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Prevalence of color vision deficiency in medical students at a Saudi University

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Abstract:

BACKGROUND: Color vision deficiency (CVD) affects approximately one in 12 men and one in 200 women in the world. It is considered a problem in the medical field since the color is often used as a sign in the practice of medicine, in observational assessment, diagnosis, and follow-up. These conditions make the appreciation of color essential in doctors' lives, thus we aimed at finding the prevalence and predictors of CVD in medical students.

MATERIALS AND METHODS: This cross-sectional study included 1115 medical students. A pretested questionnaire consisting of personal data, history of vision problems, familial color vision defect, eye surgery, bad trauma on the head or eyes, drugs taken or chemicals exposed to, other health problems, and whether sufficient amount of Vitamin A is taken was used. This was followed by the screening of the participants for CVD using the Ishihara 15-plates test.

RESULTS: A total of 1115 students participated in the study; 52.2% were females and the mean age of the participants was 21.7 years (±1.4). The prevalence of definitive CVD was found to be 2.1%; all of which comprised males. Eighty-seven percent of the affected participants were not aware of their color vision problem. A highly statistically significant association was found between history of vision problems and CVD status ($P < 0.008$). No association were found for nationality, marital status, family history of CVD, history of eye surgery, and eye trauma.

CONCLUSION: The percentage of CVD in the present study is lower than that reported by previous studies done in other countries. Many medical students with CVD remain unaware of their condition. Therefore, we recommend early screening of all school-age children, and proper counseling of medical students with definite CVD to take care of their own health and wellbeing.

Keywords:

Color blindness, color vision deficiency, Ishihara plates, medical students, Saudi Arabia, screening, X-linked recessive

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Introduction

Color vision deficiency (CVD), representing a group of conditions that disturbs perception of color, affects approximately one in 12 men and one in 200 women in the world.[1] The most common cause of CVD is the inheritance of the X-linked chromosome. It can also be acquired through such chronic illnesses that damage the retina, optic nerve, and the brain as diabetes mellitus, sickle cell anemia, and retinitis pigmentosa, or the use of some medications such as sildenafil, digoxin, ethambutol, furosemide, metronidazole, and some antimalarials.[1,2] CVD occurs when light-sensitive cells in the retina fail to respond appropriately to variations in wavelengths of light that enable people to see an array of colors.[3]

Several tools used to assess CVD in clinical practice are suitable for primary care physicians. Ishihara plates test, which detects protan and deutan defects, used for

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all new patients, as well as Richmond Hardy–Rand–Rittler (HRR) test, detects tritan defects is the ideal confirmatory test for the Ishihara test. Richmond HRR test is used to classify the severity into mild, medium, and strong. Other tests such as Medmont C-100 and the Farnsworth D15 test may be used if patients fail the Ishihara test as color vision is normal. They are all quickly performed and easily interpreted.[4]

The prevalence of CVD has been studied in different population groups around the world.[5-7] In Saudi Arabia, the CVD rate in females is reported as 0.4%.[8] In European Caucasian populations, it has been reported as 8% in male and 0.4% in female individuals and is between 4% and 6.5% in male subjects of Chinese and Japanese ethnicity.[9] Hence, CVD varies by race. However, few studies have calculated the prevalence of CVD in medical students even though it is an important problem that seems to be going unnoticed in the medical field.[10-12]

In general, people with CVD might encounter many challenges in their daily activities as well as in education. Certain subjects are problematic, which makes them less effective in their work than their color-normal peers. Medical doctors, in particular, may have difficulty in interpreting various physical signs during examination, and in identifying color slides and specimens.[13] CVD is still insufficiently explored. It is important for all health-care practitioners with CVD to be aware of their condition. Lack of awareness of one's condition could put the patient's safety at risk. Our aim was, therefore, to investigate the prevalence of CVD in Dammam medical students. This study is important and should be borne in mind when medical students and doctors with known CVD make decisions on their future specialties.

