Color vision in school-age children: assessment of a new test

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Abstract

Objective: to compare standard color vision test results (Ishihara test) with a new test developed by the authors (“crayon” test) for the detection of congenital dyschromatopsia.

Methods: cross-sectional study of 712 children from three public schools and one private school in the city of Porto Alegre, state of Rio Grande do Sul. Children with learning disabilities, or systemic and ocular diseases were excluded from this random sample. Two color vision tests, Ishihara test (short version with 14 plates) and crayon test (developed by the authors) were sequentially applied. Each test was applied by different evaluators and analyzed by a third evaluator.

Results: the crayon test showed a specificity of 100% (99.3-100%) and sensitivity of 38.5% (15.1-67.7%) when compared to Ishihara test. The prevalence of congenital dyschromatopsia in this population sample was 2.6% for male children, and 0.9% for female children.

Conclusions: the crayon test results showed greater specificity than Ishihara test in the studied group; however, sensitivity was not adequate for a screening test. It is necessary to improve the sensitivity so that congenital dyschromatopsia can be detected by the crayon test.

Introduction

Congenital dyschromatopsia, or color blindness, is a deficiency that affects color vision. The prevalence of color blindness is of approximately 7% in men and 0.5% in women. This prevalence in male patients is related to the fact that this pathology is linked to the X chromosome.

Often, young children can confuse colors despite their visual acuity being normal. In this sense, to test color vision in children is a challenge. Young children affected by congenital dyschromatopsia can present difficulties with school material and may be labeled by teachers and classmates as being less intelligent or not very cooperative. Consequently, early diagnosis of congenital dyschromatopsia would allow for minimization of these problems, improvement of adaptation of children to their dysfunction, and, also, for better planning of their professional future.

Currently, the diagnosis of congenital dyschromatopsia is carried out with tests that are expensive and are not practical for application with large population samples. In this sense, we have developed a chalk test that is very cost-effective and easy to understand.
Our objective is to compare results obtained with the Ishihara color plates test (14-plate edition) with those obtained with the chalk test.

Patients and methods

We carried out a cross-sectional study with 712 school-age children (382 boys and 330 girls) selected from different public (3 schools) and private (1 school) schools of the municipality of Porto Alegre, state of Rio Grande do Sul, Brazil. The study was carried out for two months (October 1st, 1999 to November 11th, 1999). Schools were chosen by convenience. The age of children varied from 6 to 12 years. School-age children were excluded from the study according to the following criteria, which were followed according to responses given by teachers: 1) child with learning atypical for age and 2) child with well-known systemic (mental retardation, metabolic diseases, and juvenile diabetes) and eye (congenital glaucoma, strabismus, and congenital cataract diseases) diseases. We did not receive any information on any student presenting congenital dyschromatopsia (or color blindness). Students were examined after written informed consent of parents (guardians) and teachers. Exams were carried out individually and at the school of each child. The two color vision tests, namely Ishihara with 14 color plates and the chalk test, were applied sequentially.

Students received group orientation on how to correctly fill-out the chalk test. The test consists of eight symmetrical squares distributed over two different lines. The upper line has four squares painted in chalk with the colors red, green, blue, and yellow in random sequences. Children were asked to paint the squares in the lower line using the same color of the corresponding square on the upper line (Figure 1). We placed pieces of chalk at random and in 12 different colors on a table. The exam was considered abnormal if a square on the lower line was painted in a different color than that of the upper line. After the chalk test, we carried out the 14-plate edition of the Ishihara color plate test. The location of tests were lit with natural daylight. Pseudoisochromatic plates were placed 75 cm from each other at a 90 degree angle in relation to vision. Ishihara tests were considered abnormal if the student made seven or more mistakes in reading the plates, according to orientation of the author.

Each test (Ishihara and chalk) was applied by different examinators (MBM and JCC) under the supervision of MFB. A third examiner (GMM) assessed the results. Examinators were trained by a preceptor from the Department of Pediatric Ophthalmology (NT).

Tests with abnormal results were repeated. If the results were confirmed, the parents or guardians of the child were informed and given an orientation on the pathology by the authors.

This study was approved by the Ethics Committee of the Irmandade da Santa Casa de Misericórdia of Porto Alegre, Rio Grande do Sul, Brazil.

Results

The chalk and the Ishihara color plates tests were carried out in 712 school-age children during the study period. Children aged 6 to 12 years (average of 8.5 years); on the date of the exam, 26 children were six years old, 190 were seven years old, 125 were nine years old, 101 were ten years old, 70 were eleven years old, and only 17 were twelve years old. Our population included 382 (53.7%) boys and 330 (46.3%) girls. As for color of skin, there were 626 (87.8%) whites, 39 (5.5%) blacks, and 47 (6.7%) mestizos. Five (0.7%) children presented abnormal for the chalk test and 13 (1.8%) presented abnormal for the Ishihara test. All five children abnormal for the chalk test were boys; out of the 13 children abnormal for the Ishihara test, 10 were boys and 3 were girls.

The comparison of the chalk and Ishihara tests indicated that 5 patients were positive for both tests. The chalk test indicated 38.5% sensitivity (15.1-67.7%) and 100% specificity (99.3-100%).

