Original Article

Prevalence of Color Blindness among Secondary School Students in Taif, Saudi Arabia

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Abstract

To investigate the occurrence, causes, and risk factors of color vision deficiency among Taif, Saudi Arabia secondary school students. A cross-sectional study was carried out on secondary schools, during the period from 1 to 31 June 2022. Secondary school students, of Taif city, Saudi Arabia. Data were collected using a personal interview with the students using a predesigned questionnaire covering the needed items. Students diagnosed with color blindness were 2.0%; of them, persons diagnosed with protan color blindness were 58.3%, while 41.6% had deutan color blindness, and students diagnosed with CVD were 0.4%. On the other hand, 4.2% could not see shades or tones of the same color and the same percent had difficulty distinguishing between colors. Regarding the cause of CVD, our study revealed that 4.2% of the studied population were due to primary causes (hereditary), and the same percent were due to secondary diseases. As regards family history, 1.0% had a mother and/or father affected by the disease, 0.8% had a sibling with the disease, and 96.3% had no family history. It was also found that there is a significant relationship between CVD and family history (p-value =0.008). There was a higher incidence in males than females, there is a significant relationship between gender and CVD (p-value=0.001). Students diagnosed with color blindness were 2.0%; of them, persons diagnosed with protan color blindness were 58.3%, while 41.6% had deutan color blindness, and students diagnosed with CVD were 0.4%. There was a higher incidence in males than females.

Keywords: Color vision deficiency, Secondary school students, Taif, Saudi Arabia

Introduction

The human retina has around six million cones and hundred million rods on its surface. Cones carry colour information, whereas rods are more sensitive to low-light circumstances [1]. Color vision is the consequence of a signal mixing from three visual pigments within cones: blue, green, and red, which resemble of cone L, M, and S, respectively (RGB-LMS). These colours parallel the peak light absorption strengths of the changed chromophores' wavelengths [2]. Color blindness, also known as colour vision impairment, is a disorder that impairs one's ability to see colour or colour contrasts [3]. Genetic impairment is considered the most common cause of colour blindness in the development of one or more of the eye's three sets of color-sensing cones [3].

A considerable proportion of the population is colorblind. Protanopia and deuteranopia, the two most usual inherited colour blindness kinds, are red-green colour vision defects caused by inadequate of red or green retinal photoreceptors, respectively [4].

Color vision problems are an X-linked recessive disorder, which explains why men are disproportionately afflicted [5].

The processes responsible for the appearance, detection, and discriminability of stimuli with varied wavelength composition are the focus of colour vision research. The introduction of molecular genetics technologies has substantially advanced our understanding of the biology behind colour vision; yet, our understanding is still imperfect [6].

People with congenital CVD adapt, adjust, and cope in day-to-day activities without experiencing substantial illness implications. People who work in specialised industries, such as driving and the medical and dental professions, may

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How to cite this article: Althomali TAM, Algarni FAA, Alosaimi MAN, Alharthi AAE, Alharthi KAS, Alotbi MFA, et al. Prevalence of Color Blindness among Secondary School Students in Taif, Saudi Arabia. Arch Pharm Pract. 2022;13(3):85-91. https://doi.org/10.51847/YrW0tLmdkX

suffer and be stressed; as a result, anyone pursuing such a professional path should be tested for CVD and counselled on employment possibilities accordingly. Special lenses may help people with red-green colour blindness who are exposed to bright light [7].

The frequency of congenital red-green colour vision abnormalities (CVDS) in Arab males from Riyadh, Saudi Arabia is both racial and gender dependant. The Ishihara plates and the D 15 test were used to screen for red-green colour vision abnormalities (CVDS) in Arab boys from Riyadh, Saudi Arabia. The data show a 2.93% prevalence. Deutan defect was found in 1.95% of the individuals, protan defect was present in 0.49%, and undefined colour defect was present in 0.49%. This finding verifies the previously reported low frequency of congenital red-green CVDS in adult Arab males from Saudi Arabia's central area [8].

