

Prevalence of congenital color vision defects among school children in five schools of Abeshge District, Central Ethiopia

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ABSTRACT

Background: Human color vision is normally trichromatic in the sense that a suitable mixture of red, green and blue lights can match any color that we can see. Color blindness occurs when one or more of the cone types are absent, or present but defective. It is a common X-linked genetic disorder. However, most of color blinds remain undetected due to absence of proper screening.

Objective: To determine the prevalence of congenital color blindness and identify the level of awareness about their color vision defect among school children.

Design: This was a cross sectional study.

Setting: The study was conducted in five schools of Abeshge district Central Ethiopia among school children in February 2009.

Materials and Methods: A total of 1040 male school children of grade 3 to 8 screened for color vision defect using Ishihara's pseudoisochromatic test 38 plate edition. The sociodemographic data and results of color vision test and ocular examination collected using pretested structured questionnaire. Data was entered and analyzed using SPSS statistical package version 15.0.

Results: A total of 1040 male school children were screened with a mean age of 12 ± 2.43 years. Among these 44 cases (4.2%) (95% Confidence Interval 2.98 to 5.42) were color blind. Of these 30 cases (2.89%) involved deutan, 6 cases (0.58%) protan, 6 cases (0.58%) unclassified, and 2 cases (0.19%) of totally color blind. All of the color blind subjects were not aware of their status of color vision.

Conclusion: The prevalence of congenital color blindness in this study is similar to the previous two studies among Ethiopians. Cases of total color blindness among Ethiopians reported for the first time. Early school screening for color vision defect is recommended.

Key words: Color blindness, Males, Grade school children, Level of awareness, Ethiopia

INTRODUCTION

Color blindness is the inability to distinguish certain colors. Molecular studies have shown that defects in color vision result from the absence, malfunction, or alteration of one (dichromatism), two (monochromatism) or all (achromatism) of the photopigments. Dichromats base their color vision on only two pigments¹. The class of dichromats characterized by the entire absence of green cones is called deuteranopia, while those defects characterized by the absence of red cones are called protanopia and those characterized by the absence of blue cones are called tritanopia. Anomalous trichromacy is a relatively mild form of defective color vision. The terms protanomaly, deuteranomaly and tritanomaly is given when there is defect in red, green and blue pigments, respectively. Protanomaly and protanopia are collectively referred to as protan colour vision defects, and deuteranomaly and deuteranopia are referred to as deutan defects. Protan and deutan colour vision defects are often collectively described as red-green defects. Tritanopia and tritanomaly are often described as the tritan or blue-yellow colour vision defects¹⁻³.

Impaired color vision, in the case of red-green color blindness, is genetically determined by X-linked recessive inheritance and thus occurs in males but is transmitted via the female. The defective genes for protan and deutan defects are situated at different loci on the X chromosome, and are therefore non-allelic⁴⁻⁶. The inheritance of other forms of defective color vision is complex⁶.

Congenital protan and deutan defects, which are collectively termed red-green color blindness, are common, affecting about 8.0–10.0% of Caucasian male population⁷. In contrast, congenital tritan defects are rare, affecting less than 1 in 10,000 people⁸. The prevalence of red-green color blindness has been found to vary between different races, tribes and ethnic groups⁹. The prevalence of color vision defects among non-Europeans is lower than in persons of European ancestry in whom it is reported to be 6.0% for males and 0.25% for females¹⁰. In some European countries even higher prevalence is reported; 7.8% of school boys in Germany¹¹, 7.95% among males in Greek¹², and 7.33% in young Turkish¹³ men were reported to have congenital color vision defect. A study done in Australia showed prevalence of 7.4% in males and

0.7% in females¹⁴. In the USA, the average incidence of red-green color blindness was found to be about 8.0% among males and 0.4–0.7% among females¹⁵.

Asian males have a prevalence of color vision defects of 4.9% compared to 0.64% in females. A recent study from India reported a prevalence of 8.73% of males and 1.69% of females among Muslim population¹⁶. The prevalence in Arab boys of Saudi Arabia is 2.93%¹⁷.

Individuals of African, Native American or Mexican ancestry have an even lower prevalence: 3.1% in males and 0.7% in females¹⁸. The incidence of red-green color blindness is significantly higher in North Africa than in sub-Saharan Africa which displays a very low incidence. However, in North Africa it is on the whole still appreciably lower than the usual European incidence of 7% to 9%. Studies in some of the countries of North Africa reported a prevalence of 6.56% in Algerians, 5.6% in Tunisians, 5.99% in Libyans and 10.5% in Moroccans among studied male population¹⁹. The overall incidence of red-green color blindness in sub-Saharan population was reported to be 2.63%¹⁹.

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^{20,21}.

