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ORIGINAL ARTICLE

Prevalence of color-vision deficiency among male high-school students

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ABSTRACT

Objective

This study determined the prevalence of color-vision deficiency among male high-school students in a public school.

Methods

Male high-school students were screened for color-vision deficiency using 6 plates of the Ishihara pseudoisochromatic plates. All students with one or more errors were reexamined at a later date with the full 15 Ishihara plates and the Farnsworth D15 (FD15) test. A detailed history was taken and an ocular examination was conducted. Students who identified less than 10 plates correctly on the FD15 were classified as color-deficient and underwent the Farnsworth Munsell 100 hue (FM 100) test. The results were statistically analyzed.

Results

A total of 1,258 male high-school students, aged 12 to 16 years, were included in the study, 122 of whom failed the screening test. Of these, 106 completed the 15 Ishihara plates. Sixty-five failed and were classified as color-vision-deficient, of which 64 (98%) were deutans. Deutan was also the most common deficiency determined using the FD15 (78.95%) and FM100 (44.19 %) hue tests.

Conclusion

The prevalence of color-vision deficiency among male students in a public high school was 5.17% (65/1,258). The most common deficiency was the deutan type.

Keywords: *Color blind, color-vision deficiency, Ishihara, Farnsworth, Deutan, Protan, Tritan*

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MOST people equate a visual acuity of 20/20 with normal vision. Thus, it is difficult for many to understand why they would be turned down for employment because they were found to be "color blind." Color blindness is a condition wherein a person is unable to distinguish certain colors or shades of colors to some degree. The more appropriate term may be color-vision deficiency or dyschromatopsia. Males are more frequently affected because it is a recessive trait linked to the X chromosome.

Color-vision deficiency may be congenital (inherited) or acquired. Congenital or inherited color defects are non pathologic, incurable, and constant throughout life. Acquired color defects are usually a result of degenerative diseases, toxic effect of drugs, trauma, and aging.

There are types and degrees of congenital color-vision deficiency depending on whether there is an absence of certain retinal cone pigments or just an alteration of the spectral sensitivity of the pigments. The most common type is the anomalous trichromacy in which there is an alteration in one of the three retinal cone pigments. Anomalous trichromat is further subdivided into protanomaly, tritanomaly, and deuteranomaly, with the latter being the most common.[1]

The Ishihara pseudoisochromatic plates are the most commonly used tools for testing color vision. The procedure is fast, simple, and inexpensive but highly sensitive and specific. However, the ability to distinguish these patterns is influenced by both acuity and color vision so that small deficits in color vision and large deficits in acuity can lead to many errors. On the other hand, the Farnsworth panel D15 (FD15) and Farnsworth- Munsell 100 (FM100) are hue-discrimination and arrangement tests usually recommended to classify the type of color deficiency as either red/green or blue/yellow variant. The patient's task is to place moveable caps in position according to color order. Computer analysis of Farnsworth hastens result scrutiny and veers away from manual technical error.[2] Hence, analysis of color-vision deficiency has shifted diagnostic emphasis from the Ishihara test[3] to the evaluation of quantifiable bipolarity, axis of error, and the analytical scoring of color-arrangement. However, these tests are usually not used for screening of congenital color deficiencies, but for diagnosing the type and severity of the color deficiency. They are also particularly suited for identifying and keeping track of acquired color-vision-deficiency. It is, therefore, very useful to employ both pseudoisochromatic plates and the Farnsworth D15 panel in examining retinal, macular, or optic-nerve diseases.

The gold standard in detecting color-vision deficiency is the anomaloscope, which is more difficult to administer than the pseudoisochromatic plates and arrangement tests. Because it is extensive and requires complex supervision, it is rarely used nowadays.[4] Studies have shown that the Ishihara test has a 96% sensitivity and 100% specificity while the Farnsworth test has a 100% sensitivity and specificity.[5]

Color blindness affects a significant number of people but the prevalence varies among populations. A population-based survey in China revealed a 6.5% and 1.7% incidence for males and females respectively.[6] Among Indians, the incidence was 3.69% among males and 1.04% among females.[7] A study among young Turkish men revealed that 7.33% were color blind.

