

Prevalence of Refractive Errors in Students with and without Color Vision Deficiency

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Abstract

Purpose: To evaluate refractive errors in school age children with color vision deficiency (CVD) and those with normal color vision (NCV) in order to make a better understanding of the emmetropization process.

Methods: A total of 4,400 primary school students aged 7–12 years were screened for color vision using Ishihara pseudoisochromatic color vision plate sets. Of these, 160 (3.6%) students had CVD. A total of 400 age- and sex-matched students with NCV were selected as controls. Refractive status was evaluated using objective cyclorefraction.

Results: The CVD group included 136 male (85%) and 24 female (15%) subjects with mean age of 10.1 ± 1.8 years. The NCV group comprised of 336 male (84%) and 64 female (16%) subjects with mean age of 10.5 ± 1.2 years. The prevalence of myopia (7.7% vs. 13.9%, $P < 0.001$) and hyperopia (41% vs. 57.4%, $P = 0.03$) was significantly lower in the CVD group. Furthermore, subjects with CVD demonstrated a lower magnitude of refractive errors as compared to the CVD group (mean refractive error: $+0.54 \pm 0.19$ D versus $+0.74 \pm 1.12$ D, $P < 0.001$).

Conclusion: Although the lower prevalence of myopia in subjects with CVD group supports the role of longitudinal chromatic aberration in the development of refractive errors; the lower prevalence of hyperopia in this group is an opposing finding. Myopia is a multifactorial disorder and longitudinal chromatic aberration is not the only factor influencing the emmetropization process.

Keywords: Color Vision; Hyperopia; Myopia

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INTRODUCTION

Myopia is a multifactorial disorder with a mean age of onset of about 17 years.^[1] The pathogenesis of myopia is still poorly understood; both genetic^[2] and environmental factors such as near work^[3,4] and outdoor activity^[5] influence its incidence and progression.

Emmetropization is the active phenomenon in ocular development which matches the focal plane of the image with the retina. It seems to be a vision dependent process reducing myopia or hyperopia.^[6] Changes in optical components of the eye, even artificially, during

development of the eye could lead to changes in axial length resulting in the development of myopia or hyperopia.^[7] Smith et al^[8] studied monkeys and found that imposed myopia or hyperopia could lead to shorter or longer axial length.

One of the possible factors influencing the emmetropization process is longitudinal chromatic aberration (LCA).^[6] Retinal cells of the human eye are sensitive to the wavelengths from 450 nm to 700 nm. Disruption in ocular media causes a particular object

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to produce images with different colors at different distances from the retina. LCA in the retina has been measured to be around 1.5–2.0 diopters across the visible light spectrum.^[9,10]

There are 3 types of cone cells in the retina arbitrated to color vision. Lack or disruption in one or more of these cells leads to color vision deficiency (CVD). The most common type of CVD is the red-green type which has an X-linked recessive pattern and is more prevalent in males than in females.^[6] In this study we compare the refractive status of eyes with CVD and compare it to eyes with normal color vision (NCV) for a better understanding of the emmetropization process.

METHODS

This cross-sectional study was conducted on 4,400 students who were randomly selected from 29 primary schools in Mashhad, Iran. The study followed the tenets of the Declaration of Helsinki and was approved by the Human Ethics Committee of Mashhad University of Medical Sciences (MUMS). Informed consent was obtained from all legal guardians of the participants before inclusion.

Color vision was assessed in all subjects using Ishihara pseudoisochromatic color vision plate sets (Ishihara, 1994). The test was performed binocularly with spectacle correction under artificial standard illumination. Each page of the test was shown for 2–3 s to each subject. After screening a total of 160 subjects were found to have CVD. In the next stage, 400 age- and sex-matched subjects with normal color vision (NCV) were selected as controls. Subjects with any systemic disease such as diabetes mellitus, and ocular diseases such as glaucoma, cataract, optic nerve atrophy, amblyopia, strabismus and suppression, or use of any systemic medication that might affect the eyes were excluded from the study.

The right eyes of both groups underwent a comprehensive ophthalmic examination including visual acuity (VA), objective refraction, subjective refraction based on autorefractometric results (Topcon KR 8800, Tokyo, Japan) to obtain best corrected visual acuity (BCVA), cover test, slit lamp biomicroscopy, and funduscopy. Cycloplegia was attained by administering 1 drop of cyclopentolate 1% three times at 5 min intervals. After 30 min, objective refraction was determined using an autorefractometer. Visual acuity was determined using the logMAR chart (The Lighthouse, Long Island City, NY, USA) under artificial standard illumination conditions at 4 m distance. Subjects were classified into 3 groups based on their objective refractive errors (RE) as follows: Emmetropic ($-0.50 \text{ D} \leq \text{RE} \leq +0.5 \text{ D}$), hyperopic ($\text{RE} > +0.5 \text{ D}$) and myopic ($\text{RE} < -0.5 \text{ D}$).

Statistical analysis was performed using SPSS software (version 18.0, Chicago, IL, USA). Normal distribution of data was assessed with the Shapiro-Wilk test. Independent *t*-test was used to compare mean

values of refractive errors between the two groups. Significance level was set at $P < 0.05$.