For the population of boys, the prevalence of congenital dyschromatopsia detected by the Ishihara test was 2.6% (1.3-4.8%). The sensitivity of the chalk test in relation to the Ishihara test, for the boys, was 50% (20.1-79.9%) and the specificity was 100% (98.7%-100.0). For the population of girls, the chalk test did not detect abnormalities. The Ishihara test, in turn, indicated 3 girls with congenital dyschromatopsia (Table 1).

![Figure 1 - Chalk test applied to the schoolchildren studied](attachment:image.png)
Prevalence of congenital dyschromatopsia in our population was 2.6% for boys and 0.9% for girls. Figure 2 presents this finding in comparison to other studies on the incidence of congenital dyschromatopsia.

Discussion

The most common cause of color vision deficiency is congenital dyschromatopsia. This pathology always presents bilateral, does not change with time, and cannot be treated.1 In order to establish final diagnosis, diseases of the macula and optic nerve must be excluded.1 There are authors who reported that mental retardation and eye diseases such as congenital glaucoma, diabetic retinopathy, and amblyopia or even the use of antiepileptic drugs can cause alterations of color vision, thus allowing for false-positives in screening tests for congenital dyschromatopsia.1,2 However, more recent studies have indicated that these influences may not be true.3-5

The diagnosis of congenital dyschromatopsia can be obtained with several tests such as Ishihara’s, Farnsworth Munsell’s, Nagel anomaloscope, and others.2,6 For several years different authors have tried to improve these tests, but none of them is considered complete.7

The Ishihara color plate test is extremely sensitive to green-red deficiency, but it is not appropriate for blue-yellow color deficiencies.8 Ishihara is a quantitative test that was originally developed for cases of congenital dyschromatopsia; thus, it cannot be used to detect acquired dyschromatopsias such as optic neuritis, pigmentary retinopathy, and chorioretinitis. The Ishihara test is currently the most widely used test worldwide for detection of congenital dyschromatopsia.

In relation to other tests, the 100-color Farnsworth-Munsell is a qualitative test that can also be used to diagnose congenital dyschromatopsia. It is not widely used in clinical practice since it is a slow test - in average 20 minutes per eye.9

The Nagel anomaloscope is an instrument used by ophthalmologists that is difficult to be applied to large population samples. The Holmgren test requires that patients select strips of wool of different colors in order to compare them with the samples chosen by the examinator. The disadvantage of this test is the alteration in colors of samples due to frequent handling of the material and prolonged exposure to light. Other tests include the Edridge-Green lamp, the Dvorine pseudoisochromatic plates, the American Optical-Hardy-Rand-Rittler (not commercially available), and the APT-5.6 A new test, the color vision

| Table 1 - Comparison between the chalk and Ishihara color plate tests in the studied sample; the values presented here are the percentage observed in the sample plus the confidence interval (in parenthesis) |
|---------------------------------|------------------|------------------|------------------|
|                                 | Males            | Females          | Total            |
| Sensitivity (%)                 | 50 (20.1-79.9)   | 0 (0.0-70.8)     | 38.5 (15.1-67.7) |
| Specificity (%)                 | 100 (98.7-100)   | 100 (98.9-100)   | 100 (99.3-100)   |
| Positive Predictive Value (%)   | 100 (46.3-100)   | –                | 100 (46.3-100)   |
| Negative Predictive Value (%)   | 98.7 (96.8-99.5) | 99.1 (97.4-99.8) | 98.9 (97.7-99.5) |
testing made easy (CVTMET), uses the identification of simple shapes and objects to detect red-green color deficiencies and was designed to examine patients of all age groups. The CVTMET presented 100% specificity and 90.5% sensitivity in the detection of congenital dyschromatopsia. However, the elevated cost of this test and its limited availability rendered the comparison with our test unfeasible.

It is possible to observe that tests for detection of congenital dyschromatopsia continue to be improved up until the present date. Consequently, tests become more expensive and complex for application to large populations, especially in poorer countries. In this sense, it was our objective to design a simple, cost-effective test that is easy to apply and assess. In order to assess the validity of the chalk test, we compared its results with those of a highly sensitive test for red-green color deficiencies, the Ishihara test. Despite the high specificity of the chalk test, its sensitivity is low in comparison to the Ishihara test; this finding renders the test inappropriate for screening of the pathology. However, the chalk test can be used initially by pediatricians and elementary school teachers when parents present concerns regarding the ability of children to differentiate colors. Due to its high specificity, abnormal results indicate that the patient certainly has congenital dyschromatopsia. In normal results, there is still a 1.1% chance of patients presenting the pathology.

We observed a lower prevalence of male patients affected by congenital dyschromatopsia in comparison to earlier studies carried out in Rio de Janeiro, Brazil and in other countries. The prevalence of female patients affected, however, was higher. These variations can be a result of several factors, including the region studied possibly due to genetic factors of the population. Moreover, results might have been influenced by the method employed in application of tests, and by the fact that the population was not representative of the population and was small in comparison to other studies.

In conclusion, the chalk test presented higher specificity and lower sensitivity than Ishihara’s test; this renders the earlier test inappropriate for screening of populations. This also indicates that the chalk test needs to be further improved for this application.

References