JAMA Ophthalmology | Original Investigation

Visual Impairment in Preschool Children in the United States
Demographic and Geographic Variations From 2015 to 2060

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IMPORTANCE Visual impairment (VI) in early childhood can significantly impair development.

OBJECTIVE To determine demographic and geographic variations in VI in children aged 3 to 5 years in the United States in 2015 and to estimate projected prevalence through 2060.

DESIGN, SETTING, AND PARTICIPANTS Descriptive study reporting statistics estimated based on prevalence data from 2 major population-based studies conducted in the United States between 2003 and 2011. Using US census projections, prevalence of VI and cause-specific VI in the better eye were reported by race/ethnicity, state and region, and per capita prevalence of VI by state. The study included preschool children in the United States. Analyses for this study were conducted between February 2016 and March 2017.

MAIN OUTCOMES AND MEASURES Prevalence of VI among children aged 3 to 5 years in the United States.

RESULTS In 2015, more than 174 000 children aged 3 to 5 years in the United States were visually impaired. Almost 121 000 of these cases (69%) arose from simple uncorrected refractive error, and 43 000 (25%) from bilateral amblyopia. By 2060, the number of children aged 3 to 5 years with VI is projected to increase by 26%. In 2015, Hispanic white children accounted for the highest number of VI cases (66 000); this group will remain the most affected through 2060, with an increasingly large proportion of cases (37.7% in 2015 and 43.6% in 2060). The racial/ethnic group with the second most VI is projected to shift from non-Hispanic white children (26.3% in 2015 decreasing to 16.5% in 2060) to African American children (24.5% in 2015 and 22.0% in 2060). From 2015 to 2060, the states projected to have the most children with VI are California (26 600 in 2015 and 38 000 in 2060), Texas (21 500 in 2015 and 29 100 in 2060), and Florida (10 900 in 2015 and 13 900 in 2060).

CONCLUSIONS AND RELEVANCE These data suggest that the number of preschool children with VI is projected to increase disproportionally, especially among minority populations. Vision screening for refractive error and related eye diseases may prevent a high proportion of preschool children from experiencing unnecessary VI and associated developmental delays.

JAMA Ophthalmol. 2017;135(6):610-616. doi:10.1001/jamaophthalmol.2017.1021
Published online May 4, 2017.

Supplemental content

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Visual impairment (VI) in early childhood can significantly impair development of visual, motor, and cognitive function[1-3] and lead to adverse psychosocial consequences.[4] For example, the Vision in Preschoolers study[5] reported that VI from uncorrected hyperopia was associated with deficits in early literacy and in other essential skills for school readiness. More importantly, interventions, such as spectacle correction in preschool children, have been shown to restore the visual-motor function of affected ametropic preschool children back to emmetropic levels.[3]

In the United States, reducing VI in children and adolescents is one of the objectives of Healthy People 2020.[6] However, to our knowledge, there is no coordinated surveillance of eye and vision health in the United States. As a result, there has been a lack of accurate data characterizing the prevalence of VI in the US preschool population. Two large-scale, population-based studies, the Multi-Ethnic Pediatric Eye Disease Study (MEPEDS)[7,8] and the Baltimore Pediatric Eye Disease Study (BPEDS),[9] were conjointly designed to estimate the prevalence of ocular disease and refractive error (RE) among preschool children from the 4 most populous racial/ethnic groups (African American, Asian American, Hispanic/Latino, and non-Hispanic white), using shared protocols. Between 2008 and 2013, these studies published their estimates on the prevalence of early childhood VI based on the standardized, comprehensive ophthalmic examination of approximately 12 000 children aged 6 to 72 months. In the MEPEDS, a higher prevalence of presenting RE-related VI was seen in African American and Hispanic children than in either Asian or non-Hispanic white children. Using age- and race/ethnicity–specific prevalence data on VI from these 2 studies, coupled with the 2015 updates in the national population projections from the US Census Bureau,[10] this study provides estimates of the current and expected numbers of VI cases among preschool children in the United States from 2015 to 2060. Furthermore, we identified subgroups (race/ethnicity and regions/states) expected to experience a higher number and/or prevalence of VI cases over the next 4.5 decades within the United States and estimated the current and expected numbers and prevalence of VI potentially improved through refractive correction (eg, glasses, contact lenses, or refractive surgery). We limited our analyses to children aged 3 to 5 years, among whom visual acuity (VA) can be more reliably assessed than in younger children[11] and among whom VA screening is recommended.[12] Findings from this study will be useful for the design of vision screening among preschool children, allocation of public health resources, and policy planning.