Materials and Methods

A quantitative cross-sectional study was conducted at Imam Abdulrahman bin Faisal University, Saudi Arabia. The data were collected between January and March 2020, prior to the COVID-19 lockdown. Ethical approval was obtained from the Institutional Review Board (IRB) vide letter No. IRB-UGS-2018-01-213 dated 10/04/2019, and informed written consent was taken from all participants after they were reassured that all data will be kept confidential.

The study had male and female medical students of all levels (from 2nd to 6th year). Those with glaucoma, retinal/optic nerve disease, significant cataract, diabetes, any other ocular or systemic disease which may lead to CVD, and those who took concomitant medications known to affect color perception were excluded from the study. The total number of both male and female medical students at the university was 1242. Of these, 1129 students completed the questionnaire, 14 were excluded leaving a total of 1115 students, and a response rate of 89.8%.

Students were asked to fill the questionnaire, and read the 15-plates on the Ishihara's chart. A self-administered precoded questionnaire of 15 questions in two sections had been designed on a pretested survey taken from a previous study conducted by Alharfi *et al*., 2016.[10] Part one: the personal data included age, gender, academic year, nationality, marital status, and any information on CVD. Part two: information on history including vision problems (refractive errors, nyctalopia, cataract, glaucoma, congenital color vision abnormalities, and others), familial color vision defect, eye surgery, bad trauma on the head or eyes, prescribed drugs (specifically digoxin, barbiturate, sildenafil, ethambutol, and chloroquine), other health problems (diabetes mellitus, sickle cell anemia, hypertension, and others), and whether or not sufficient amounts of Vitamin-A are taken. Regarding the Ishihara test, the participant was requested by a trained data collector to read 15 plates held 75 cm away from the participant at eye level under natural daylight conditions.

The Ishihara 15-plate test results are categorized into three groups. Students who scored 13 or more were considered normal, students scoring between 11 and 12 were considered to have CVD with slight changes (2%) or misdiagnosis, and a score of 10 or less was considered as deficient.[4,14,15] Descriptive analyses were obtained by counts and percentages, and potential associations were tested through the Pearson Chi-squared test. The 0.05 cutoff point for the P value was used to assess significance. Analyses were performed in Stata version 15.[16]

Results

Of a total of 1115 students who participated in this study, the prevalence of definitive CVD was 2.1%, as shown in Figure 1, 87% of who were unaware of their color vision problem. Females accounted for 52.2% of the total sample and the mean age of the participants was 21.7 years (±1.4 standard deviation). Sociodemographic variables by CVD status are presented in Table 1. All 23 students definitively diagnosed with CVD were males and a highly statistically significant association ($P < 0.000$) was found between sex and CVD status, as well as year of education and CVD ($P < 0.000$). More than half of the students with deficient CVD were in their preclinical years, and 43.5% of students with deficient CVD were in their clinical years. No statistically significant associations were found of nationality or marital status with CVD status.

Table 1: Sociodemographic characteristics of medical students according to their color vision deficiency status (*n*=1115)

Factors	CVD status*			*P*-value
	Deficient[a] (*n*=23; 2.0%) *N* (%)	Small change (2%)/misdiagnosed[b] (*n*=31; 2.8%) *N* (%)	Normal[c] (*n*=1061; 95.2%) *N* (%)	
Age (Mean±SD)	21.0±4.0	20.0±1.0	22.0±6.0	0.28
Sex				
Males	23 (100)	29 (93.6)	481 (45.3)	<0.000
Females	0	2 (6.5)	580 (54.7)	
Year of education				
Preclinical	13 (56.5)	28 (90.3)	432 (40.7)	<0.000
Clinical	10 (43.5)	3 (9.7)	629 (59.3)	
Nationality				
Saudi	23 (100)	30 (96.8)	1049 (98.9)	0.49
Non-Saudi	0	1 (3.2)	12 (1.1)	
Marital status				
Single	21 (91.3)	30 (96.8)	943 (88.9)	0.63
Married	2 (8.7)	1 (3.2)	112 (10.6)	
Divorced	0	0	5 (0.5)	
Widowed	0	0	1 (0.1)	

