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A Cross-Sectional Study about the Prevalence of Color Vision Deficiency among School Children in Benghazi

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Abstract

Background Color vision deficiency (CVD) is a common disorder caused by damage to retinal photoreceptors and cones. The disorder makes a person less able to perceive color variations.

Aims The objective of the study was to assess the prevalence of CVD among the school children in Benghazi, Libya.

Methods This cross-sectional study was performed in the Department of Ophthalmology, Benghazi University, Benghazi, Libya, during the period from December 2023 to March 2024. The study included 1,022 students aged 6 to 18 years to assess the prevalence of CVD. Visual acuity assessment was performed in a place with good daylight illumination using the standard Snellen Tumbling E chart at a distance of 6 m. Color vision evaluation was performed in the schools using Ishihara color plates (24 plate–edition). The quantitative variables were presented as mean ± standard deviation, and the qualitative variables were presented as frequencies and percentages. The Student's *t*-test was used for comparing means, whereas the chi-square test was applied for comparing the frequencies. A *p*-value of < 0.05 was considered statistically significant.

Results CVD was present in 15 cases (1.5%). There were 13 males (2.6%) and 2 females (0.38%) with a statistically significant difference regarding gender. Among the 13 males with CVD, 7 students (53.8%) had deuteranomaly, 2 students (15.4%) had deuteranopia, 1 student (7.7%) had protanomaly, and 3 students (23.1%) had color blindness. The two females with CVD both had deuteranomaly.

Conclusion Early detection of CVD is vital to making informed decisions about a student's future career. With early detection, parents and teachers can adjust their educational strategies to ensure the best learning outcomes for the student.

Keywords
- color vision disorder
- school children
- prevalence
- visual activities
- Ishihara

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ملخص المقال باللغة العربية

دراسة مقطعية عن انتشار خلل رؤية الألوان بين الأطفال في المدارس في بنغازي

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الخلفية: يعتبر نقص رؤية الألوان اضطراب شائع يحدث بسبب تلف المستقبلات الضوئية والمخاريط الشبكية. يجعل هذا الاضطراب الشخص أقل قدرة على إدراك الاختلافات اللونية.

الهدف: الهدف من هذه الدراسة تقييم انتشار نقص رؤية الألوان بين أطفال المدارس في بنغازي، ليبيا.

الطرق: أجريت هذه الدراسة المستعرضة في قسم طب وجراحة العيون، جامعة بنغازي خلال الفترة من ديسمبر 2023 إلى مارس 2024. شملت الدراسة 1022 طالبًا تتراوح أعمارهم بين 6 و 18 عامًا لتقييم انتشار نقص رؤية الألوان. تم إجراء تقييم حدة البصر في مكان به إضاءة نهارية جيدة باستخدام مخطط سنيلين القياسي E على مسافة 6 أمتار. تم إجراء تقييم رؤية الألوان في المدارس باستخدام لوحات ألوان إيشيهارا (Ishihara color plates إصدار 24 لوحة). تم تقديم نتائج المتغيرات الكمية كمتوسط ± انحراف معياري، كما تم تقديم نتائج المتغيرات النوعية كترددات ونسب مئوية. تم استخدام اختبار t للطلاب لمقارنة المتوسطات، في حين تم تطبيق اختبار مربع كاي لمقارنة الترددات. تم اعتبار القيمة $p<0.05$ ذات دلالة إحصائية.

النتائج: كان هناك خلل رؤية الألوان في 15 حالة (1.5%). منهم 13 ذكراً (2.6%) و2 أنثى (0.38%) مع وجود فرق ذي دلالة إحصائية بين الجنسين. من بين الذكور الـ 13 المصابين بخلل في رؤية الألوان، كان لدى 7 طلاب (53.8%) فقدان كامل لرؤية الأخضر (Deuteranomaly)، وطالبان (15.4%) مصابان بانخفاض الحساسية للون الأخضر (Deuteranopia)، وطالب واحد (7.7%) مصاب بانخفاض الحساسية للون الأحمر (Protanomaly)، وثلاثة طلاب (23.1%) مصابون بعمى الألوان بالكامل (Colour Blindness). كلتا الأنثيين المصابتين بفقدان كامل لرؤية الأخضر (Deuteranomaly).

الاستنتاج: يعتبر الاكتشاف المبكر لقصور رؤية الألوان أمرًا حيويًا لاتخاذ قرارات مدروسة بشأن مستقبل الطالب المهني. حيث أن هذا الاكتشاف المبكر يمكن للآباء والمعلمين تعديل استراتيجياتهم التعليمية لضمان تحقيق أفضل نتائج في تعلم الطالب.

