ORIGINAL ARTICLE

Disabilities among Medical Students: Prevalence of Color Vision Deficiency as an Example

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ABSTRACT

Background: **Color vision deficiency (CVD) is a relatively common disorder, particularly in men. This poses a problem for the medical field worker since color vision can be used as a tool in investigations and follow-ups.**

Objective: **The aim of this study is to determine the prevalence of color vision deficiency as a visual disability among medical students at the University of Tabuk.**

Methods: **This cross-sectional study was conducted at the University of Tabuk, Saudi Arabia. The study enrolled medical students of both genders. The participants completed a self-administered questionnaire about their personal and medical history; then, they were screened for CVD using the Ishihara 15-plate test.**

Results: **The study included 300 medical students. The prevalence of CVD with slight changes and CVD were 10.3% and 3.7%, respectively. The CVD with slight changes and CVD were significantly associated with male gender ($p < 0.001$), sixth academic year ($p = 0.015$), presence of vision problems ($p = 0.002$), family history of CVD ($p = 0.003$), previous eye surgery ($p < 0.001$), head/eye trauma ($p = 0.009$), and exposure to drugs/chemicals ($p = 0.001$).**

Conclusions: **The rate of CVD among medical students at the University of Tabuk is approximate to the reported rates elsewhere. Early screening of medical students is recommended to identify those suffering from CVD and provide them with the required consultation.**

KEY WORDS

color blindness, color vision defect, Ishihara plates, medical school

INTRODUCTION

The perception of colors by humans is a process that entails the reaction of the light with the retinal photoreceptors, which in turn send a signal along the optic nerve to the occipital cortex[1). The human retina contains two types of photoreceptors: the rods and the cones. The cones are implicated in form and color vision. Three types of cones are identified: the long-wavelength (L-cones), the medium-wavelength (M-cones), and the short-wavelength (S-cones) with a greater sensitivity to red, green, and blue[2).

Color vision deficiency (CVD) is a disorder in which the ability to distinguish certain colors or shades of colors is impaired. The disorder is also known as color blindness, color vision defect, and dyschromatopsia. CVD occurrence is attributed to the absence or abnormal functioning of one type or more cones, reducing the number of separate visible hues perceived by the patients. The condition may be congenital or acquired. Commonly known hereditary CVD include congenital red-green deficiency, X-linked recessive, and blue deficiency, an autosomal dominant[3,4). Acquired color defects are usually a result of degenerative diseases, the toxic effect of drugs, trauma, and aging[5).

The prevalence rates of CVD widely vary in the literature according to race and geographical regions. Higher rates of CVD have been reported in European males (8%) compared to African (3% — 4%) or Asian (3%) males[1). Individuals with CVD often report problems with their daily activities and work tasks. These problems are particularly augmented with doctors having CVD. Distinguishing colors is crucial for identifying various clinical signs (e.g., pallor, cyanosis, jaundice) and interpreting stained histological slides and laboratory test results. Medical students with CVD may have problems while studying specialties that require distinguishing objects based on colors, such as histology, pathology, microbiology, dermatology, pediatrics, internal medicine, and ophthalmology.

Moreover, doctors with CVD are prone to commit diagnostic errors that can seriously affect the patients' health and safety[6-8).

Having disabilities during medical school may impact medical students' performance. Reports from the United States and the United Kingdom documented that medical students who disclosed their disabilities to school officials have either visual, sensory, or motor disability, these disabilities impacted their performance in medical school. However, those students view themselves to be more empathetic to patients and better understand their needs. They can have the skills, knowledge, and communication skills that can positively impact patients' lives[9,10). Thus, identifying medical students with visual disabili-

Received on May 2, 2023 and accepted on May 29, 2023

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Table 1: Characteristics of the enrolled medical students (total n = 300)

