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Prevalence of Myopia and Hyperopia in 6 to 72 Months Old African American and Hispanic Children: The Multi-Ethnic Pediatric Eye Disease Study

Multi-Ethnic Pediatric Eye Disease Study Group*

Abstract

Purpose—To determine the age-, gender- and ethnicity-specific prevalence of myopia and hyperopia in African American and Hispanic children aged 6 to 72 months.

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 ages 6–72 months in Los Angeles County, California. Seventy-seven percent of eligible children completed a comprehensive eye exam. This report focuses on results from 2994 African American and 3030 Hispanic children.

Methods—Eligible children in 44 census tracts were identified during an in-home interview and scheduled for a comprehensive eye examination and in-clinic interview. Cycloplegic auto-refraction was used to determine refractive error.

Main outcome measures—The proportion of children with spherical equivalent (SE) myopia <=−1.00 diopter (D) and SE hyperopia >=+2.00 D in the worse eye. Prevalence of myopia and hyperopia are also reported using alternative threshold definitions.

Results—Prevalence of myopia was higher in African American (6.6%) compared to Hispanic children (3.7%; $P<0.001$). Hispanics showed a higher prevalence of hyperopia than African American children (26.9% vs. 20.8% respectively, $P<0.001$). The prevalence of myopia showed a

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significant decreasing trend with age (P<0.001). Hyperopia prevalence reached a low point around 24 months of age, but increased and remained higher than that thereafter. No significant gender differences were found in the prevalence of refractive error for either ethnic group.

Conclusion—We observed ethnicity-related differences in both hyperopia and myopia prevalence in preschool children. The age-related decrease in myopia prevalence in preschool children could reflect early emmetropization, and contrasts with the increase in myopia prevalence known to occur in older school-aged children. The limits of emmetropization are evident, however, in the persistently elevated prevalence of hyperopia beyond 24 months of age.

Introduction

Refractive error is considered the leading cause of vision impairment in children.[1–8] The Refractive Error Study in Children (RESC) surveys were conducted in populations with different ethnic origins and environments. [2–7] Using consistent definitions and cycloplegic refraction methods, they provided comparative data in school-aged children as young as 5 years of age. However, there is no population-based study that has used cycloplegic refraction to assess refractive error in children younger than 5 years of age.

The ongoing 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 four racial/ethnic groups (African-American, Asian, Hispanic, Non-Hispanic White) in Los Angeles County, California. To address the issues related to refractive error, cycloplegic refractions were performed. To date, examination of the African American and Hispanic cohorts has been completed. This report presents the age- and gender-specific prevalence of spherical equivalent refractive errors in African American and Hispanic preschool children. Data on astigmatic refractive errors will be presented in a separate report.

Materials and Methods

This study was supported through a cooperative agreement with the NationalEye Institute of the National Institutes of Health and was conducted in Los Angeles County, CA. The protocol and informed consent forms were reviewed and approved by the Institutional Review Board (IRB)/Ethics Committee of the Los Angeles County University of Southern California Medical Center and a parent or guardian (referred to subsequently as “parent”) of each study participant gave written informed consent. An independent data monitoring and oversight committee provided study oversight.

Study Cohort

The study population consisted of 6 to 72 month old children, who were participants in the Multi-Ethnic Pediatric Eye Disease Study (MEPEDS) and living within 44 census tracts in and around the city of Inglewood and adjacent communities in Los Angeles County, California. The particular census tracts were chosen because they encompassed primarily residential neighborhoods with a high proportion of African American and Hispanic children, with a sufficient census to ascertain precise prevalence estimates. Details of the study design and sampling plan have been described previously. [9]

In brief, after conducting a door-to-door census of all dwelling units within the targeted census tracts, eligible children (aged 5–70 months on the day of the household screening) whose parents consented to participate were identified. Following an interview consisting of questions regarding the child's eyesight and current or past use of spectacles or contact lenses, an appointment was scheduled for an eye examination at the local MEPEDS examination center. Responses to interview questions were not used to diagnose myopia or hyperopia. African

American race and Hispanic ethnicity were determined through parental report of the child's race/ethnicity, according to National Institutes of Health guidelines (http://grants.nih.gov/grants/guide/notice-files/NOT-OD-01-053.html accessed on April 16, 2009).

In-Clinic Ocular Examination and Interview

The clinic visit included a structured interview and a comprehensive eye examination performed by MEPEDS optometrists or ophthalmologists who specialized in pediatric eye care and who were trained and certified using standardized protocols. [9] Details of the interview and eye examination can be found elsewhere. [9]

Refractive error was determined by cycloplegic refraction performed with the Retinomax Auto-refractor (Right Manufacturing, Virginia Beach, VA) at least 30 minutes after instillation of the last of two drops of 1% cyclopentolate (0.5% if child <=12 months) separated by 5 minutes. Cycloplegic retinoscopy was performed if Retinomax readings with confidence ratings of >=8 were not obtained in both eyes after 3 attempts. Non-cycloplegic retinoscopy was performed if parents did not allow cycloplegic eye drops.

Definitions of Myopia and Hyperopia

Spherical equivalent (SE) refractive error was calculated as the sphere power plus ½ of the cylinder power. Myopia was defined as SE myopia of =<−1.00 diopter (D), and hyperopia as SE hyperopia >=+2.00 D in the worse eye for the primary analysis. We also calculated myopia and hyperopia prevalence for the worse eye using a variety of threshold definitions of myopia and hyperopia, varying by 1.00 D increments. Emmetropia was defined as SE refractive error between −1.00D and +1.00 D, non-inclusive. The worse eye was defined as the eye with the greater absolute value of SE refractive error. In case of ties (equal absolute values, but one eye myopic and the other hyperopic), the child would be classified both as a myope and as a hyperope (there were no such cases; see results). If only one eye had refractive error data, that eye was considered to be the worse eye. Refractive error in the worse eye was categorized by 1 D increments for histograms of refractive error distribution. Prevalence data for myopia and hyperopia in the right eye and in the better eye are available online.

Statistical Analysis

Prevalence was calculated as the ratio of participants with the particular type of refractive error to the total number of children who successfully completed refraction for at least one eye. Logistic regression was used to compare the prevalence of myopia and hyperopia between ethnic, gender and age groups. Trends over age were analyzed using logistic regression and chi square analysis for trend. All analyses employed SAS 9.1 software (SAS institute, Inc., Cary, NC) and a 0.05 significance level. A locally weighted regression line of estimated prevalence of myopia and hyperopia by months of age was fitted using MATLAB 7.7 software (The Mathworks, Inc., Natick, MA).