*Scoring of Ishihara test: [a]Students who have scored 10 or less were considered as deficient, [b]Students scoring between 11 and 12 were considered to have CVD with a small change (2%) or misdiagnosis, [c]Students who have scored 13 or more were considered normal. SD: Standard deviation, CVD: Color vision deficiency

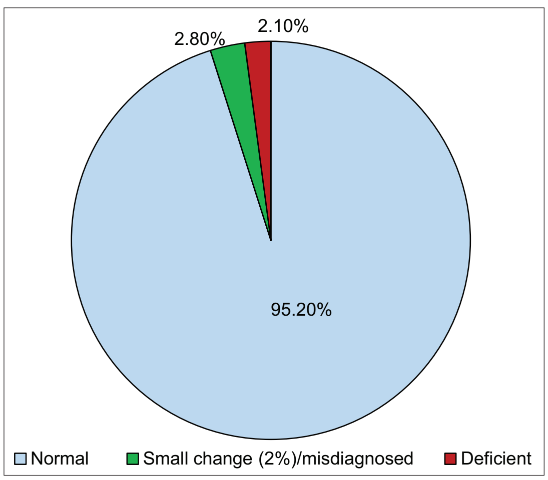

Figure 1: Color vision deficiency status of medical students according to Ishihara test

Table 2 presents personal and family history by CVD status. A highly statistically significant association was found between history of vision problems and CVD status ($P < 0.008$), with 65.2% reporting vision problems, while 34.8% did not. Only 21.7% of deficient students reported a family history of CVD, while of the deficient or misdiagnosed group, only 9.7% reported a family history of CVD. Family history of CVD was not statistically significantly associated with personal CVD status. Neither history of eye surgery nor eye trauma was statistically significantly associated with CVD. Of the students who had CVD, 8.7% had current health problems, compared to 9.7% of the deficient or misdiagnosed group and 15.1% of the normal group. No statistically significant association was found between current health problems and CVD in spite of 7.9% reporting sickle cell anemia. However, consumption of a Vitamin-A-rich diet was borderline significant ($P = 0.05$) with CVD status, as 69.6% of the students in the deficient category and 68.3% of the normal category had a history of Vitamin-A-rich diet.

Figure 2 shows that different chemical students had been exposed to according to CVD status. Around 4% of deficient students were exposed to digoxin, and a similar percentage (0.1%) was found for students within the normal CVD status for digoxin, barbiturate, and chloroquine. Figure 3 shows different vision problems according to CVD status. The most common problem of the color vision deficient students was refractive errors (1.4%).

Discussion

This study investigated the prevalence and predictors of CVD in medical students. The current study showed that the prevalence of definitive CVD was 2.1%. This result is in accord with a cross-sectional study done by Alharfi *et al*., 2016 of medical students in Al-Ahsa, Saudi Arabia (2.7%) as well as in Cameroon (2%)[10,17] However, our prevalence was lower than similar studies conducted on medical students in Malaysia,[18] Bangladesh,[19] Pakistan,[12] two studies in Nepal,[20,21] and India[11] where the prevalence of CVD was 3.2%, 3.4%, 3.7%, 5.6%, 5.8%, and 6.2%, respectively. Further, the current prevalence was somewhat higher than another study done in India (1.8%).[22] Consanguineous marriages are very common in the Saudi population; however, contrary to our expectations, the prevalence was not as high as

Table 2: Personal and family history of medical students according to their color vision deficiency status (*n*=1115)

