

Prevalence and Awareness of Congenital Color Vision Deficiency during Pre-Enrollment Screening of Medical Students of Ain Shams University in Egypt: A Cross-sectional Study

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Abstract

Purpose: To screen for congenital color vision deficiency (CCVD) among newly admitted first-year medical students of Ain Shams University presenting for pre-enrollment health examination and to detect their awareness about deficiency if present.

Patients and Methods: A cross-sectional study design was adopted for 304 medical students (116 males and 188 females) before the first year in Ain Shams University. All of them underwent comprehensive eye examination and color vision testing using Ishihara pseudoisochromatic plates for screening of CCVD. All color deficient students were asked about their family history, awareness of their anomalous vision and its possible impact on future medical specialty.

Results: The overall prevalence of CCVD was 2.96%. It was found to be more in males (6.9%) than females (0.5%). Only 11% of the students having CCVD were aware of deficiency and 0% aware of its impact on the future medical specialty.

Conclusion: The male prevalence among medical students is close to highest reported in previous studies and awareness is low. Incorporation of CCVD screening in pre-enrollment examination for medical schools is essential to prevent struggle in education and future specialty selection.

Keywords: Color Vision Deficiency; Medical Specialty; Medical Students

Introduction

Normal color vision is trichromatic and 3 classes of photo pigments (opsin proteins) differ in their spectral sensitivities and are controlled by genes. Red and green opsins have 96% similarity, while they have only a 46% similarity with the blue opsin. Congenital color vision deficiency (CCVD) is inherited nonpathological, permeant, bilateral and stationary. Acquired forms of are rare and caused by pathology as macular degenerations or optic neuropathies [1].

The red and green opsin genes (OPN1LW and OPN1MW) are located on the X chromosome long arm at Xq28 band. Red-green defects (protan and deutan) are x-linked recessive and affects variably 8% of males and 0.4% of females. The blue pigment gene (OPN1SW) is located on autosome 7q32 band and is transmitted with incomplete penetrance. Blue-yellow CCVD (tritan) are autosomal dominant, affect both sexes equally and occurs in less than 0.01% [2].

Anomalous trichromatic CCVD have 3 photo pigments including abnormal one. Trichromacy is more common and is further subdivided into tritanomaly protanomaly, and deuteranomaly with the latest being the most common type of CCVD. Dichromatic deutanope and protanope have 2, instead of the 3 photo pigments [1,2].

Total CCVD is due to either rod monochromacy (RM) which is 1/30000 [3] or Blue cone monochromacy (BCM) which is caused by mutations in red-green genes, is X-linked affecting males more than females and is affecting 0.001% [4]. Awareness of CCVD was variable in same study subsamples [5].

Earliest authority to report results of color vision examination in first year health service students in university of Belfat [6]. Some physicians described their self-experience with CCVD [7,8]. Spalding [9], the leading authority reporting color vision deficiencies in medicine, himself a retired deuteranopic general practitioner. He stated that we in the medical profession do less for our colleagues with CCVD than other occupations and stated missing the pallor of anemia, cyanosis and traces of blood.

He reported learning difficulties in microscopy (histology, bacteria and blood), chemistry colors, clinical colors and teaching aids [10] as well as difficulties in detection of pallor, jaundice, and red rashes in photographs [11]. Later he reported that CCVD doctors compared to normal matched blood glucose sticks to a wider range with less confidence [12] and detected with more difficulty colored signs as blood in vomits and stools, skin rash, stained bacilli in photographs [13]. Between 40 practitioners percentage of difficulties in different specialties are shown in figure 1 [14].