Results

Study Cohort

As reported previously, the participation rate (completing both in-home interview and clinical exam) for the MEPEDS cohort was 77%. [10] There was a slightly higher proportion of males, families with higher income, and very good to excellent self-reported health among non-participants. Compared to participants, fewer parents of non-participants had been told by their doctor that their children needed a refractive correction (1.18% vs. 1.89%, P=0.049) and their children were less likely to use a refractive correction (0.71% vs. 1.38% P=0.02). There were no significant differences in age, insurance coverage, self-reported eye health, and ethnicity.

Of the children who completed both the in-home interview and clinical examination, 6043 were African American or Hispanic. Twelve African American and 6 Hispanic children could not be refracted in either eye. One child was excluded because of bilateral aphakia, leaving 6024 (99.7%) children who were successfully refracted in at least one phakic eye. Except for 8 participants for whom refraction was possible in only one eye, refraction data were available for both eyes of all children. There were no cases with myopia in one eye and hyperopia in the other of equal magnitude of 1 D or more.

The demographic characteristics of these participants are shown in Table 1. An equal proportion (50%) of children were Hispanic (n = 3030) and African American (n = 2994); 49% were female.

The parents of 161 participants (2.7%) refused cycloplegic eye drops; these children were examined with non-cycloplegic retinoscopy. This occurred more frequently for African American than Hispanic children (4.2% vs. 1.1%, P<0.001). Cycloplegic auto-refraction was unsuccessful in one or both eyes of 618 (10.5%) children who received cycloplegic eye drops; in these cases, cycloplegic retinoscopy was performed and analyzed for both eyes. The frequency of unsuccessful auto-refraction showed a significant decreasing trend with age in both ethnic groups (P<0.001, Cochran-Armitage trend test). African American children were slightly more likely to require cycloplegic retinoscopy due to unsuccessful Retinomax readings than Hispanic children (11.2% vs. 9.4%, P=0.02).

Distribution of Refractive Error by Age and Ethnicity

The overall mean SE refractive error was 0.94 D (±1.37) for the right eyes and 0.99 D (±1.47) for the left eyes of African American children. For Hispanic children, the mean refractive error was 1.23 D (±1.37) and 1.28 D (±1.43) for the right and left eyes, respectively. Table 2 provides mean SE refractive error for both eyes stratified by age for both ethnic groups.

Figure 1 shows the histograms of SE refractive error of the worse eye in 1D intervals for the six age groups for both ethnicities. The distributions show peaking around the mean. Figure 2 compares the frequency distribution of worse eye refractive error of youngest (6–<12 months) and oldest (60–<72 months) children for both ethnicities.

Panels A and B show the shift in the distribution from youngest to oldest children for each ethnicity. The peaking increases with age in both ethnicities. From the histograms of Figure 1 it is evident that this change occurs especially after 3 years of age. In Hispanic children, there is loss from both tails of the distribution, with little shift in the position of the hyperopic peak value. In the African American children there is an overall shift of the distribution and a shift of the peak toward more hyperopic values.

Panels C and D in Figure 2 compare the refractive error distributions by ethnicity for both the youngest and oldest age groups. The distribution for Hispanic children is shifted toward greater hyperopia relative to that for African American children in both age groups, but the difference is greater in the youngest age group.

Prevalence of Myopia and Hyperopia

Table 3 provides the prevalence of myopia, hyperopia, and emmetropia determined by different threshold values of refractive error for the worse eye, stratified by age group, for both African American and Hispanic children 6 to 72 months of age.

The overall prevalence of myopia (<= −1 D) was 6.6% in African American and 3.7% in Hispanic children; this was significantly different after adjustment for age (P<0.001, logistic regression). The prevalence of myopia among only those children whose refractions were determined by cycloplegic auto-refraction (not including cycloplegic and non-cycloplegic retinoscopy refractions) was similar, 6.9% in African American and 3.8% in Hispanic children.

No difference was seen in the prevalence of myopia between genders in either ethnic group. Myopia prevalence decreased with age in both African American and Hispanic children (P<0.001, logistic regression). Analyses which excluded participants whose refractions were determined by non-cycloplegic or cycloplegic retinoscopy revealed a similar trend with age (P<0.001).

To ensure that the decreasing trend of myopia with age was not a result of using a lower concentration of cyclopentolate in the youngest age group, we conducted the analysis for trend excluding the 6–11 month-old children. The analysis still showed a decreasing trend with increasing age in both ethnic groups (P<0.0001, Cochran-Armitage trend test).

Hyperopia (SE>=+2D) was present in 20.8% of African Americans and 26.9% of Hispanics; this difference is statistically significant after adjustment for age (P<0.001, logistic regression). The prevalence of hyperopia for only those children who underwent cycloplegic auto-refraction was similar, 21.1% in African Americans and 27.1% in Hispanics.

There was no significant gender difference in the prevalence of hyperopia in either ethnic group. Hyperopia showed a significant association with age in Hispanic children (P=0.0017, logistic regression), with a significantly higher prevalence of hyperopia in the youngest age group compared to the oldest (reference) age group (OR 1.46; 95% CI 1.08–1.98). This remained true after excluding children with non-cycloplegic retinoscopy (P= 0.0025, logistic regression), and also after excluding cases with either cycloplegic or non-cycloplegic retinoscopy rather than auto-refraction (P=0.0027, logistic regression). Hyperopia did not show any significant association with age in African American children either overall, or after exclusion of children who were refracted by methods other than cycloplegic auto-refraction.

Figure 3 shows the prevalence of myopia (<=−1D) and hyperopia (>=+2D) by month of age in 6 to 72 month old children. In Hispanic children, the prevalence decreases to its lowest point just under 24 months of age, but rises again and remains higher thereafter. In African American children there is little decrease in prevalence over the first 24 months of age, and the prevalence trends upward thereafter.

Tables 4 and 5 (available at http://aaojournal.org).show the prevalence of myopia, hyperopia, and emmetropia determined by different threshold values of refractive error for the better eye and right eye, stratified by age group, for both African American and Hispanic children 6 to 72 months of age.

Discussion

Using the data from this large, population-based study conducted in Los Angeles County, California, we present prevalence estimates of myopia and hyperopia in African American and Hispanic children aged 6 to 72 months old.

Mean SE refractive error was hyperopic in both ethnic groups at all ages examined. The refractive error distributions peaked around their hyperopic mean values in both ethnic groups. Compared to infants, refractive error in older children was more tightly clustered, with fewer children at the myopic (both ethnic groups) and hyperopic (Hispanic children) ends of the spectrum. African American children also showed a shift of the mean toward greater hyperopia with increasing age. Although this is not a longitudinal study, the narrowing of refractive error distributions after infancy suggests a process of active emmetropization in the first years of life.