Key Points

Question What are the demographic and geographic variations in visual impairment in preschool children in the United States in 2015 and what is the projected prevalence through 2060?

Findings In this prevalence study, the number of preschool children with visual impairment is projected to increase by 26% in 2060, with 69% of visual impairment resulting from simple uncorrected refractive error. Hispanic white children will account for the largest number and proportion of cases, followed by African American children.

Meaning Vision screening and early intervention targeting preschool populations might prevent unnecessary VI and associated developmental delays such as poor reading skills.

Methods

We estimated the prevalence and number of preschool children aged 36 to 72 months in the United States overall and in subgroups defined by race/ethnicity and by state and region of residence. The projected number of children with VI was estimated by multiplying the age- and race/ethnicity–specific prevalence rate of VI by the number of corresponding children. For children aged 36 to 72 months, there was no evidence that VI prevalence varied by sex.[7,8] Neither institutional review board approval nor patient consent was required because this study was based on (1) published prevalence estimates by the MEPEDS and BPEDS and (2) census estimates on US population. No individual-participant data were used.

We calculated the prevalence and numbers of children with VI in the United States for 6 racial/ethnic groups: African American children, Asian American children, Hispanic white children, non-Hispanic white children, other minority children, and multiracial American children. The term *other minority children* is based on the census data on race/ethnicity and refers to populations classified as American Indian, Alaskan Native, Native Hawaiian, or other Pacific Islander alone. Multiracial American children refers to American children who chose 2 or more racial/ethnic categories. All US population estimates and projections were obtained from data available at http://www.census.gov. Hispanic origin was considered an ethnicity, and Hispanic children may be of any race. In 2015, 50% of children aged 3 to 5 years were non-Hispanic white, 22% were Hispanic white, 15% were African American, 5% were Asian American, and 6% were multiracial American. The corresponding figures in 2060 are projected to be 34%, 28%, 15%, 8%, and 12%, respectively.

Age-specific prevalence of VI for African American children, Asian American children, Hispanic white children, and non-Hispanic white children were estimated by the MEPEDS[7,8] and the BPEDS,[9] which are, to our knowledge, the only 2 population-based pediatric eye studies undertaken in the United States. The MEPEDS enrolled 9197 children aged 6 to 72 months (80% participation) living in 100 selected census tracts in Los Angeles County, California, in and around the cities of Alhambra, Inglewood, and Glendale and in Riverside County, California, in the city of Riverside. The BPEDS enrolled 2546 children (62% participation) aged 6 to 71 months from 54 contiguous census tracts in northeastern and eastern Baltimore City, Maryland, and adjacent portions of Baltimore County. Participating children underwent comprehensive ophthalmic evaluation including presenting monocular VA testing (with correction, if worn), cover testing, cycloplegic autorefraction, fundus evaluation, and VA retesting with refractive correction. Visual impairment was defined as decreased VA (<20/50 in children 36 to 47 months of age or <20/40 in children 48 months of age or

Table 1. Estimated Numbers of Children Aged 36 to 72 Months With Visual Impairment in the United States, Stratified by Race/Ethnicity, Region, and Ophthalmic Cause in 2015

