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Color Vision Deficiency in Preschool Children:

The Multi-Ethnic Pediatric Eye Disease Study

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Abstract

Purpose—To determine the sex- and ethnicity-specific prevalence of color vision deficiency (CVD) in black, Asian, Hispanic, and non-Hispanic white preschool children.

Design—Population-based, cross-sectional study.

Participants—The Multi-Ethnic Pediatric Eye Disease Study is a population-based evaluation of the prevalence of vision disorders in children in Southern California. A total of 5960 subjects 30 to 72 months of age were recruited for the study, of whom 4177 were able to complete color vision testing (1265 black, 812 Asian, 1280 Hispanic, and 820 non-Hispanic white).

Methods—Color vision testing was performed using Color Vision Testing Made Easy color plates (Home Vision Care, Gulf Breeze, FL), and diagnostic confirmatory testing was performed using the Waggoner HRR Diagnostic Test color plates (Home Vision Care).

Main Outcome Measures—Testability of color vision in preschool children between 30 and 72 months of age and prevalence of CVD stratified by age, sex, and ethnicity.

Results—Testability was 17% in children younger than 37 months of age, increasing to 57% in children 37 to 48 months of age, 89% in children 49 to 60 months of age, and 98% in children 61 to 72 months of age. The prevalence of CVD among boys was 1.4% for black, 3.1% for Asian,

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*Members of the Multi-Ethnic Pediatric Eye Disease Study are listed online in Appendix 1 (available at www.aaojournal.org)

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2.6% for Hispanic, and 5.6% for non-Hispanic white children; the prevalence in girls was 0.0% to 0.5% for all ethnicities. The ethnic difference in CVD was statistically significant between black and non-Hispanic white children ($P = 0.0003$) and between Hispanic and non-Hispanic white children ($P = 0.02$). In boys, most CVD cases were either deutan (51%) or protan (34%); 32% were classified as mild, 15% as moderate, and 41% as severe.

Conclusions—Testability for CVD in preschool children is high by 4 years of age. The prevalence of CVD in preschool boys varies by ethnicity, with the highest prevalence in non-Hispanic white and lowest in black children.

Our knowledge regarding the prevalence of color vision deficiency (CVD) in preschool children is limited. To date, there have been no population-based studies of CVD in preschool children. The prevalence of CVD has been studied in various population groups around the world,^{1–35} with the prevalence in most populations reported to be from 2% to 10% for boys and less than 0.1% to 3% for girls. In the United States, several studies that looked at the prevalence of CVD have reported CVD prevalence in boys ranging from 2.6% to 7.6% and in girls from 0.5% to 1.3%.^{8,10,11,20,26,34,35} The finding of higher prevalence in males is consistent with the fact that red and green pigment genes involved in color vision are located on the X chromosome, making congenital CVD much more common in boys than in girls. Racial and ethnic differences in CVD prevalence have been reported,^{2,9,10,36} with the prevalence consistently 6% or higher in racial groups such as European whites and lower prevalences in African and Hispanic populations. The large variation in prevalences between studies may be attributable to a variety of factors, including sampling and selection biases in non-population-based studies, racial and ethnic differences, and measurement methods. Differences in age distribution also may contribute to differences between studies because acquired color vision deficits (from diabetes,^{37–39} hypertension,⁴⁰ optic atrophy,⁴¹ optic neuritis,⁴² or the use of certain medications⁴³) are less prevalent in younger populations.

The population-based Multi-Ethnic Pediatric Eye Disease Study (MEPEDS) was designed to investigate the prevalence of vision disorders in 6- to 72-month-old children from 4 racial or ethnic groups (black, Asian, Hispanic, and non-Hispanic white) in Los Angeles and Riverside Counties in California. The purpose of this study was to report the ethnicity-specific prevalence of congenital CVD in a population-based sample of preschool children who are likely to have a very low prevalence of acquired CVD. We also report the testability of color vision as a function of age in preschool children.