الكلمات المفتاحية: اضطراب رؤية الألوان، أطفال المدارس، معدل الانتشار، الأنشطة البصرية، إيشيهارا

Introduction

Human beings have the special ability to see in color, which distinguishes them from other species. Color vision is the ability to discriminate a light stimulus as a function of its wavelength. The Young–Helmholtz theory of trichromatic color vision postulates the existence of three kinds of cones, each containing a different photopigment which is maximally sensitive to one of the three primary colors. Normal, or trichromatic, color vision is mediated by three types of cone photoreceptors—designated short- (S), middle- (M), and long- (L) wavelength-sensitive, showing peak absorbencies at light wavelengths of 415, 530, and 560 nm, respectively. Blue, green, and red are thus called primary colors as any color can be produced by mixing appropriate proportion of these three colors.[1]

Color vision deficiency (CVD) arises when there is a fault in the development of one or more types of the retinal cone cells (photoreceptors) that control color discrimination in light and conducting them into the optic nerve.[2] The most common color vision defects are red-green type (protan-deutan). In red-green CVD, males are often affected much more than females. Among people with Northern European descent, it occurs in almost 1 in 12 males and 1 in 200 females. Color vision defects of the blue-yellow type affect males and females equally. This complaint occurs in less than 1 in 10,000 people worldwide. Color vision defects of the red-green type are inherited as an X-linked recessive pattern. The mutant genes responsible for CVD are located on the X chromosome, which is one of the two sex chromosomes. In males (who have only one X chromosome), one genetic change in each cell is enough to cause the condition, so disorders are much more frequent in males than females.[3]

Using color vision is a fundamental need for daily tasks like driving, cooking, working, and dressing.[4] CVDs can significantly negatively affect quality of life, studying, and occupation, and can increase the risk of road traffic accidents. People with CVDs are at a distinct disadvantage when performing certain visual activities, and they might also be excluded from pursuing particular occupations.[5]

Male sex, consanguineous marriage, and a positive family history of CVDs are the key risk factors for CVDs.[6] There are not many extensive studies about the prevalence rate of CVDs in Libya. Rahman et al, [7] studied the incidence of red-green color blindness in a Libyan population compared with two samples of Indian population where the incidence of color blindness was found to be 2.209% in the Libyan population.[7]

The current rationale for school screening for CVD is the potential preclusion from occupations such as driving, flying, defense services, engineering, and medicine. School children should know if they have CVD so they can be helped more quickly to find adaptive strategies and be able to take it into account when planning their career. The objective of the study was to assess the prevalence of CVD among school children in Benghazi, Libya.

Methods

This cross-sectional study was conducted in the Ophthalmology Department at Benghazi University, Benghazi, Libya during the period from December 2023 to March 2024. The target population of the study was 1,022 students aged 6 to 18 years, from all educational levels before university (primary, preparatory, and secondary), from 7 different schools in Benghazi. A written informed consent was obtained from

all parents or guardians of the children and the study was approved by the research ethics committee of the Faculty of Medicine, Benghazi University (Institutional Review Board).

Study Population and Sampling Method

A multistage sampling method was employed. First, 7 school**s** were randomly selected from the 250 schools in Benghazi using a random number table. Next, from each selected school, school children aged 6 to 18 years who were able to read numbers were selected. Children who were healthy with no abnormal ocular findings were included in the study. Participants on chronic drug therapy for more than 1 month, with a systemic illness, or with a history of ocular or head injury that significantly affected vision were excluded.

Using the World Health Organization Manual for sample size determination in health studies, with an anticipated population proportion of 8%, an absolute precision of 2% at a 95% confidence interval, a design effect of 2, and an assumed 90% response rate, the minimum sample size required for this study was calculated to be 1,022.[8] All 1,022 selected students were interviewed and tested for CVD.

Inclusion Criteria

1. Libyan students with visual acuity 6/6 or 6/9, with or without glasses.
2. Students aged between 6 and 18 years.
3. Students who agreed to participate in the study.

Exclusion Criteria

1. Non-Libyan students.
2. Students with visual acuity worse than 6/9.
3. Students who did not agree to participate in the study.
4. Children with any evidence of ocular pathology, such as congenital cataract, congenital glaucoma, ocular trauma, previous ocular surgery, or long-term use of medication.

Visual Acuity Assessment

In the first step, the participants were asked to answer a demographic questionnaire completed by their parents at home (►**Fig. 1**). Then, the examinations were performed.