No previous population based studies have ever studied the changes in the frequency distribution of refractive error with age in these ethnic groups over this age range. Our knowledge of refractive error distribution in younger children is mainly based on non-population based studies. [11–14] Similar to our study, data from the population-based study in 6 year old Australian children [15] shows peaking of the curve with a mean SE in the hyperopic range. Refractive error distributions of 5–7 year-old children also have shown hyperopic peaks in some reports from the RESC. [2, 4–6]

Myopia and hyperopia were not associated with gender in any age or ethnic group. The association of refractive error with gender has been controversial in studies of older children. Although some studies have found that myopia [2, 3, 7] as well as hyperopia. [2, 4–6] are more common in girls than boys, other studies have found no difference. [3–7]

African American children showed higher levels of myopia and lower levels of hyperopia than Hispanic children overall, with the greatest differences seen in the youngest age groups. Interestingly, the classic (though not population-based) study of Cook and Glasscock of newborn infants similarly found a higher prevalence of myopia greater than 1 D in African American children (23.5%) compared to White children (14.3%), using atropine cycloplegia. [11]

To be able to compare our results with other RESC-reported prevalence rates, we have presented our data for 5-year-old children alone, using RESC refractive error definitions (Figure 4). RESC data do not exist for children younger than 5 years of age. Interestingly, we found a similar prevalence of refractive error in our Hispanic participants compared to children in Chile with the same ethnicity. Like the present study, the RESC also found a lower prevalence of hyperopia in children of African ancestry than in children of Hispanic ethnicity. However, the prevalence of refractive error in our African American cohort was considerably higher than that in non-white South African children, for both hyperopia and myopia. It is not clear what environmental or genetic factors may account for this difference.

Surprisingly, we found a decreasing prevalence of myopia with increasing age in preschool children. This decreasing trend continued long after 12 months of age, so it cannot be attributed simply to the study's use of a lower concentration of cyclopentolate in children less than 12 months of age. Furthermore, the decreasing trend of myopia prevalence with age remained significant after excluding the 6–11 month old children. This decreasing trend with age is in contrast to existing data for older, school-aged children, in whom the prevalence of myopia increases with age. [2–5, 7, 8] However, the decreasing prevalence of myopia in the first few years of life is similar to that observed by Ingram and Bar [16] and Ehrlich et al,[17] and may reflect active emmetropization. The slight increase observed in the prevalence of myopia in the very oldest Hispanic children may be an early manifestation of school-age onset myopia.

The prevalence of hyperopia >= 2.00 D decreases from 6 months of age to a low point around 24 months of age in both ethnicities. This is consistent with previous reports describing early emmetropization. [13, 18, 19]. The drop is more prominent in Hispanic compared to African American children, perhaps because of higher initial levels of hyperopic refractive error in Hispanic children, since previous studies have shown that the rate of emmetropization is greater with larger initial refractive errors. [13, 20]

After approximately 24 months of age, however, the prevalence of hyperopia does not decrease further in either ethnicity; in fact, it increases, and remains higher than at 24 months at all ages thereafter. The overall pattern of persistent hyperopia between 24 and 72 months of age is robust to the threshold definition of hyperopia employed (Table 3), and is reflected also in the relative stability of the mean spherical equivalent refractive error over this same age range (Table 2). This finding is in marked contrast to the popularly held belief that hyperopia declines continuously with increasing age from infancy through adolescence, exemplified by an often-cited paper by Mayer et al. [21] The authors studied a non-population based sample of children 1 to 48 months of age, and compiled the results together with those from other non-population based studies in a graph that suggested continuous loss of hyperopia throughout childhood. In fact, the authors' own data showed relative stability of mean spherical equivalent refractive error after 12 months of age. The findings of the present study echo other lesser-known observations in the literature showing relative stability of hyperopia prevalence in young children after infancy. [16, 22] This has important implications for the follow-up of early childhood hyperopia, since it cannot be assumed that all children will “grow out of” their hyperopia, with its associated risk of complications such as accommodative esotropia. Indeed, it is tempting to speculate whether the increase in hyperopia prevalence beginning around 24 months of age is somehow related to the frequent onset of accommodative esotropia in children 2 to 3 years of age.

The prevalence data presented here provide an indication of the normal range of refractive error in children under 6 years of age. In both African American and Hispanic populations, around 90% of children overall have less than 1 D of myopia, and less than 4 D of hyperopia, even in the more ametropic eye. However, in younger age groups, low degrees of myopia may be a normal, transient phenomenon; this is especially true for African American infants (6–11 months of age), 14% of whom show 1 D or more of myopia in at least one eye, compared to only 4% at older ages (48 months and older).

One limitation of the current study is that infants underwent cycloplegia with 0.5% cyclopentolate, while older children received 1% cyclopentolate, a protocol that was adopted in order to minimize the risk of side effects for infants. This raises the possibility that the higher prevalence rates of myopia in children 6 to 11 months of age than in older children could be due in part to less complete cycloplegia in children who received 0.5% cyclopentolate. Similarly, the difference in hyperopia prevalence between the 12 to 23 month-old children and younger infants might in reality be larger than described herein. However, as shown by our analyses excluding infants, this methodological issue does not negate our overall conclusions regarding the decreasing prevalence of myopia with increasing age. Similarly, it does not impact our novel findings regarding the persistence of hyperopia after 24 months of age.

The use of autorefraction as the primary method of measurement of refractive error in this study is supported by the improved repeatability of autorefraction as compared to retinoscopy. [2, 5–7, 23] Large epidemiological studies of refractive error in children of similar ethnicity to the children studied here have found no clinically significant difference between cycloplegic autorefraction and cycloplegic retinoscopy. [5, 7] Although a minority of children in this study could not be measured using autorefraction, and were evaluated using retinoscopy instead, our secondary analysis excluding these children found similar results to our primary analysis, for both overall prevalence and age-related trends of myopia and hyperopia.

There was a statistically significant difference between study participants and non-participants with regard to spectacle wear. However, this potential selection bias is unlikely to have affected our prevalence estimates, because the overall frequency of previous diagnosis and spectacle correction of refractive error in this population was very low compared to the prevalence of refractive error.

A final caveat regarding our findings is that while cross-sectional refractive error distributions in different age groups suggest age-related trends such as emmetropization, only longitudinal data can provide definitive evidence that refractive error distributions change over time in a given group of children. Furthermore, cross-sectional data cannot predict the longitudinal behavior of individuals. For example, we do not know whether the persistent hyperopia seen after 24 months of age in our study reflects persistence of hyperopia in all individuals who are hyperopic at 24 months, or a combination of emmetropization in some children and the development of new hyperopia in others. Population-based longitudinal studies are required to further elucidate age-related trends in refractive error in individual children.

Strengths of the MEPEDS include population-based data that was collected with rigorous interview and examination protocols with excellent quality control, high participation rates, and a large sample size. We believe our findings are generalizable to African American and Hispanic children throughout the United States.

