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Frequency of Color Blindness Among Secondary School Students in Al-Diwaniya City, Iraq

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Abstract

Background: Color blindness (also known as color vision deficiency, or CVD) is an inherited or acquired condition that interferes with the ability to discriminate certain wavelengths of the visible light spectrum. CVD has a well-documented prevalence among the Middle Eastern population and has been shown to have negative effects on academic achievement. No systematic epidemiological studies have been carried out in Al-Diwaniya City, Iraq concerning the prevalence and type distribution of CVD in secondary school students.
Objective: This cross-sectional study aims to assess the prevalence and type distribution of CVD in secondary school students in Al-Diwaniya City, Iraq, and to evaluate the level of prior awareness and diagnosis among individuals diagnosed with CVD.
Methods: A sample of 1500 secondary school students (762 males, 738 females) aged 12-18 years old was randomly selected from 20 secondary schools in Al-Diwaniya City and surveyed during the 2023-2024 academic school year. A color vision examination was administered using Ishihara pseudoisochromatic plates (38-plate edition) as the primary screening tool and the Farnsworth-Munsell 100 Hue test as the confirmatory classification tool for the screen positive cases. Demographic information was obtained, including prior awareness and formal diagnosis, as well as academic difficulties experienced due to CVD using a structured questionnaire.
Results: CVD was identified in 69 students, which resulted in an overall prevalence of 4.6% (95% CI: 3.58-5.82). The prevalence of CVD was statistically higher in males (7.48%) compared to females (1.63%; $p<0.001$). Of the 69 students diagnosed with CVD, 89.9% of the cases were red-green deficiencies and the most common type of CVD was deuteranomaly. Only 13.0% of the secondary school students diagnosed with CVD had received a formal diagnosis before the current study, while 59.4% have reported experiencing academic difficulties due to CVD.
Conclusion: CVD is prevalent among secondary school students attending school in Al-Diwaniya City; however, most students diagnosed with CVD have not received prior formal diagnoses. Therefore, routine color vision screening should be added to the school enrollment process in addition to modifications to color-coded educational materials.

Keywords:

Color blindness; color vision deficiency; Ishihara plates; prevalence; secondary school; Iraq; Al-Diwaniya.

1. Introduction

Color vision deficiency (CVD), also known as color blindness, is a group of disorders in which people cannot see particular colours correctly (or at all). This condition is typically due to genetic changes that alter the photopigments of one or more classes of cone photoreceptors in the retina. The three types of cones (long-wavelength [L], medium-wavelength [M], and short-wavelength [S]) of the human visual system function together to allow for the experience of trichromatic colour vision. CVD occurs due to a defect (or absence) of one or more of these photopigments or a change in the spectal response of one or more of the photopigments, resulting in being classically categorised as either red-green or blue-yellow CVD (1). Red-green CVD is the most common form and is an X-linked recessive condition, which is why the condition is so much more common in males than females. Males only need one copy of the defective allele in order to actually show a deficiency, whereas females must inherit two copies of the defective alleles (one from each X chromosome) in order to display the condition. This means that most females who have the X-linked defect are actually carriers. This explains the observed consistent male predominance observed in all populations studied so far (1,2). While there are significant differences in the prevalence of CVD among ethnic groups globally, these differences are due to differences in the underlying frequencies of OPN1LW and OPN1MW allelic variants located on the X chromosome. The original studies of populations using the Ishihara pseudoisochromatic plates, in individuals of European ancestry, reported an approximate prevalence of CVD of 8% in males and 0.4–0.5% in females (3). Studies conducted in East Asia, South Asia, and the Middle East data have generally shown lower rates of CVD prevalence, but there is considerable variation in CVD prevalence among these continents.Cole's (4) comprehensive international literature review indicated that the percentage of men with color deficiency was generally in the range of 4.2% in China(4) to 9% in Switzerland(4). In the Arabic countries, there was very little data available, but population-based estimates for male prevalence of color deficiencies were approximately 5%–8% based on existing studies from Middle Eastern populations.(5)Currently, published research on the epidemiology of color vision deficiency in Iraq is very limited. Most of the few available reports are based on military or occupational data, thus not representing community-based estimates. There was a study of university students in Baghdad(6) where investigators found a male prevalence of approximately 6.3%, while a study of school-aged children in Mosul reported a male prevalence of 5.9% and a female prevalence of 0.8%.(7) Neither study measured the epidemiology of color deficiency among the same demographic group, as neither of these studies was evaluated among students in Al-Diwaniya and neither study evaluated the secondary school population, which is the most important group of students for the use of color-dependent instructional materials in courses such as biology, chemistry, geography, and physical education.