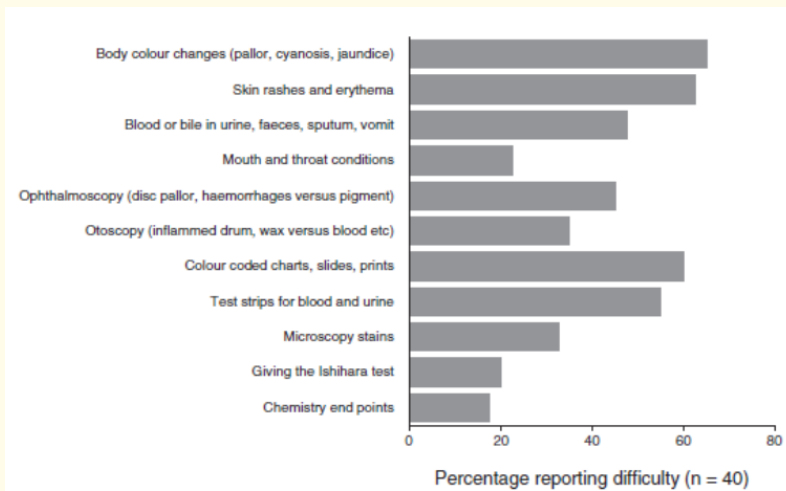


Figure 1: Percentage of practitioners with CCVD having difficulties in different medical tasks.

The standard test in detection of CCVD is the anomaloscope, but it is extensive and requires complex settings. Ishihara is a simple test and has 96% sensitivity and 100% specificity. Ishihara ability is not only affected by color vision but also visual acuity [15]. Farnsworth hue-discrimination tests have a 100% sensitivity and specificity and are needed for classification and grading of CCVD [16].

Physicians with CCVD are unaware of the problem and those who are aware report strategies to overcome [8]. Prevalence of CCVD was reported by Patel., *et al.* [17] among medical students in India being 1.8%, Pramanik., *et al.* [18] among health science students in Nepal being 5.58% and by Dohvoma., *et al.* [19] in Cameroon among biomedical students as 1.6%. To our knowledge, there is a paucity of local

literature on CCVD among Egyptians especially in the medical field. The frequency of color blindness was reported to be 5% in upper Egypt in the start of the past century [20]. Computer-based testing of CCVD was performed and included medical students as a subsample and found CCVD in 8.75% of males and 0% of females [21]. Prevalence of CCVD among dentistry students in Alexandria, Egypt was 4.5% of males and none of females [22]. In Egypt, CCVD testing is not a part of the pre-enrollment assessment of medical students.

Aim of the Study

The aim of the present study was to screen for CCVD during pre-enrollment mandatory examination in medical students at Ain Shams University, Cairo and to evaluate the state of awareness regarding their anomaly in order to raise awareness to guide their choice of future specialty.

Subjects and Methods

A cross-sectional and descriptive study design was adopted between October 2015 to March 2016 during routine pre-enrollment examination. They included first academic year students at Ain Shams University, faculty of medicine. A detailed history was taken from students, including medications that are known to be toxic for the retina or the optic nerve, past ocular surgery and family history of hereditary or CCVD. Autorefractometry was performed and refractive error (RE) correction monocular to get best corrected visual acuity (BCVA) at distance (6 meters). All students underwent comprehensive eye examination including ocular tension measurement by Goldmann tonometer, ocular motility, cover-uncover test, alternate cover tests, slit lamp examination for the anterior segment and posterior segment examination. Exclusion criteria are BCVA less than 0.5 Decimal notations, known toxic drugs and any ocular surgery or disease.

The pseudoisochromatic plates of Ishihara (38 plates edition full version) were used binocularly. They were displayed in daylight with plates held 75 cm from the subject and tilted to be perpendicular to the line of vision. Students wore correcting spectacles during testing. Each plate is allowed for 3 seconds to be recognized. Screening version of the test, which is composed of 4 sets of preselected six plates (No. 1; one of Nos. 2, 3, 4, 5; one of Nos. 6, 7, 8, 9; one of Nos. 10, 11, 12, 13; one of Nos. 14, 15, 16, 17; and one of Nos. 18, 19, 20, 21). If a student missed plate 1, the test was discontinued. If a student missed 1 of the subsequent 5 plates, was examined by the detailed method composed of 24 plates at two stages (plates 2 - 21 for red-green defects, and plates 22 - 25 for further classification). If 13 or fewer plates were read normally it was considered CCVD, and if 17 or more plates were read normally, color vision was considered normal. It is beyond the scope of this study to measure severity of CCVD and to sub classify them.

All CCVD students were asked about family history and if they underwent previous color vision testing. They were asked if they had visual difficulties and if they were aware of their anomalous vision and its possible impact on future medical specialty.