Variables		All participants (n = 300)
Age (year) *Mean ± SD (Min — Max)*		21.7 ± 1.8 (18.0 - 27.0)
Gender, *n (%)*	Female	130 (43.3%)
	Male	170 (56.7%)
Academic year, *n (%)*	1	16 (5.3%)
	2	43 (14.3%)
	3	60 (20.0%)
	4	79 (26.3%)
	5	63 (21.0%)
	6	39 (13.0%)
Nationality, *n (%)*	Non-Saudi	2 (0.7%)
	Saudi	298 (99.3%)
Marital status, *n (%)*	Married	2 (0.7%)
	Single	298 (99.3%)
Vision problem, *n (%)*	No	163 (54.3%)
	Yes	137 (45.7%)
Familial CVD, *n (%)*	No	267 (89.0%)
	Yes	33 (11.0%)
Eye surgery, *n (%)*	No	261 (87.0%)
	Yes	39 (13.0%)
Trauma history, *n (%)*	No	264 (88.0%)
	Yes	36 (12.0%)
Drug or chemical exposure, *n (%)*	No	282 (94.0%)
	Yes	18 (6.0%)
History of chronic illness, *n (%)*	No	238 (79.3%)
	Yes	62 (20.7%)
Vit. A rich diet, *n (%)*	No	254 (84.7%)
	Yes	46 (15.3%)

Max: maximum; Min: minimum; n: number; SD: standard deviation

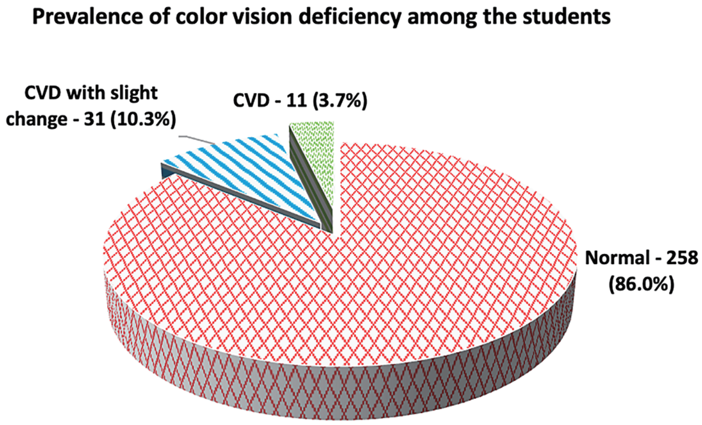

Figure 1: Prevalence of color vision deficiency among the enrolled medical students (total n = 300).

ties such as CVD is essential to provide early counseling and aid to help them overcome this deficiency or make decisions considering their future careers. Determination of the problem magnitude and potential risk factors will help to screen students at risk of having CVD. Therefore, this study was carried out to determine color vision deficiency prevalence among medical students at the University of Tabuk. This will a gateway for future research to assess the other visual disabilities among medical students in the region.

METHODS

Study design and settings

This quantitative, observational, cross-sectional study was conducted at the Faculty of Medicine, the University of Tabuk, from December 2021 to January 2022. After fully explaining the study's aims and methods, written consent was obtained from all participants. Confidentiality of the 'participants' data was preserved by keeping the records anonymous after assigning a code number for each participant.

Study population:

The study enrolled male and female medical students at the University of Tabuk. The study sample was collected using a convenient, non-probability sampling technique. This study included medical students of both genders at the University of Tabuk from the first to the sixth academic year.

Data collection tools:

A self-administered, pre-coded questionnaire of 15 questions was distributed. The questions were derived from a pre-tested questionnaire used by Alharfi *et al.*[11]. The questionnaire consisted of two sections. The first section included the participants' personal data (age, gender, academic year, nationality, and marital status). The second section inquired about the history of vision problems, family history of color vision defect, eye surgery, history of head or eye trauma, medications, exposure to chemicals, other health problems (including diabetes mellitus, sickle cell anemia, hypertension, and others), and whether sufficient vitamin A is consumed. The questionnaire was followed by screening the participants for CVD using the Ishihara 15-plates test.

The Ishihara test:

A trained data collector requested the participants to read 15-plates held 75 cm away at the 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 or misdiagnosis, and a score of 10 or less was considered CVD[12].

Statistical analysis

The collected data were entered into an Excel spreadsheet and then analyzed using the Statistical Package for Social Sciences (IBM SPSS Statistics) for Windows, version 26 (IBM Corp., Armonk, N.Y., USA). The age was summarized as mean ± SD. Categorical variables were summarized as frequencies. The difference in age among the groups was tested using the one-way analysis of variance (ANOVA) test. The association of CVD with categorical variables was assessed using 'Pearson's Chi-square test for independence and Fisher-Freeman-Halton exact tests. A p-value < 0.05 was adopted to interpret the significance of statistical tests.