Visual acuity assessment was performed in a place with good daylight illumination using the standard Snellen Tumbling E chart at a distance of 6 m. All students who wore spectacles had their visual acuity assessed while wearing their spectacles. Students with decreased visual acuity were referred for further evaluation and refraction at an ophthalmology clinic.

Ishihara color vision plates were used to detect and classify red-green CVDs, which are the most common types of CVD.

Color vision evaluation was performed in the students' schools by an ophthalmologist using Ishihara color plates (24 plate–edition). Before performing the test, the procedure was clearly explained to the students. The plates were held at a distance of 75 cm, and the students were asked to read the numerals that were visible on the plates within 3 to 5 seconds. A pass of the Ishihara test was the ability to read all plates or an incorrect response in not more than two plates.

استبيان حول ضعف رؤية الألوان لدى طلاب المدارس

Questionnaire on color vision deficiency among school students

١. الاسم : Name

٢. الجنس: ذكر/أنثى Gender: Male/ Female

٣. العمر: Age

٤. هل توجد صلة قرابة بين الوالدين؟ نعم/لا

Is there a consanguinity between the parents? YES/ NO

٥. هل تم ملاحظة وجود أي عدم تمييز للألوان لدى الطالب/الطالبة؟ نعم/لا

Has there been any observed colour blindness in the student? YES / NO

٦. هل يوجد أي شخص في العائلة يعاني من عدم تمييز الألوان؟ نعم/لا

إذا كان الجواب نعم، يرجى ذكر صلة قرابته بالطالب /الطالبة

Is there any one in the family who is colour blind? Yes/ NO. If yes, please specify the relationship to the student

٧. هل يوجد إمراض عيون وراثية في العائلة (مثل ضعف النظر، العشى الليلي، الماء الأزرق، أمراض الشبكية)؟ نعم/لا

اذا كان الجواب نعم ، يرجى ذكر نوع المرض وصلة القرابة بين المريض والطالب/ الطالبة

Are there any hereditary eye diseases in the family (such as error of refraction, night blindness, glaucoma, retinal diseases) ? YES/ NO. If yes, please mention the type of disease and the relationship of the patient to student

٨. هل توافق على إجراء اختبار النظر واختبار تمييز الألوان للطالب/ الطالبة؟ إذا كنت توافق، يرجى التوقيع كولي الأمر/الوصى.

Do you agree to have the student undergo a vision test and colour blindness test? If you agree , please sign as the parent/ gurdian

Fig. 1 Questionnaire on color vision deficiency in school students.

The results were classified based on the instructions provided in the manual for the Ishihara test plates.

To determine the normality or defectiveness of color vision, plates 1 to 15 were evaluated. If 13 or more plates were read normally, the color vision was regarded as normal. If 9 or fewer plates were read normally, the color vision was regarded as color blind (as per the Ishihara 24-plate edition guidelines). For plates 14 and 15, only those who read the numerals "5" and "45" and did so more easily than the numerals on plates 10 and 9 were considered to have abnormal readings. Plates 16 and 17 were used to determine the presence of protanopes and deuteranopias. All children with CVDs were referred to the base hospital for further evaluation and management.

Statistical Analysis

The data were entered into Microsoft Excel, and the statistical analysis was performed using the statistical software SPSS version 21.0. The quantitative (numerical) variables were presented as mean and standard deviation, and the qualitative (categorical) variables were presented as frequency and percentage.

The Student's *t*-test was used for comparing the mean values between the two groups, whereas the chi-square test was applied for comparing the frequencies. A *p*-value less than 0.05 was considered statistically significant.

Results

►**Table 1** shows that a total of 1,022 students with a mean age of 12.5 ± 5.4 years were studied. They were 496 (48.5%)

Table 1 Basic characteristics of the study participants ($n = 1,022$)

Variable	*N*	Percent (%)
Gender		
Male	496	48.5
Female	526	51.5
Age (mean ± SD)	12.5 ± 5.4	
Visual accuracy		
6-Jun	847	82.9
9-Jun	121	11.8
Visual accuracy corrected		
6-Jun	43	4.2
9-Jun	11	1.1
Consanguinity between parents		
No	811	79.4
Yes	211	20.6
Family history of color vision deficiency		
No	983	96.2
Yes	39	3.8
Family history of eye disease		
No	698	68.3
Yes	324	31.7
Total color vision deficiency	15	1.5
With family consanguinity	3	0.3
With family history of eye disease	8	0.8
With family history of color vision deficiency	3	0.3
Without family history or consanguinity	1	0.1

Abbreviation: SD, standard deviation.

males and 526 (51.5%) females. Consanguinity between the parents was present in 211 cases (20.6%), family history of CVD was present in 39 cases (3.8%), family history of eye disease was present in 324 cases (31.7%), and family history of CVD was present in 39 cases (3.8%). CVD was present in 15 cases (1.5%), including 3 cases (0.3%) with family consanguinity, 8 cases (0.8%) with a family history of eye disease, 3 cases (0.3%) with a family history of CVD, and 1 case (0.1%) without a family history or consanguinity.