A colour vision screening was conducted in Riyadh, Saudi Arabia to determine the prevalence of congenital red-green colour vision defects among Saudi Arabian male and female children. It was discovered that 5.85% of the 838 male participants had red-green colour vision deficiency (CVD), with 1.55% and 4.3% of the 49 males having protan and deutan defects, respectively. 0.75% of the 800 female participants had CVD, with 0.25% and 0.5% having protan and deutan deficiencies, respectively [9].

A cross-sectional study was conducted in Al-Madinah Al-Munawara, Saudi Arabia, to investigate the incidence of congenital colour vision impairments among male secondary school students. 1154 male secondary school students were chosen at random using a multi-stage sampling technique. Ishihara 24-plates were used to identify colour blindness. Congenital colour vision impairments were discovered in 3.3 percent of the population, including 1% of protanopes and 2.3 % of deuteranopes. Color vision problems were discovered in 2.48 percent of Saudis and 5.48 percent of non-Saudis [10].

Alabdelmoneam (2011) investigated the incidence of congenital colour vision impairments among Saudi girls of Arab heritage in Saudi Arabia. He evaluated 7,467 female Saudi Arabian individuals using both Ishihara pseudoisochromatic plates and the Farnsworth Dichotomous test (D-15). The Farnsworth-Munsell 100 Hue test was used to better assess CVD patients. A total of 26 individuals were found to have poor colour vision, with a frequency of 0.35%. Sixteen patients had deutan defects, whereas ten had protan defects. When compared to published statistics from other races of females, Arab ladies had a much lower prevalence of CVD. The analysis of Saudi Arabia's five areas revealed no substantial differences between them [11].

Another Saudi study sought to determine if spectacle-mounted Chromagen lenses would improve colour perception in those with poor colour vision. According to the study, chromagen lenses might improve colour vision perception in some cases of red-green colour vision abnormalities. Clients suffering from CVD should be treated on an individual basis [12].

In 2017, a cross-sectional suevey was carried out in Makkah, Saudi Arabia, to evaluate the degree and causes of colour vision deficiencies (CVD). The subjects were tested using the 24-plate Ishihara's Test of Color Vision chart. If 9 plates were correctly read, colour vision was deemed poor. CVD was connected to gender, family history of CVD, and other visual impairments. 1126 students were evaluated (552 males, 49%; mean age: 18.7±0.7 years). CVD was discovered in 1.77% of the population. It was 3.5% among male students. CVD was identified in only one female student. Duran CVD was found in 18 (1.6%) of the students. However, only two students had Tritan CVD. Three of the twenty CVD students were aware that they had the disease. CVD was connected with a family history of CVD and male gender, but it was not associated with other visual impairments [13].

Alqahtani *et al*. (2021) conducted a cross-sectional research on 203 dental students interning in male/female dental clinics of King Khalid University College of Dentistry (KKUCOD), Saudi Arabia, to assess the prevalence of color-vision deficit. The Ishihara color-vision deficit (CVD) test with 24 plates was used to detect the disorder. Total CVD was discovered in 3.9 percent of the population. While the association between gender and total CVD was found to be statistically negligible, the link between red-green colour deficiency and gender was shown to be statistically significant. Out of a total of 203 patients, 44 males were found to have red-green colour dearth, whereas three females were found to have this disease, indicating that CVD is more frequent in men. The study found a relationship between age and red-green colour vision deficiency, protanopia, and total CVD [14].

Alamoudi *et al*. (2021) conducted a cross-sectional study with 1115 medical students to determine the prevalence and determinants of CVD in medical students. A pretested questionnaire was used, which covered biographical information, a history of vision problems, a family history of colour vision deficit, eye surgery, bad head or eye trauma, drugs used or chemicals exposed to, other health concerns, and if adequate Vitamin A was taken. The individuals were then tested for CVD using the Ishihara 15-plates test. The research comprised 1115 students, 52.2 percent of whom were females, with an average age of 21.7 years (1.4). The prevalence of definite CVD was discovered to be 2.1 percent, with men accounting for the vast majority of cases. 87 percent of the patients were unaware they had a colour vision problem. A statistically significant association between CVD and a history of visual impairment was established [15].