Subgroup	Region, No. (%)				
	Northeast	Midwest	South	West	All Regions
Total	26 088 (100.0)	30 688 (100.0)	71 439 (100.0)	46 349 (100.0)	174 564 (100.0)
Race/ethnicity					
Non-Hispanic white	8096 (31.0)	12 815 (41.8)	16 361 (22.9)	8688 (18.7)	45 960 (26.3)
African American	7252 (27.8)	7783 (25.4)	24 023 (33.6)	3687 (8.0)	42 744 (24.5)
Hispanic white	7644 (29.3)	6737 (22.0)	24 989 (35.0)	26 571 (57.3)	65 942 (37.8)
Asian American	1100 (4.2)	709 (2.3)	1298 (1.8)	1909 (4.1)	5015 (2.9)
Other minority	289 (1.1)	560 (1.8)	980 (1.4)	1820 (3.9)	3649 (2.1)
Multiracial	1708 (6.5)	2083 (6.8)	3789 (5.3)	3674 (7.9)	11 254 (6.4)
Ophthalmic cause					
VI from simple uncorrected RE	17 899 (68.6)	20 820 (67.8)	49 477 (69.3)	32 354 (69.8)	120 551 (69.1)
VI in best-corrected vision owing to bilateral amblyopia	6516 (25.0)	7712 (25.1)	17 485 (24.5)	11 322 (24.4)	43 035 (24.7)
VI in best-corrected vision owing to ocular disease	1673 (6.4)	2155 (7.0)	4477 (6.3)	2674 (5.8)	10 979 (6.3)

Abbreviations: RE, refractive error; VI, visual impairment.

older) in the better-seeing eye in the presence of an identifiable ophthalmic etiology. An analysis of VA norms in MEPEDS[13] showed that while 99% of children aged 48 months or older achieved at least 20/40, only 91% of children aged younger than 48 months did; however, 96% of these younger children achieve at least 20/50. Visual impairment was further classified into 3 types based on the identified ophthalmic causes: (1) simple uncorrected RE if VA normalized with retesting (resolving) in the presence of visually significant uncorrected RE at presentation (spherical equivalent myopia of at least −0.5 diopters [D], spherical equivalent hyperopia of at least 3.0 D, or astigmatism of any axis of at least 1.5 D); (2) bilateral amblyopia if VA did not normalize with retesting (nonresolving) in the presence of criteria for bilateral amblyopia (bilateral decreased best-measured VA after retesting with refractive correction and 1 of the following risk factors: bilateral hyperopia of at least 4 D, bilateral myopia of at least 6 D, bilateral astigmatism of at least 2.5 D, or bilateral form deprivation) or probable bilateral amblyopia (bilateral decreased best-measured VA, meeting risk factor criteria in 1 eye, and within 0.25 D of meeting risk factor criteria in the other eye); and (3) ocular disease if VA did not normalize with retesting (nonresolving) in the presence of visually significant ocular disease (normal vision precluded by an anterior segment abnormality, fundus abnormality, or nystagmus).

Because there were no prevalence data available for other minority children and multiracial American children, we used the unweighted mean of the pooled age-specific rates for non-Hispanic white children, African American children, Hispanic white children, and Asian American children. Age-specific prevalence of VI was assumed to be constant throughout the projection period to 2060.

Summary descriptions of these studies are given in eTable 1 in the Supplement. Age-specific and cause-specific summary pooled prevalence estimates of VI and blindness were calculated by combining age, race/ethnicity, and cause-specific numbers from the 2 studies (eTable 2 in the Supplement).

Statistical Methods

Estimates of pooled prevalence for VI by age and race/ethnicity were multiplied by corresponding stratum-specific population estimates to obtain the number of children aged 36 to 72 months with VI in the United States from 2015 to 2060. Similar calculations were completed for each state and region. Prevalence per capita was defined as the number of children aged 3 to 5 years with VI as a proportion of the number of children aged 3 to 5 years in each state based on the US census. Conservative confidence intervals for the estimated prevalence were calculated based on a γ distribution using the Fay and Feuer[14] method available in SAS, version 9.4 (SAS Institute Inc).