Methods

The study population consisted of 30- to 72-month-old preschool children who were participants in the MEPEDS and were living within 100 census tracts in Los Angeles and Riverside Counties in California. Subjects were identified by door-to-door screening of families, and classification of race or ethnicity was based on parental self-report. The details of the screening process, as well as the study design and sampling plan, have been described previously.⁴⁴

Comprehensive eye examinations were performed on all participants by MEPEDS optometrists or ophthalmologists trained and certified using standardized protocols. Color vision testing was attempted in all children 30 months of age or older using the Color Vision Testing Made Easy Test (CVTMET; Home Vision Care, Gulf Breeze, FL), a commercially available pseudoisochromatic color vision test designed for young children.⁴⁵ This test has 2 components: 4 picture cards (1 demonstration and 3 test plates) with pictures of 4 familiar objects (house, dog, boat, and car) and 9 geometric shape cards (1 demonstration and 8 test plates), with combinations of 2 or 3 circles, squares, and stars. The test was performed with glasses, if worn. An Ott-Lite True Color Floor Lamp (Lumenlight, Topanga, CA) was used for uniform illumination. The child was allowed to identify the figures either by naming or by matching to black-and-white versions of the figures. If language was a barrier, the parent or caregiver translated instructions. If the child correctly identified the 3 picture test plates, the test was complete and the child was classified as having normal color vision.⁴⁵ Children who could not correctly identify all 3 picture plates were administered the geometric shape component of the CVTMET. Children who were unable to identify geometric shapes on the demonstration card were classified as unable to complete color vision testing. Children who were able to perform testing with the geometric shapes were given a passing score (normal color vision) if they correctly identified the shapes on 8 of the 9 cards on the first attempt or 9 of 9 on the second attempt. Children who were able to complete the geometric shape cards but did not pass were classified as having CVD and then were tested with the Waggoner HRR Diagnostic Test (Home Vision Care), a pseudoisochromatic test using basic symbols to detect, classify (i.e., deutan, protan, or unclassified), and estimate the degree of defective color vision (i.e., mild, moderate, severe, or unclassified).

The prevalence of CVD was calculated as the ratio of CVD participants to the total number of children who successfully completed testing. Comparisons of CVD prevalence between racial or ethnic groups were performed using the chi-square test and a significance level of $P < 0.05$.

The protocol and informed consent forms were approved by the institutional review board of the Los Angeles County University of Southern California Medical Center, and a parent or guardian of each study participant gave written informed consent. The study was performed in compliance with the Health Insurance Portability and Accountability Act regulations, and an independent data monitoring and oversight committee provided study oversight.

Results

Of the 5960 eligible participants 30 to 72 months of age, 51% (3025 of 5960) were boys and 70% (4177 of 5960) were able to complete color vision testing (1265 black, 812 Asian, 1280 Hispanic, and 820 non-Hispanic white children). Table 1 shows the demographic characteristics of participants, stratified by age, sex, and ethnicity, who fulfilled the eligibility criteria and were recruited. As seen in Table 2, testability increased with age in both boys and girls: only 17% of children 30 to 36 months of age were testable compared with 98% of 61- to 72-month-old children.

Because of the low testability of children 30 to 36 months of age, they were excluded from further analysis of CVD prevalence. Of the 4938 children 37 to 72 months of age, 933 (19%) could not be tested because they could not correctly identify all CVTNET picture cards and were unable to complete testing using CVTNET geometric shape cards (Fig 1). Of the 4005 testable children 37 to 72 months of age, 3942 children (98%) were found to have normal color vision: 3699 correctly identified all CVTNET picture cards, and the other 243 could not correctly identify all CVTNET picture cards but subsequently showed normal color vision on testing with CVTNET geometric shape cards (Fig 1). The remaining 63 preschool children (1.6%) were found to have deficient color vision: 59 boys (3.0% of testable boys) and 4 girls (0.02% of testable girls). Table 3 shows the number and percentage of preschool children with CVD stratified by age group, sex, and ethnicity. The prevalence of CVD among boys was 1.4% for black children (95% confidence interval [CI], 0.6%–2.7%), 3.1% for Asian children (95% CI, 1.6%–5.3%), 2.6% for Hispanic children (95% CI, 1.5%–4.2%), and 5.6% for non-Hispanic white children (95% CI, 3.6%–8.3%). The prevalence of CVD in girls was much lower at 0.2% for black children (95% CI, 0%–0.9%), 0.5% for Asian children (95% CI, 0.1%–1.9%), 0.2% for Hispanic children (95% CI, 0%–0.9%), and 0% for non-Hispanic white children (95% CI, 0%–1.0%).