To evaluate the prevalence of congenital red-green colour vision impairments in elementary school kids in an Iranian

cross-sectional research. 1154 male secondary school students were chosen at random using a multi-stage sampling technique. Ishihara 24-plates were used to identify colour blindness. Congenital colour vision impairments were detected in 3.3 percent of the population, with protanopes accounting for 1% and deuteranopes accounting for 2.3%. Color vision problems were discovered in 2.48 percent of Saudis and 5.48 percent of non-Saudis [16].

A population-based research was conducted in Tehran to assess the prevalence of colour impairments in secondary-school students (ages 12-14). A total of 2,058 students were evaluated using Ishihara pseudoisochromatic colour plates (1,136 males and 922 females). Color vision impairment was detected in 97 people, 93 men and 4 women. Everyone who was affected had no prior history of systemic or ocular disease or prolonged drug use. The visual acuity was 20/20 in all affected kids, and the fundus was normal. Among the 93 instances of defective colour vision in men (8.18%), there were 56 (4.93%) cases of deuteranomaly, 13 (1.14%) cases of protanomaly, 13 (1.14%) cases of deuteranopia, and 11 (0.97%) cases of protanopia. Deuteranomaly was discovered in three of the four female cases (0.43 percent), whereas protanomaly was discovered in one (0.11 percent). Females had neither deuteranopia nor protanopia [17].

A cross-sectional study of schoolchildren in Gurage Zone, Southern Ethiopia, was conducted in 2018. Color vision was tested on 844 pupils (471 boys and 373 girls). The overall prevalence of colour vision impairment was 4.1 percent, with males accounting for 3.6 percent and females accounting for 0.6 percent. 15 (42.9%) and 20 (57.1%) of the 35 colorblind subjects had protan and deutan errors, respectively. The vast majority of colorblind subjects were completely ignorant of their condition. Consequently, the researchers concluded that colour vision impairment is common in our study and that school-based colour vision screening should be implemented [18].

It is critical to analyse and diagnose the problem as soon as feasible in order to lessen the handicap associated with CCVD. Multistage sampling was used in Durban, South Africa, to determine the prevalence of CCVD among Black South African pupils. The examination included visual acuity testing, ocular motility testing, retinoscopy, auto-refraction, and inspection of the anterior segment, media, and fundus. Color Vision Evaluation Made Color vision was tested using simple colour plates (Home Vision Care, Gulf Breeze, FL). The poll included 1305 Black school students (704 boys and 601 females). The overall colour vision deficiency prevalence was 29 (2.2%), with males having a higher frequency (25, 4.2%) than females (4, 0.6%). The prevalence of protanopia and deuteranopia was observed to be 10 (0.7%) and 19 (1.9%), respectively. Males had nine (1.5%) protanopia and 16 (2.7%) deuteranopia, which was substantially greater than females, who had one (0.1%) protanopia and three (0.4%) deuteranopia ($p < 0.05$) [19].

To asses the frequency and congenital colour vision deficit pattern, a descriptive cross-sectional research was undertaken among students from three public secondary schools using a multi-staged sampling strategy. The Ishihara plate was used to evaluate all students' colour vision. Those who did not pass the Ishihara exam were given another shot with the Farnsworth-Munsell D-15 panel. With an average age of 13.9 1.9 years, 769 (47.0 percent) of the 1635 students were men. The overall prevalence of congenital colour vision deficiency was 2.3 percent, with males and females having a statistically significant ($P = 0.00112$) prevalence of 3.8 percent and 0.9 percent, respectively, and an equal proportion of deutans 11 (32.0 percent) and protans 12 (35.0 percent) ratio of 1:1.1 [20].

According to Marechal *et al*. (2019), genetic colour vision loss affects 9% of males and 0.5% of females. It is frequently misdiagnosed and identified late, endangering these individuals' career goals. The red-green chromatic axis is affected by the majority of colour vision disorders induced by X chromosome involvement. They are caused by either a L or M cone malfunction (protanomaly or deuteranomaly) or the lack of a L or M cone (protanopia or deuteranopia). Confusion and equalisation tests, as well as ergonomic and professional assessments that measure aptitude for a specific industry, can be used to discover and diagnose colour vision deficiencies [21].

To our knowledge, no prior research has been shown to determine the prevalence and/or determinants of colour vision deficit among secondary school students in Taif, Saudi Arabia.