Al-Diwaniya is for the Al-Qadisiyah Governorate in the southern-central region of Iraq, and is estimated to have more than 400,000 residents and many school-age children. The population is large and the population has not had any significant published reports that are relevant to students in this educational phase (grades 7–12) as it relates to their ability to distinguish colors in diagrams, charts, histological slides, and tests that utilize color indicators.Undetected CVD can create a disadvantage for students academically, affect how they interpret colour-coded materials and affect their performance in labs based on their colour vision deficiency (CVD) status.(8,9) Despite the well-established impact that colour vision deficiency has on the ability to engage in education, routine vision screenings provided to children in Iraq's public schools do not systematically include colour vision testing as part of those screenings. School health programs within many low- and middle-income countries tend to focus on visual acuity (VS) and refractive error (RE) correction and do so because these types of visual deficits cause immediate and obvious functional disadvantage. Colour vision testing is perceived as less urgent and therefore is frequently excluded from screenings conducted school-aged children.(10,11) As a result, children who experience CVD complete the entire national secondary school (grades 7 through 12) without knowledge that they have a visual deficiency and therefore do not have accommodations made for them while they are members of the school.

Studies conducted with students from higher-income countries suggest that identifying colour vision deficiency at the time students enter school or begin secondary school can significantly reduce the academic differences associated with that deficiency when there are adequate environment and instructional changes available to the student. Colour-safe laboratory equipment, adapted print materials through the use of texture and pattern in addition to colour, and using accessible digital media, have been shown to decrease the functional limitations created by CVD.(12,13) However, in order for these changes to occur, it is assumed that individuals have knowledge of the prevalence or distribution of CVD among the school-aged population.

CVD prevalence has also been studied as it relates to consanguineous marriage, where there is a higher rate of recessive genes in populations with high rates of consanguinity. Consanguineous marriages are common in Iraq, with 45% of marriages occurring between first or second cousins.(14) Consanguinity theoretically can result in increased numbers of female carriers of red-green color vision deficiencies (CVD) producing homozygous daughters, which could possibly lead to higher prevalence of CVD in females than in outbred populations. Consequently, an Iraqi school-based study is timely.

Ishihara pseudoisochromatic plates were developed in 1917 by Shinobu Ishihara, and remain the most common method of worldwide screening for red/green CVD; they are also simple, short, and have a high degree of specificity and sensitivity for detecting protans and deutans, making them very appropriate for large-scale screening of school-aged children.(15,16) The Farnsworth-Munsell 100 Hue test and/or anomaloscopes are recommended for confirmatory diagnosis and more precise classification of CVD, as they distinguish between the various subtypes and degrees of severity of CVD.(17)

Aside from the epidemiological justification, the importance of identifying CVD in a school population has far-reaching vocational implications. Numerous professions—which include medicine, pharmacy, aviation, military service, electrical engineering, and law enforcement—have color vision requirements that disqualify people with any significant degree of CVD.(18,19) Early identification of CVD also enables students and their families to make education and career decisions with the possibility to gain the guidance they may need to pursue additional choices. In Iraq, public-service jobs have color vision standards, and late or no identification of CVD can prevent anyone from obtaining those jobs and can have significant psychosocial ramifications.

Several studies look at the emotional and social effects of having CVD; adolescents who have CVD but do not know they have it may mistakenly attribute having trouble with colors to clumsiness or lack of intelligence and thus experience excessive anxiety and low self-efficacy in their schoolwork.(20,21) Additionally, teachers and peers who do not know a student has CVD may also erroneously attribute any errors regarding color to the same reasons and increase that student's distress. This supports the rationale that screening should not be viewed only as a clinical intervention, but rather as an educational and psychosocial intervention.

The burden of sensory/visual disability and chronic disease among school-aged children in Iraq has not been accurately measured because of the disruption of research infrastructure due to years of war and economic instability. Since re-establishing a secondary education system after 2003, school enrollment rates have increased substantially and present an opportunity to conduct systematic health surveillance of school-aged children.(22) Color vision screening is a low-cost, non-invasive, easily repeatable aspect of health surveillance.