In conclusion, this is the first population based study using cycloplegic refraction to assess refractive error in children younger than 5 years of age. We identified ethnicity related differences in both hyperopia and myopia prevalence in African American and Hispanic preschool children. However, children of both racial/ethnic groups showed similar age-related distributions of myopia and hyperopia by age. The observed lower prevalence of myopia in older children is suggestive of early emmetropization in preschool children and contrasts with the higher prevalence of myopia that is known to occur in older school-aged children. The persistence of hyperopia beyond 24 months of age, however, may suggest the age-related limits of emmetropization in preschool children.

PRECIS

In a population-based sample of children aged 6–72 months, hyperopia prevalence is higher and myopia prevalence is lower in Hispanics compared to African American children. Hyperopia prevalence does not decrease in children aged 24–72 months.

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References

1. Robaei D, Rose K, Ojaimi E, et al. Visual acuity and the causes of visual loss in a population-based sample of 6-year-old Australian children. Ophthalmology 2005;112:1275–82. [PubMed: 15921756]
2. Zhao J, Pan X, Sui R, et al. Refractive Error Study in Children: results from Shunyi District, China. Am J Ophthalmol 2000;129:427–35. [PubMed: 10764849]
3. He M, Zeng J, Liu Y, et al. Refractive error and visual impairment in urban children in southern China. Invest Ophthalmol Vis Sci 2004;45:793–9. [PubMed: 14985292]
4. Murthy GV, Gupta SK, Ellwein LB, et al. Refractive error in children in an urban population in New Delhi. Invest Ophthalmol Vis Sci 2002;43:623–31. [PubMed: 11867576]
5. Maul E, Barroso S, Munoz SR, et al. Refractive Error Study in Children: results from La Florida, Chile. Am J Ophthalmol 2000;129:445–54. [PubMed: 10764851]
6. Pokharel GP, Negrel AD, Munoz SR, Ellwein LB. Refractive Error Study in Children: results from Mechi Zone, Nepal. Am J Ophthalmol 2000;129:436–44. [PubMed: 10764850]
7. Naidoo KS, Raghunandan A, Mashige KP, et al. Refractive error and visual impairment in African children in South Africa. Invest Ophthalmol Vis Sci 2003;44:3764–70. [PubMed: 12939289]

8. Dandona R, Dandona L, Srinivas M, et al. Refractive error in children in a rural population in India. Invest Ophthalmol Vis Sci 2002;43:615–22. [PubMed: 11867575]
9. Varma R, Deneen J, Cotter S, et al. Multi-Ethnic Pediatric Eye Disease Study Group. The Multi-Ethnic Pediatric Eye Disease Study: design and methods. Ophthalmic Epidemiol 2006;13:253–62. [PubMed: 16877284]
10. Multi-ethnic Pediatric Eye Disease Study Group. Prevalence of amblyopia and strabismus in African American and Hispanic children ages 6 to 72 months: the Multi-ethnic Pediatric Eye Disease Study. Ophthalmology 2008;115:1229–36. [PubMed: 17953989]
11. Cook RC, Glasscock RE. Refractive and ocular findings in the newborn. Am J Ophthalmol 1951;34:1407–13. [PubMed: 14877971]
12. Mohindra I, Held R. Refraction in humans from birth to five years. Doc Ophthalmol Proc Ser 1981;28:19–27.
13. Ehrlich DL, Braddick OJ, Atkinson J, et al. Infant emmetropization: longitudinal changes in refraction components from nine to twenty months of age. Optom Vis Sci 1997;74:822–43. [PubMed: 9383797]
14. Wood IC, Hodi S, Morgan L. Longitudinal change of refractive error in infants during the first year of life. Eye 1995;9:551–7. [PubMed: 8543071]
15. Ojaimi E, Rose KA, Morgan IG, et al. Distribution of ocular biometric parameters and refraction in a population-based study of Australian children. Invest Ophthalmol Vis Sci 2005;46:2748–54. [PubMed: 16043846]
16. Ingram RM, Barr A. Changes in refraction between the ages of 1 and 3 1/2 years. Br J Ophthalmol 1979;63:339–42. [PubMed: 465408]
17. Ehrlich DL, Atkinson J, Braddick O, et al. Reduction of infant myopia: a longitudinal cycloplegic study. Vision Res 1995;35:1313–24. [PubMed: 7610592]
18. Pennie FC, Wood IC, Olsen C, et al. A longitudinal study of the biometric and refractive changes in full-term infants during the first year of life. Vision Res 2001;41:2799–810. [PubMed: 11587728]
19. Mutti DO, Mitchell GL, Jones LA, et al. Axial growth and changes in lenticular and corneal power during emmetropization in infants. Invest Ophthalmol Vis Sci 2005;46:3074–80. [PubMed: 16123404]
20. Saunders KJ, Woodhouse JM, Westall CA. Emmetropisation in human infancy: rate of change is related to initial refractive error. Vision Res 1995;35:1325–8. [PubMed: 7610593]
21. Mayer DL, Hansen RM, Moore BD, et al. Cycloplegic refractions in healthy children aged 1 through 48 months. Arch Ophthalmol 2001;119:1625–8. [PubMed: 11709012]
22. Fulton AB, Dobson V, Salem D, et al. Cycloplegic refractions in infants and young children. Am J Ophthalmol 1980;90:239–47. [PubMed: 7425037]
23. Harvey EM, Miller JM, Dobson V, et al. Measurement of refractive error in Native American preschoolers: validity and reproducibility of autorefraction. Optom Vis Sci 2000;77:140–9. [PubMed: 10772231]

