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Original Article

Identification of colorblindness among selected primary school children in Hararghe Region, Eastern Ethiopia

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ABSTRACT

Background: Color vision deficiency or colorblindness, is the inability or reduced ability to distinguish different color spectra, particularly, red & green under normal lighting conditions with unaided eye. Red-green colorblindness is heritable genetic disorder and most prevalent type of color vision deficiency and its incidence varies between different ethnicity and sex and shows disparity in different parts/regions of the world.

Objectives: This study was conducted to find out the prevalence of colorblindness in Eastern part of Ethiopia and identify its distribution among Harari, Oromo and Ethio-Somali ethnic groups.

Methods: A total of 2103 (1043 male & 1060 female) students belonging to the three ethnic groups were randomly selected from nine selected primary schools and were screened for color vision deficiency by using Ishihara's tests for color vision deficiency and the data analysis was carried out with SPSS version 16.0.

Results: Among those screened for color vision deficiency, 33 of them (1.6%) were diagnosed with colorblindness out of which 31 were male and 2 were female. Out of this; 15, 7 and 11 were from Harari, Oromo and Somali ethnicity respectively. The highest incidence was observed among Harari males (4.2%) and no color vision deficiency was recorded among Oromo females. Deuteronomally was the most frequent color vision defect detected (16, 48.5%) and protanopia was the least detected color vision deficiency with 4 cases (12.1%).

Conclusion: Results from this study show similar prevalence rate with previously reported study in Ethiopia for Harari ethnic group but lower prevalence rates for Somali and Oromo ethnic groups. Early detection of colorblindness is important for children to select their future profession and take necessary precautions in their everyday activities. Families and other concerned bodies should also take the case of children with colorblindness into consideration while dealing with them.

1. Introduction

Colorblindness, also known as color vision deficiency (CVD) is inability or reduced ability to clearly differentiate different colors under normal lighting conditions. Human with no such defect can clearly distinguish different spectra of colors and are trichromatic, which is a mixture of red, green and blue colors.[1] Mostly color vision defects are inherited and permanent with no treatment to cure it so far. Nevertheless, its diagnosis at early stage in life is imperative in understanding limitations that may occur as a result and making necessary adjustment to some daily activities and career goals.[2] Red-green color defect (Protan and Deuteran) is the most prevalent type of colorblindness in overall populations across the world.[3]

Red-green color vision deficiency is a recessive X-linked genetically inherited congenital trait which mostly affects males. About 8% of females are carriers of the gene and transfer it to their offsprings.[4,5] The chromosome on which the genes responsible for protan and deuteran CVD are found on the long arm of the X – chromosome at different loci within the Xq28 band.[6] However, the gene that codes for the blue pigment is located on chromosome number seven.[7] Congenital colorblindness was first described by John Dalton in 1978 who himself was affected with the defect.[8]

Color vision deficiency is one of widely investigated genetic marker in the study of human variation and it is an essential

Abbreviations: CVD, color vision deficiency; CCB, congenital colorblindness.

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genetic trait in the area of human genetics. It has been pointed out that natural selection functions more intensively on colorblindness among many primitive populations of the world.[9] In a normal individual or trichromat, three wavelengths are required to match wavelength of a light. Abnormal (red-green) or dichromacy occurs when there are only two cones operate in distinguishing the wavelength of a light. More severe type of color vision defects, monochromacy and achromacy only has a single wavelength to match the reference color.[10]

Colorblindness is hereditary defect and can be grouped as monochromacy, dichromacy and trichromacy. Monochromacy is the total colorblindness that is very rare and it is manifested when two or all three of the cone pigments are not functioning or missing. However, dichromacy includes protanopia which is caused as a result of the complete absence of red retinal color receptors, and deuteranopia which results from the absence of green retinal color receptors and tritanopia which occurs when blue retinal photoreceptors are completely absent. In abberant trichromacy one of the three retinal photoreceptors is altered in its spectral sensitivity and results in protanomaly, deuteranomaly and tritanomaly in which the spectral specificity of the red, green and blue or yellow receptors is not functioning well. Achromatopsia is the most severe and rarest type of color vision impairment which occurs when an individual is unable to see any color due to absence of all the three retinal photoreceptors.[11] The most common type of CVD is termed as Red-green CVD, which is also known as Daltonism.[10]