The purpose of this study is to address the lack of epidemiological data regarding CVD in Al-Diwaniya city's secondary school-aged children. Specifically, the goals of this study are: (i) to determine the overall and sex-based prevalence of CVD; (ii) to clarify the distribution of CVD forms; (iii) to estimate the number of students who were aware of their CVD status; and (iv) self-report of educational challenges due to color. The objective is to provide information to the local health policy, school health programs, and curriculum guidelines in (and outside of) Al-Qadisiyah Governorate.

2. Methodology

2.1 Study Design and Setting

A descriptive cross-sectional investigation on secondary school students in Al-Diwaniya City (Al-Qadisiyah Governorate) during academic year 2023-2024 (October 2023-March 2024). There are a total of 74 registered secondary schools (7–12) owned and operated by the Al-Qadisiyah Directorate of Education with both public and private sectors represented within Al-Diwaniya City, which is largely composed of Arab Muslims who have an exceptionally high rate of consanguinity and no health-related data of students previously available prior to this date to conduct further research.(14,22)

2.2 Sample Size and Sampling Strategy

The sample size was determined using the formula to compute the number of subjects necessary to estimate population proportions with a finite population. It was conservatively estimated that approximately 6% of people would be male in this study population based on regional statistics for the Arab population (5,7). With a confidence interval of ± 1.5%, and a confidence level of 95%, we needed to sample at least 1,011 males from our population. Assuming that 10% of males in the sample would not participate and also that females were included in the total sample for purposes of sex-stratified analysis, we set our sample size at 1,500 total students: 762 males and 738 females.

The study used a stratified random sampling approach to select subjects for inclusion in the study. The first step was to stratify the 74 participating secondary schools according to both school type (i.e., public or private) and geographic zone (i.e., north, central and south sub-districts of the city). Proportional probability sampling was then used to select 20 schools out of the original sample. Once the 20 schools were randomly chosen, each school identified classroom rosters for all students enrolled at the school. Subjects were then selected through the procedure of using systematic random sampling (i.e., every kth student from the alphabetically sorted class roster).

2.3 Inclusion and Exclusion Criteria

To participate, subjects had to satisfy the following eligibility criteria: (1) Was a secondary student in the city of Al-Diwaniya when the study was conducted, (2) Was between the ages of 12-18 years at the time of the study, and (3) Provided written informed consent by the parent/guardian and provided written assent by the child.

Subjects were excluded from the study if they met any of the following exclusion criteria: (1) Pre-existing eye disease other than a refractive error (glaucoma, cataracts, diabetic retinopathy, or optic neuropathy) that may have affected color discrimination; (2) Use of drugs that have an adverse effect on color vision (e.g., hydroxychloroquine, digoxin, or phosphodiesterase type-5 inhibitors); (3) Presence of a significant cognitive impairment that would have hindered their ability to understand the testing instructions; and/or (4) Declined to participate in testing or failed to complete any part of the testing or assessment.

2.4 Color Vision Testing Protocol

The color vision tests were done by an experienced eye doctor, who did not have any information on people's survey answers, all tests were done in each of the schools, and all of the tests were completed in accordance with the manufacturer's instructions and using the same type of lighting for all tests.(15)

Students were screened using the Ishihara plates. This edition contained 38 plates, and all were supplied by the Kanehara Corporation (Kanehara & Co,. Ltd., Tokyo, Japan.) All students tested were seen with both eyes.There is a maximum of five seconds to check each plate. Students were required to report the number on each plate. Refractive errors were corrected, and if students were unable to read the Ishiara plates without their corrective lenses, they were required to wear their corrective lenses when they were tested. With six or more errors on the first 21 plates, students were defined as screened positive for colour vision deficiency (CVD). This is in accordance with previously established diagnostic criteria.(15,16)

All students who were screened to be positive for CVD underwent FM100 testing to confirm their CVD status and classify it. The FM100 test was conducted according to standardised guidelines for the lighting used and in a quiet environment. In the FM100 testing procedure, now the subjects will have to arrange 100 coloured caps according to hue. The results of the FM100 test will provide the base for the calculation of total errors and axes of confusion as they relate to classification of whether subjects have protan, deutan, or tritan colour vision deficiencies and will differentiate between anomalous trichromat and dichromat colour vision terms. All of the boxes used contained 100 caps of the same shade colour and were tested for two minutes each according to standardised FM100 testing for colour vision deficiencies.(17) The classification scheme developed by Vingrys and King-Smith(23) was implemented to derive deficiency types using FM100 Testing Results.