Color is routinely used to code and convey information as well as finding extensive application in the educational system. Currently, no treatment exists for congenital color vision defects. However, studies showed that diagnosis of these defects early in life may help children adjust better to tasks at school and may help adults understand their limitations at work. Undiagnosed Color Vision Defect (CVD) could pose a handicap to the scholarly performance of an affected student²². It is therefore important that children of school age, particularly boys, should be tested early.

The objective of this study was to determine the prevalence of congenital color blindness among male school children in Abeshge district and to identify the level of awareness about their color vision defects.

MATERIALS AND METHODS

A descriptive cross-sectional study was conducted in February 2009 in Abeshge District of Gurage zone, central Ethiopia. Multistage sampling method was employed. First, five primary schools in the district were selected randomly by using table of random numbers among 15 primary schools in the district. Next, from each selected school, all of the male school children from grades 3 to 8 who were able to read the numbers were selected. All male children from selected grades, who were healthy participants with normal ocular examination findings, were included in the study. Participants on chronic drug therapy for more than one month or with systemic illness or who have

history of ocular or head injury which significantly affected vision were excluded from the study. However, we didn't encounter participants with these exclusion criteria during the survey and all of the male students from the selected five schools were screened for color vision defect. Snellen's E chart was used to test the visual acuity at 6 meters distance and color vision was assessed with each subject's best-corrected acuity. All of the participants had normal near vision.

A sample size of 850 was calculated by taking the prevalence of 4.2% obtained from previous study in Ethiopia²¹, with 95% confidence interval, 2% margin of error, design effect of 2 and with the assumption of 90% response rate using the standard formula for the calculation of sample size.

$$n = \frac{Z^2 P(1-P)}{d^2}$$

where

n = sample size

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

P = estimate of the proportion (0.042)

d = degree of accuracy (0.02)

A total of 1040 male students with the age ranging from 8 to 20 years were screened for color vision using Ishihara pseudoisochromatic 38 plate edition which was administered to participants by the principal investigator in a room with sufficient indirect natural tropical daylight in the morning hours of the dry season. Examination was conducted in class rooms consisting of multiple wider windows with adequate bright light and with subjects sitting near the window side. Direct sunlight was avoided and no electric light was used as it was not available in that set up. The test was conducted based on the standard recommendation of color vision test^{2, 23, 24}. All testing was done under binocular viewing conditions. The plates were held at arms length from the subject and tilted so that the plane of the paper is at right angles to the line of vision and set at eye level of subjects. Before the test each participant was given the following instruction using the local language which was understandable by students: "on each page you may see a number or you may not see anything. Tell me what you see as I turn each page as soon as possible." The first plate was presented first to check whether they followed instruction correctly or not. All of the participants were active and responded within an average duration of 2 seconds per each test plate. Participants who made more than five typical red-green defective responses between plates 2 and 21 were judged to have failed the test^{3, 24}. Such participants were then shown the diagnostic plates (22, 23, 24 and 25) to determine the type and severity of the defect. Those who failed the test were immediately retested and the result recorded. For all individuals who missed 5 or more plates, dilated fundusoscopic examination was conducted with direct ophthalmoscope to rule out any

ocular pathology. However no ocular pathology was detected in the eyes of subjects found to have color vision defect.

Demographic data including age, sex, grade, address, history of eye disorder, eye injury, use of medications, awareness about their color vision defect along with findings of ocular examination and results of color vision test were recorded in pre-tested structured questionnaire. The demographic part of the questionnaire was filled by trained integrated eye care worker. Data was entered, analyzed, the frequencies of study variables and cross tabulations were done using SPSS statistical package version 15.0.

Ethical clearance was obtained from research and publication review board of the Department of Ophthalmology, Faculty of Medicine, Addis Ababa University. Informed consent was obtained from parents or guardians of the children. Guidelines of the declaration of Helsinki were adhered during the study. Those study participants with color vision defect were explained about their problem and advised about the selection of their future carrier.

RESULTS

A total of 1040 participants were screened with mean age of 12 ± 2.43 years. The majority of participants were in the age group of 11-15 years [718(69%)]. The distribution of participants by schools includes Garaba 267(25.7%), Fenta 241(23.1%), Fekado 227 (21.8%), Rimuga 175 (16.8%), and Hole 130 (12.5%).

In the study population, 44 (4.2%) cases of defective color vision were detected [95% Confidence interval 2.98 to 5.42]. Of 44 cases of color blind 30 (2.89%) cases involved deutan, 6(0.58%) protan, 6(0.58%) unclassified, and 2 (0.19%) cases of totally color blind. The two participants with total color blindness had normal visual acuity and no retinal pathology was detected with dilated direct ophthalmoscopic examination. The prevalence of red-green color blindness excluding totally color blind subjects was 4.04% (95% CI 2.84 to 5.24). Almost all of the study subjects were not aware of their color vision status and only 2 (0.19%) students reported that they have difficulty of differentiating different colors. Overall only one student reported that he had undergone eye examination at least once in his life time.