Red-green CVD is divided into two main categories, namely protan and deuteran. The protan impairments are distinguished by an absence or anomaly of L-cone function, while deuteran defects are distinguished by an absence or abnormality of M-cone function.[12] Deuteranopia, green CB) or protanopia, red CB occurs as a result of absence of photo pigment of the green or red cone. However, when the photo pigment response of the green cones is shifted towards that of the red cones it becomes deuteranomaly which is mild green colorblindness and when the photo pigment response of the red cone is shifted towards that of green cone it becomes protanomaly which is mild red colorblindness.[13]

Red-green CVD is by far the most common type of colorblindness. This is mainly due to sequences in the DNA of the red and green receptor genes which are very similar, that it is easy for mistakes/mutations to occur during gametogenesis, as genetic material replicates and exchange between chromosomes occur.[14]

Being a genetically heritable defect, the prevalence of colorblindness, shows disparity between different races in different parts of the world inhabited by people of different ethnicity.[15] For instance, the prevalence of congenital colorblindness in Caucasian is about 8% in males and 0.4% in females, which results either from alterations or absence in the absorption spectrum of photo pigment.[16] Prevalence of CVD in Asian males is relatively lower with about 4.9% and its prevalence in females is about 0.6%; African males have an average prevalence of 4% and 0.3% in females.[17,18] Previous studies conducted in central part of Ethiopia revealed 4.2% prevalence among males and 0.2% among females.[19] There is no report of such study undertaken about the prevalence of colorblindness in Eastern part of Ethiopia. Therefore, the present study was conducted to find out the prevalence of colorblindness and its distribution among students of different ethnic groups in selected schools in Eastern Ethiopia.

2. Methods

The study was conducted in nine randomly selected primary schools in Eastern Ethiopia. Block randomization technique was applied to select three schools from each of the following areas: Harari region, Dire Dawa city administration, and Eastern Hararghe zone of Oromia regional state targeting Harari, Ethio-Somali and Oromo ethnic groups, respectively. Informed consent letters were obtained from legal guardians and principals of all schools after explanation about the procedures of the test. Both male and female students (in equal proportion) from grades 3 to 8 who were able to read numbers were the study population. The age of the participants ranges from 9 to 18 years old. Further, all the selected students were subjected to test of Snellen chart to test the visual acuity at 6 m distance and students with history of eye treatment were excluded. Participation was voluntarily and the objectives and benefits of the study were explained to the participants before administering the test. Red-green CVD test was conducted according to instructions from Ishihara's tests for color deficiency 14 plates latest edition.[20]

Demographic data including age, sex, grade, address, history of eye disorder, eye injury, use of medications (e.g. sildenafil, digoxin, ethambutol), and awareness about their color vision defect was gathered through interview survey. In addition, ethnicity of the students was recorded through interview and those with mixed ethnicity were not included during data analysis. The collected information was entered into SPSS 16.0 for analysis. The Chi-square test was used to test differences in prevalence between ethnic groups at 95% confidence level.

3. Results

A total of 2103 students with average age of 12.73 years were screened for CVD from nine randomly selected schools from Eastern Ethiopia. Among them, 1043 (49.6%) were males and 1060 (50.4%) were females. These participants were from three ethnic groups; Harari 692 (32.9%), Oromo 714 (34.0%) and Ethio-Somali 697 (33.1%). Those subjects with history of eye ailments were excluded from the study and only those with normal vision were utilized for data analysis. Those considered as normal vision have a visual acuity of 6/6 without eye glasses, contact lenses or corrective surgery. All of the students diagnosed were unaware of their color vision status and appropriate counseling was provided to those who were diagnosed with CVD by a physician. The overall prevalence of CVD detected was 33 (1.6%) and the total prevalence among males and females was 31 (3.0%) and 2 (0.2%), respectively.

From those who were diagnosed with CB, 15 (45.5%) were from Harari ethnicity, 11 (33.3%) and 7 (21.2%) were from Ethio-Somali and Oromo ethnicity, respectively.

The highest rate of incidence was observed among Harari male (4.2%) and no CVD was recorded among Oromo females. The incidence of color vision defect among Oromo and Ethio-Somali male were 1.9% and 3%, respectively. The prevalence of color vision defect among Harari and Ethio-Somali female was 0.3% (Table 1).

