set out to estimate the prevalence and types of color vision deficiency among Injibara University students in Amara, Ethiopia, in relation to sex and ethnic groups.

Materials and method

Description of the study Area

The study was conducted at Injibara University, which is located in Awi Zone, Injibara Town, and west-northern Amara Regional State, Ethiopia. The Awi Zone's administrative is Injibara Town, which is located in Ethiopia's Amara Region. It is situated at 2560 meters above sea level, at 10°57′N, 36°56′E.

Research design

A descriptive cross-sectional study was used for determining the prevalence and frequency of color vision deficit among Injibara University students. The inclusion criteria were Ethiopian students, above 18 years old, with normal eye sight, and who gave their consent for the study[9].

Color vision deficiency test

Demographic data, including age, sex, ethnicity, history of eye disorder, use of medications, awareness about their color vision defect, findings of an ocular examination, and results of a color vision test, were recorded in a pre-tested structured questionnaire[10]. Permanent plates of the Ishihara were used, and the defects were identified following Ishihara's recommendation. The color vision testing plates were held 75 cm away from the individuals and placed at 90° to the line of vision in the room. The individuals should not be given more than 3–4 seconds per plate. All tests were done under binocular viewing conditions. The individual students were asked to read the number seen on the test plates 1–17, which each contained a number and some were viewed as image.

The reading plates 1 to 15 belong to the normality or defectiveness of color vision. If thirteen or more Ishihara plates were read correctly by the students, their color vision is considered normal. If only nine or fewer plates were read correctly, the color vision was regarded as red-green color deficient. Individuals who were classified as color-deficient were re-tested using plate numbers 16 and 17. The plates leveled at 16 and 17 were used to identify deutan and protan types of color vision defectiveness[11].

Sampling size determination and study population

A descriptive cross-sectional survey was carried out to determine the prevalence and frequency of color vision deficiency among Injibara University under graduate regular student. There were a total of 2130 participants in this study, consisting of 1112 females and 1018 males. A sample size was calculated by taking the prevalence of 4.2% obtained from a previous study in Ethiopia with a 95% confidence interval, a 2% margin of error, a design effect of 4, and the assumption of a 90% response rate using the standard formula for the calculation of the sample size [10].

$$n = \frac{z^2 \alpha/2 \; p(1-p)}{d^2}$$

Where

n = sample size

Z = z-score for 95% confidence level (1.96)

P = estimate of the proportion (0.042)

d = margin of error (0.02)

Statistical analysis

Through SPSS version 26, descriptive statistical analysis was carried out. To determine whether there was a significant difference between ethnic categories and between the genders of females and males, the Chi-square ($\chi 2$) analysis was used.

Allelic percentage determination

Assuming that the populations are non-consanguineous, the gene count was used to determine the frequencies of the normal allele, deutan allele (q), and protan allele (r) for colorblind individuals based upon the Hardy-Weinberg law p2 + 2pq + q2 = 1[12].

According to Oktarianti, Azizah [13] the prevalence of color blindness was calculated using the formula

$$\text{Color blindness Prevalence} = \frac{\text{Number of Colorblind Individuals}}{\text{Number of Research Samples}} * 100$$

According to Fareed, Anwar [9] male and female allele frequencies was calculated using the following formula:

$$\text{male color blindness, q} = \frac{\%\ \textbf{color blind phenotype}}{100}$$

Then, p = 1-q.

$$Famale\ color\ blindness, q = \frac{\sqrt{\%\ \textbf{color blind phenotype}}}{100}$$

Male and female color blindness

$$q = \frac{1}{3} * (l) + \frac{2}{3} * q(pr)$$

$$p = 1 - q$$

Where p is the normal allele frequency and q is a color-blind allele frequency. The homozygous (H_0 and heterozygous (Ht) was determined using formula

$Ho = \sum pi2$, where pi represents the allele(C/c) so, $Ht = 1 - \sum Ho$

Result

Sex and color vision status cross-tabulation

A chi-square test of independence was performed to evaluate the relationship between sex and color blindness defect status. The relation between these variables was significant ($\chi 2$ (4, N = 2130) = 11.998, p = 0.17 at 5% CI). Males (3.1%) were more likely to have a color blind defect than were females (1.6%). Females (98.4%) were more likely to be normal than males (96.9%).

Table 1: Chi-Square Tests for sex and color vision

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	11.998[a]	4	.017
Likelihood Ratio	13.126	4	.011
Linear-by-Linear Association	5.422	1	.020
N of Valid Cases	2130		

a. 4 cells (40.0%) have expected count less than 5. The minimum expected count is 2.87.

Ethnicity and status of color vision cross

With the exception of the Oromo, Amhara, and Agew, the sample sizes for a lot of ethnic groups were small, thus they were combined to provide an equitable sample size. Only individuals from the Amhara, Oromo, and Agew ethnic groups were found to be color blind.