Study Objectives

This study investigates the prevalence, causes, and risk factors of color vision deficiency among Taif, Saudi Arabia secondary school students.

Materials and Methods

Study Design, Sitting, and Period

A cross-sectional study was carried out on secondary schools, during the period from 1 to 31 June 2022

Study Subjects

Secondary school students, of Taif city, Saudi Arabia.

Sample Size

The sample size was formulated using the following formula:

$$N = Z^2 \times P(1-P)/E^2 \quad (1)$$

Where:

N = sample size

Z^2 = 1.96 (The critical value that divides the central 95% of the Z distribution from the 5% in the tail)

P=Prevalence of color vision deficiency among Taif, Saudi Arabia secondary school students.

E^2 = the margin of error (=width of confidence interval) (2)

Therefore, by calculation, the sample size equals 284 children with a 10% drop-out rate, so the total sample size was 315 children.

Sampling Technique

The students were selected using a multistage random method. Initially, one school was chosen randomly from the male secondary and one from the female secondary schools. Second, one class per grade was randomly selected in every school. Third, all students in the designated class were encompassed.

Data Collection

Personal interviews with students were used to gather data, and a pre-designed questionnaire containing the necessary items was used.

The color vision deficiency was determined using the 24-plate Ishihara's Test of Color Vision [1].

The colour vision testing plates were placed 75 cm away from the student and angled at a right angle to the sight line. The experiment was carried out in an adequately lit environment that mimicked the influence of natural sunshine. The student was entreated to read the numbers 1 to 17 visible on the test plates, and the time allotted for telling the number was less than 5 seconds. The reading of plates 1 to 15 indicates whether colour vision is normal or impaired. Color vision was regarded normal if 13 or more plates were accurately read. Color vision was classified red-green inadequate if only 9 or fewer plates were successfully read. Plates 16 and 17 were utilised to distinguish between protan and deutan colour vision efficiency kinds.

This questionnaire also addressed socio-demographics, causes, risk factors, and environmental aspects. Data on age group, family history of colour vision insufficiency, history of chronic illnesses, and if the condition interferes with medical studies, social and daily life are collected.

Ethical Considerations

Taif University's research ethics committee granted ethical authority to conduct the study. Students were informed that their participation was entirely optional, and written agreement was acquired from each participant prior to being subjected to the study after discussing the goal with him/her. The surveys did not include any names. Adequate training was provided to data collectors to ensure confidentiality and the security of all surveys.

Statistical Analysis

The collected data were coded and analysed using a social science statistical software (SPSS Inc., Chicago, Illinois, USA). For the qualitative and quantitative variables, descriptive statistics were utilised. The $\chi 2$-test was employed as a significance test, and differences were judged significant when they had a P value of 0.05 or below.

Results and Discussion

The research comprised 1230 people, 49.6% of whom were men. Color blindness was identified in 2.0% of students **(Table 1)**, with protan colour blindness accounting for 58.3%, deutan colour blindness accounting for 41.6%, and CVD accounting for 0.4%. 4.2%, on the other hand, were unable to perceive tints or tones of the same hue, and the same percentage struggled to discriminate between colours. In terms of the cause of CVD, our study found that 4.2% of the population was affected by main reasons (hereditary), and the same percentage was affected by secondary disorders. In terms of family history, 1.0% had a mother and/or father who were afflicted by the disease, 0.8% had a sibling who was impacted by the disease, and 96.3% had no family history **(Table 2)**. **Table 3** shows the relationship between CVD and gender, grade, and family history of CVD. A significant link between CVD and family history was also discovered (p-value =0.008). In terms of gender, our study found that males have a greater incidence than females, and there is a significant association between gender and CVD (p-value =0.001). In terms of eye disease history, our study found that 73% had no history, whereas 1.4% had amblyopia, 6.2% had astigmatism, 17.6% had myopia, and 1.8% had hyperopia. In terms of a history of chronic illnesses, our study found that 86.6% had no history of chronic disease, whereas 5% had bronchial asthma, 3.7% had diabetes, and 2.6% had hypertension.