Total of 33 students were diagnosed with CVD from the three ethnic groups. Among them, 16 (48.5%) were diagnosed with deuteronomaly (mild green color blindness) out of which 15 were male. The prevalence of deuteranopia (green colorblindness) among those detected with CVD was 21.2% (7) all of them were males. The incidence of protanomaly (mild red colorblindness) was 18.4% (6) none of them were females. Those detected with protanopia (red colorblindness) were 4 (12.1%) out of which 1 was female (Fig. 1).

The highest phenotypic frequency of type of CVD detected among the three ethnic groups was deuteranomalic which was detected in Harari ethnic groups. This defect was also the highest type of CVD diagnosed in both Oromo and Somali ethnicity. In Harari ethnic group, deuteranopic CVD was the second most frequent defect detected, and protanomalic and protanopic defects show the same prevalence rate. In Oromo and Ethio-Somali ethnic groups, deuteranopic and protanomalic CVDs show similar incidence rates.

Table 1
Frequency of CVD among three ethnic groups of Eastern Ethiopia.

Ethnicity				Sex		
				Male	Female	Total
Harari	Color vision test	Normal	Total	323	354	677
		Deficient	Total (%)	14 (4.2%)	1 (0.3%)	15 (2.2%)
	Total		Total	337	355	692
Oromo	Color vision test	Normal	Total	363	344	707
		Deficient	Total (%)	7 (1.9%)	0 (0.0%)	7 (1.0%)
	Total			370	344	714
Ethio_Somali	Color vision test	Normal	Total	326	360	686
		Deficient	Total (%)	10 (3.0%)	1 (0.3%)	11 (1.6%)
	Total			336	361	697

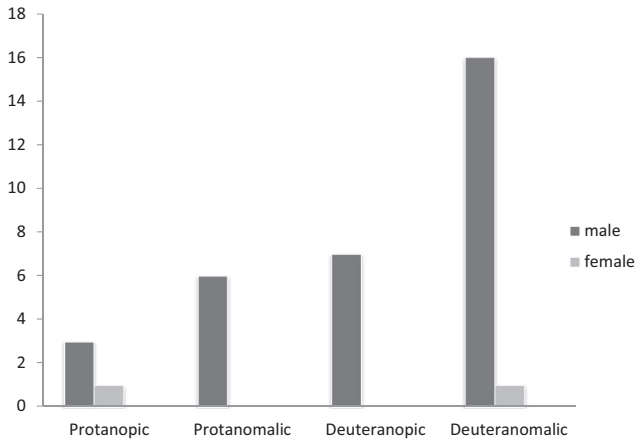

Fig. 1. Overall prevalence of types of color vision defects detected.

The incidence of protanopic CVD detected among Ethio-Somali ethnicity is the same as protanomalic CVD, however there was no protanopic CVD detected in Oromo Ethnicity (Table 2).

4. Discussion

Red-green color vision deficiency was determined by Ishihara plates which is a most commonly used and efficient tool for detection of CVD.[16,21] The overall CVD prevalence rate identified for males in this study is lower than previously reported prevalence rate (4.2%) for males in central Ethiopia.[19,22] However, the incidence rate for males of Harari ethnicity is the same with previously reported study in central Ethiopia (Abshenge district). This similarity is probably because of the low genetic pool (relatively smaller population size) of both Harari and Gurage ethnicity (Gurages' are the main inhabitants of Abshenge district) and the effect of consanguineous marriages in both populations.

The prevalence rate for Oromo males and Ethio-Somali males has not been studied before but shown lower incidence rate, possible explanation for this could be due to the high genetic pool of both of the populations. Oromo constitute the largest ethnicity in Ethiopia and Ethio-Somali are the third largest ethnicity. In addition, consanguineous marriage is less common in Oromo culture. The incidence rate reported for Oromo males is somehow similar to the rates reported in sub-Saharan African countries like Uganda and Congo as reviewed by Niroula and Saha.[23]

Overall, the incidence rate observed for males in this study is higher than Sub-saharan Africa and lower than that of North Africa as reviewed by Mulusew and Yilikal.[19] The main reason for this might be due to culture of consanguineous marriages in many parts of North Africa.[24]

The prevalence of CCB for females is generally low and the finding of this study is no exception. The result from this study is similar with previously reported studies done in Ethiopia (0.2%), for Harari and Ethio-Somali females.[19,22] However, there is no CCB detected among Oromo females. Even though low frequency of CVD for females is common in many parts of the world, no incidence rate was also reported from some parts of the world for some ethnic groups.[17,25] This is the first study of CCB done in Ethiopia by taking ethnicity into consideration; therefore it is not possible to tell if other ethnicities have the same or different prevalence rate with the result of this study. The no incidence rate in females Oromo ethnicity is probably attributed to lower incidence rate in males when compared to Harari and Ethio-Somali ethnic groups.