Census estimates for state resident populations for the 6 racial/ethnic groups by single year of age are available for 2015 but not for 2060. To obtain 2060 estimates, we calculated the stratum-specific change rates in the national population from 2015 to 2060 and applied these change rates to the stratum-specific state populations in 2015.

Sensitivity analyses were performed on prevalence estimates by using pooled prevalence from MEPEDS and BPEDS (eTable 3 in the Supplement: main model) vs only from MEPEDS (scenario 1). We then compared the estimates from scenario 1 with those obtained from the main model. All reported *P* values were 2-sided with a significance level set at .05.

Results

Current and Projected Estimates of VI in Preschool Children in the United States in 2015 and 2060

In 2015, for preschool children aged 36 to 72 months in the United States, the overall estimated prevalence of VI was 1.5% (95% CI, 1.2% to 1.8%). We based these summary estimates on pooled prevalence estimates by age and race/ethnicity (eTable 2 in the Supplement), which reveal a higher prevalence of VI among Hispanic American and African American children than among Asian American and non-Hispanic white children.

In the United States in 2015, 174 600 children aged 36 to 72 months were visually impaired (**Table 1**) based on present-

Table 2. Projected Numbers of 36- to 72-Month-Old Children With Visual Impairment in the United States by Race/Ethnicity or Ophthalmic Cause From 2015 to 2060

Subgroup	Calendar Year, No. (%)					
	2015	2020	2030	2040	2050	2060
Total VI	174 591 (100)	177 317 (100)	190 881 (100)	199 173 (100)	209 344 (100)	220 576 (100)
Race/ethnicity						
Non-Hispanic white	45 922 (26)	46 571 (26)	44 531 (23)	40 806 (20)	38 644 (18)	36 422 (17)
African American	42 831 (25)	42 573 (24)	44 797 (23)	44 648 (22)	46 414 (22)	48 518 (22)
Hispanic white	65 782 (38)	66 319 (37)	75 415 (40)	83 518 (42)	89 537 (43)	96 110 (44)
Asian American	5049 (2.9)	5577 (3.1)	6597 (3.5)	7459 (3.7)	8288 (4.0)	9154 (4.2)
Other minority	3693 (2.1)	3385 (1.9)	3602 (1.9)	3607 (1.8)	3579 (1.7)	3592 (1.6)
Multiracial	11 315 (6.5)	12 892 (7.3)	15 939 (8.4)	19 135 (9.6)	22 883 (10.9)	26 779 (12.1)
Ophthalmic cause						
VI from simple uncorrected RE	120 591 (69)	122 509 (69)	132 323 (69)	138 521 (70)	145 906 (70)	154 057 (70)
VI in best-corrected vision owing to bilateral amblyopia	43 030 (25)	43 695 (25)	46 938 (25)	48 808 (25)	51 188 (24)	53 846 (24)
VI in best-corrected vision owing to ocular disease	10 971 (6.3)	11 113 (6.3)	11 619 (6.1)	11 844 (5.9)	12 250 (5.9)	12 673 (5.7)

Abbreviations: RE, refractive error; VI, visual impairment.

ing VA of the better-seeing eye. In 2060, an estimated 220 600 children (**Table 2** and **Figure 1**) are projected to be visually impaired (an increase of 26%), while the total number of children aged 36 to 72 months is expected to increase by 14%.

