• Original Article •

Prevalence of inherited color vision deficiency among male school teenagers in Nablus, Palestine

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Abstract

● **AIM:** To find out the prevalence of inherited color vision deficiency (CVD) among Palestinian male-school children aged 14-18 and compare it with other eastern and western countries.

● **METHODS:** Six hundred and thirty-four male subjects (*n*=634) aged 14-18 from Palestinian Governorate of Nablus were randomly selected and screened using Ishihara pseudoisochromatic plates. Subjects who failed Ishihara screening were tested further with computer software of Farnsworth-Munsell 100 Hue test.

● **RESULTS:** Out of the 634 male participants, 597 were included in the study and 8.0% of them (48 males) demonstrated red-green CVD. 5.4%, 2.3% and 0.3% of the 48 males exhibited deutan, protan and total color vision deficiency (monochromacy), respectively.

● **CONCLUSION:** The results show that the prevalence of red-green CVD among the male school children from Palestinian Governorate of Nablus is not significantly different from that of male populations in nearby and Western countries.

● **KEYWORDS:** color vision; deuteranomaly; protanomaly; prevalence; Palestine

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INTRODUCTION

The ability to perceive colors is one of the most important functions of human vision. Color vision not only enhances human perceptual capabilities but also serves as a visual cue for daily life activities. The retina consists of photoreceptors which are rods and cones. Rods are responsible for night time vision (dim lighting conditions) whereas cones are responsible for daytime vision (bright lighting conditions). The retinal cone photoreceptors, which are mainly located at the fovea, produce color sensation and high-resolution visual information, it convert light energy into electrical signals that are sent through the visual pathway for the brain to produce color sensation. Color vision is mediated by three cone photoreceptors, the blue, green, and red cones (also known as the short (S)-, medium (M)-, and long (L)- wavelength cones, respectively). Normal sighted individuals are referred to as trichromats because they can perceive a wide range of colors. An absence or alteration of any cone type results in color vision deficiency (CVD). CVD, one of the most common inherited vision disorders, is a condition where a person cannot differentiate between certain colors or shades of color. It can be either inherited (color blindness) or acquired. Inherited CVD can be classified by either severity (anomalous trichromacy, dichromacy, and monochromacy) or by the type (s) of cone (s) affected. Anomalous trichromacy is the mildest form of CVD in which the patient has all three cone photopigments, but one photopigment is anomalous. In deuteranomalous trichromacy, the green cones are anomalous, whereas in protanomalous and tritanomalous trichromacy, the red cones and blue cones are anomalous respectively. The prevalence of Inherited CVD may be as high as 8% in males and 0.5% in females. The incidence of CVD varies from race to race and across different geographic areas across the world as it's a genetic disorder in most of the cases. Acquired CVD is a less common condition secondary to ocular or visual pathway disease that may results from retinal disorders, ocular media disorders, drug-induced or environmental factors (Toxins, Hypoxia). Inherited CVD is said to be present from birth, bilaterally symmetrical, stable and is thought to affect the entire field of vision. On the other hand, acquired CVD may demonstrate progression or regression, may affect one eye or both eyes asymmetrically, and only a portion of the visual field may be affected. Patients with CVD do not have complete blindness, not physically

debilitating so in the absence of proper screening most of the cases remain undetected[1-3].

Patients often lack awareness of its extent and effect. In a study by Cole and Steward, 5% of dichromats and 25% of anomalous trichromats were not aware of their deficiency. Although there is no available therapeutics that can treat CVD, awareness of the patients of their condition and earlier detection in children allows teachers and parents to make necessary adjustments to the teaching methods for appropriate learning as it can affect the students scholarly performance[4]. Career choice and job performance can also be adversely affected by CVD since many professions' activities depend on color discrimination ability. Color vision discrimination is essential in professions such as aviation, railway operation, marine navigation, construction, transportation, armed services, photography, biomedical lab workers and physicians. People with CVD in such professions will find it difficult to discriminate natural surface colors (*e.g.* fluids, tissues, body skin) as well as man-made surface colors (*e.g.* wires, color display, chemical substances, art prints)[5]. Organizations such as the Federal Aviation Administration (FAA), the Federal Bureau of Investigation (FBI), and the American Society of Mechanical Engineers are now all requiring applicants to conduct color vision testing[6].