Ethical considerations

The present study protocol was reviewed and approved by the Research Ethical Committee of the Faculty of Medicine of Ain Shams University which functions as per the guidelines of the Helsinki declaration. Medical students were informed and consenting that data will be used for research purpose and will be maintained confidential for protecting career and privacy of all participants.

Statistical method

Data were reviewed for completeness and consistency. Double data entry on SPSS program version 20 was performed. Quantitative data were summarized by the mean and standard deviation, while qualitative data were summarized by frequencies and percentages. The odds ratio (OR) and 95% confidence interval (CI) for comparison of rates of CCVD in gender were also calculated. The chi square test was used in the analysis. A p value of less than 0.05 was considered statistically significant.

Results

Among 304 Egyptian students were enrolled including 116 males (38.2%) and 188 females (61.8%). The mean age was 18.60 ± 0.85 years with range of 17 - 22 years. The mean UCVA Log MAR was 0.44 ± 0.49 (Snellen acuity 20/55) in the right eye and 0.43 ± 0.49 (Snellen acuity 20/53) in the left eye. The mean BCVA Log MAR was 0.01 ± 0.05 in the right eye and 0.02 ± 0.08 in the left eye (Snellen acuity 20/20). The mean SE in right eye was -2.09 ± 1.83 and left eye was -2.18 ± 1.93 .

The prevalence of CCVD using screening and detailed Ishihara methods was among all students 9/304 (3.0%), among male students 8/116 (6.9%) and among female students (0.5%).

Red-green CCVD prevalence among all students was 5/304 (1.6%). It varied between males 4/116 (8.5%) and females 1/188 (0.5%). Other forms of CCVD that did not fit plates of red-green defects were seen in 3/304 students (1%). These were in males 3/116 (2.6%) and 0% in females.

There was one male student who had complete CCVD 1/304 (0.3%). He is described as cone monochromacy (CM) because he had normal visual acuity and responded only to the first plate of Ishihara (Table 1).

Type of CCVD	Male (116)		CI* 95%	Female (188)		CI* 95%	P value	Test used
	No	%		No	%			
All	8/116	6.9%	3.0 - 13.1	1/188	0.5%	0.01 - 2.9	0.001	Chi square test
Red-green CCVD	4/116	3.4%	0.9 - 8.5	1/188	0.5%	0.01 - 2.9	0.02	
Undetermined CCVD	3/116	2.6%	0.5 - 7.3	0/188	0.00%	---	0.002	
Monochromacy	1/116	0.9%	0.02 - 4.7	0/188	0.00%	---	0.8	

Table 1: Distribution of CCVD by Ishihara test according to sex.

Note: *CI (Confidence Interval).

None of the CCVD students including CM were aware of visual difficulties, and none had ever taken a color testing before. Only one student (11%) was aware of his anomaly; however he was unaware of any future precautions in specialty selection.

Discussion

Most of CCVD disrupt color perception but usually do not affect the sharpness of vision. Mostly people consider normal visual acuity of 20/20 as normal visual function. It is difficult for them to consider value of preemployment color vision screening. Color vision is important in some medical specialties and doctors with CCVD may struggle to practice with risk in patient safety from possible diagnostic errors [6-14]. The study focused on medical students in the pre-enrollment stage for awareness detection. Due to relative rarity of tritan and less impact on clinical practice, the main objective of this study was to identify prevalence of red green CCVD. Red-green CCVD affects 1 in 12 males and 1 in 200 females while blue-yellow CCVD affects males and females equally and occurs in fewer than 1 in 10,000 people worldwide [1,2]. Tritan may have less prominent effect on clinical practice than dutan-protan as was shown in interpretation in blood glucose tests where normal and tritan do the same while dutan-protan were unable to use interpret test [12].

The prevalence of CCVD varies according to race and geographic areas [23-36] (Table 2) although Ishihara test was used for screening in almost all. The variability was reported by same researcher same continent due to different countries [19,26] and in same country due to different ethnic groups [28,29] because of genetic nature of CCVD.