DISCUSSION

In the screening process of color vision, the question is simply if there is a color deficiency present or not. Since the prevalence of protan and deutan defects are by far the highest in congenital color deficiencies, most screening color vision tests only identify these red-green deficiencies. Screening of color vision deficiencies is usually done with so called pseudoisochromatic plates of which the Ishihara test probably is the most well-known. In the three studies performed to evaluate the

sensitivity of Ishihara pseudoisochromatic test, there was no evidence that Ishihara's test was less valid than any other screening tests²⁵⁻²⁷. Based on these studies, Ishihara test has the mean sensitivity of 96% and the mean specificity of 98.5%²⁸. The Ishihara's test showed good retest reliability²⁹. In this study we used Ishihara's test 38 plate edition which is generally considered to be the most efficient for screening red and green congenital defects. And only one ophthalmologist interpreted the results. The gold standard in color vision testing is the anomaloscope which was not used in our study because of unavailability.

Ethiopians have a much higher incidence of color blindness (4.2%) than other sub-Saharan population examined when atypical undiagnosed forms of color blindness are included as reported by Adam²⁰. Another study conducted by Zein²¹ in 954 boys and 1064 girls attending two schools in North-west Ethiopia in 1988 using the Ishihara 24 plate edition reported a total of 40 color blind (4.2%) among males and 2 (0.2%) among females. In this study there were 31(3.2%) deutan and 9 (0.9%) protan among males. Both female color blinds were deutan. This study reported prevalence of color blindness among female Ethiopian population for the first time.

According to our study the frequency of congenital color blindness in males including totally color blind subjects was found to be 4.2%, which is the same as the rates reported in the previous two studies^{20,21}. The prevalence rate of congenital red-green defect was 4.04% which is also nearly similar with other studies among Ethiopians. The commonest type of color vision defect was deutan with deutan/protan ratio of 5(30/6) which was higher than that reported by Zein²¹ of 3.4. This high ratio may be partially explained, because there were six unclassified cases of red-green defects which might have affected the proportion. On the basis of his limited and incomplete data on the frequency of deutan and protan genes, Adam²⁰ postulated that, analogous to Yemenite Jews, the frequency of protan genes among Ethiopians would be more common than deutan genes. However, the findings of this study do not confirm this postulate. In contrast to this, the usual deutan/protan ratio of 2.2 to 4.2 was reported in most other populations, including the Europeans, Far and Middle Easterners and Indians³⁰.

In this study, two cases of totally color blind individuals were identified for the first time among Ethiopians. Monochromacy, more commonly referred to as "total color blindness", is caused by the total absence of either 2 or 3 of the pigmented retinal cones, reducing vision to one dimension. This type of color vision defect is reported to occur very rarely and it is severe form associated with reduced vision especially if rod monochromatism. In this study we were not able to diagnose the specific type, however, considering the fact that both subjects had normal vision it is possible

to postulate that they might be classified under cone monochromatism.

Detection of color vision defect early in life of an individual is very important to make informed decision on future career. Early detection of color vision malfunction in children allows parents and teachers to make necessary adjustments to the teaching methods for appropriate learning. However this is not always possible in developing countries like Ethiopia with lack of awareness. Of the approximately 7% of male population with congenitally impaired color vision about 40% of that population appeared to be unaware of the defect prior to leaving secondary school²⁸. Ganley and Lian³¹ reported that 18% of the university students screened for color vision defect did not know their color vision status and among confirmed cases of color blind 33.3% reported that they are not color blind. However in our study among 44 cases of color defective individuals only one case had undergone eye examination at least once in his life and the majority of children did not have a chance of eye examination at all. This study proved that all the subjects involved in this study were not aware of their status of color vision. But only two cases (0.2%) reported to have a subjective difficulty in identifying different colors and one of these participants was diagnosed to have total color blindness. The remaining cases (99.8%) did not know their color vision status. It is unfortunate that a high proportion of school children are unaware of their color vision deficiency which will negatively affect their future career.

In this study anomaloscope, the gold standard in color vision test was not used to confirm the diagnosis, further classify the types and determine the severity of CVD. The instrument was not available in our set up. Of course the Ishihara test with 38 plate edition has been reported to have high sensitivity and specificity in identifying red-green color vision defects. Although we have tried to screen participants under bright natural day light with all possible consideration of maintaining good illumination, not using the artificial light source with fairly constant illumination was another limitation of this study.

CONCLUSION

The prevalence of congenital color blindness among school children in Abeshge district of Gurage zone was 4.2% among males which is similar to the previous two studies among Ethiopians. Cases of total color blindness among Ethiopians reported for the first time. The majority of school children were not aware of their problem. Early screening of school children for color vision defect is highly recommended, so that the affected individuals would be able to adjust their future career. We also recommend further studies to be done to determine the magnitude and severity of color vision defects using anomaloscope.

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