Within Palestine there is no awareness or screening programs for CVD. Additionally, no studies have been conducted on the prevalence of CVD in Palestine. The purpose of this study is to determine the prevalence of inherited CVD among male school children aged 14-18 in the Palestinian Governorate of Nablus.

SUBJECTS AND METHODS

Ethical Approval This research followed the tenets of the Declaration of Helsinki. Ethical approval to conduct this study was obtained from the Institutional Review Board (IRB) committee at ANNU. Informed consent was obtained from all the participants surveyed in the study. All consent forms entailing study objectives and significance were provided to students in Arabic language to ensure they fully understand what their participation requires.

A cross-sectional descriptive study aimed to evaluate the CVD in male school children between the ages of 14 and 18y. The study was conducted on six hundred thirty-four (n=634) male school children that were recruited using a two-stage random sampling technique. The public schools were randomly selected based on their location relative to city center. The mean age for this group was 15.58. All students selected were of Palestinian origin. In the estimation of the prevalence of inherited CVD 597 subjects were included, and 37 were excluded as they did not meet the inclusion criteria (males, age: 14-18, healthy with normal medical and ocular histories and negative history of long-term medication use). Of those who were included, the mean age was 15.58y. Six schools in Nablus Directorate were chosen on random basis depending on the location as North, East, West and Central. Schools located in the southern region were not included as they were not part of the Nablus directorate. The age distribution of the study sample is shown in Table 1.

In the study sample, 29.6% was 14y, 19.9% was 15y, 23.5% was 16y, 16.6% was 17y, and 10.4% was 18y. Students were selected after passing the visual acuity test (passing criteria ≥20/30) with or without spectacles.

All procedures conducted throughout the study were conducted privately for each student. All selected subjects were first tested for visual acuity using a Snellen Visual Acuity Chart. Students with visual acuity less than 20/30 were excluded from the beginning. A face-to-face questionnaire was then used to gather demographic information, as well as information on medical and ocular history, and medication use. Only healthy males, with no medical or ocular disease history, and with visual acuity 20/30 or better were enrolled in the study to minimize the inclusion of subjects with possible acquired CVD. Color vision awareness and parental consanguinity were also assessed. All students who were excluded from the study based on their reduced visual acuity were referred for comprehensive eye examinations. Students from the same age and school were chosen randomly to account for the number of students who were excluded from the study.

The Ishihara pseudoisochromatic plates were then used to screen for CVD under day light illumination. The plates were viewed at a distance of 50-75 cm (arm's length). The number plates of the Ishihara were used, and those who made more than five typical R-G defective responses between plates 2 and 14 were considered to have failed the color vision screening. Plates 22 to 25 were used to differentiate between the subtypes of R-G CVD. The test was repeated twice for all subjects who failed the first time to confirm accuracy of results. Computer software of FM 100-Hue test was used for those who failed the Ishihara screening test. Trained medical students performed both the Ishihara screening, and the FM 100-Hue test.

Statistical Analysis The Statistical Package of Social Sciences version 16.0 (SPSS Inc., Chicago, IL, USA) was utilized for data entry and statistical analysis. Only the participants who completed the study were included in data analysis. Chi-square test was used to compare the characteristics of each classification group. A multivariate analysis was used to evaluate the associations with KC. P≤0.05 were considered statistically significant.

RESULTS

Color Vision Deficiency Prevalence A total of 48 (8%) of students were found to have CVD. 32 (5.4%) students were deutans, and 14 (2.3%) were protans. Two students (0.3%)