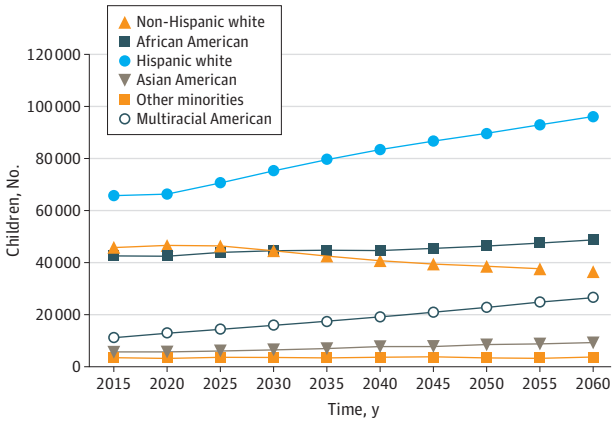
In 2015, with respect to race/ethnicity, Hispanic white children represented the largest proportion of VI cases (n = 65 942; 38%), followed by non-Hispanic white children (n = 45 960; 26%), African American children (n = 42 744; 25%), multiracial American children (n = 11 254; 6.4%), Asian American children (n = 5015; 2.9%), and other minority children (n = 3649; 2.1%). Through 2060, the number of children with VI is projected to increase for multiracial, Asian American, Hispanic white and African American children but decrease for non-Hispanic white and other minority children. By 2060, multiracial children will have the largest increase (137%), followed by Asian American children (81%), Hispanic white children (46%), and African American children (13%), whereas non-Hispanic white children will have the greatest decrease (−21%), followed by other minority children (−3%). Most VI cases will remain among Hispanic white children but to a greater degree (44% in 2060 vs 38% in 2015, Table 2). The race/ethnicity group with the second highest number of VI cases is projected to shift from non-Hispanic white (n = 36 422; 16.5%) to African American children (n = 48 518; 22.0%). Similar race/ethnicity-specific patterns are projected for both resolving and nonresolving VI (eFigure 1 in the Supplement).

Geographic Distribution of the Estimated Number of Preschool Children With VI in the United States in 2015 and 2060

In 2015, the 3 states with the highest numbers of children aged 36 to 72 months with VI were California, Texas, and Florida (26 600, 21 500, and 10 900, respectively). In 2060, these states are projected to continue having the most cases (38 000, 29 100, and 13 900, respectively), with increases of 43% in California, 35% in Texas, and 27% in Florida. These states also represent the largest projected increase, accounting for approximately 48% of the national growth in VI cases.

In 2015, the states with the highest per capita prevalence of VI were the District of Columbia, New Mexico, and Texas (19.2, 18.5, and 18.0 cases per 1000 children, respectively; **Figure 2**). In 2060, the prevalence of VI is projected to be highest in New Mexico, followed by the District of Columbia and Texas (19.9, 19.7, and 19.4 cases per 1000 children, respectively; **Figure 3**). By 2060, the prevalence of VI is projected to increase and reach at least 14 per 1000 children in 29 states and at least 17 per 1000 children in 8 states.

Figure 1. Projected Number of Children Aged 36 to 72 Months With Visual Impairment From All Causes in the United States by Race/Ethnicity and Year