There is a paucity of local literature on color blindness among Filipinos. The only published local report was that of Nañagas and Flaminiano published in 2001 comparing the use of Ishihara plates and Farnsworth 100 hue tests in a small group of high-school male students.[8]

This study determined the prevalence of color-vision deficiency among male high-school students of Cayetano (Manila North) Arellano High School and classified the type of deficiency (deutan, protan or tritan). In the course of the study, the students, their parents, and teachers were educated on color blindness, and were offered help in finding alternative career options for those affected.

METHODOLOGY

A cross-sectional study was conducted involving male high-school students of Cayetano Arellano High School.

All male students present during the scheduled visits of the research team underwent color-vision screening using the short method consisting of 6 Ishihara pseudoisochromatic plates. A short lecture on color blindness and the nature of the test was given prior to testing. The result was considered normal when all the plates were read correctly and abnormal when any plate was missed. All subjects who failed the screening were scheduled for repeat examination at the Jose Reyes Memorial Medical Center Department of Ophthalmology. At the follow-up visit, a complete ocular history including the use of antituberculosis and other medications was taken. They underwent visual-acuity testing, direct funduscopy, and the full 15 Ishihara plates. The prevalence rate was determined by the number of patients who failed the Ishihara 15-plate test. In addition, they were tested with the Farnsworth D-15. Passing the two color test was necessary to be classified as having normal color vision. Failing either the Ishihara or the FD15 required undergoing the FM100 hue test to further classify the type of color deficiency. Parental or guardian consent was obtained and at least a parent or a guardian was present during the comprehensive phase of the examinations.

Ishihara Color-Vision Test

In a room adequately lit by daylight, the color vision plates were held about 75 centimeters from the subject, and tilted so that the plane of the paper was at right angle

to the line of vision. The correct position of each plate was indicated by the number printed on the back of the plate. Two sets of Ishihara plates with pre-selected six plates were used in the short method for the large-scale examination. The subjects were randomly assigned to either one: Plates 1, 2, 4, 8, 12, and 14 were used for Set A, while plates 1, 3, 7, 9, 11, and 15 were used for Set B. All investigators alternately took part in the screening. Subjects were tested binocularly.

For the repeat examination, the same method was employed except that all 15 plates were used. If 13 or more plates were read normally, the color vision was deemed normal. If 9 or fewer plates were read normally, the color vision was deemed deficient. In reference to plates 14 and 15, only those who read the numerals 5 and 45 and read them easier than those in plates 10 and 9 were recorded as abnormal readings.[9]

Farnsworth D15 and Farnsworth-Munsell 100 Hue Tests

This study made use of the Color Vision Recorder (Optical Diagnostics, Culemborg, The Netherlands). The computer monitor was calibrated based on the standards set by the International Color Consortium (ICC).

In the Color Vision Recorder, the conventional FD15 and FM100 tests were simulated. At the top, the caps were positioned according to color order. The moveable caps were positioned randomly in the boxes below. The individual cap diameters subtended an angle of approximately 1.5° to ensure that observations were made with the rod-free retinal area. This meant that for normal cap sizes the distance to the screen was approximately 50 centimeters. The subject was directed to look at the screen straight to make sure that the brightness and color were correct. To avoid contrast reduction due to ambient light reflecting off the monitor, the ambient lights were dimmed. The patient placed the moveable caps in an order either by clicking on the caps or dragging them.[10]

In the results diagram of the FD15 tests, the horseshoe diagram was drawn as graphical presentation of the caps in order. The type of color deficiency (protan, deutan, or tritan) was determined from the horseshoe diagram by evaluating in what direction the crossings were made. The three different types of color deficiency have their own confusion axes in the horse-shoe diagram, which were represented by the dashed lines. In the results diagram of the FM100 test, a polar or linear graph of the Kinnear error score was drawn.[10]

The main diagnosis of the color-vision test consisted of two parts: pass/fail (automatic, pass, fail, undetermined), and type of color deficiency (automatic, protan, deutan, tritan, unclassified, NA). By default, the diagnosis for both parts was set to automatic. In this mode, a suggestion was made by the software. It was still the physician's responsibility to make the final diagnosis, which can be made by clicking on the buttons and selecting the appropriate items.[10]

After collating and analyzing the data, descriptive statistics were employed. Univariate statistical analysis determined the association of demographic variables with color- vision deficiency.