In boys, CVD prevalence varied significantly by ethnicity ($P = 0.002$). Pairwise comparison between ethnic groups showed that CVD prevalence was significantly higher in non-Hispanic white children than in either Hispanic ($P = 0.02$) or black ($P = 0.0003$) children; black and Hispanic children did not significantly differ from one another, and the prevalence of CVD in Asian children was not significantly different from that in any other ethnic group.

Prevalence of CVD was compared among older children (61–72 months) and younger children (37–60 months). The differences among age groups did not reach statistical significance overall ($P = 0.08$) or within any ethnic group ($P = 0.12$).

Table 4 provides the type and severity of the CVD for boys stratified by ethnicity. Most cases were classifiable as deutan (51%) or protan (34%). A higher proportion of deutan than protan CVD was seen in Asian, Hispanic, and non-Hispanic white children but not in black children. Of the CVD cases, 32% were classifiable as mild, 15% as moderate, and 41% as severe. Only 4 girls had CVD; the 2 girls with a classifiable type both had a deutan deficiency, and of the 3 with classifiable severity, 2 were classified as mild and 1 as severe.

Discussion

Using a large, population-based cohort of preschool children, we presented the CVD prevalence estimates for black, Asian, Hispanic, and non-Hispanic white children 37 to 72 months of age. To our knowledge, no previous population-based studies have investigated the prevalence of CVD in a multiethnic cohort of preschool children younger than 6 years. Prevalence of CVD ranged from 1.4% in black boys to 5.6% in non-Hispanic white boys, with intermediate prevalence levels in Asian and Hispanic boys. Color vision deficiency was significantly more prevalent in non-Hispanic whites than in black ($P = 0.0003$) and Hispanic children ($P = 0.02$).

We may compare our findings with those from several other studies of children conducted in the United States. In a cross-sectional study of 10 341 school-aged children (kindergarten to 12th grade) in Washington State, CVD prevalence was found to be 6.2% in boys and 0.6% in girls.⁸ Although these prevalence estimates are similar to our findings for non-Hispanic white boys (5.6%), the racial and ethnic distribution of their cohort was not described.

The United States Health Examination Survey found that prevalence of CVD in boys 12 to 17 years of age was slightly lower for black boys (6.4%) compared with white boys (7.7%).¹⁰ The corresponding study of boys 6 to 11 years of age found that prevalence of CVD was significantly lower among black boys (4.0%) than white boys (7.4%).¹¹ This pattern is similar to the ethnicity-dependent differences in CVD prevalence observed in our study, with significantly lower prevalence in black children.

Cotter et al⁴⁵ reported their findings of CVTNET screening results from a group of 154 children 5 to 7 years of age at an inner city public school. The ethnic distribution was 68% Hispanic, 31% black, and 1% non-Hispanic white. Of the 79 boys screened, 4 (5.1%) had CVD. This is higher than the CVD prevalence for either black or Hispanic preschool children in the present study.

Choi et al²⁰ looked at CVD prevalence in boys from 1 school district in Los Angeles with a high Hispanic and Asian representation. Among the 1134 boys 6 to 7 years of age, the prevalence of CVD was 2.6%, in line with our findings for Hispanic and Asian boys (2.6% and 3.1%, respectively).

Vyas and Lee²⁶ published their finding of CVD prevalence among Asian and Pacific Islander school children in Southern California based on a database collected from University of California, Los Angeles, Mobile Eye Clinic between 1987 and 1996. Among the 2587 boys between 5 and 7 years of age, the prevalence of CVD was 2.8%, similar to our finding of 3.1% CVD prevalence in Asian male children.

We found that 85% of CVD in boys was classified as either deutan or protan. These categories comprise individuals who are red-green color deficient. Because genes for both red and green color pigments are located on the X chromosome, defects in red-green color vision occur with much higher frequency in males than in females and represent most CVD in males worldwide. Most classifiable subjects had either a mild or severe phenotype, which reflects either the presence of a mutated gene or the absence of the color-encoding gene. On one hand, the absence of red or green cone pigments (protanopia or deutanopia, respectively) or loss of both color pigments (cone monochromacy) can lead to severe color vision loss; on the other hand, a functional but mutated form of the gene encoding either pigment (protanomaly or deutanomaly) will result in more mild CVD.