2.5 Data Collection Instrument

A questionnaire which had previously been tested on patients was given to all of the subjects regardless of their screening result. This questionnaire was written in Arabic and contained four sections: (i) sociodemographic data (i.e. age, sex, type of school, grade, and residence), (ii) ocular family history (i.e. presence of oculopathy in first- and second-degree relatives; whether or not the child's parents were related); (iii) prior knowledge and diagnosis (that is whether the participant was aware of having difficulty telling colors apart and whether or not a doctor or optometrist had given an official diagnosis to him/her); and lastly, (iv) self-reported effect of color blindness on education (i.e. having difficulty reading colored charts;

reading colored maps; reading diagrams of the human anatomy; etc.) Three ophthalmologists and one public health expert were consulted for establishing face validity for this questionnaire. A pilot study with 30 participants (excluding from final data analysis) was conducted to assess the feasibility and clarity of the survey instrument.

2.6 Ethical Considerations

Permission for administration was granted from the Al-Qadisiyah Director of Education. All research activities were performed according to the Declaration of Helsinki. Informed consent was obtained from the parents/guardians of students under 15 years old and written assent was obtained from students aged 15 and older. Student participation was voluntary, and there were no incentives for participation. Students with CVD were given a printed information leaflet about their diagnosis and were referred to the ophthalmology outpatient clinic at Al-Diwaniya Teaching Hospital for further support.

2.7 Statistical Analysis

Excel 2019 and IBM SPSS Statistics, version 26, were used for data entry and data analysis respectively. The prevalence estimates were generated by calculating 95% confidence intervals (CIs) using the Wilson score method. Chi-square tests were performed to compare the prevalence between males and females; Fisher's exact test was used when the expected value of an individual cell was less than 5. The statistical significance of the results was defined as a $p<0.05$. The analysis of the data does not include logistic regression since the primary purpose of analysis was to be descriptive in nature as opposed to analytical in the more common sense. However, regardless of whether an association between two variables was established, both the 95% CIs and odds ratios of associations tested with chi-square tests are reported.(24)

3. Results

A total of 1,500 students were enrolled in the study. No participant was excluded after enrolment, yielding a response rate of 100%. Table 1 presents the sociodemographic characteristics of the study population.

Table 1. Sociodemographic characteristics of the study population (n = 1,500)

Characteristic	Category	n	%
Sex	Male	762	50.8
	Female	738	49.2
Age group (years)	12–14	498	33.2
	15–17	714	47.6
	18	288	19.2
School type	Public	1122	74.8
	Private	378	25.2
Total	—	1500	100.0

Of the 1,500 students screened, 69 (4.60%; 95% CI 3.58 - 5.82) were diagnosed with a color vision deficiency. The prevalence is also shown by sex (Table 2). There was a prevalence of 7.48% (95% CI 5.74 - 9.61) among males, while there was a prevalence of 1.63% among females (95% CI 0.84 - 2.83), which is statistically significant ($X^2 = 31.47$, $p < 0.001$). The male to female ratio among the students with a color vision deficiency was approximately 4.75:1.

Table 2. Prevalence of color vision deficiency by sex

Sex	Screened (n)	CVD Positive (n)	Prevalence (%)	95% CI
Male	762	57	7.48	5.74–9.61
Female	738	12	1.63	0.84–2.83
Total	1500	69	4.60	3.58–5.82

By using the FM100 confirmatory testing to determine types and subtypes in all 69 students diagnosed with CVD it was established that red/green (deuteranopia, protanopia, etc.) comprised the majority of the cases at 89.9% with deuteranomaly as the predominant subtype, followed by the other subtypes (deuteranopia, protanomaly, protanopia). Both blue/yellow (tritan) deficiency as well as complete achromatopsia were infrequent and provided in Table 3.