Table 1 Distribution of the sample

School names	Location of the school in relation to the city	Total sample	Age of selected subjects (a)	No. and percentage according to age
Ibn Qutaybah Basic School	Center	144 (24.1%)	14-15	14:127 (88.2%)
				15:17 (11.8%)
Abdul Hamid Al-Sayeh Secondary School	Center	74 (12.4%)	14-17	14:8 (10.8%)
				15:37 (50%)
				16:13 (17.6%)
				17:16 (21.6%)
King Talal Secondary School	Center	97 (16.2%)	16-18	16:21 (21.7%)
				17:50 (51.5%)
				18:26 (26.8%)
Northern Asira Secondary School	North	86 (14.4%)	15-18	15:20 (23.2%)
				16:42 (48.8%)
				17:9 (10.4%)
				18:15 (17.4%)
Azmout Secondary School	East	121 (20.2%)	14-18	14:41 (33.9%)
				15:23 (19.0%)
				16:25 (20.7%)
				17:13 (10.7%)
				18:19 (15.7%)
Lutfeyyah Al-Seife Secondary School	West	75 (12.5%)	14-18	14:1 (1.3%)
				15:22 (29.4%)
				16:39 (52.0%)
				17:12 (16.0%)
				18:1 (1.3%)

were totally color blind (monochromats). There was a deutan to protan ratio of 2.3:1. Of those who had CVD, 33 students (68.7%) were found to have mild CVD (Deuteranomalous and Protanomalous), 13 (27.1%) students were found to have severe (Deuteranopia and Protanopia) CVD, and 2 students (4.2%) were found to have total CVD (Monochromats) as shown in Table 2.

Regional Distribution Samples were selected based on the four Directorate regions of Nablus. The highest prevalence of CVD was observed in the Eastern region (14%) followed by Central (6.55%), Northern (5.8%) and Western (5.8%).

Color Vision Deficiency & Consanguinity All 172 of 597 (28.8%) students indicated the presence of parental consanguinity in the questionnaire. The highest prevalence of parental consanguinity was observed in the Eastern region (68.8%) followed by Central (20.7%), Western (16.4%) and Northern (12.9%) regions. Of those who were found to have CVD 14 of 48 (29.1%) students were found to have parental consanguinity. The highest prevalence of consanguinity among CVD students was found in the Eastern region, where 10 of 17 (58.8%) students had CVD and parents with consanguineous marriages, followed by 4 of 23 (17.3%) students in the central region. All students from the Northern and Western regions who have CVD denied any history of parental consanguinity, as shown in Table 3.

Color Vision Deficiency Awareness Out of the total inclusion sample, only 0.8% (5 of 597 students) had difficulty with color discrimination. All these 5 students were found to have CVD, thus 10.4% (5 of 48) of CVD students had difficulty with color discrimination. Three of them had deuteranopia, and the remaining two had total color vision deficiency (monochromacy). None of the 48 CVD students were previously diagnosed to have CVD. All students enrolled denied that they knew any relative with a problem in color discrimination.

DISCUSSION

Color vision problems can make learning and reading hard for children, which can lead to poor schoolwork and low self-esteem. As this condition can have a big impact on a person's life. So, it's important to detect the problem as early as possible. Early diagnosis of this condition and a subsequent full eye examination can help find possible acquired causes which can be managed, on the other hand, affected persons can learn to make up for their problems seeing colors.

Table 2 The types and prevalence of color vision defects

CVD category	CVD type	Prevalence (M)	Total
Anomalous trichromacy	Protanomaly	2.0%	5.53%
	Deuteranomaly	3.5%	
Dichromacy	Protanopia	0.3%	2.18%
	Deuteranopia	1.8%	
Monochromacy	-	0.33%	0.33%
Total	-	-	8.04%

CVD: Color vision deficiency.

Table 3 The prevalence of parental consanguinity according to the regions

Regions	Percentage of parental consanguinity	Percentage of parental consanguinity in subjects with CVD
Eastern	(68.8%)	(58.8%)
Central	(20.7%)	(17.3%)
Western	(16.4%)	(0.0%)
Northern	(12.9%)	(0.0%)
All regions	(28.8%)	(29.1%)

CVD: Color vision deficiency.