RESULTS

In this study, 300 medical students completed the questionnaire and the Ishihara 15-plates test. The 'students' age ranged from 18 to 27 years, with an average (SD) of 21.7 (1.8) years. Male students slightly overnumbered female students (56.7% vs. 43.3%, respectively). About one-quarter of the students were in the fourth academic year and one-fifth in the third and fifth years. Almost all students were Saudi (99.3%). The majority of students were single (99.3%). Vision problems were reported in 137 students (45.7%). Familial CVD, previous eye surgery, history of head/eye trauma, drug/chemical exposure, and chronic illnesses (including diabetes mellitus, sickle cell anemia, or hypertension) were reported by 33 (11%), 39 (13%), 36 (12%), 18(6%), and 62 (20.7%), respectively. A small percentage of students reported consuming a vitamin A-rich diet 46 (15.3%), Table 1.

Table 2: Association of the 'students' demographic data and history with color vision deficiency (total n = 300)

Variables		Normal (13 - 15) (n = 258)	CVD with slight change (11 - 12) (n = 31)	CVD (10 or less) (n = 11)	Test statistic	p-value
Age (year) *Mean ± SD (Min — Max)*		21.6 ± 1.7 (18.0 - 27.0)	22.1 ± 2.3 (18.0 - 27.0)	22.5 ± 2.7 (18.0 - 26.0)	2.228 [a]	0.110
Gender, *n (%)*	Female	124 (48.1%)	3 (9.7%)	3 (27.3%)	19.547 [b]	< 0.001*
	Male	134 (51.9%)	28 (90.3%)	8 (72.7%)		
Academic year, *n (%)*	1	12 (4.7%)	3 (9.7%)	1 (9.1%)	22.088 [b]	0.015*
	2	36 (14.0%)	4 (12.9%)	3 (27.3%)		
	3	54 (20.9%)	6 (19.4%)	0 (0.0%)		
	4	74 (28.7%)	4 (12.9%)	1 (9.1%)		
	5	56 (21.7%)	5 (16.1%)	2 (18.2%)		
	6	26 (10.1%)	9 (29.0%)	4 (36.4%)		
Nationality, *n (%)*	Non-Saudi	2 (0.8%)	0 (0.0%)	0 (0.0%)	1.282 [b]	1.000
	Saudi	256 (99.2%)	31 (100.0%)	11 (100.0%)		
Marital status, *n (%)*	Married	1 (0.4%)	1 (3.2%)	0 (0.0%)	4.126 [b]	0.261
	Single	257 (99.6%)	30 (96.8%)	11 (100.0%)		
Vision problem, *n (%)*	No	150 (58.1%)	8 (25.8%)	5 (45.5%)	12.023 [b]	0.002*
	Yes	108 (41.9%)	23 (74.2%)	6 (54.5%)		
Familial CVD, *n (%)*	No	236 (91.5%)	23 (74.2%)	8 (72.7%)	10.458 [b]	0.003*
	Yes	22 (8.5%)	8 (25.8%)	3 (27.3%)		
Eye surgery, *n (%)*	No	235 (91.1%)	18 (58.1%)	8 (72.7%)	22.765 [b]	<0.001*
	Yes	23 (8.9%)	13 (41.9%)	3 (27.3%)		
Trauma history, *n (%)*	No	233 (90.3%)	23 (74.2%)	8 (72.7%)	8.784 [b]	0.009*
	Yes	25 (9.7%)	8 (25.8%)	3 (27.3%)		
Drug or chemical exposure, *n (%)*	No	248 (96.1%)	26 (83.9%)	8 (72.7%)	13.103 [b]	0.001*
	Yes	10 (3.9%)	5 (16.1%)	3 (27.3%)		
History of chronic illness, *n (%)*	No	209 (81.0%)	20 (64.5%)	9 (81.8%)	4.393 [b]	0.098
	Yes	49 (19.0%)	11 (35.5%)	2 (18.2%)		
Vit A rich diet, *n (%)*	No	217 (84.1%)	29 (93.5%)	8 (72.7%)	3.239 [b]	0.197
	Yes	41 (15.9%)	2 (6.5%)	3 (27.3%)		

Max: maximum; Min: minimum; n: number; SD: standard deviation; * significant at p < 0.05.