Table 3. Type and subtype distribution of color vision deficiency among affected students (n = 69)

Type of CVD	Subtype	Males (n)	Females (n)	Total (%)
Red-green deficiency	Deuteranomaly	22	5	39.1
	Deuteranopia	14	3	24.6
	Protanomaly	8	2	14.5
	Protanopia	7	1	11.6
Blue-yellow deficiency	Tritanomaly / Tritanopia	4	1	7.2
Complete achromatopsia	—	2	0	2.9
Total	—	57	12	100.0

Of the 69 students who are affected, just 18 (26.1%) had any idea they were having trouble distinguishing colors before taking this test, while only nine (13.0%) had received some sort of formal diagnosis before participating in this study. Of the total number of affected students, 41 (59.4%) reported experiencing difficulty completing color-dependent tasks at school. Additionally, 42.0% of students reported having a family member with CVD. The statistics regarding these findings are presented in the chart listed as Table 4.

Table 4. Awareness, prior diagnosis, and educational impact among students with color vision deficiency (n = 69)

Variable	Yes (n / %)	No (n / %)	p-value
Previously aware of any visual problem	18 (26.1%)	51 (73.9%)	—
Formally diagnosed before this study	9 (13.0%)	60 (87.0%)	—
Difficulty in school tasks (reading coloured charts/maps)	41 (59.4%)	28 (40.6%)	<0.001
Family history of color vision deficiency	29 (42.0%)	40 (58.0%)	0.003

4. Discussion

To our knowledge, this study is the first systematic, school-based epidemiological evaluation of CVD conducted in Al-Diwaniya city, Iraq, and produces an estimate of CVD prevalence of 4.60% overall in the sample and 7.48% (males) and 1.63% (females).

The CVD prevalence of 7.48% among males is consistent with similar reported values in neighbouring and genetically related populations. The range of reported male prevalence for CVD in the literature is between 5.6% and 8.2%, with a male prevalence of 6.8% among secondary schoolchildren in Jordan.(25) The present male percentage is comparable to the male percentages reported from Baghdad (6.3%)(6) and Mosul(7) in Iraq; however, in terms of a comparison of estimates between the present study and these other reports, we can only speak in generalities, as there are significant methodological differences in inclusion criteria, age ranges, and testing devices chosen.

In contrast, the present study employed a more rigorous methodology using both Ishihara plates to screen for CVD and the FM100 to classify CVD confirmatorily than many previous reports, which employed only Ishihara plates and did not include any confirmatory testing, and thus may have produced a substantial number of false positives and negatives. Female carriers of color vision deficiency (CVD) have been shown to exhibit a higher incidence of occurrence than previously reported in the literature. The current research indicates that the female prevalence of 1.63% is considerably greater than previously reported rates of 0.4-0.5% for European populations, and also exceeds estimates for some Asian populations. However, the finding does fit within the range of 0.5-2.0% reported for populations with high levels of consanguinity. The high prevalence of consanguinity in Iraq may increase the chances of each daughter of two carries being homozygous for either a defective OPN1LW or an OPN1MW allele. This biological mechanism warrants further investigation via formal genetic epidemiologic approaches in the future. Another potential explanation for the high female prevalence could relate to the fact that many carriers of CVD are heterozygous and may possess mild degrees of color-discrimination deficits that would be detected using other sensitive tests, such as the FM-100 test, but possibly would be missed using only the test as used by Ishihara through the present study's confirmatory testing protocol for carriers. The ratio of males to females (approximately 4.75:1) in this study is less than the expected male to female ratio of approximately 16:1, given that the expected male prevalence is 8.0%, and expected female prevalence is 0.5%. Thus, this finding is consistent with the finding of an elevated 2.62-fold higher prevalence of female CVD. In addition, similar compression of the male to female ratio of CVD has been noted in some other Middle Eastern studies. This finding further elucidates the hypothesis that various genetic and/or demographic related factors, such as consanguinity within populations, are contributing to the high rates of female carriers of CVD within the region. The high percentage of males with red-green deficiencies (deutan and protan) in this study (89.9%) is consistent with the established global prevalence of red-green deficiency and supports the theory that most CVD will be attributed to males with either deutan or protan defective alleles, given how few-totals of males and females have tritan or complete color vision deficiencies. The most common type of color vision deficiency (CVD) revealed in this study was Deuteranomaly (39.1%). The high prevalence rates associated with this CVD variant are due to the high frequency of genetic variations that result in a changing spectral response of the M cone (1, 2, 28). Tritan defects were also found to be relatively uncommon (7.2%) due to their autosomal dominant inheritance pattern and lower population prevalence (29). We have also documented two cases of complete achromatopsia, a severe and rare defect affecting approximately 1 in 30,000 people; their involvement in this study may imply the value of thorough screening of CVD even in locations lacking clinical resources.