Place of study	Population number M/F	Ethnic group	Age (years)	Prevalence of CCVD %		Test	Reference
				M	F		
Saudi Arabia	410	Arab	11-18	2.93	-----	Ishihara and D15 test	Osuobeni [23]
Jordan	1200/218	Jordanian	18-27	8.72	0.33	Ishihara test	Al aqtum [24]
Iran	169/449	Persian	25-55	2.2%	0.2%	Ishihara test	Dragahi [25]
Cameroon	155/148	Cameroonian	18-22	3.3	0.00	Ishihara test and Roth	Dohvoma [19]
Ethiopia	2833/1171	Ethiopian	18-47	3.75	0.68	Ishihara test	Mitiku [26]
Italy	3285	Caucasian	13-20	6.10	-----	Ishihara test, F M test and D15	Malaspina [27]
Denmark	173/186	Danish	15-41	8.67	0.54	Ishihara test	Norn [28]
Greenland	290/250	Inuit	15-41	1.0	0.4	Ishihara test	Norn [28]
New Zealand	1432/1033	Caucasians	School age	6.50	0.00	Ishihara test	Grosvenor [29]
		Polynesians		2.60	0.00	Ishihara test	Grosvenor [29]
Spain	174/218	Basques	15-25	4.02	0.46	Ishihara test	Rebato [30]
Britain	175/118	Manx	11-18	4.0	0.85	Ishihara test	Mitchell [31]
Britain	540/685	Cumbrian	11-18	5.0	0.29	Ishihara test	Mitchell [31]
Hungary	33876/6869	Hungarian	17-18	3.28	0.42	Ishihara test and anomaloscope	Pap., <i>et al.</i> [32]
Korea	4678/4760	Korean	School age	5.90	0.44	HRR plates	Kim., <i>et al.</i> [33]
India	654/292	Indian	17-19	3.69	1.04	Ishihara test	Panat and Kulkarni [34]
China	1567/2166	Chinese (Xinjiang)	15-18	3.69	0.69	Ishihara test and FM 100 hue test	Qiant [35]
United kingdom	4351/4491	British	17-33	6.7	1.06	Ishihara test	Cumberland [36]
USA	242/101	N/A	University students	7.8	0.00	Doverine pseudo-isochromatic	Davidson [37]
India	185/315	Indian	18-26	1.6	0.2	Ishihara test and FM100 hue test	Patel., <i>et al.</i> [17]
Nepal	215	Nepal	19-26	5.8	00	Ishihara test	Pramanik [18]
Cameroon	155/148	Cameroonian	18-22	3.3	0.00	Ishihara test and Roth	Dohvoma [19]

Table 2: CCVD in previous studies of different ethnic groups.
M: Males; F: Females; N/A: Not Available.

Comparing total prevalence of CCVD in this study to other studies on medical students [17-19,26] we found that our prevalence (3%) was similar only to Mitiku., *et al.* [26] although it included nonmedical personnel as well. This study prevalence in males was 6.9% similar only to study on medical students in Nepal [18] (5.8%) and different from others (1.6% [17], 3.319, 3.7526). It was like results in Caucasian nonmedical males in Italy (6.1%) [27], New Zealand (6.5%) [29] and UK (6.7%) [36]. Higher prevalence in nonmedical males were reported in Jordan (8.72%) [24], Iran (8.18%) [25], Denmark (8.67%) [28] and the USA (7.8%) [37]. The differences could be explained by the difference in ethnic groups and the fact that green pigment genes are variable in number among normal individuals [38]. The true differences in the gene pool as reported difference between aborigines (1.9%) and white Australians (7.3%) in the same land [39].

Prevalence in males was higher in another study set in Egypt (8.75%) in which volunteer participants were asked for by announcement in university campus [21]. This is considered nonrandomization with tendency to get people with CCVD. Our prevalence in males was higher than another study in Alexandria, Egypt [22] (4.5%) in which Ishihara was performed by dentist and not by ophthalmologist. They used 14 Ishihara plates while we used 38 plates edition. Accordingly, there are hardly any literatures locally on CCVD testing and awareness especially in medical profession.