[a] ANOVA test; [b] Pearson' 's Chi-square and Fisher-Freeman-Halton exact tests

The Ishihara 15-plates test revealed that the prevalence of CVD with slight changes was 10.3% (n = 31), while the prevalence of CVD was 3.7% (n = 11, Figure 1). The prevalence of definite CVD among male students was 4.7%, while the rate among female students was 2.3%. The rate of CVD with slight changes was 16.5% and 2.3% in male and female students, respectively.

The association between the 'students' demographic data and history with CVD was assessed, Table 2. There was no significant difference between normal students and those with CVD regarding the age, nationality, marital status, chronic illnesses, or consumption of a vitamin A-rich diet (p-value > 0.05). CVD with slight changes and CVD were significantly associated with male gender (p < 0.001), the sixth academic year (p = 0.015), presence of a vision problem (p = 0.002), family history of CVD (p = 0.003), previous eye surgery (p < 0.001), trauma to the head or eye (p = 0.009), and exposure to drugs/chemicals (p = 0.001).

DISCUSSION

Medical students with CVD may face several difficulties during their studies or after graduation while performing clinical examinations or interpreting investigations. Besides, CVD may cause misinterpretation and misdiagnosis of the patient' 's' condition, thus exposing the 'patients' safety to risk[8]. Unfortunately, a considerable proportion of students with CVD are not aware of this condition, which warrants the design of a screening program for early identification. Therefore, this study aimed to determine the prevalence of color vision deficiency among medical students at the University of Tabuk.

The present study included 300 medical students. Among our participants, the prevalence of CVD with slight changes and CVD were 10.3% and 3.7%, respectively. The prevalence of definite CVD was 4.7% and 2.3% in male and female students, respectively, while the corresponding rates of CVD with slight changes were 16.5 and 2.3%.

The prevalence rates of CVD among the medical students widely varied across the previous studies. Rates similar to those reported in the current study were reported in studies from Saudi Arabia[13)], Malaysia[14)], Bangladesh[15)], Pakistan[16)], with CVD detected in 3.9%, 3.2%, 3.4%, and 3.7% of their samples, respectively. However, much higher rates were reported by studies from Nepal (5.6 and 5.8%)[17,18)], India (6.2%)[19)], and Pakistan (6%)[20)]. On the other hand, lower rates of CVD among medical students were reported from different regions in Saudi Arabia (1.77% and 2.1%)[21,22)] as well as the Cameroon (1.96%)[23)].

The differences among the studies considering the prevalence rates of CVD may be attributed to racial differences, variations in the proportions of enrolled male and female students, and the use of different tests (other than the Ishihara 15-plate test). Moreover, some studies excluded students with a history of administering potentially toxic drugs to the eye, which may have lowered the prevalence by excluding drug-induced CVD.

The current study included a slightly higher percentage of male students than female students (56.7% vs. 43.3%, respectively). The male gender was significantly associated with CVD (p < 0.001). This association agreed with several previous studies[14,21-26]. On the other hand, a study in Pakistan[27] and another study in Saudi Arabia[13] found a lack of significant association between total CVD and gender. The prevalence of red-green CVD is more significant in males than females because it is inherited as an X-linked recessive disorder[3].

Among our sample, CVD with slight changes and CVD were significantly associated with the academic year, with a significantly higher percentage of those with CVD being in the sixth year (p = 0.015). On the contrary, Alamoudi *et al.*[22] reported that a significantly higher percentage of students with CVD and CVD with slight changes were in their preclinical years compared to their normal color vision peers.

According to its etiology, color vision deficiency can be classified into congenital (inherited) and acquired. Acquired CVD may develop due to chronic diseases that affect the retina, optic nerve, and the brain, such as diabetes mellitus, sickle cell anemia, and retinitis pigmentosa. In addition, the administration of some drugs may affect color vision, such as sildenafil, digoxin, ethambutol, furosemide, and metronidazole[28].