A main clinical and policy-relevant finding in the study is the gap between actual prevalence rates of CVD for the sample population, and historical diagnoses. Only 13.0% of students identified with CVD had ever received a clinical diagnosis prior to participation in this study. This is a very low number and supports findings from other countries located in low- and middle-income (10, 11). For example, a study conducted in Nigeria revealed that fewer than 5% of color-deficient school children had received an accurate diagnosis (30), and similar results have also been found in Pakistan and Bangladesh (31,32); while even in countries where colour vision screening is routinely conducted in schools, there have been many documented cases of underdiagnosis due (i.e. in a UK sample approximately 20% of adolescents identified as colour-deficient went undiagnosed until after secondary school) (33).

The implications of this diagnostic gap cannot be understated. Of the affected students in our sample (N = 60), 59.4% reported having difficulties performing school tasks that required use of colour, such as reading biology diagrams, interpreting colour change due to chemistry indicators, and reading colour-coded maps. Functional limitations due to CVD in school environments have been reported in the literature. (8,9,12) In Iraqi secondary schools, biology and chemistry utilize color-coded images (histology section, titration indicators, and ecological maps) as part of the curriculum. The students with red-green CVD would be at an inherent disadvantage with the color-coded images without accommodations. The students that have silently coped with a disadvantage (often we see that many of the students do not know why they are having difficulties) have implications for public health to facilitate early detection of CVD.

The family history of students who have been diagnosed with CVD can be useful for two main reasons. First, if an individual has a family member who has been diagnosed with CVD, this would be an automatic flag for targeted screening, as well as help to reduce the burden of universal testing should resources be limited. Second, there were 58.0% of the students who did not have an identified family history of CVD. This shows that family history alone is not a sufficient screening criterium and will not replace systematic testing of all students.

A major strength of this study is that all testing was done under standardized lighting conditions. Lighting is frequently an ignored variable in the completion of color vision assessment and differences in illuminants can significantly change the perceived accuracy of Ishihara plates and decrease performance on the FM100 test. (34,35) All tasks took place under a lighting source using a calibrated daylight equivalent lamp (6500 K) within the dedicated testing room, which eliminated this source of variability. All students who had a positive result on the Ishihara have been tested using the FM100 (a test of colour vision), and this strengthens the validity of the data used to classify colour vision deficiency, because the Ishihara does not allow proper identification of whether the student is a protan or deutan, nor does it provide any idea of the severity of the condition.

There are a few limitations associated with interpreting these results. The first limitation is that we have conducted a cross-sectional study, and therefore we cannot ascertain whether there are longitudinal changes in CVD status. This is more important for acquired types of CVD (e.g., caustic or secondary) than it is for those who were tested and found to be congenital (as this is a very small proportion of those who were tested). Second, the Ishihara plate test has a high level of sensitivity to the red and green component of CVD; however, it has a very low level of sensitivity to the blue-yellow component (also referred to as tritan CVD); therefore, a number of students with blue-yellow CVD may have been missed as they were only tested with the Ishihara plates (the FM100 is only given to students who are identified as having a positive result using the Ishihara). Third, the research was carried out in one city, so it is unclear how representative this sample is of each of the different regions of Iraq, which could have very different demographic features. Fourth, there may be recall bias associated with self-reported family history and reported difficulty during school. Finally, the category for parental consanguinity was recorded dichotomously (yes vs no), and therefore we will not be able to analyse the relationship between consanguinity and prevalence as it pertains to degree of consanguinity as there is no way of determining the degree of consanguinity for these individuals.

Given the potential implications for school health policy in Iraq, the study presents a very significant opportunity. In recent years, the Iraqi Ministries of Health and Education have made considerable investments in school health programs as part of the efforts for reconstruction after conflict and normalizing service delivery.(22) The inclusion of a brief, standardized color vision screening protocol that utilizes Ishihara plates would be both feasible and cost-effective as part of the routine annual medical examination performed by school nurses who receive training to administer the plates. The estimated cost of Ishihara screening for the sample of students in this study was less than 1,000 Iraqi dinars (approximately US$0.70) per student upon amortization based on the useful life of a set of plates. This cost is comparable to the long-term educational and psychosocial costs associated with undetected CVD.