All patients who were diagnosed to have color vision deficiency were advised regarding the results of the test. The results were also submitted to the teachers and school administrators for possible use in their career-orientation program. Likewise, the parents and guardians were counseled about the implications of the results on future career options of the affected students.

RESULTS

A total of 1,713 male students were enrolled at the Cayetano Arellano High School for school year 2008 to 2009. But only 1,258 were examined from August to September 2008. The study population consisted of 456 (36.25%) students in the first year, 328 (26.07%) in the second year, 228 (18.12%) third year, and 246 (19.55%) fourth year.

The mean age was 13.7 ± 1.65 years (range, 12 to 16), while the mean visual acuity was 0.96 ± 0.13 [range, 20/20 (1.0) to 20/40 (0.5)]. Out of 1,258 students, 122 (9.69%) failed the initial Ishihara 6 plates screening. Out of the 122 who were scheduled for repeat evaluation, 16 (13.11 %) did not return for the full plate series and other tests, and were considered dropped from the study. Every effort was made to encourage them to return. The tests and ocular examination were made available at no cost.

One hundred and six (106) participated in the second phase of the study, consisting of a detailed history and ocular examination that included visual-acuity testing and funduscopy. The Ishihara 15 color plates were administered. Forty-one (38.68%) out of the 106 passed the 15-plate test; 65 failed, giving a final prevalence rate of color-vision deficiency at 5.17 % (65/1258) (Figure 1). The 65 subjects who failed the Ishihara test underwent the FD15 and FM100 hue tests with 1 subject dropping out. Thirty-eight (59.38%) out of the 64 failed the FD15 and were further classified into their corresponding color deficiency (Figure 2), while 26 (40.62%) passed the test. In the FM100 hue test, 43 (67.19%) failed and were further classified according to the type of deficiency (Figure 3), while 21 (32.81%) passed. In the FD15 test, 30 (78.95%) out of 38 subjects were deutan while in the FM100 test, 19 (44.19%) out of 43 were deutan. Twenty-three out of the 43 (54.49%) were considered unclassified.

Five (5) tritans identified by the FD15 (Figure 2) had a history of antituberculosis-drug intake.

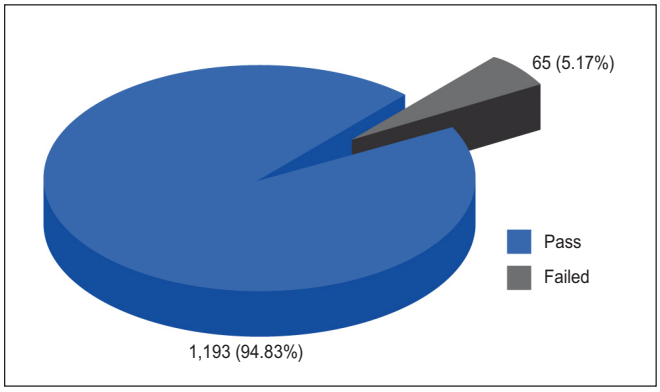

Figure 1. Prevalence of color-vision deficiency at Cayetano Arellano High School (5.17%).

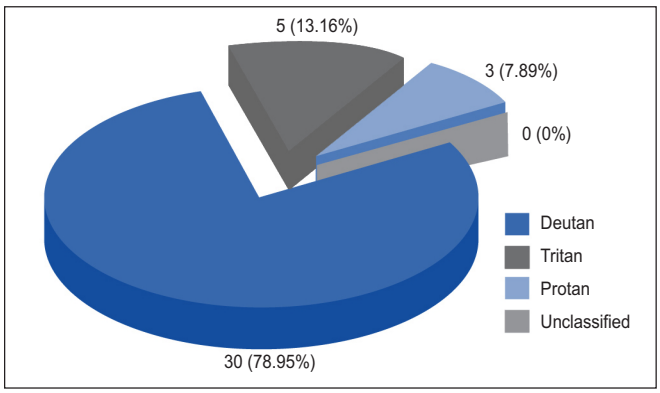

Figure 2. Color classification of the 38 subjects who failed the Farnsworth Panel D-15 test.