RESULTS

A total of 560 students including 160 subjects with CVD and 400 age- and sex-matched normal controls were studied. The CVD group included 136 male (85%) and 24 female (15%) subjects with mean age of 10.1 ± 1.8 years. The NCV group comprised of 336 male (84%) and 64 female (16%) subjects with mean age of 10.5 ± 1.2 years.

Visual acuity in logMAR notations was 0.0 or better in 328 (58.6%) eyes, 0.1 in 152 (27.1%) eyes, 0.2 in 44 (7.9%) eyes, 0.3 in 12 (2.1%) eyes, 0.4 in 12 (2.1%) eyes, 0.5 in 8 (1.4%) eyes and 0.6 in 4 (0.7%) eyes.

Overall, 68 (12.1%) subjects (64 male and 4 female) were myopic and 296 (52.9%) subjects (260 male and 36 female) were hyperopic based on objective refraction [Table 1]. The CVD group had a lower prevalence of both myopia ($P < 0.001$) and hyperopia ($P = 0.03$). The magnitude of refractive errors was higher in the NCV group (mean error, $+0.74 \pm 1.12 \text{ D}$) as compared to the CVD group (mean error, $+0.54 \pm 0.19 \text{ D}$) ($P < 0.001$). The mean amount of myopia was $-0.75 \pm 1.16 \text{ D}$ in the NCV group versus $-0.45 \pm 1.12 \text{ D}$ in the CVD group ($P = 0.003$) and the mean amount of hyperopia was $+0.85 \pm 1.14 \text{ D}$ in the NCV group versus $+0.60 \pm 1.12 \text{ D}$ in the CVD group ($P = 0.012$).

DISCUSSION

The effect of different wavelengths of light on refractive power and consequent disruption of emmetropization has been described in the chick eye.^[7] Because of the chromatic aberration in ocular media, a chromatic difference of focus across the visible spectrum (380–760 nm) is separated by about 2.0 D.^[11] Therefore, a lack in one or more wavelengths of the visible spectrum during the critical period of the eye development could affect the emmetropization process and shift the refractive error of the eye toward myopia or hyperopia.^[6,7]

In the current study, we evaluated the prevalence of hyperopia and myopia in 160 students with CVD and 400 age- and sex-matched normal subjects and observed that CVD subjects had a lower prevalence and magnitude of myopia. Qian et al^[12] evaluated 309 high school students with red-green CVD and 927 matched controls. CVD was

Table 1. Different types of refractive errors in the study groups

Group	Myopic %	Hyperopic %	Emmetropic %
NCV	13.9	57.4	28.7
CVD	7.7	41	51.3
Total	12.1	52.9	35

NCV, normal color vision; CVD, color vision deficiency

determined using Yuziping pseudoisochromatic plate. Then Farnsworth Munsell 100-Hue Test (FM-100 test) was used to confirm the diagnosis and to investigate the type of CVD (i.e. protan or deutan). In their study, the incidence of myopia in the CVD group was significantly lower than that in the NCV group. They explained the lower incidence of myopia in the CVD group by the focal plane of a shorter wavelength in the protan group. The luminance channel for protan eyes is commanded by M-cones, therefore these eyes are more sensitive to shorter wavelengths of light. This process might lead to lower demand of accommodation, less globe elongation, shorter axial length and consequently a lower prevalence of myopia. But, deutan subjects also showed the same refractive state as protan subjects that cannot be explained by the luminance channel theory. Finally, they explained the lower prevalence of myopia in the CVD group by chromatic opponent mechanisms.

The prevalence and magnitude of hyperopia in our series was lower in the CVD group as compared to the NCV group. Conversely, Qian et al^[12] reported a higher prevalence of hyperopia in the CVD group (14.2%) as compared to the NCV subjects (10.1%). The lower prevalence of hyperopia in CVD subjects in our study could challenge the theory of the role of focal plane or chromatic opponent mechanisms in determination of refractive errors. However, the differences between the 2 studies could be explained by the differences in age and ethnicity. In this study we evaluated primary school students that were indicated to have higher prevalence of hyperopia compared to the high school students.^[13] Furthermore, our study included an Iranian population while Qian et al evaluated Chinese students who are reported to have a lower prevalence of hyperopia in comparison with Iranian population.^[5,13] Further studies are required to assess CVD in a population with the same incidence of myopia and hyperopia.

One limitation of our study was the lack of measurement of the axial length. It would be of more interest if we could assess axial length to determine the role of LCA in axial elongation of the globe. Furthermore, by controlling other factors such as duration of reading and status of parental refractive errors in a longitudinal study, a better understanding of the effect of LCA on myopia development can be provided. Since the Ishihara test is not sensitive enough to detect all types of CVD, it is suggested to use other tests such as the Farnsworth Munsell 100-Hue Test in future studies.

Although the observed lower prevalence of myopia in children with CVD supports the role of LCA in

development of refractive errors, the lower prevalence of hyperopia in the CVD group is in contrast with this theory. Concerning the fact that myopia is a multifactorial disorder, it seems that LCA is not the only factor influencing the emmetropization process.

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