►**Table 2** shows that among the students with CVD, there were 13 males (prevalence of 2.6%) and 2 females (prevalence of 0.38%), with a statistically significant difference regarding gender ($p < 0.03$).

►**Table 3** shows that among the 13 male students with CVD, 7 (53.8%) with deuteranomaly, 2 (15.4%) with deuteranopia, 1 (7.7%) with protanomaly, and 3 (23.1%) with color blindness. The 2 female students with CVD had deuteranomaly. ►**Table 4** provides a summary of studies reporting prevalence rates similar to the current study.

Table 2 Prevalence of color vision deficiency according to sex ($n = 15$)

Sex	*n* (%)	Chi-square	*p*
Male (496)	13 (2.6)	3.129	0.03[a]
Female (526)	2 (0.38)		

[a]Ask corresponding author about the method used to calculate this *p*-value.

Discussion

Color vision is an integral part of a child's life, as they are often exposed to colorful objects at school and during day-to-day activities. For example, they are asked to describe certain items by their colors and fill in coloring sheets at school. Children with CVD are not able to learn to their full capacity, which can undermine their confidence and provide a faulty foundation for future learning.[9] Poole et al[10] proved that color blindness can be a prohibitive factor in some cases, such as for histopathologists and medical laboratory technologists.

CVD may be congenital or acquired. Congenital color defects are nonpathological, incurable, and constant throughout life. There are also different causes for acquired color vision defects, such as ocular or neurological disease, some metabolic disorders, drug toxicity, and exposure to certain solvents.[11]

CVD does not cause complete blindness, and there are no available therapeutics that can treat CVD. However, color vision is crucial to an individual's understanding of their visual world, and those with color vision defects can experience difficulties in everyday life.[12] Those who have CVD will be better able to adapt and make more informed career choices if they know about their color vision status. However, a high proportion of school children are unaware of their color vision status, and undiagnosed CVD could pose a handicap to the academic performance of an affected student. Moreover, early detection of color vision malfunction in children allows parents and teachers to make necessary adjustments to the teaching methods for appropriate learning.[12]

Screening of color vision defects only requires detection of the presence or absence of a defect. Since the prevalence of protan and deutan defects are by far the highest among congenital color deficiencies, most screening tests for color vision only identify red-green deficiencies. Screening of CVDs is usually done with pseudoisochromatic plates, of which the Ishihara test is probably the most well-known.[1] Ishihara plates can only be used to detect and classify red-green CVDs, which are the most common types of CVD.[13]

The current study showed that the prevalence of CVD was 1.5%, which is almost similar to the study of Geletu et al,[14] who reported a prevalence of CVD of 1.6%, and the study of Khairoalsindi et al,[6] who reported a prevalence of CVD of 1.77%. Elshazly et al[15] reported a prevalence of CVD of 1.9% in their study. Additionally, in a study conducted by Moudgil et al,[16] the prevalence of CVD was 1.87% among 3,259

Table 3 Distribution of the cases of CVD according to gender and type

Type of CVD	Male ($n = 13$)		Female ($n = 2$)	
	Number	Percentage	Number	Percentage
Deuteranomaly	7	53.8	2	100
Deuteranopia	2	15.4	0	0
Protanomaly	1	7.7	0	0
Protanopia	0	0	0	0
Color blindness	3	23.1	0	0
Total	13	2.6	2	0.38

Abbreviation: CVD, color vision deficiency.

Table 4 Summary of studies quoting prevalence rates similar to the current study

Author	Variables		
	Total CVD prevalence	CVD in males	CVD in females
Current study	1.5%	2.6%	0.38%
Khairoalsindi et al[6]	1.77%	3.5%	0.5%
Elshazly et al[15]	1.9%	2.8%	0.9%
Moudgil et al[16]	1.87%	1.69%	0.184%
Mashige and van Staden[19]	2.2%	4.2%	0.6%
Chhipa et al[20]	0.9%	1.4%	0.4%

Abbreviation: CVD, color vision deficiency.

students. In contrast, the prevalence in the male population among other studies was 3.90% in the study by Shrestha et al[17] and 3.35% in a study conducted by Oriowo and Alotaibi[18] among 1,632 school children in Saudi Arabia. This variability in the prevalence of CVD may be due to differences in study groups, geographical areas, and ethnicity. In comparison to the above studies, the prevalence of CVD is low in Benghazi city.