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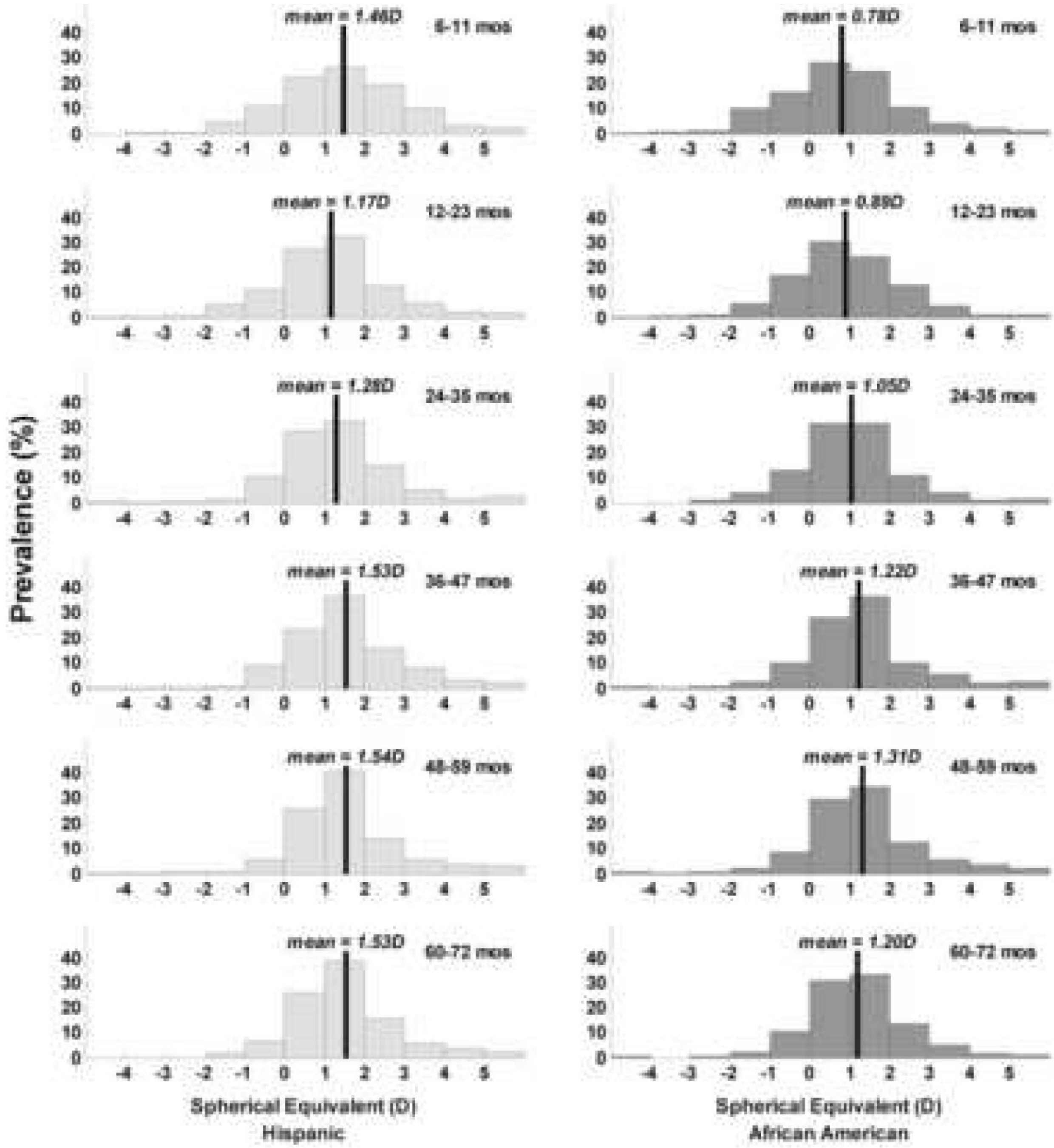

Figure 1.

Prevalence of spherical equivalent refractive error of the worse eye stratified by level of refractive error, age and ethnic group in the Multi-ethnic Pediatric Eye Disease Study. Vertical axis shows the prevalence (%) of refractive error. Horizontal axis shows the spherical equivalent refractive error in 1 diopter intervals. AA: African American; H: Hispanic, mos: months; Numbers presented in legends show the age groups in months.

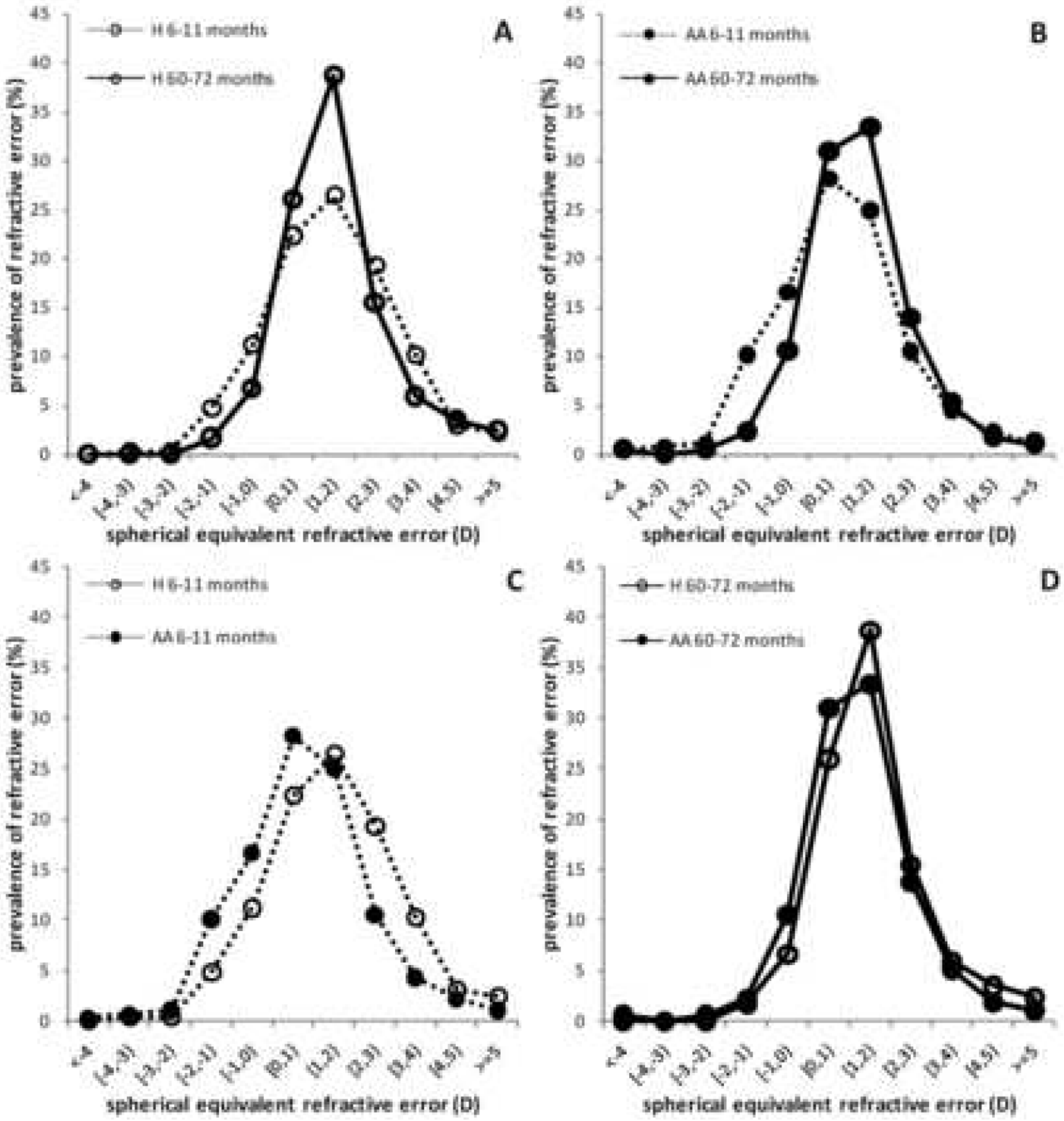

Figure 2.