History	CVD status*			*P*-value
	Deficient[a] (*n*=23; 2.0%) *N* (%)	Small change (2%)/misdiagnosed[b] (*n*=31; 2.8%) *N* (%)	Normal[c] (*n*=1061; 95.2%) *N* (%)	
Vision problem				
Yes	15 (65.2)	8 (25.8)	543 (51.2)	0.008
No	8 (34.8)	23 (74.2)	518 (48.8)	
Family history of CVD				
Yes	5 (21.7)	3 (09.7)	94 (08.9)	0.09
No	18 (78.3)	28 (90.3)	967 (91.1)	
History of eye surgery				
Yes	1 (4.4)	1 (03.2)	78 (7.3)	0.63
No	22 (95.7)	30 (96.8)	983 (92.6)	
History of eye trauma				
Yes	4 (17.4)	1 (03.2)	80 (07.5)	0.14
No	19 (82.6)	30 (96.8)	981 (92.5)	
Exposure to chemicals				
Yes	2 (08.7)	0	37 (03.5)	0.21
No	21 (91.3)	31 (100)	1024 (96.5)	
Current health problems				
Yes	2 (08.7)	3 (09.7)	160 (15.1)	0.64
No	21 (91.3)	28 (90.3)	901 (84.9)	
Consume Vitamin-A-rich diet				
Yes	16 (69.6)	15 (48.4)	725 (68.3)	0.05
No	7 (30.4)	16 (51.6)	336 (31.7)	

*Scoring of Ishihara test: [a]Students who have scored 10 or less were considered as deficient, [b]Students scoring between 11 and 12 were considered to have CVD with a small change (2%) or misdiagnosis, [c]Students who have scored 13 or more were considered normal.[4] CVD: Color vision deficiency

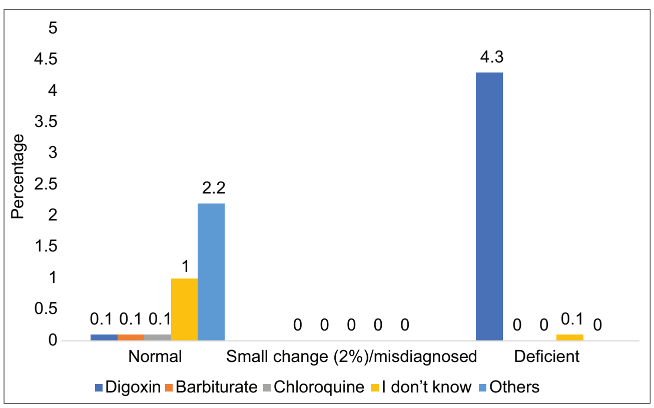

Figure 2: Exposure of medical students to chemicals according to color deficiency status

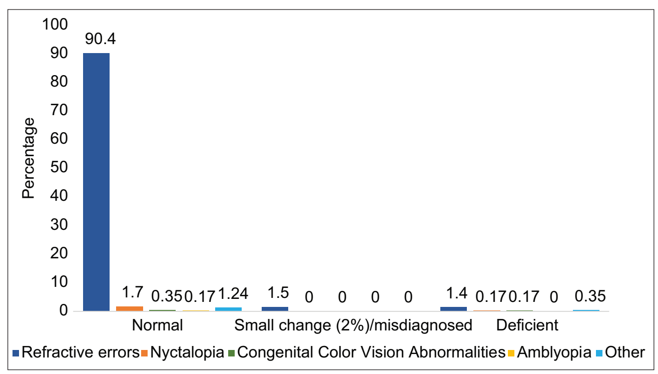

Figure 3: Vision problems of medical students according to color vision deficiency status

found in a previous study conducted on South Asian populations.[23]

All the affected participants with CVD in our study population were males and as was reported in India and Cameroon, no case of CVD was observed in females[11,17] Despite the absence of affected females, other studies on medical students have found cases in females, though the incidence is lower than in their male counterparts.[17,18,22-24] However, Mughal *et al*., 2013.[12] reported the opposite (4.5% and 2.4%, females and males, respectively) in the study conducted in Pakistan. Nonetheless, this could be due to the fact that their study population had a very high number of females ($n = 1250$) in comparison to their male counterparts ($n = 750$). They concluded that more research was needed to explore this problem. Therefore, it is generally thought that these results indicate that males are at a greater risk of being affected more than females because of the X-linked mode of inheritance of red–green CVD.