The current study showed that the average prevalence of CVD was 2.6% in males and 0.38% in female children, which is almost similar to the study of Elshazly et al[15] who found that the prevalence of CVD was 2.8% in males and 0.9% in females, which was a statistically significant difference. In the same line, the study of Mashige and van Staden[19] reported that among 704 (53.9%) females and 601 (46.1%) males, the prevalence was 4.2 and 0.6% in males and females, respectively. Also, the study of the Khairoalsindi et al[6] found that the prevalence was 3.5% in males and 0.5% in females, while in the Chhipa et al[20] study, it was 1.4% in males and 0.4% in females. This higher prevalence of CVD in males than in females may be attributed to the fact that male children tend to have a higher CVD frequency, which reinforces the X-linked recessive nature of the trait (i.e., the single X-chromosome in males is predominant to color blindness, while females with two X-chromosomes can act as dosage compensation and decrease the risk of the disease).

The current study showed that there were 13 males (2.6%) with color vision defects, 7 students (53.8%) had deuteranomaly, 2 students (15.4%) had deuteranopia, 1 student (7.7%) had protanomaly, and 3 students (23.1%) had color blindness. There were 2 females with CVD, and they were shown to have deuteranomaly. Similarly to our results, the study of Geletu et al[14] found that the prevalence of deuteranomaly was 48.5%, that of deuteranopia was 21.2%, and that of protanomaly was 18.4%. In addition, this was also confirmed by Nazeer et al,[21] who found the prevalence of deuteranomaly to be 41.6% and that of protanomaly to be 25%.

In the current study, the prevalence of color blindness was relatively high (3 students out of the 13 with CVD). This may be attributed to various factors that can affect color blindness prevalence, including genetic factors, which are considered among the most important determinants of the dispersion of the disease and its prevalence in the communities, as well as sampling and analytical techniques, racial differences, and different instruments of examination, which can also lead to inconsistent results.

Congenital and genetic ocular disorders are linked to parental consanguinity. Due to several mechanisms, there is an increased risk of refractive errors (REs) with parental consanguinity. Specifically, the risk of vision impairment is among the genetic disorders that could be included in preconception genetic counseling for consanguinity. This would show the presence of a genetic or hereditary disorder in the ancestors. In the field of ophthalmology, few studies have explored the relationship between consanguinity and ocular or vision disorders. Consanguinity is rarely associated with acquired blindness.[22] Further, an autosomal recessive disorder (e.g., retinitis pigmentosa) could be more common a

finding in populations where consanguinity is more prevalent. An increased prevalence of congenital cataracts has also been reported in those populations. There are suggestions that improved screening methods (especially for REs), obtaining genetic counseling, and early therapeutic interventions can reduce the effect of childhood blindness.[23]

Because color blindness is an asymptomatic and nonfatal disorder, most sufferers are usually unaware of the defect since their vision is otherwise normal. However, early diagnosis of CVD is important for preparing color-blind individuals for future careers and to avoid mistakes in situations that might involve lives. In some jobs such as medical practices, traffic control, and driving, color discernment has profound implications. Hence, it is essential that CVD is detected at an early age to guide against certain occupational hazards.[24]

Limitations

This study has several limitations that may affect the validity and generalizability of its findings. The most significant limitation is the sample bias resulting from the use of a school-based sample, which may not accurately reflect the wider population. Additionally, the participants did not undergo detailed eye examinations, leading to a lack of crucial data. Finally, the absence of genetic counseling means that important hereditary factors influencing the study's focus were not taken into account, potentially missing out on insights that could have enriched the research.

Conclusion

The prevalence of CVD among school children in Benghazi, Libya, was 1.5%, with males having a significantly higher prevalence than females. Screening of school children can be a simple and highly effective strategy in detecting color vision impairment. Early detection of color vision impairment is crucial for making well-informed decisions about a person's future profession. When children's color vision problems are identified early on, parents and educators can modify their teaching strategies to ensure that their students learn in the best possible way. However, in developing nations, this is not always feasible.

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Conflict of Interest
None declared.

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