Table 4 Comparison of the present study results (prevalence %) with samples of previous studies from different populations of certain countries

Countris of the study	Sample size (M)	Prevalence of CVD (%)	References
Jordan (2001)	218	8.72	Al-Qwasmeh[7]
Turkey (2005)	941	7.3	Citirik *et al*[8]
Iraq: Erbil (2013)	1275	8.47	Karim J. Karim, Mohammed A. Saleem[9]
Iraq: Kurdistan (2017)	283	6.3	Masood Abdulrahman[10]
Saudi Arabia (2008)	838	5.8	Oriowo & Alotaibi[11]
Iran: Zahedan (2014)	1000	1.6	Momeni-Moghaddam H[12]
Iran: Mashhad (2017)	877	15.85	Hassan Hashemi *et a*l[13]
Germany	6863	7.75	Birch[14]
Norway	9049	8.01	Birch[14]
United Kingdom	1338	8.82	Birch[14]
Belgium	1241	8.48	Birch[14]
Switzerland	1036	8.20	Birch[14]
France	6635	8.95	Birch[14]
North America	-	8	N.R.C[15]
India (2013)	1352	8.73	Ahsana SHAH *et al*[16]
Korea (1989)	4678	5.9	Kim *et al*[17]
China (1976)	19459	4.6	Iinuma and Handa[18]
Taiwan (1976)	8050	5.3	Iinuma and Handa[18]
Mexico (1990)	-	2.57	Ceda *et al*[19]
Pakistan(2016)	452	5.75	Hamida Tehmina *et al*[20]
South-West Nigeria (2016)	769	3.8	Mary Ogbenyi Ugalahi[21]

CVD: Color vision deficiency.

The Prevalence of Color Vision Deficiency The results of this study showed a prevalence of congenital red-green CVD of 8% among male students aged 14-18 in the Palestinian governorate of Nablus. By comparing this result with the nearby countries, it is noticed that the prevalence was almost similar to studies conducted in some countries in the Middle East. A study done in Jordan in 2001 showed a prevalence of (8.72%)[7], a study done in Turkey in 2005 showed a prevalence of (7.3%)[8] and other studies done in different regions in Iraq showed similar results[9-10]. On the other hand, comparing the result with a study done in Saudi Arabia in 2008, it is noticed that a relatively higher prevalence in Palestine (8% *vs* 5.8%)[11], same as in a study done in Iran[12]. Table 4 shows the prevalence of CVD in different countries.

Comparing the results of this study with the prevalence of red-green CVD worldwide, it is found that it is within similar range as when compared to studies done in Germany, Norway, United Kingdom, Belgium, Switzerland, India, France and North America[14-16]. On the other hand, when compared to studies done in Asian countries such as Korea, China and Taiwan (in which the color vision deficiency according to such studies were 5.9%, 4.6%, and 5.3% respectively) the prevalence of color vision deficiency in this study was higher[17-18]. It was also higher than the prevalence of color vision deficiency in studies done in Mexico, Pakistan and Nigeria (2.57%, 5.75% and 3.8% respectively)[19-21].

Subtypes of Red-green CVD The majority of subjects discovered with color vision deficiency were deutan followed by protan. The deutan / protan ratio was (2.3:1) which was slightly lower than the worldwide ratio (3:1) and higher than the ratio of a study done in Jordan in 2001 (1.71:1). In this study, the prevalence of total color vision deficiency

(Monochromats) was (0.33%) among the whole subjects which was exactly as the worldwide prevalence (0.3%).

CVD and Parental Consanguinity Inherited red-green CVD is a sex-linked recessive condition with a higher probability to occur when consanguinity is present between parents. In this study, the highest prevalence of color vision deficiency was observed in the Eastern region (14%). This region showed to have the highest prevalence of parental consanguinity (68.8%), it also showed that (58.8%) of subjects who discovered to have color vision deficiency in that region had parental consanguinity. On the contrary, the prevalence of color vision deficiency in the Western region was (3.8%) and the prevalence of consanguinity was (16.4%) of the whole subjects and Zero in whom discovered with color vision deficiency. The low incidence of color vision deficiency observed in the Western region compared to the Eastern one in our study might be attributed to the minimal genetic mixing within its population. By using Chi Square, the p value of the relation between color vision deficiency and consanguinity was not significant (P>0.05).

The results of this study were similar to studies conducted in the nearby countries and to a greater extent it was consistent with the worldwide prevalence of inherited red-green CVD. The study also showed an increase in the prevalence of CVD in areas where high degrees of parental consanguinity were present.

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