The most frequent type of CVD detected in this study is deuteranomalic (48.5%), this is lower than the incidence rate reported by Mulusew and Yilikal (68.2%). The disparity is probably due to some unclassified cases in the previously mentioned study that might have increased the ratio in formerly conducted study. Similarly, deuteranomaly is the most frequent type of red-green color defect observed in various studies in many parts of the world.[10,17]

The occurrence of deuteranopia and protanomally show more or less the same incidence rate in all the three ethnic groups in this study. However, the type of CVD that showed the lowest rate of

Table 2
Phenotypic frequency of types of CVD among the three ethnic groups.

			Type_of_color_vision_defect				Total
			Protanopic	Protanomalic	Deuteranopic	Deuteranomalic	
Ethnicity	Harari	Total CVD	2	2	3	8	15
		% of CVD	13.3%	13.3%	20.0%	53.3%	100.0%
	Oromo	Total CVD	0	2	2	3	7
		% of CVD	0.0%	28.6%	28.6%	42.9%	100.0%
	Ethio_Somali	Total CVD	2	2	2	5	11
		% of CVD	18.2%	18.2%	18.2%	45.5%	100.0%
Total		Total CVD	4	6	7	16	33
		% of CVD	12.1%	18.2%	21.2%	48.5%	100.0%

incidence was protanopia. The same prevalence patterns were observed in various studies conducted in the past in many parts of the world.[26,27]

The types of CVD detected among females in this study were protanopia and deuteranomally. Both cases were detected only once in Ethio-Somali and Harari ethnic groups, respectively. There is no conclusive data that shows any association of different types red-green color vision defects with sex.[28,29]

5. Conclusion and recommendation

Diagnosis of colorblindness at early stage in life is imperative for students in setting the appropriate carrier goals and to take necessary precautions in daily activities. In this study, all of the students diagnosed have no information about CVD and all of them were unaware of their status. During the experimental works, the students were briefed about CVD and the consequences it might have on career and day to day activities. Those with such defect were seriously advised to reconsider some of their professional ambitions that may require CVD test (e.g. pilot, paint industry, artist) and to take necessary precautions in daily activities (e.g. traffic lights, gardening, outfit selection).

Moreover, on the course of this study, the teachers were advised to take into consideration the case of colorblind children since they may rely on utilizing colors while teaching and examination. The parents of the students with CVD were also notified and advised on how to help the student in daily activities. However, the status of the student with CVD was kept confidential or not disclosed to their classmates to avoid probable mocking that may arise from their classmates. In fact, all of the students involved in this study were instructed that CVD is not considered as any kind of impairment and an individual with CVD can live normal life with few adjustments.

Fortunately, the overall prevalence of CVD detected among the three ethnic groups studied in Eastern part of Ethiopia is relatively low when compared to previously reported results and many Western and Asian countries. Nevertheless, we recommended every child should be diagnosed as early as possible, and the parents and teachers work in harmony to help the child with CVD.

Overall, this study is the first to report the prevalence of CVD in eastern part of Ethiopia and also it is the first study of its kind conducted in Ethiopia by taking ethnicity into consideration. Thus, it can be used as a reference point for future studies that may be conducted in other parts of Ethiopia in different ethnic groups.

Conflict of interest

The authors declare no conflict of interest.