Comparison of frequency distributions of refractive error of the worse eye in youngest and oldest age group of African American and Hispanic children in the Multi-ethnic Pediatric Eye Disease Study. Panels A and B compare the frequency distributions of youngest and oldest age group within each ethnicity. Panels C and D compare the distributions of the youngest and oldest age groups between the two ethnic groups. Vertical axis shows prevalence (%) of refractive error; horizontal axis represents spherical equivalent refractive error in 1diopter (D) intervals. [,) shows a right open interval, for example [2,3) means an interval of spherical equivalent refractive error values equal to or greater than 2 D but less that 3 D. AA= African American; H= Hispanic.

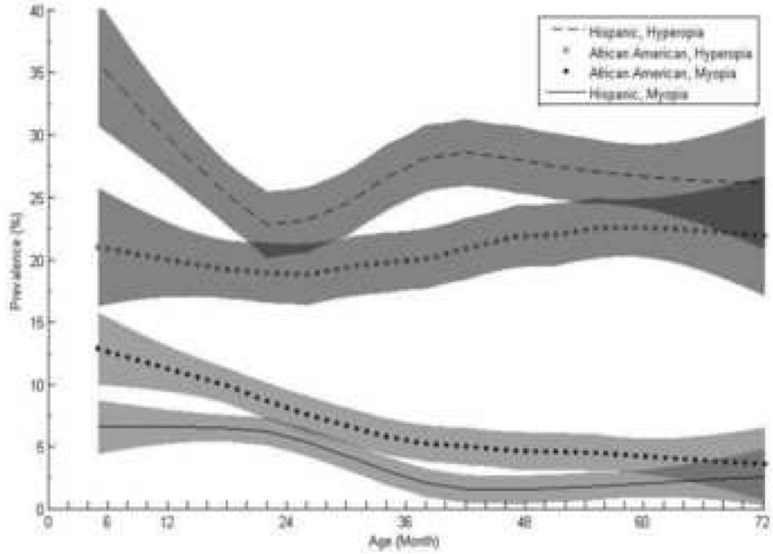

Figure 3.

Locally weighted regression line of estimated prevalence of myopia and hyperopia by months of age in African American and Hispanic children in Multi-Ethnic Pediatric Eye Disease Study. Vertical axis shows the estimated prevalence of spherical equivalent (SE) myopia<=−1diopters (D) and SE hyperopia>=+2D of the worse eye. Horizontal axis shows the age of children in months. Gray shading represent 95% confidence interval of the estimated prevalence.

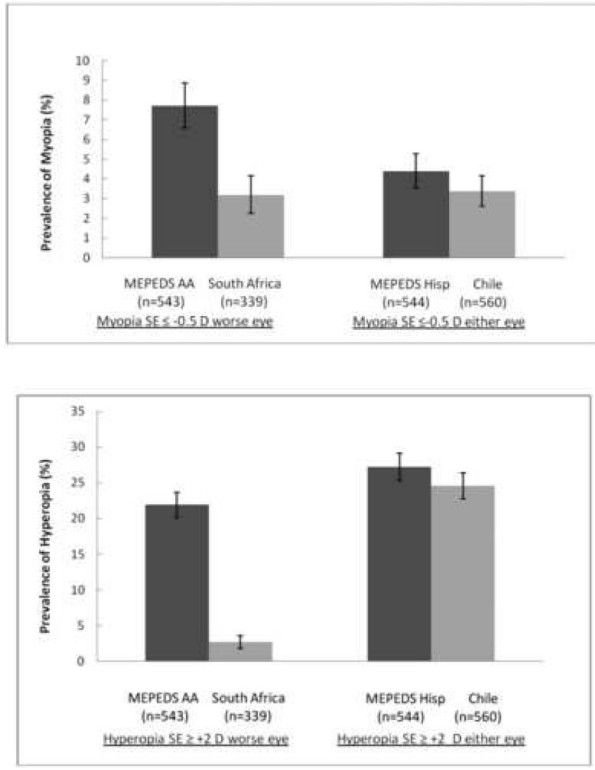

Fig 4.

Comparison of prevalence of myopia and hyperopia in 5 year old Hispanic and African American children in the Multi-Ethnic Pediatric Eye Disease Study (MEPEDS) in the United States and Hispanic children in Chile and African children in South Africa. Vertical axis shows the prevalence of myopia (upper graph) and hyperopia (lower graph) in the United States (Multi-ethnic Pediatric Eye Disease Study), South Africa (Naidoo et al) [7] and Chile (Maul et al) 5. The prevalence of myopia and hyperopia for MEPEDS participants are presented using the definitions used in the study with the comparable race/ethnicity. Error bars represent the estimated standard error of the prevalence. AA: African American, Hisp: Hispanic.

Table 1

Age and gender frequency distributions of the African American and Hispanic children in the Multi-Ethnic Pediatric Eye Disease Study.

Age Group	Hispanic n (%)	African American n (%)	Total n (%)
6–11 months	296 (10%)	277 (9%)	573 (10%)
12–23 months	543 (18%)	549 (18%)	1092 (18%)
24–35 months	572 (19%)	545 (18%)	1117 (19%)
36–47 months	532 (17%)	532 (18%)	1064 (18%)
48–59 months	543 (18%)	548 (18%)	1091 (18%)
60–72 months	544 (18%)	543 (18%)	1087 (18%)
Total	3030 (100%)	2994 (100%)	6024 (100%)
Gender			
Male	1557 (51%)	1514 (51%)	3071 (51%)
Female	1473 (49%)	1480 (49%)	2953 (49%)

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Table 2

Mean spherical equivalent refractive error in right and left eyes of the African-American and Hispanic children stratified by age in the Multi-Ethnic Pediatric Eye Disease Study

Age Group	African American			Hispanic		
	n*	Mean (SD) Spherical Equivalent, in diopters Right eye	Mean (SD) Spherical Equivalent in diopters, Left eye	n*	Mean (SD) Spherical Equivalent in diopters, Right eye	Mean (SD) Spherical Equivalent in diopters, Left eye
6 to 11 months	277	0.60 (1.41)	0.69 (1.47)	296	1.29 (1.42)	1.30 (1.47)
12 to 23 months	549	0.74 (1.28)	0.77 (1.38)	543	1.02 (1.46)	1.09 (1.48)
24 to 35 months	545	0.90 (1.30)	0.96 (1.33)	572	1.07 (1.40)	1.13 (1.47)
36 to 47 months	532	1.08 (1.43)	1.12 (1.56)	532	1.32 (1.38)	1.40 (1.45)
48 to 59 months	548	1.14 (1.45)	1.18 (1.61)	543	1.39 (1.33)	1.41 (1.41)
60 to 72 months	543	1.05 (1.32)	1.08 (1.38)	544	1.35 (1.24)	1.38 (1.26)
Total	2994	0.94 (1.37)	0.99 (1.47)	3030	1.23 (1.37)	1.28 (1.43)

SD = standard deviation

* n: number of children with data for one or both eyes. One African American and 3 Hispanic children had data for right eye only; one African American and 3 Hispanic children had data for left eye only.