In the current study, potential factors contributing to CVD were explored. We found that familial CVD was reported by 11%; nearly a quarter of students with CVD and CVD with minimal changes reported a positive family history (p = 0.003). Similarly, Khairoalsindi *et al.*[21] found a significant association between positive family history and CVD status, with stated family history in 30% of CVD students vs. 10% of their normal color vision peers (p = 0.02). However, the association with familial history was non-significant in the study by Alamoudi *et al.*[22], though 21.7% of students with CVD had a family history compared to only 8.9% of students with normal color vision (p = 0.09). The association between CVD and positive family history could be explained by the mode of inheritance of some CVD types. In addition, consanguinity plays a role in families that carry the disorder' 's alleles. A study in Saudi Arabia found a significant association between CVD and consanguinity of the parents of secondary school students[29]. Consanguinity may be an essential factor contributing to CVD rates in Saudi Arabia, where the rate of consanguinity is high[30].

Vision problems were reported in 45.7% of our participants and were significantly associated with CVD (p=0.002). More than half the students with CVD and 74.2% of those with CVD with slight changes reported vision problems. This aligns with the findings of Alamoudi *et al.*[22], as a significant association was observed between vision problems and CVD (p = 0.008), with 65.2% of students with CVD having vision problems. On the other hand, Khairoalsindi *et al.*[21] did not detect a significant association between other visual problems and CVD (p = 0.6).

History of eye surgery, head/eye trauma, drug/chemical exposure, and chronic illnesses was reported by 13%, 12%, 6%, and 20.7% of students, respectively. The CVD was significantly associated with previous eye surgery (p < 0.001), trauma to the head/eye (p = 0.009), and exposure to drugs/chemicals (p = 0.001). Contradictory to these findings, Alamoudi *et al.*[22] stated that no significant association was observed between CVD and the history of eye surgery (p = 0.63), eye trauma (p = 0.14), or exposure to chemicals (p = 0.21).

Some diseases are known to affect color vision. However, in the current study, chronic illnesses were reported by 20.7% of students, with no significant association with CVD status (p = 0.098), which is in line with the results of Alamoudi *et al.*[22].

Only 15.3% of the studied students reported consuming a vitamin A-rich diet. There was no significant association between CVD and the consumption of a vitamin A-rich diet. Meanwhile, a borderline significant association (p = 0.05) between the consumption of a vitamin A-rich diet and CVD status was observed by Alamoudi *et al.*[22].

The present study results provide important insight into the prevalence of CVD among medical students at the University of Tabuk. To the best of the authors' ' knowledge, no other studies assessed the problem in this region of Saudi Arabia. In addition, we identified factors that are associated with CVD - including gender, positive family history, vision problems, previous eye surgery, trauma to the head/eye, and exposure to drugs/chemicals. These factors could aid the selection of students at high risk for whom the conduction of a CVD-screening program will be beneficial, particularly if the screening of all students is not feasible.

Nevertheless, the study results were restricted by some limitations. The study was cross-sectional, and the participants were recruited from a single university, which may limit the generalization of the results to other populations. The type of CVD was not classified as protan or deutan. Moreover, no confirmatory test was used to identify tritan defects. Furthermore, the impact of CVD on the 'students' performance was not assessed.

We recommend the conduction of a CVD-screening program for at-risk medical students. Those identified with CVD should obtain counseling and help to overcome their disability. This is particularly important as a considerable proportion of students may not be aware of having CVD, yet it may still impact their performance. Students who become aware of their CVD status become more attentive during the examination of patients or the assessment of investigations, and they seek help from colleagues.

Several measures were developed to aid students with CVD, including the adjustment of computer monitors to grayscale or the production of grayscale photomicrographs for laboratory results instead of the original, colored ones. The use of grayscale emphasizes the contrast between the different structures in the photomicrographs, enabling students with CVD to focus on differentiating the illustrated tissues according to their structure[31].

CONCLUSION

In conclusion, the rate of CVD among medical students at the University of Tabuk is approximate to the reported rates elsewhere. Early screening of medical students is recommended to identify those suffering from CVD, provide them with the required consultation, and help them choose their future specialties to minimize the problems they encounter during the practice of medicine and ensure 'patients' health and safety.

CONFLICT OF INTEREST

Each of the authors declares that they have no conflict of interest.

ETHICS APPROVAL

This study adhered to the ethical standards of the institutional and national research committee and the declaration of Helsinki. We hereby confirm that the present study conforms to the ethical standards and guidelines of the journal.

INFORMED CONSENT

Informed consent to participate was obtained from all individuals who participated in this study.

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