Even though a number of affected participants (21.7%) reported familial CVD, there was no statistically significant association. The same percentage was reported in another study of Saudi medical students in Al-Ahsa (22%), which was also not statistically significant.[10] This may be mostly because both populations are from the same region of Saudi Arabia (Eastern Province).

CVD can be either inherited or acquired. Students with a family history of CVD were classified as having hereditary CVD (21.7%), and those who had no family history were classified under the acquired category (78.3%). Besides, Alharfi *et al*., 2016.[10] reported that the number of Saudi medical students who had acquired CVD was greater than those with inherited CVD (2.2% and 0.6%, respectively). In Iran, a study showed that of the 2157 participants, 9.3% had hereditary CVD and 20.2% had acquired.[25] The high percentage of acquired CVD in various studies could be due to changes associated with age, differences in race and environment, current health problems, and ocular conditions such as vision problems which were significantly associated with CVD in our study. However, because CVD is an unrecognized problem, the number of acquired CVD might include those with familial defects because of their lack of awareness of their condition.[26]

Color-deficient people may face many difficulties in their daily activities. This is particularly important for physicians owing to the nature of their work.[27] Dhingra *et al*., in 2017 reported difficulties physicians faced. These problems begin in medical school for medical students with CVD since they tend to make more errors than their color-normal peers. The nature of their errors suggested that the students had issues in learning specific subjects and specialties.[13] There is notable evidence that some medical professionals with CVD perform less effectively than others in other occupations. However, medical doctors with mild CVD reported fewer issues in their practice than those with severe forms. It has been mentioned that the most common problems experienced because of CVD include: misinterpretation of the widespread body color changes of pallor, cyanosis, jaundice, rashes, and erythema of skin.[26] Similarly, the study by Campbell *et al*., in 2005, showed that physicians with CVD had difficulty in identifying ten clinical photographs, in comparison with their color-normal peers who did so easily.[28]

Our study showed that the majority of the affected participants were not aware of their color vision problems. This is not uncommon. In Cameroon, no medical student was aware of their deficiency.[17] Moreover, many doctors do not know the severity of their condition and tend to assume it is slight, and a few do not even know they have a disability.[27] Therefore, it is recommended that medical students be screened before the start of their medical school training, as obtained in India, to make them aware of their CVD status and understand their limitations, in order to ensure safe practice.[13]

As color recognition is essential in life, the importance of screening may be extended to school-age children since CVD has been reported in several studies conducted on school-age students with a prevalence ranging from 1.7% to 8.2% in boys and from 0.2% to 2.9% in girls[5,6,29-36] to avert the risk to patients during a physician's clinical practice. Early detection allows parents to give proper support to their children, and teachers to adjust their teaching methods to make them more beneficial to their students.

Although the tool used was a screening tool for protan and deutan defects with high sensitivity and specificity,[4,14,15] it is recommended that a further confirmatory tool (Richmond HRR test) be used to detect tritan defects. Differentiating protan from deutan defects is also recommended for the affected participants using Medmont C100 Test, and Farnsworth–Munsell 100 Hue Test to assess severity and different patterns. Furthermore, the cross-sectional nature of this study and the sample used limit the generalization to only a similar age group. We recommend further explanation on different age groups, i.e., children, adolescents, adults, and geriatrics for an in-depth exploration of the nature of the disease whether acquired or inherited, and its impact on their lives.

Conclusion

The current percentage is lower than many previous studies done in other countries. All definitively diagnosed CVD were males and a highly statistically significant association was found between sex and CVD. Yet, many medical students with CVD remain unaware of their condition and consequently may have a lot of issues in their medical education, particularly in identifying color slides, specimens, and in examining certain physical signs. We recommend early screening of all school-age children, and proper counseling for medical students with definitive CVD to take care of their own health and wellbeing, and be mindful of their condition when choosing their specialties for future. This will ensure avoidance of mistakes and any consequent medicolegal litigations in their professional life.

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Conflicts of interest

There are no conflicts of interest.

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