Table 1. Characteristics of the studied students, Taif, Saudi Arabia (N=1230)

	Frequency (N)	Percent (%)
Gender		
Male	611	49.6
Female	619	50.4
Grade in the secondary school		
1st	466	37.9
2nd	332	27.0
3rd	432	35.1
Family history of color deficiency		
Mother and/or father	12	1.0
Sibling	10	0.8
Others	23	1.9
None	1185	96.3
History of chronic diseases		
No	1066	86.6

Bronchial asthma	62	5.0
Diabetes mellitus	45	3.7
Hypertension	32	2.6
Cardiac disease	10	.8
Others	16	1.3
History of eye diseases		
Amblyopia	17	1.4
Astigmatism	76	6.2
Hyperopia	22	1.8
Myopia	217	17.6
None	899	73.0
Previously diagnosed with color blindness		
Yes	5	0.4
No	1225	99.6
Total color blindness cases after our testing		
Yes	24	2.0
• Protan	14	1.1
• Deutan	10	0.9
No	1206	98.0

Table 2. characteristics of CVD patients, Taif, Saudi Arabia (N=24)

	Frequency (N)	Percent (%)
Gender		
Male	20	83.3
Female	4	16.7
Grade in the secondary school		
1st	11	45.8
2nd	9	37.5
3rd	4	16.7
Age at the time of discovering (in years)		
Less than 10	0	0.0
10-15	1	4.2
More than 15	1	4.2
During our testing	22	91.6
Symptoms		
Difficulty distinguishing between colors	1	4.2
Inability to see shades or tones of similar color	1	4.2
Not previously diagnosed	22	91.6
Diagnosis		
Protan	14	58.3
Deutans	10	41.6
The cause of CVD		
Primary	1	4.2
Secondary to other diseases	1	4.2
Don't know	22	91.6
The severity of the case		
Mild	23	95.8
Moderate	1	4.2
Effect of CVD on daily life		
Yes	1	4.2
No	23	95.8
Effect of CVD on social life		
Yes	1	4.2
No	23	95.8
Effect of CVD on studying		
Yes	1	4.2
No	23	95.8
Trial of treatment of CVD		
No	22	87.5
Chromagen lenses	1	4.2
Glasses	1	4.2
Result of treatment of CVD		
No trial of treatment	22	91.6
No improvement	1	4.2
Improvement	1	4.2

Table 3. The relationship between CVD and gender, grade, and family history of CVD

Parameters		CVD		Total (n=1230)	P value
		No (n=1206)	Yes (n=24)		
Gender	Females	615	4	619	0.001
		51.0%	16.7%	50.3%	
	Males	591	20	611	
		49.0%	83.3%	49.7%	
Grade in the secondary school	1st	455	11	466	0.151
		37.7%	45.8%	37.9%	
	2nd	323	9	332	
		26.8%	37.5%	27.0%	
	3rd	428	4	432	
		35.5%	16.7%	35.1%	
Family history of CVD	Mother and/or father	21	2	23	0.008
		1.7%	8.3%	1.9%	
	Sibling	9	1	10	
		0.7%	4.2%	0.8%	
	Others	11	1	12	
		0.9%	4.2%	1.0%	
	Non	1165	20	1185	
		96.6%	83.3%	96.3%	

Color vision perception is one of a healthy person's visual functions. Three kinds of cones cause trichromacy in colour perception. Congenital colour vision impairments are caused by abnormalities in these retinal cells (CVD) [5]. Color vision deficit (CVD), a collection of diseases that impact colour perception, affects around one in 12 males and one in every 200 women worldwide. The most prevalent cause of CVD is X-linked chromosomal inheritance [22]. It can also be acquired through chronic illnesses that damage the retina, optic nerve, and brain, such as diabetes mellitus, sickle cell anaemia, and retinitis pigmentosa, or through the use of certain medications such as sildenafil, digoxin, ethambutol, furosemide, metronidazole, and some antimalarials, but the

most common cause of colour blindness is a hereditary defect in the development of one or more [15].

Because abnormal colour vision is not progressing and untreatable, it does not fulfil the requirements for health screening [23]. Screening for CVD is a well-established procedure in the United Kingdom, with the rationale that individuals diagnosed may be counselled without shame and given employment advice when they leave school and begin driving.