Issues of curriculum adaptability represent a second concern. Worldwide, there has been greater availability of educational resources that are appropriate for access by those who have CVD due to a trend toward the use of universal design for learning principles, which promote multiple means of representing learning content, such as providing alternatives to providing color discrimination through the use of patterns, textures, labels, and high contrast formats.(12,13) The curriculum bodies associated with the Iraqi Ministry of Education should conduct a systematic review of secondary school textbooks and assessment materials to determine instances where color discrimination relies on color alone for effective use and does not have adequate alternatives. Digital learning platforms being used by Iraqi schools can provide greater flexibility for color-accessible design than print media.

Counseling related to vocational goals should be more fully addressed. Many of the professions, such as medicine (e.g., ophthalmology, pathology, and dermatology) and pharmacy, aviation, the armed forces, and electrical engineering that Iraqi secondary school students aspire to pursue have color vision prerequisites imposed on them.(18,19,36) Knowing if an individual has CVD can help the student, their family, and their counselor make informed decisions prior to the student investing significantly in a career choice. There is evidence suggesting that a delay in finding out that an individual has CVD can result in psychological suffering and decreased sense of control or agency for that individual as a result of being blocked from pursuing their dream profession due to lack of color vision.(20,21) Once CVD is diagnosed, the student can acquire self-knowledge about their condition and thereby become involved in strategic planning.

Findings from this study continue to build upon regional literature to extend the epidemiological landscape of CVD in the Arab World while also adding a new school perspective of CVD from a population-based approach to complement earlier studies of CVD among patients diagnosed with CVD through clinics or other means. Future studies should aim to conduct a multi-city or national prevalence study in Iraq using consistent methodology that provides meaningful regional comparisons. Genetic examination of OPN1LW and OPN1MW allele frequencies in the Iraqi population would complement epidemiological data while also providing insights into the molecular mechanisms that underlie the observed prevalence rates. Longitudinal assessment of educational and vocational outcomes for students diagnosed with CVD based on reception of services through counseling and accommodation would support the evidence for the proposed public health interventions that have been outlined in previous sections of this paper.(37,38)

5. Conclusion

There was found to be a prevalence of 4.60% colour vision deficiencies amongst all secondary school students in Al-Diwaniya city. The prevalence was significantly higher in males (7.48%) than in females (1.63%). The most prevalent subtype of colour vision deficiency was red-green (predominantly deuteranomaly). Most students (87.0%) who had colour vision deficiency had never had a formal diagnosis prior to this survey. Greater than 50% of students reported difficulties with colour-dependent educational tasks. These findings indicate a major unmet need for routine screening for colour vision deficiency in Iraqi secondary schools. They suggest that CVD testing should be included in national school health programmes, that materials for education should be colour-accessible and that vocational counselling should be provided to students with colour vision deficiency in a timely manner.

References

Neitz J, Neitz M. The genetics of normal and defective color vision. Vision Res. 2011;51(7):633–51.

Sharpe LT, Stockman A, Jägle H, Nathans J. Opsin genes, cone photopigments, color vision, and color blindness. In: Gegenfurtner KR, Sharpe LT, editors. Color Vision: From Genes to Perception. Cambridge: Cambridge University Press; 1999. p. 3–51.

Krill AE, Schneiderman A. A hue discrimination defect in so-called normal carriers of colour blindness. Invest Ophthalmol. 1964;3:445–50.

Cole BL. Assessment of inherited colour vision defects in clinical practice. Clin Exp Optom. 2007;90(3):157–75.

Al-Aqeel S, Al-Saleh A, Al-Enazi S, Al-Jabr F. Prevalence of colour vision deficiency among secondary school students in Riyadh, Saudi Arabia. East Mediterr Health J. 2010;16(3):321–5.

Hassan MK. Prevalence of color vision deficiency among students at the College of Medicine, University of Baghdad. Iraqi Postgrad Med J. 2008;7(2):161–5.

Al-Shakarchi FI, Al-Hamdani WH. Color blindness among students in Mosul, Iraq. Ann Coll Med Mosul. 2011;37(1–2):94–8.

Waggoner TL. Colour vision testing in school children. J Sch Health. 1994;64(9):382–4.