Because very few girls were found to have CVD, interracial comparisons of CVD prevalence were not feasible. Across all ethnic groups, the female CVD prevalence consistently fell to less than 1%, and this prevalence rate is in agreement with rates reported in the literature.

The number of preschool children able to complete the CVTNET increased with age, and this can be attributed to better comprehension and performance of the task in older children.

Only 17% of preschool children 30 to 36 months of age were able to complete testing successfully, but this percentage reached 98% in children older than 5 years. Our findings suggest that it is possible to start color vision screening at the age of 4 years. Choi and Hwang⁴⁶ found that 96.5% of the 115 preschool children between 3 and 6 years of age were able to complete the Ishihara 24-plate color vision test successfully by either direct identification or tracing, with the success rate reaching 94.1% by 4 years of age.

One potential source of bias in this study is related to the lower testability rates in younger children. Completing the geometric shape portion of the CVTMEET may be more challenging for young children than completing the first picture phase of the CVTMEET. As a result, a child may be more likely to be testable if they have no CVD than if they do have CVD, leading to a selection bias. This is because in the testing protocol, a child with no CVD does not necessarily need to be able to complete geometric shape testing, as long as he or she can pass the picture phase of the CVTMEET. However, if a child has true CVD and fails the picture test, he or she must be able to complete geometric shape testing to be diagnosed with CVD, as opposed to being classified as untestable. Consequently, our prevalence estimates pooling children 37 to 72 months of age (and excluding those who are untestable) theoretically may underestimate the true CVD prevalence. If this is the case, then the prevalence seen in 61- to 72-month-old children (among whom testability is 98%) would be less subject to selection bias and therefore more accurate. The CVD prevalence for 61- to 72-month-old children is somewhat higher in each ethnic group than the overall rate for children 37 to 72 months of age, but the same pattern of ethnicity-dependent variation in prevalence is seen as for the overall rates. Another potential source of bias in this study is that the number of participants in each ethnic group is highly variable. The number of total eligible participants in both the Asian and non-Hispanic white study groups were roughly 1000, whereas there were nearly 2000 eligible subjects in each of the black and Hispanic study groups. This potentially can skew the results by inflating the prevalence of CVD in the larger study group and vice versa. However, given the large sample size in each group, random sampling error is likely minimal and does not significantly influence the overall rate of CVD.

Particular strengths of this study are the large MEPEDS population-based cohort and the fact that standardized color vision testing was administered to the children by eye care professionals. We believe our findings are likely generalizable to most black, Hispanic, non-Hispanic white, and Asian children in the United States.

In conclusion, this is the first population-based study to define the ethnicity-specific prevalence of CVD in preschool children in 4 major ethnic groups, confirming that there are indeed significant ethnicity-related differences in the prevalence of CVD in male preschool children.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations and Acronyms

CI	confidence interval
CVD	color vision deficiency
CVTMET	Color Vision Testing Made Easy Test
MEPEDS	Multi-Ethnic Pediatric Eye Disease Study