CVD prevalence has been investigated in several population groups worldwide [24]. In Saudi Arabia, the female CVD rate is stated to be 0.4%. It has been recorded in European Caucasian populations to be 8% in males and 0.4% in females, and between 4% and 6.5% in male Chinese and Japanese people. As a result, CVD differs by race. Still, few research have assessed the incidence of CVD in medical students, despite the fact that it is a significant issue that appears to be going unrecognised in the medical community [25]. The research aimed to examine the incidence, aetiology, and risk factors of colour vision deficit among Taif, Saudi Arabia secondary school students.

In our study, 58.3% of people were diagnosed with protan colour blindness, 41.6% with deutan colour blindness, and 0.4% with CVD. 4.2%, on the other hand, had difficulties discriminating between colours and seeing shades or tones of the same hue. According to a research done in Wolkite, Southern Ethiopia, the frequency of colour blindness varies by geographical location and ethnicity [26] The prevalence of colour vision insufficiency was found to be 4.1%, which is almost identical to the prevalence rates reported in prior investigations [26]. This conclusion was consistent with a study conducted in Thailand, which revealed a 4.2% prevalence rate [27].

Regarding the aetiology of CVD, our study found that 4.2% of the population was affected by a fundamental cause (hereditary), and the same percentage was affected by secondary disorders. Many other studies have also shown that [5], However, Alharfi *et al*., 2016 [7], revealed that the proportion of Saudi medical students with acquired CVD was higher than that of those with hereditary CVD (2.2% versus 0.6%, respectively). In Iran [28], According to research, 9.3% of the 2157 individuals had genetic CVD and 20.2% had acquired CVD.

In terms of family history, 1.0% had a mother and/or father with the condition, 0.8% had a sibling with the disease, and 96.3% had no family history. A significant link between CVD and family history was also discovered (p-value =0.008). On the other hand, research on preparatory university students in Makkah, Saudi Arabia found that a positive family history of CVD was a substantial predictor of CVD in students (p value=0.02). CVD was linked to parents' consanguineous conduct in another research of Saudi students [29]. A significant consanguinity rate in the Saudi population has been observed, as have high rates of congenital impairments and genetic illnesses, prompting genetic screening and premarital genetic counselling [30]. Regarding gender, Our study found a greater prevalence in males than females, as well as a significant link between gender and CVD (p-value =0.001), which is in relation to the findings of many other surveys in this field [15, 31], However, Mughal *et al*., 2013 [32] In a research done in Pakistan, girls and males reported the reverse (4.5% and 2.4%, respectively). Nonetheless, this might be because their research sample included a significantly higher proportion of girls (n = 1250) than men (n = 750). They came to the conclusion that additional study was needed to investigate this issue. As a result, it is widely assumed that these findings imply that males are at a higher chance of being impacted than females due to the X-linked method of inheritance.

In terms of the history of chronic illnesses, our study found that 86.6% had no history of chronic disease, while 5% had a history of bronchial asthma, 3.7% had a history of diabetes, and 2.6% had a history of hypertension, which is consistent with the findings of many other studies in this field [33].

Regarding eye disease history, our study found that 73% had no history, whereas 1.4% had amblyopia, 6.2% had astigmatism, 17.6% had myopia, and 1.8% had hyperopia. Other research, on the other hand, found that CVD was not substantially related with other ocular or visual disorders. Another research was undertaken on Saudi medical students [34] found that ocular disorders such as visual difficulties were strongly linked to CVD.

Conclusion

Color blindness was identified in 2.0% of students, with protan colour blindness accounting for 58.3%, deutan colour blindness accounting for 41.6%, and CVD accounting for 0.4%. The probability of Males to be affected than females is enomous. As a result, we urge large-scale community-based research to explore the prevalence and causes of colour blindness in all Saudi children, adolescents, and adults.

ACKNOWLEDGMENTS: Many thanks to Dr. Talal Abdulrahman M Althomali; Professor of ophthalmology, Taif University, Kingdom of Saudi Arabia, for his continuous help, support and encouragement to complete this work.
CONFLICT OF INTEREST: None
FINANCIAL SUPPORT: None
ETHICS STATEMENT: None

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