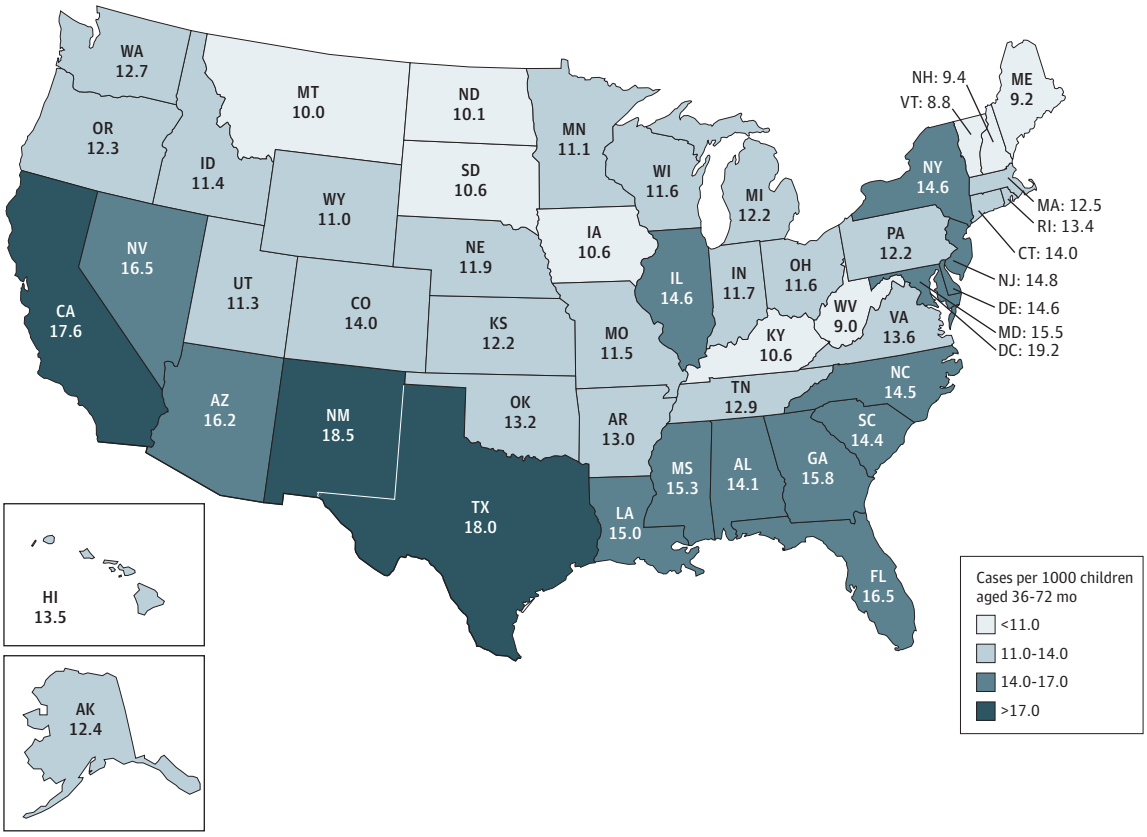


In 2015, most cases were located in the South (Table 1, n = 71 400), followed by the West (n = 46 300), Midwest (n = 30 700), and Northeast (n = 26 100). While similar geographic distribution is projected for 2060 (eTable 4 in the Supplement), the region with the largest growth is projected to be the West (38%), followed by the South (25%), Northeast (23%), and Midwest (16%). Similar geographic distribution was observed for VI from different causes (eFigures 2 and 3 in the Supplement).

Projected Number of Preschool Children With VI From Uncorrected RE and Other Causes in 2015 and 2060

By ophthalmic cause, in 2015, most VI cases were owing to simple uncorrected RE (Table 2; n = 120 591; 69%), followed

Figure 2. Per Capita Prevalence of Visual Impairment in the United States in 2015



by bilateral amblyopia (n = 43 030; 25%) and ocular disease (n = 10 971; 6%). By 2060, we project a 28% increase in VI from simple uncorrected RE and a 25% increase in VI from bilateral amblyopia but only a 16% increase in VI from ocular disease. Simple uncorrected RE is projected to remain the cause of most VI cases in 2060 (70%).

Sensitivity Analysis

For the projections for 2015 and 2060, the sensitivity analyses for VI revealed minimal differences between models (eTable 3 in the Supplement), ranging from 2.5% to 3.3%.