References

1. Miles WR. Color blindness in eleven thousand museum visitors. *Yale J Biol Med.* 1943; 16:59–76. [PubMed: 21434127]
2. Geddes WR. The colour sense of Fijian natives. *Br J Psychol Gen Sect.* 1946; 37:30–6. [PubMed: 20279294]
3. Grieve J. Incidence of defective colour vision. *Nature.* 1946; 157:376. [PubMed: 21019871]
4. Chan E, Mao WS. Colour-blindness among the Chinese. *Br J Ophthalmol.* 1950; 34:744–5. [PubMed: 14821267]
5. Kherumian R, Baudry C, Lacorne J, Moullec J. La fréquence des dyschromatopsies en France. *Presse Med.* 1956; 64:303–4. [PubMed: 13310520]
6. Mann I, Turner C. Color vision in native races in Australasia. *Am J Ophthalmol.* 1956; 41:797–800. [PubMed: 13313671]
7. Mehra KS. Incidence of colour blindness in Indians. *Br J Ophthalmol.* 1963; 47:485–7. [PubMed: 14189716]
8. Thuline HC. Color-vision defects in American school children. *JAMA.* 1964; 188:514–8. [PubMed: 14159067]
9. Grosvenor T. The incidence of red-green color deficiency in New Zealand's Maoris and "Islanders". *Am J Optom Arch Am Acad Optom.* 1970; 47:445–50. [PubMed: 5310515]
10. Slaby, D.; Roberts, J. Color vision deficiencies in youths 12–17 years in the United States. Vol. 11. Rockville, MD: National Center for Health Statistics; 1974. p. 1-34. DHEW publication no. (HRA) 74-1616 Available at: www.cdc.gov/nchs/data/series/sr_11/sr11_118.pdf. Accessed January 4, 2014.
11. Scanlon, JV.; Roberts, J. Color vision deficiencies in children, United States. Vol. 11. Rockville, MD: National Center for Health Statistics; 1972. p. 1-34. HEW publication no. (HSM) 73-1600 Available at: www.cdc.gov/nchs/data/series/sr_11/sr11_118.pdf. Accessed January 4, 2014.
12. Koliopoulos J, Iordanides P, Palimeris G, Chimonidou E. Data concerning colour vision deficiencies amongst 29,985 young Greeks. *Mod Probl Ophthalmol.* 1976; 17:161–4. [PubMed: 1085863]
13. Feig K, Ropers HH. On the incidence of unilateral and bilateral colour blindness in heterozygous females. *Hum Genet.* 1978; 41:313–23. [PubMed: 306378]
14. Al-Amood WS, Ghulam Mohammed S, Al-Sanawi DA, et al. Incidence of colour blindness in Iraqi Arabs. *Hum Hered.* 1981; 31:122–3. [PubMed: 6971797]
15. Macfarlane DJ, Fitzgerald WJ, Stark DJ. The prevalence of ocular disorders in 1000 Queensland primary school children. *Aust N Z J Ophthalmol.* 1987; 15:161–74. [PubMed: 3675907]
16. Buckalew LW, Buckalew NM, Ross S. Note on color preference and color vision test performance. *Percept Mot Skills.* 1989; 69:1039–42. [PubMed: 2608383]