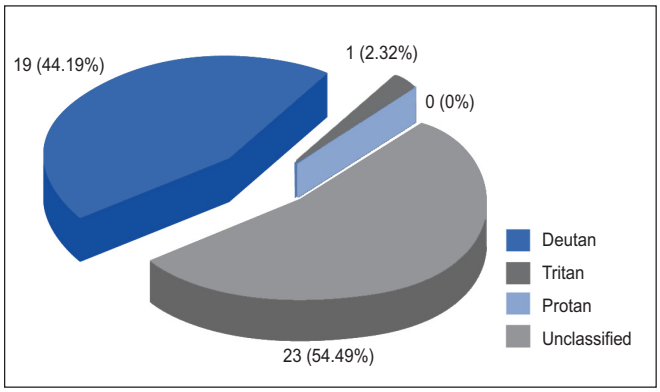

Figure 3. Color classification of the 43 subjects who failed the Farnsworth Munsell 100 hue test.

DISCUSSION

Color vision in humans is normally trichromatic and requires at least 3 cone photo pigments, 1 from each of 3 well-separated spectral classes. The 3 classes of pigment differ in their relative spectral sensitivities, and are commonly referred to as the blue, green, and red. The inherited color-vision defects in which one pigment class is absent are not usually associated with any other vision loss. Rare conditions do exist, however, wherein more than 1 class of cone is absent and vision loss is severe. They are called achromatopsias because color vision is essentially absent.[1]

Using the Color Vision Recorder requires a logical sequence to carry out the color-vision testing. The subjects are first screened for red-green color deficiency with the Ishihara test. Those who fail this screening are tested with the Farnsworth D-15. Subjects who fail the FD15 are considered to have color deficiency ranging from medium to severe. Those that pass but fail the Ishihara screening are deemed mildly color deficient.[4] In this study, 26 subjects failed the Ishihara 15-plate screening but passed the FD15 and were deemed mildly color deficient.

Computer-based Farnsworth tests, exemplified by the Color Vision Recorder, have been validated in previous studies and shown to offer fewer technical errors in computing the scores. They provided automatic recording and straightforward diagnosis of the color-vision deficiency,[5] with sensitivity and specificity of 100%.[11]

There are hardly any literature locally on color-vision testing except for the study by Flaminiano and Nañagas that reported the sensitivity of Ishihara in identifying red-green deficiency and the use of FM100 hue test in jobs requiring superior degree of hue discrimination.[8]

Our study showed that the prevalence of color vision deficiency among male high-school students at the Cayetano Arellano High School was 5.17%. Since color blindness is genetically determined, its prevalence may vary among races. In a previous study among male population in Belgium, 8% were affected. The average red-green deficiency among males in the United States was also estimated at 8%. The prevalence rate in our study was much lower than those of Turkey (7.33%), China (6.5%),[6] Belgium (8%), and USA (8%), but much higher than in India (3.69%).[7] It is possible that the differences observed may reflect true differences in the gene pool as exemplified by the aborigines in mainland Australia who have the lowest rate of 1.9 % as against 7.3% among white Australians.[12]

In this study, the prevalent color-vision deficiency was of the deutan type, similar to the result obtained in the study of Chan and colleagues in China.[6] In Turkey, protan was the prevalent type.[13] Inheritance pattern of color-vision deficiency accounted for the pronounced gender difference in the frequency of color blindness. X-linked recessive inheritance is the most common mode of transmission of this condition.

This study raised awareness about color blindness among the population, and enlightened affected individuals on possible career options. Congenital color blindness cannot be treated; therefore, early diagnosis, education, and awareness of this condition can guide young Filipino males

who are interested in occupations that require good color perception. The Philippines is a known major supplier of skilled maritime workers all over the world, and many young males dream of a career in the maritime industry. Unfortunately, ophthalmologists often have the unpleasant task of informing applicants that they could not be given clearance for such employment because they were color blind. Frustration and disappointment could be prevented if those affected have known their condition early on. They could opt for other careers instead.

Thus, we recommend that children should undergo color-vision testing before entering high school.

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