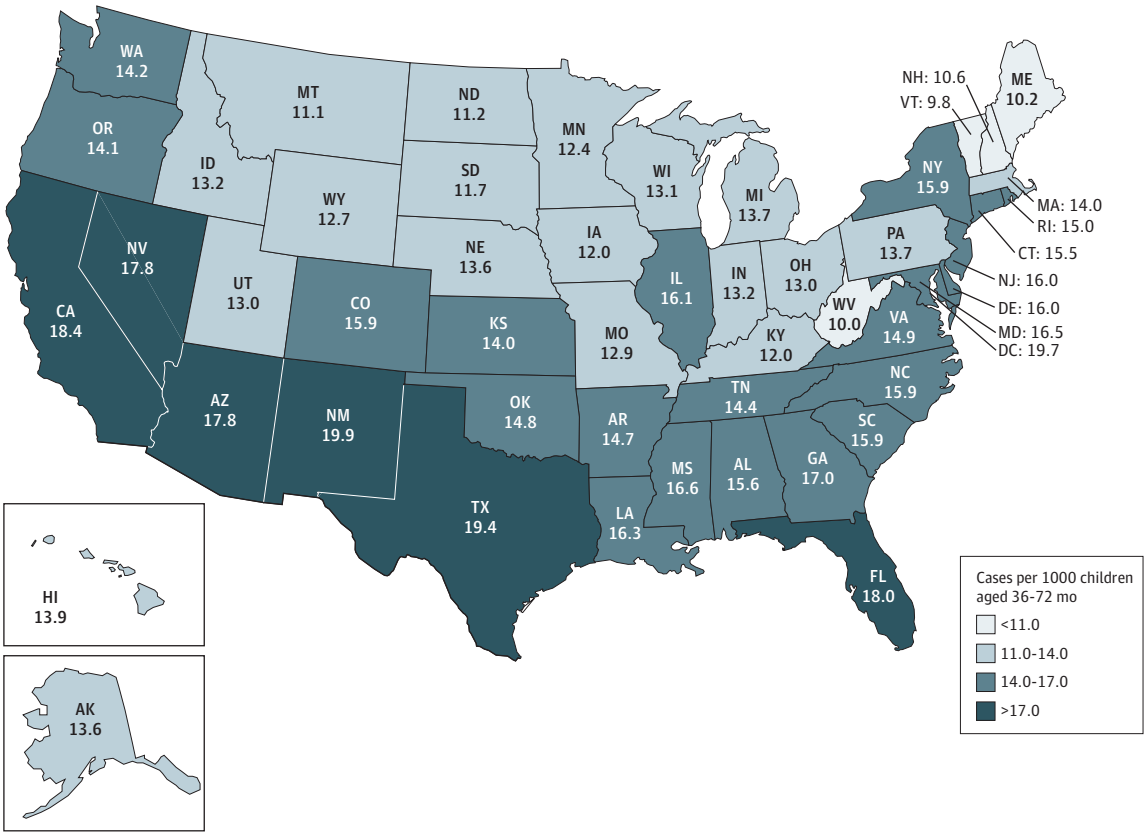
Discussion

We estimate that in 2015 in the United States, 174 00 children aged 3 to 5 years were visually impaired, most (n = 120 600; 69%) owing to simple uncorrected RE, and that Hispanic white children were the most affected (n = 65 942; 38%). Our 45-year projections indicate a 26% increase in VI in 2060. During this period, Hispanic white children will remain the largest demographic group in terms of the absolute numbers of VI cases (44% of the total). Multiracial American children will have the greatest proportional increase (137%), and non-Hispanic white children will have the largest proportional decrease (21%) in the number of VI cases.

In 2015, Hispanic white children and African American children accounted for 62% of preschool children with VI in the United States (n = 108 686). This was partly owing to a higher prevalence of VI in both African American children (2.35% in the better eye) and Hispanic white children (2.47%) than in either Asian American children (0.81%) or non-Hispanic white children (0.77%). As a result, for 2015, the highest per capita prevalence of VI is estimated for the District of Columbia, New Mexico, and Texas, the district/states with the highest proportion of African American children and Hispanic children (69%, 55%, and 59% respectively in 2015). Over time, multiracial and Hispanic children will contribute to an increasingly larger proportion of prevalent VI. In particular, contributions from multiracial children will increase by 137%, approaching the contribution from non-Hispanic white children. This shift in the groups most affected by preschool VI results from the projected trend of an increasingly racially and ethnically diverse child population in the United States.[10] According to the US census's projection, during the next 45 years, the multiracial, Asian, and Hispanic populations will be the fastest-growing groups, and by 2060, 64% of children younger than 18 years will be racial and ethnic minorities.