Our study prevalence in females was 0.5% similar only to study on medical students in Ethiopia [26] (0.68%) and different from others (0.2% [17], 0.018, 19). Other studies [21,22] did not find female CCVD in Egypt. Other studies [24,28,30,32,33,35] on nonmedical females found similar prevalence to our study although our study included more percent of female participants (61%). This was representative to ratio of females from official records of the faculty (58%). Rarity of studies [34,36] had higher female prevalence than our study and other studies [29,37] found zero prevalence in females. Generally, low female prevalence is explained by x linked recessive inheritance accounting for the pronounced gender difference in CCVD. One report among medical students found 2.4% in males and 4.48% in females [40]. They did not mention what version of Ishihara used and students were not examined by trained ophthalmologist.

In this study, the main CCVD was red-green affecting males by 3.4%. We described types of CCVD as undetermined (3.4% of males) by the Ishihara test. These forms were described in other studies variably in males (1.25% [21] and 0.3% [27]) in other studies. The determined red green and undetermined CCVD in this study is more prevalent in males (6.9%) indicating X linked recessive inheritance pattern. These CCVD is transmitted via females to males and significant percent of all females are carriers. These carriers could be protan or deutan heterozygous or compound heterozygous (double carrier) [41]. This study found a rare case of cone monochromacy with good vision and no photophobia and ability to identify plate 1 Ishihara. These criteria differentiate the students from RM [3] and BCM [4]. Cone monochromacy fitting these criteria are very rarely reported in literature [42,43].

This study found 10% aware of anomaly, 0% aware of CCVD possible visual difficulties and impact on future medical specialty. No one of participant underwent color vision testing in any educational stage. Awareness of CCVD was previously reported as 4% of middle school students, 16% of military men, 35% of the university students and none of the artistic teachers at the middle school were aware of difficulties [5]. In Spalding's report [9] about himself as a doctor with CCVD did not realize his problem until after 25 years in practice. We tried to raise awareness about CCVD among the affected pre-enrolled medical students and enlightened them on future career options. Early detection and awareness of CCVD can help medical students especially males for easy learning, development of strategies to overcome CCVD and for safe practice. Doctors with red green CCVD are better to avoid hematology (red cells, hemoglobin, purpura rash and anemia) histology (stains), bacteriology (Mycobacterium), ophthalmology (Kayser-Fleischer ring and retinal hemorrhages), cardiology (red graduations on the sphygmomanometer, ECG papers) and gastroenterology (types of bleeding and endoscopy) [44].

There is reported many difficulties in different specialties [14]. Rigby., *et al.* studied color vision among histopathologists and found CCVD with only 30% aware of the problem and inability to interpret variable range subtle stains [45]. In male histopathologists 11.4% with CCVD had reported difficulties in the identification of slides [46]. An optometrist with CCVD reported difficulty in differentiation between retinal hemorrhages from melanin pigments as well as judging the pallor of the optic nerve head [47].

In medical schools in United Kingdom screening for CVD performed in 16.7% and only 50% made variable adaptations to examinations for students with CVD. A clinician with CVD, especially if unaware could be life threatening if correct interpretations of pH test color of aspirate following nasogastric tube insertion [48]. Eleven patients died following incorrectly placed feeding tubes and check by measuring the pH of aspirate using pH indicator strips became mandatory safety measure [49].

Recommendations

- **Future career:** Medical students should be screened before first year of medical school by trained ophthalmologist and further tests should be used to know type and severity of CCVD. Specialized committee in each specialty for guiding choices and not to compromise safe practice.
- **Adaptation:** Reasonable changes should be made to CCVD students in education and examinations and not left to develop their own adapting mechanisms. Good observation conditions, especially lighting and better equipment can overcome the problem. Following the research update into technologies as special glasses is essential
- **Awareness:** Raising awareness for reduction of anxiety during learning. Admission to medical faculties can be regulated rather than blocked to remove prejudice against CCVD individuals. Color blindness should be considered nonscientific and not suitable.

Conclusion

Prevalence and awareness of CCVD in medical students are not different from general population. Failure to screen and address CCVD in childhood continues to the medical faculty stage. Raising awareness of medical students with CCVD may help them to go through education and future practice without struggling with in certain specialties.

Disclosure

No conflicts of interest for the authors.

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