

# Color Vision Deficiency in Preschool Children

## *The Multi-Ethnic Pediatric Eye Disease Study*

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**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, 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. *Ophthalmology* 2014;■:1–6 © 2014 by the American Academy of Ophthalmology.



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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,<sup>1–35</sup> 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%.<sup>8,10,11,20,26,34,35</sup> 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,<sup>2,9,10,36</sup> 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,<sup>37–39</sup> hypertension,<sup>40</sup> optic atrophy,<sup>41</sup> optic neuritis,<sup>42</sup> or the use of certain medications<sup>43</sup>) 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.

Table 1. Age, Sex, and Ethnicity Distribution of Preschool Children Eligible for Color Vision Testing in the Multi-Ethnic Pediatric Eye Disease Study

	Ethnicity, No. (%)				Total (n = 5960)
	Black (n = 1945)	Asian (n = 1018)	Hispanic (n = 1959)	Non-Hispanic White (n = 1038)	
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)

## 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.<sup>44</sup>

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.<sup>45</sup> 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.<sup>45</sup> 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 CVTMET picture cards and were unable to complete testing using CVTMET 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 CVTMET picture cards, and the other 243 could not correctly identify all CVTMET picture cards but subsequently showed normal color vision on testing with CVTMET 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

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)

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