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Table 3

Frequency distribution and prevalence of spherical equivalent refractive error in the worse eye of the African-American and Hispanic children stratified by age in the Multi-Ethnic Pediatric Eye Disease Study

African American children										
Age Group in months (n)	Level of myopia				Emmetropia	Level of hyperopia				
	≤−4D* n (%)	≤−3 D n (%)	≤−2 D n (%)	≤−1 D n (%)	]−1to+1D[† n (%)	≥+1 D n (%)	≥+2 D n (%)	≥+3 D n (%)	≥+4 D n (%)	≥+5 D n (%)
6 to 11 (277)	1 (0.4)	3 (1.1)	7 (2.5)	38 (13.7)	120 (43.3)	119 (43.0)	50 (18.1)	21 (7.6)	9 (3.3)	3 (1.1)
12 to 23 (549)	2 (0.4)	5 (0.9)	13 (2.4)	50 (9.1)	254 (46.3)	245 (44.6)	111 (20.2)	38 (6.9)	12 (2.2)	6 (1.1)
24 to 35 (545)	0 (0.0)	2 (0.4)	10 (1.8)	35 (6.4)	238 (43.7)	272 (49.9)	102 (18.7)	42 (7.7)	19 (3.5)	12 (2.2)
36 to 47 (532)	5 (0.9)	7 (1.3)	11 (2.1)	29 (5.5)	200 (37.6)	303 (57.0)	110 (20.7)	56 (10.5)	26 (4.9)	15 (2.8)
48 to 59 (548)	4 (0.7)	5 (0.9)	13 (2.4)	23 (4.2)	207 (37.8)	318 (58.0)	130 (23.7)	61 (11.1)	31 (5.7)	12 (2.2)
60 to 72 (543)	3 (0.6)	3 (0.6)	6 (1.1)	22 (4.1)	221 (40.7)	300 (55.3)	119 (21.9)	44 (8.1)	16 (3.0)	6 (1.1)
Total (2994)	15 (0.5)	25 (0.8)	60 (2.0)	197 (6.6)	1240 (41.4)	1557 (52.0)	622 (20.8)	262 (8.8)	113 (3.8)	54 (1.8)

Hispanic children										
Age Group in months (n)	Level of myopia				Emmetropia	Level of hyperopia				
	≤−4 D n (%)	≤−3 D n (%)	≤−2 D n (%)	≤−1 D n (%)	]−1 to +1 D[n (%)	≥+1 D n (%)	≥+2 D n (%)	≥+3 D n (%)	≥+4 D n (%)	≥+5 D n (%)
6 to 11 (296)	0 (0.0)	1 (0.3)	2 (0.7)	19 (6.4)	95 (32.1)	182 (61.5)	104 (35.1)	47 (15.9)	17 (5.7)	8 (2.7)
12 to 23 (543)	2 (0.4)	3 (0.6)	9 (1.7)	39 (7.2)	204 (37.6)	300 (55.3)	123 (22.7)	55 (10.1)	23 (4.2)	10 (1.8)
24 to 35 (572)	3 (0.5)	5 (0.9)	10 (1.8)	23 (4.0)	222 (38.8)	327 (57.2)	141 (24.7)	56 (9.8)	26 (4.6)	16 (2.8)
36 to 47 (532)	2 (0.4)	3 (0.6)	4 (0.8)	8 (1.5)	171 (32.1)	353 (66.4)	159 (29.9)	75 (14.1)	33 (6.2)	16 (3.0)
48 to 59 (543)	1 (0.2)	2 (0.4)	6 (1.1)	10 (1.8)	170 (31.3)	363 (66.9)	141 (26.0)	66 (12.2)	36 (6.6)	16 (3.0)
60 to 72 (544)	0 (0.0)	0 (0.0)	1 (0.2)	13 (2.4)	173 (31.8)	358 (65.8)	148 (27.2)	64 (11.8)	32 (5.9)	13 (2.4)
Total (3030)	8 (0.3)	14 (0.5)	32 (1.1)	112 (3.7)	1035 (34.2)	1883 (62.2)	816 (26.9)	363 (12.0)	167 (5.5)	79 (2.6)

Refractive error is reported in spherical equivalent (SE) using the eye with the greater refractive power (greater absolute value of SE refractive error).The above reported rates show the prevalence of the defined refractive error within the corresponding age group.

* D: diopters,

†]−1 to +1 D[: greater than −1 D and less than +1 D

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Table 4

Frequency distribution and prevalence of spherical equivalent refractive error in the better eye of the African-American and Hispanic children stratified by age in the Multi-Ethnic Pediatric Eye Disease Study

African American children										
Age Group in months (n)	**Level of myopia**				**Emmetropia**	**Level of hyperopia**				
	≤−4D* n (%)	**≤−3 D n (%)**	**≤−2 D n (%)**	**≤−1 D n (%)**	**]−1to+1D[† n (%)**	**≥+1 D n (%)**	**≥+2 D n (%)**	**≥+3 D n (%)**	**≥+4 D n (%)**	**≥+5 D n (%)**
6 to 11 (277)	0 (0.0)	1 (0.4)	4 (1.4)	25 (9.0)	165 (59.6)	87 (31.4)	39 (14.1)	13 (4.7)	7 (2.5)	2 (0.7)
12 to 23 (549)	1 (0.2)	2 (0.4)	6 (1.1)	27 (4.9)	329 (59.9)	193 (35.2)	73 (13.3)	20 (3.6)	6 (1.1)	3 (0.6)
24 to 35 (545)	0 (0.0)	0 (0.0)	2 (0.4)	20 (3.7)	313 (57.4)	212 (38.9)	74 (13.6)	26 (4.8)	10 (1.8)	8 (1.5)
36 to 47 (532)	1 (0.2)	4 (0.8)	5 (0.9)	19 (3.6)	275 (51.7)	238 (44.7)	84 (15.8)	43 (8.1)	19 (3.6)	9 (1.7)
48 to 59 (548)	3 (0.6)	3 (0.6)	9 (1.6)	18 (3.3)	265 (48.4)	265 (48.4)	99 (18.1)	43 (7.9)	17 (3.1)	8 (1.5)
60 to 72 (543)	2 (0.4)	2 (0.4)	3 (0.6)	14 (2.6)	287 (52.9)	242 (44.6)	86 (15.8)	33 (6.1)	12 (2.2)	4 (0.7)
Total (2994)	7 (0.2)	12 (0.4)	29 (1.0)	123 (4.1)	1632 (54.6)	1237 (41.3)	455 (15.2)	178 (6.0)	71 (2.4)	34 (1.1)