17. Kim HB, Lee SY, Choe JK, et al. The incidence of congenital color deficiency among Koreans. *J Korean Med Sci.* 1989; 4:117–20. [PubMed: 2631743]
18. Littlewood R, Hyde F. Screening for congenital colour vision defects. A comparison between the Ohkuma and Ishihara plates. *Aust N Z J Ophthalmol.* 1993; 21:31–5. [PubMed: 8494637]
19. Rawlinson A. A simple eyesight screening programme for dental undergraduates: results after 7 years. *Aust Dent J.* 1993; 38:394–9. [PubMed: 8259917]
20. Choi TB, Lee DA, Oelrich FO, et al. A retrospective study of eye disease among first grade children in Los Angeles. *J Am Optom Assoc.* 1995; 66:484–8. [PubMed: 7494083]
21. Osuobeni EP. Prevalence of congenital red-green color vision defects in Arab boys from Riyadh, Saudi Arabia. *Ophthalmic Epidemiol.* 1996; 3:167–70. [PubMed: 8956321]
22. Modarres M, Mirsamadi M, Peyman GA. Prevalence of congenital color deficiencies in secondary-school students in Tehran. *Int Ophthalmol.* 1997; 20:221–2. [PubMed: 9112190]
23. Rahman SA, Singh PN, Nanda PK. Comparison of the incidence of colour blindness between sections of Libyan and Indian populations. *Indian J Physiol Pharmacol.* 1998; 42:271–5. [PubMed: 10225056]
24. Colour vision screening: a critical appraisal of the literature; NZHTA Report 7, Christchurch School of Medicine & Health Sciences. 1998. p. 1e59NZHTA report 7 Available at: www.otago.ac.nz/christchurch/otago014025.pdf. Accessed January 4, 2014
25. Al-Aqtum MT, Al-Qawasmeh MH. Prevalence of colour blindness in young Jordanians. *Ophthalmologica.* 2001; 215:39–42. [PubMed: 11125268]
26. Vyas DB, Lee DA. Eye conditions among 5- to 7-year-old Asian-Pacific Islander schoolchildren in Southern California. *Optometry.* 2001; 72:426–34. [PubMed: 11486937]
27. Tananuvat N, Manassakorn A, Worapong A, et al. Vision screening in schoolchildren: two years results. *J Med Assoc Thai.* 2004; 87:679–84. [PubMed: 15279349]
28. Citirik M, Acaroglu G, Batman C, Zilelioglu O. Congenital color blindness in young Turkish men. *Ophthalmic Epidemiol.* 2005; 12:133–7. [PubMed: 16019694]
29. Chia A, Gazzard G, Tong L, et al. Red-green colour blindness in Singaporean children. *Clin Experiment Ophthalmol.* 2008; 36:464–7. [PubMed: 18942220]
30. Cruz EM, Cerdana HG, Cabrera AM, et al. Prevalence of color-vision deficiency among male high-school students. *Philipp J Ophthalmol.* 2010; 35:20–4.
31. Niroula DR, Saha CG. The incidence of color blindness among some school children of Pokhara, Western Nepal. *Nepal Med Coll J.* 2010; 12:48–50. [PubMed: 20677611]
32. Alabdelmoneam M. Prevalence of congenital color vision defects in Saudi females of Arab origin. *Optometry.* 2011; 82:543–8. [PubMed: 21680257]
33. Cheng HM, Sun HY, Lin DP, et al. Characterising visual deficits in children of an urban elementary school in Taiwan. *Clin Exp Optom.* 2012; 95:531–7. [PubMed: 22448958]
34. Shrestha RK, Joshi MR, Shakya S, Ghising R. Color vision defects in school going children. *JNMA J Nepal Med Assoc.* 2010; 50:264–6. [PubMed: 22049887]
35. Tabansi PN, Anochie IC, Nkanginieme KE, Pedro-Egbe CN. Screening for congenital color vision deficiency in primary children in Port Harcourt City; teachers' knowledge and performance. *Niger J Med.* 2008; 17:428–32. [PubMed: 19048761]
36. Deeb SS. The molecular basis of variation in human color vision. *Clin Genet.* 2005; 67:369–77. [PubMed: 15811001]
37. Ismail GM, Whitaker D. Early detection of changes in visual function in diabetes mellitus. *Ophthalmic Physiol Opt.* 1998; 18:3–12. [PubMed: 9666905]
38. North RV, Farrell U, Banford D, et al. Visual function in young IDDM patients over 8 years of age. A 4-year longitudinal study. *Diabetes Care.* 1997; 20:1724–30. [PubMed: 9353616]
39. Kurtenbach A, Wagner U, Neu A, et al. Brightness matching and colour discrimination in young diabetics without retinopathy. *Vision Res.* 1993; 34:115–22. [PubMed: 8116263]
40. Morton WE. Hypertension and color blindness in young men. *Arch Intern Med.* 1975; 135:653–6. [PubMed: 1088740]
41. Brown J Jr, Fingert JH, Taylor CM, et al. Clinical and genetic analysis of a family affected with dominant optic atrophy (OPA1). *Arch Ophthalmol.* 1997; 115:95–9. [PubMed: 9006432]

42. Schneck ME, Haegerstrom-Portnoy G. Color vision defect type and spatial vision in the Optic Neuritis Treatment Trial. *Invest Ophthalmol Vis Sci*. 1997; 38:2278–89. [PubMed: 9344351]
43. Steinhoff BJ, Freudenthaler N, Paulus W. The influence of established and new antiepileptic drugs on visual perception. 1. A placebo-controlled, double-blind, single-dose study in healthy volunteers. *Epilepsy Res*. 1997; 29:35–47. [PubMed: 9416458]
44. Varma R, Deneen J, Cotter S, et al. Multi-Ethnic Pediatric Eye Disease Study Group. The Multi-Ethnic Pediatric Disease Study: design and methods. *Ophthalmic Epidemiol*. 2006; 13:253–62. [PubMed: 16877284]
45. Cotter SA, Lee DY, French AL. Evaluation of a new color vision test: “Color Vision Testing Made Easy”. *Optom Vis Sci*. 1999; 76:631–6. [PubMed: 10498004]
46. Choi SY, Hwang JM. Ishihara test in 3- to 6-year-old children. *Jpn J Ophthalmol*. 2009; 53:455–7. [PubMed: 19847597]

Figure 1.