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References

1. Curcio CA, Sloan KR, Kalina RE, Hendrickson AE. Human photoreceptor topography. *J Comp Neurol*. 1990;292:497–523.
2. Melamud A, Hagstrom S, Traboulsi EL. Color vision testing. *Ophthal Genet*. 2004;25:159–187.
3. Citrik M, Acaroglu G, Batman C, Zilelioglu O. Congenital color blindness in young Turkish men. *Ophthal Epidemiol*. 2005;12:133–137.
4. Guyton AC, Hall JE. Textbook of medical physiology. 11th ed. Elsevier Publication; 2005.
5. Neitz J, Neitz M. The genetics of normal and defective color vision. *Vis Res*.. 2011;51:633–651.
6. Deeb SS, Kohl S. Genetics of color vision deficiencies. *Dev Ophthalmol*. 2003;37:170–187.
7. Deeb SS. Molecular genetics of color vision deficiencies. *Clin Exp Optom*. 2004;87:224–229.
8. Hunt DM, Dulai KS, Bowmaker JK, Mollon JD. The chemistry of John Dalton's color blindness. *Science*. 1995;267(5200):984–988.
9. Roberts DF. Red green color blindness in Niger Delta. *Eugen Quart*. 1967;14:7–13.
10. Adam A, Mwesigye E, Tabani E. Ugandan colorblinds revisited. *Am J Phys Anthrop*. 1970;32:59–64.
11. Tortora GJ, Grabowski SR. *Principles of anatomy and physiology*. New York: Harper Collins; 1996.
12. McClements M, Davies WI, Michaelides M. X-linked cone dystrophy and color vision deficiency arising from a missense mutation in a hybrid L/M cone opsin gene. *Vision Res*. 2013;80:41–50.
13. Cole BL. Assessment of inherited colour vision defects in clinical practice. *Clin Exp Optom*. 2007;90:157–175.
14. Deeb SS. Genetics of variation in human color vision and the retinal cone mosaic. *Curr Opin Genet Dev*. 2006;16:301–307.
15. Rahman SA, Singh PN, Nanda PK. Comparison of the incidence of color blindness between sections of Libyan and Indian Populations. *Indian J Phsiol Pharmacol*. 1998;42:271–275.
16. Birch J. Identification of red-green colour deficiency: sensitivity of the Ishihara and American Optical Company (Hard, Rand and Rittler) pseudo-isochromatic plates to identify slight anomalous trichromatism. *Ophthal Physiol Opt*. 2010;30:667–671.
17. Shah A, Ruqaiya H, Mohd F, Mohammad A. Prevalence of red-green color vision defects among Muslim males and females of Manipur, India. *Iran J Publ Health*. 2013;42:16–24.
18. Qian YS, Chu RY, He JC, Sun XH, Zhou XT, Zhao NQ. Incidence of myopia in high school students with and without red-green color vision deficiency. *Invest Ophthalmol Vis Sci*. 2009;50:1598–1605.
19. Mulusew A, Yilikal A. Prevalence of congenital color vision defects among school children in five schools of Abeshge District, Central Ethiopia. J Ophthalmol Eastern Central Southern Africa. <http://www.coecsa.org/ojs2.4.2/index.php/JOECSA/article/download/65/pdf_24>; 2013 [accessed 22 February 2016].
20. Ishihara S. Test for color blindness. 14 Plates Latest Edition. Tokyo, Japan: Kanehara & Co., Ltd.; 1960.
21. Birch J. Efficiency of Ishihara test for identifying red- green color deficiency. *Ophthal Physiol Opt*. 1997;17:403–408.
22. Zein ZA. Gene frequency and type of color blindness in Ethiopians. *Ethiop Med J*. 1990;28:73–75.
23. Niroula DR, Saha GC. The Incidence of Color Blindness among some school children of Pokhara, Western Nepal. *Nepal Med Coll J*. 2010;12:48–50.
24. Wagida AA, Meriem K, Kari H. Consanguinity and genetic diseases in North Africa and immigirants to Europe. *Eur J Pub Health*. 2014;24:57–63.
25. Grosvenor T. The incidence of red-green colour deficiency in New Zealand's Maoris and "Islanders". *Am J Optom Arch Am Acad Optom*. 1970;6:445–450.
26. Sunderland E, Rosa PJ. The incidence of red- green color blindness in the population of Tripolitania, cyreniaca, & Fezzan in Libia and of the Kikuyu, Kamba, Taita, Taveta & Luo tribes of Kenya. *Am J Phys Anthrop*. 1976;44:151–156.
27. Oriowo OM, Alotaibi AZ. Color vision screening among Saudi Arabian children. *S Afr Optom*. 2008;67:56–61.
28. Mussaed A. Prevalence of congenital color vision defects in Saudi females of Arab origin. *Optometry*. 2011;82:543–548.
29. Spalding JA. Colour vision deficiency in the medical profession. *Br J Gen Pract*. 1999;49:469–475.