Hispanic children										
Age Group in months (n)	**Level of myopia**				**Emmetropia**	**Level of hyperopia**				
	≤−4 D n (%)	**≤−3 D n (%)**	**≤−2 D n (%)**	**≤−1 D n (%)**	**]−1 to +1 D[n (%)**	**≥+1 D n (%)**	**≥+2 D n (%)**	**≥+3 D n (%)**	**≥+4 D n (%)**	**≥+5 D n (%)**
6 to 11 (296)	0 (0.0)	1 (0.3)	1 (0.3)	11 (3.7)	125 (42.2)	160 (54.1)	75 (25.3)	30 (10.1)	11 (3.7)	3 (1.0)
12 to 23 (543)	1 (0.2)	3 (0.6)	5 (0.9)	26 (4.8)	270 (49.7)	247 (45.5)	94 (17.3)	40 (7.4)	14 (2.6)	8 (1.5)
24 to 35 (572)	3 (0.5)	4 (0.7)	6 (1.1)	16 (2.8)	295 (51.6)	261 (45.6)	92 (16.1)	41 (7.2)	16 (2.8)	8 (1.4)
36 to 47 (532)	2 (0.4)	3 (0.6)	3 (0.6)	8 (1.5)	212 (39.9)	312 (58.7)	120 (22.6)	48 (9.0)	21 (4.0)	6 (1.1)
48 to 59 (543)	0 (0.0)	1 (0.2)	4 (0.7)	8 (1.5)	231 (42.5)	304 (56.0)	104 (19.2)	49 (9.0)	24 (4.4)	11 (2.0)
60 to 72 (544)	0 (0.0)	0 (0.0)	0 (0.0)	5 (0.9)	232 (42.7)	307 (56.4)	108 (19.7)	39 (7.2)	18 (3.3)	6 (1.1)
Total (3030)	6 (0.2)	12 (0.4)	19 (0.6)	74 (2.4)	1365 (45.1)	1591 (52.5)	593 (19.6)	247 (8.2)	104 (3.4)	42 (1.4)

Refractive error is reported in spherical equivalent (SE) using the eye with the smaller refractive power (smaller absolute value of SE refractive error).The above reported rates show the prevalence of the defined refractive error within the corresponding age group.

* D: diopters,

†]−1 to +1 D[: greater than −1 D and less than +1 D

Table 5

Frequency distribution and prevalence of spherical equivalent refractive error in the right eye of the African-American and Hispanic children stratified by age in the Multi-Ethnic Pediatric Eye Disease Study

African American children										
Age Group in months (n)	**Level of myopia**				**Emmetropia**	**Level of hyperopia**				
	≤−4D* n (%)	**≤−3 D n (%)**	**≤−2 D n (%)**	**≤−1 D n (%)**	**]−1to+1D[† n (%)**	**≥+1 D n (%)**	**≥+2 D n (%)**	**≥+3 D n (%)**	**≥+4 D n (%)**	**≥+5 D n (%)**
6 to 11 (277)	0 (0.0)	2 (0.7)	5 (1.8)	30 (10.8)	147 (53.1)	100 (36.1)	43 (15.5)	14 (5.1)	7 (2.5)	3 (1.1)
12 to 23 (549)	1 (0.2)	4 (0.7)	9 (1.6)	38 (6.9)	291 (53.0)	220 (40.1)	90 (16.4)	27 (4.9)	7 (1.3)	3 (0.6)
24 to 35 (545)	0 (0.0)	2 (0.4)	5 (0.9)	28 (5.2)	280 (51.5)	236 (43.4)	82 (15.1)	31 (5.7)	14 (2.6)	9 (1.7)
36 to 47 (532)	2 (0.4	4 (0.8)	6 (1.1)	24 (4.5)	246 (46.2)	262 (49.3)	99 (18.6)	46 (8.7)	23 (4.3)	10 (1.9)
48 to 59 (548)	4 (0.7)	5 (0.9)	12 (2.2)	20 (3.7)	241 (44.0)	287 (52.4)	110 (20.1)	48 (8.8)	21 (3.8)	10 (1.8)
60 to 72 (543)	2 (0.4	2 (0.4)	4 (0.7)	17 (3.1)	255 (47.0)	271 (49.9)	101 (18.6)	36 (6.6)	15 (2.8	4 (0.7)
Total (2994)	9 (0.3)	19 (0.6)	41 (1.4)	157 (5.3)	1460 (48.8)	1376 (46.0)	525 (17.5)	202 (6.8)	87 (2.9)	39 (1.3)

Hispanic children										
Age Group in months (n)	**Level of myopia**				**Emmetropia**	**Level of hyperopia**				
	≤−4 D n (%)	**≤−3 D n (%)**	**≤−2 D n (%)**	**≤−1 D n (%)**	**]−1 to +1D[n (%)**	**≥+1 D n (%)**	**≥+2 D n (%)**	**≥+3 D n (%)**	**≥+4 D n (%)**	**≥+5 D n (%)**
6 to 11 (296)	0 (0.0)	1 (0.3)	2 (0.7)	15 (5.1)	113 (38.3)	167 (56.6)	89 (30.2	39 (13.2)	13 (4.4)	3 (1.0)
12 to 23 (543)	1 (0.2	3 (0.6)	8 (1.5)	33 (6.1)	240 (44.2)	270 (49.7)	108 (19.9	46 (8.5)	15 (2.8)	8 (1.5)
24 to 35 (572)	3 (0.5)	5 (0.9)	8 (1.4)	21 (3.7)	258 (45.2)	292 (51.1)	110 (19.3)	46 (8.1)	21 (3.7)	10 (1.8)
36 to 47 (532)	2 (0.4)	3 (0.6)	3 (0.6)	8 (1.5)	196 (36.9)	327 (61.6)	137 (25.8)	56 (10.6)	23 (4.3)	6 (1.1)
48 to 59 (543)	0 (0.0)	1 (0.2)	5 (0.9)	9 (1.7)	203 (37.4)	331 (61.0)	120 (22.1)	53 (9.8)	27 (5.0)	15 (2.8)
60 to 72 (544)	0 (0.0)	0 (0.0)	0 (0.0)	11 (2.0)	199 (36.6)	334 (61.4)	133 (24.5)	50 (9.2)	24 (4.4)	8 (1.5)
Total (3030)	6 (0.2)	13 (0.4)	26 (0.9)	97 (3.2)	1209 (39.9)	1721 (56.9)	697 (23.0)	290 (9.6)	123 (4.1)	50 (1.7)

The above reported rates show the prevalence of the defined refractive error within the corresponding age group.

* D: diopters,

†]−1 to +1 D[: greater than −1 D and less than +1 D