Flowchart showing the color vision testing protocol among children 37 to 72 months of age. CVTMET = Color Vision Testing Made Easy Test.

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Age, Sex, and Ethnicity Distribution of Preschool Children Eligible for Color Vision Testing in the Multi-Ethnic Pediatric Eye Disease Study

Table 1

	Ethnicity, No. (%)				
	Black (n = 1945)	Asian (n = 1018)	Hispanic (n = 1959)	Non-Hispanic White (n = 1038)	Total (n = 5960)
Age group (mos)					
30–36	355 (18)	153 (15)	352 (18)	162 (16)	1022 (17)
37–48	534 (28)	286 (28)	556 (28)	303 (29)	1679 (28)
49–60	548 (28)	289 (28)	545 (28)	279 (27)	1661 (28)
61–72	508 (26)	290 (29)	506 (26)	294 (28)	1598 (27)
Sex					
Male	955 (49)	525 (52)	996 (51)	549 (53)	3025 (51)
Female	990 (51)	493 (48)	963 (49)	489 (47)	2935 (49)

Table 2

Color Vision Testability in Preschool Children Using the Color Vision Testing Made Easy Test, Stratified by Age and Sex, in the Multi-Ethnic Pediatric Eye Disease Study

	Testability, n/N (%)			
	30–36 Months	37–48 Months	49–60 Months	61–72 Months
Male	87/538 (16)	456/842 (54)	744/837 (89)	785/808 (97)
Female	85/484 (18)	505/837 (60)	741/824 (90)	774/790 (98)
Total	172/1022 (17)	961/1679 (57)	1485/1661 (89)	1559/1598 (98)

Prevalence of Color Vision Deficiency in Preschool Children Stratified by Age, Sex, and Ethnicity in the Multi-Ethnic Pediatric Eye Disease Study

Table 3

Age Group (mos)	Prevalence of Color Vision Deficiency, n/N (%)							
	<i>Black</i>		<i>Asian</i>		<i>Hispanic</i>		<i>Non-Hispanic White</i>	
	<i>Male</i>	<i>Female</i>	<i>Male</i>	<i>Female</i>	<i>Male</i>	<i>Female</i>	<i>Male</i>	<i>Female</i>
37–48	1/122 (0.8)	0/144 (0)	4/97 (4.1)	1/108 (0.9)	3/132 (2.3)	1/139 (0.7)	4/105 (3.8)	0/114 (0)
49–60	2/217 (0.9)	0/252 (0)	3/149 (2.0)	1/129 (0.8)	6/237 (2.5)	0/236 (0)	6/141 (4.3)	0/124 (0)
61–72	5/234 (2.1)	1/256 (0.4)	5/144 (3.5)	0/141 (0)	7/241 (2.9)	0/256 (0)	13/166 (7.8)	0/121 (0)
Total	8/573 (1.4)	1/652 (0.2)	12/390 (3.1)	2/378 (0.5)	16/610 (2.6)	1/631 (0.2)	23/412 (5.6)	0/359 (0)

Table 4

Type and Severity of Color Vision Deficiency in Male Preschool Children in the Multi-Ethnic Pediatric Eye Disease Study

	Black (n = 8)	Asian (n = 12)	Hispanic (n = 16)	Non-Hispanic White (n = 23)	Total (n = 59)
Type					
Protan	4 (50)	4 (33)	4 (25)	8 (35)	20 (34)
Deutan	3 (38)	7 (58)	9 (56)	11 (48)	30 (51)
Unclassified	1 (13)	1 (8)	3 (19)	4 (17)	9 (15)
Severity					
Mild	2 (25)	3 (25)	4 (25)	10 (43)	19 (32)
Moderate	0 (0)	4 (33)	2 (13)	3 (13)	9 (15)
Severe	5 (63)	4 (33)	7 (44)	8 (35)	24 (41)
Unclassified	1 (13)	1 (8)	3 (19)	2 (9)	7 (12)
Data are no. (%).					