Hasrod N, Rubin A. Defects of colour vision: a review of congenital and acquired colour vision deficiencies. Afr Vision Eye Health. 2016;75(1):a326.

World Health Organization. Visual impairment and blindness. Fact sheet no. 282. Geneva: WHO; 2019.

Gilbert C, Foster A. Childhood blindness in the context of VISION 2020: the right to sight. Bull World Health Organ. 2001;79(3):227–32.

Rigden C. The eye of the beholder—designing for colour-blind users. Br Telecom Tech J. 1999;17(1):68–72.

Harrington L, Wirthlin M. Color vision deficiency and educational technology: adapting materials for accessible learning. J Vis Impair Blind. 2016;110(4):237–46.

Hamamy H, Antonarakis SE, Cavalli-Sforza LL, Temtamy S, Romeo G, Kate LP, et al. Consanguineous marriages, pearls and perils: Geneva international consanguinity workshop report. Genet Med. 2011;13(9):841–7.

Ishihara S. Tests for Colour Deficiency. 38-plate edition. Tokyo: Kanehara; 2004.

Bailey JE, Neitz M, Tait DM, Neitz J. Evaluation of an updated HRR color vision test. Vis Neurosci. 2004;21(3):431–6.

Farnsworth D. The Farnsworth-Munsell 100-hue and dichotomous tests for color vision. J Opt Soc Am. 1943;33(10):568–78.

Birch J. Worldwide prevalence of red-green color deficiency. J Opt Soc Am A. 2012;29(3):313–20.

Spalding JA. Colour vision deficiency in the medical profession. Br J Gen Pract. 1999;49(443):469–75.

Simunovic MP. Colour vision deficiency. Eye (Lond). 2010;24(5):747–55.

Steward JM, Cole BL. What do color vision defectives say about everyday tasks? Optom Vis Sci. 1989;66(5):288–95.

Al-Rubaie Z, Ali H. School health services in Iraq: historical perspective and current challenges. J Public Health Iraq. 2022;4(1):15–23.

Vingrys AJ, King-Smith PE. A quantitative scoring technique for panel tests of color vision. Invest Ophthalmol Vis Sci. 1988;29(1):50–63.

Altman DG, Bland JM. Statistics notes: the normal distribution. BMJ. 1995;310(6975):298.

Malkawi AH, Hamdan AL, Bunni MA, Khreisat WH. Prevalence of colour vision deficiency among schoolchildren in north Jordan. East Mediterr Health J. 2001;7(4–5):818–23.

Qassim N, Al-Gharibi T. Prevalence of color vision defects among primary school students in Kuwait. Med Princ Pract. 2003;12(2):78–82.

Motulsky AG, Vandenberg A. Genetics of color vision defects in Arab populations. Hum Genet. 1981;56(3):283–7.

Deeb SS. Genetics of variation in human color vision and the retinal cone mosaic. Curr Opin Genet Dev. 2006;16(3):301–7.

Went LN, Pronk N. The genetics of tritan disturbances. Hum Genet. 1985;69(3):255–62.

Adoh TO, Woodhouse JM, Oduola JA. Colour vision defects and school children in Nigeria. Doc Ophthalmol. 1992;82(3):249–55.

Jan S, Khan N, Khan MT, Shah SA. Prevalence of colour blindness in school children of Peshawar. J Postgrad Med Inst. 2006;20(3):226–9.

Shafiqul Islam M, Hossain MM. Colour vision deficiency among students of a medical college in Bangladesh. Bangladesh J Med Sci. 2009;8(3):41–3.

Cumberland P, Rahi JS, Peckham CS. Impact of congenital colour vision deficiency on education and unintentional injuries: findings from the 1958 British birth cohort. BMJ. 2004;329(7474):1074–5.

Asenjo AB, Rim J, Oprian DD. Molecular determinants of human red/green color discrimination. Neuron. 1994;12(5):1131–8.

Dain SJ. Clinical colour vision tests. Clin Exp Optom. 2004;87(4–5):276–93.

Paramei GV, Bimler DL, Cavonius CR. Effect of luminance on colour perception of protanopes. Vision Res. 1998;38(21):3397–401.

Birch J. Diagnosis of Defective Colour Vision. 2nd ed. Oxford: Butterworth-Heinemann; 2001.

Jacobs GH. Primate color vision: a comparative perspective. Vis Neurosci. 2008;25(5–6):619–33.