Table 2: The frequency of color blind tested ethnic groups of Injibara University

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Oromo	946	44.4	44.4	44.4
	Amara	615	28.9	28.9	73.3
	Agew	424	19.9	19.9	93.2
	Others	145	6.8	6.8	100.0
	Total	2130	100.0	100.0	

Others refers to: Afar (7), Anyuak (4), Arri (3), Bench (7), Burji (1), Dawuro (2), Dorze (2), Gamo (13), Gedeo (5), Gumuz (3), Gurage (8), Hadya (3), Halaba (2), Hamar (4), Harari (1), Kafa (9), Kambata (4), Konso (4), Kore (2), Kucha (3), Shinasha (3), Sidama (9),Silte (9), Somali (2), Tegaru (3), Wolaita (19), and Yem (13) ethnic groups. The numbers in the brackets are the sample size subjects from the respective ethnic groups.

A chi-square test of independence was performed to evaluate the relationship between ethnic group and color blindness defect status. The relation between these variables was highly significant ($\chi 2$ (3, N = 2130) = 14.434, p = 0.002 at 5% CI). The Oromo ethnic groups were more likely to affect with color blind vision.

Table: 3 Chi-Square Tests for ethnicity and status of color vision

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	14.434[a]	3	.002
Likelihood Ratio	15.779	3	.001
Linear-by-Linear Association	.444	1	.505
N of Valid Cases	2130		

A. 1 cell (12.5%) has expected count less than 5. The minimum expected count is 3.45.

Table 4: Frequency of different types of color blindness in relation to sex

		Frequency	Percent	Valid Percent	Cumulative Percent		
Sex	male	1018	47.8	47.8	47.8		
	female	1112	52.2	52.2	100.0		
	Total	2130	100.0	100.0			
		types of color blindness					
		Deutan	Protan	Achromacy	Uncategorized	Trichromacy	Total
sex	male	12	14	4	2	986	1018
	female	10	2	2	4	1094	1112
Total		22	16	6	6	2080	2130

Table 4 demonstrates that 50 (2.34%) of the 2130 students who were tested for color blindness at Injibara University were

identified as having the condition. Of these, 18 (0.84%) were female and 32 (1.5%) were male. Twelve (0.56%) of the thirty-two males suffering from color blindness were deutan, fourteen (0.64%) were protan, four (0.18%) had achromacy, and two (0.08%) were uncategorized (mixed form). There were ten (0.46%) female colorblind, two (0.08%) protan, two (0.08%) achromacy, (Participants read correctly plate one only) and four (0.18%) uncategorized (mixed form) colorblind people. Participants classified as uncategorized interpret plates 16 and 17 in a different way than students who were color blind of red and green.

Table 5: Frequency of color vision defects among university students

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	normal	2080	97.7	97.7	97.7
	Defect	50	2.3	2.3	100.0
	Total	2130	100.0	100.0	

Among the 2130 subjects' tested, 2080 (97.65%) of the participants were found to have normal color vision, and 50 (2.35%) had a color vision defect, which includes 32 (1.5%) males and 18 (0.84%) females.

The frequency of red-green colorblindness in males was higher than in females by 2.2%. Males have a higher CVD frequency, which reinforces the fact that due to the X-linked recessive nature of the trait, a single X-chromosome in males is predominant to color blindness, while females can function as dose compensation and lower the chance of defects in females with two X chromosomes. Protan males are more frequent than the other color blind students. The frequency of the different types of colorblindness in this study shows that the percentage of Protan was higher than other types of color blindness.

Considering males and females separately, the percentage of colorblindness among males and females was different. Out of 1018 males tested, 32 were colorblind. This makes 32/1018, or 12% of the total males tested. Only 18 females were colorblind out of the total 1112 females tested; this makes 18/1112, or 1.6% of the total females tested. For the two common types of red-green color vision deficiency, the allelic and genotypic frequencies were calculated for male and female populations separately. For simplicity, protan was represented as the locus gene. The OPN1LW gene codes for a protein that is necessary for healthy color vision. This protein is found in the retina. The calculation shows that in males, the dominant normal allele (L) had a frequency of P = 0.986 and the recessive (l) frequency of q = 0.014. In females, the dominant phenotype frequency is p2+2pq = 0.999996, and the frequency of the recessive phenotype is q2 = 0.00004. The allelic frequency is 0.998 for (L) and 0.004 for (L). The genotypic frequency for LL (p2) = 0.998, heterozygous Ll = 2pq = 0.004, and homozygous recessive is q2 = 0.999.

Phenotypic, allelic, and genotypic frequencies of deutan

The phenotypic, allelic, and genotypic frequencies were calculated for male and female populations separately for the two common types of red-green color vision deficiency. Protan and deutan. The deutan locus gene (OPN1LW) was represented by L for normal and l for the mutant allele. The calculation shows that in males, the dominant normal allele (L) had a frequency of P = 0.988 and the recessive (l) frequency of q = 0.012. The dominant phenotype frequency in females is = p2+2pq = 0.999919, and the frequency of the recessive phenotype is q2 = 0.000081. The genotypic frequency for LL (p2) = 0.982081, heterozygous Ll = 2pq = 0.017838, and homozygous recessive is q2 = 0.000081.

Table 6: The prevalence percentage of types color vision deficiency

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Deutan	22	1.0	1.0	1.0
	Protan	16	.8	.8	1.8
	Achromacy	6	.3	.3	2.1
	Uncategorized	6	.3	.3	2.3
	Trichromacy	2080	97.7	97.7	100.0
	Total	2130	100.0	100.0	

Discussion

Color blindness is most frequently inherited as a sex-linked recessive disorder. Its incidence is much more common in males as compared to females, who studied the incidence of color blindness in different parts of the world and different ethnic groups in regions of Ethiopia. The incidence in the present study in males was found to be 1.5% and in females (0.84%), and this study was similar to the study done by[14]. The overall prevalence of CVD in the present study was lower compared to previous studies such as in Addis Ababa (Ethiopia), 4.52%, by Abebe and Wondimkun in Saudi Arabia, 3.36%, by Oriowo and Alotaibi, in Manipur (India), 5.28%, by Shah et al., in Shekhan City/Kurdistan region (Iraq), 3.28%, by Abdulrahman, in Welkite town (central Ethiopia), and 4.10%, by Woldeamanuel and Geta [12]. The current study's smaller sample size may be the reason for the lower prevalence of CVD compared to prior research done in Ethiopia. With the exception of those studying health science and medicine, the majority of students in this study were unfamiliar with the disease known as color vision insufficiency. The frequencies of deutan and protan in the male patients were 2 (0.08%) uncategorized (mixed form), 4 (0.18%) achromacy, 14 (0.64%) protan, and 0.56% deutan. These frequencies pale in comparison to a recent study conducted by [11] among university students at Hawassa, Ethiopia. In Indian populations, the frequency of the CVD allele is lower in females than in males; however, it is similar to a recent study conducted in Hawassa, Ethiopia. Comparatively speaking to the Indian population, the level of heterozygosity among female students of Amhara and Oromo ethnic origin was also low in this study. Positive family history of CVD was strong predictor of CVD in students in our study. Positive family history seems to be a proxy indicator for high consanguinity in the population carrying the

genes responsible for the CVD in family[15]. The higher incidence of this disorder among males is not unexpected since colour blindness is an X-linked recessive disorder. This type of trait usually affects more males than females because males have one X chromosome; hence, there is no second X chromosome to counter the effect of the recessive allele. Females will have to be homozygous recessive to exhibit the disorder. The single X chromosome in males, if affected, is predominant to colour blindness, while females with two X chromosomes can compensate for an affected X chromosome, thereby decreasing the risk of CVD. In the current study, the average heterozygosity for females was lower than the prevalence in male students[16].

The prevalence of CVD, in the present study, was 2.34%; which is nearly comparable with the prevalence rates of previously conducted research: 4.2% in Abeshege district and 4.1% in Wolkite (both from Southern parts of Ethiopia), 4.43% in Jammu and Kashmir of India and 4.2% in Thailand. However, the result of this study is higher than the incidence of color blindness among school children in Kathmandu valley of Nepal at 3.9% and 2.6% in Nigeria. A higher prevalence rate of CVD, 5.3% in Singapore, 5.9% in Korea and 7.47% in Turkey was reported[17]. Various factors can affect color blindness prevalence, including genetic factors, which are considered among the most important determinants of the dispersion of the disease and its prevalence in the communities[1].

Conclusion

The findings of this study showed the presence of protan, deutra, achromacy, and uncategorized types of color blindness among Injibara University students. The frequency of deutan is higher than the other type of colorblindness. Red-green colorblindness (protan and deuteran) was the most common type of color blindness, which is in agreement with various reports for different populations. The combined frequencies of color blindness among male and female students were 50 (2.34%). This result showed that males suffered more than females. In this study, all of the students tested had no information about CVD, and all of them were not aware of their status.

Color vision defects should be tested, particularly in males, to make informed decisions in the early years of life. Early detection of color blindness allows people to make necessary adjustments for the affected students. In our country, much has to be done to screen children for color blindness. The Ministry of Education, non-governmental organizations, and the Ministry of Health place more emphasis on color blindness defects.

List of abbreviations

CVD- Color vision-deficient

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