The high prevalence of VI among Hispanic white, African American, and multiracial children is of particular concern, because children of these groups were shown to receive less vision care than non-Hispanic white children. Data from the National Health Interview Survey[15] indicated that among

Figure 3. Per Capita Prevalence of Visual Impairment in the United States in 2060



children aged 6 to 17 years, Hispanic children and African American children were more than 30% less likely to have received eye care than non-Hispanic/nonblack children, regardless of age, sex, family income, health insurance, and receipt of well-child care. In addition, several studies have indicated that children with VI often have other disabling conditions that would qualify them as children with special health care needs, requiring more extensive and tailored vision care.[16] This further compounds the inequity, because children with special health care needs of African American, Latino, and multiracial backgrounds were 2 to 3 times as likely to have unmet need for vision care as white children with special health care needs,[16] even after controlling for differences in household structure, socioeconomic status, health status, use of health services, and perceptions of service professionals.

Refractive error is the leading cause of VI in preschool children in the United States.[7-9] We estimate that in 2015, approximately 69% of preschool children aged 3 to 5 years with VI (n = 120 600) could have experienced immediate vision improvement through proper refractive correction. In addition, 25% of VI consisted of cases of bilateral amblyopia, almost entirely owing to refractive error. These data suggest that a high proportion of preschool children experience unnecessary vision loss that could be prevented by early detection and treatment of significant RE. The National Expert Panel recommends[12] that children aged 36 months to younger than 72 months should be screened annually or at least once.[12] Unfortunately, according to the National Health Interview Survey, only approximately 40% of preschool children aged 5 years and younger received vision screening in 2008.[6] In addition, according to a multiclinic study in North Carolina,[17] only 48% of children aged 3 to 5 years with an abnormal screening result were reportedly referred for follow-up evaluation. This underscores the need for increased vision screening and follow-up care for preschool children.[12,18,19]

Limitations

Our study has several limitations. First, inherent errors in the prevalence data from the selected studies and the US census might skew the accuracy of our predictions. For instance, the race/ethnicity and age data in the census are self-reported and therefore may not be accurate. Second, this projection assumes that the age- and race/ethnicity-specific prevalence of VI will not vary dramatically over time, although future screening and treatment changes could substantially affect the prevalence of VI in preschool children. A well-designed national surveillance system that continuously collects population data in a standardized manner is needed to detect and monitor trends in the effect of VI and blindness across the United States.[20] Third, the estimated VI among children of mixed race or other minorities (including American Indian, Alaskan Native, Native Hawaiian, or other Pacific Islander) may not be accurate because of the lack of population-based data on these child populations.[21] Finally, our estimated prevalence of correctable VI could have been inflated: studies have shown that some

preschool VI cases associated with RE and resolved through retesting with correction may actually be attributable to poor initial test performance. Some such cases can resolve with retesting alone before refractive correction.[7,8,11] Despite these limitations and inherent uncertainties, this study, using the best currently available data, provides valuable insight into projected caseloads and trends with regard to VI in the preschool population in the United States from 2015 to 2060.

Conclusions

The number of preschool children with VI is projected to increase disproportionally. Given that most preschool VI can be prevented or treated by low-cost refractive correction and that early intervention is critical for better visual outcomes, vision screening in preschool age and follow-up care will have a significant, prolonged effect on visual function and academic and social achievements and therefore should be recommended for all children. Hispanic white children represent most preschool VI cases and are projected to represent an increasingly larger proportion in the next few decades. However, the largest proportional increase in VI cases is projected to occur among multiracial children. Consequently, regions with different demographic compositions will experience the effect of VI differentially. A coordinated surveillance system is needed to continuously monitor the effect of preschool VI on the national, state, and local levels over time.

ARTICLE INFORMATION

Accepted for Publication: March 20, 2017.

Published Online: May 4, 2017. doi:10.1001/jamaophthalmol.2017.1021

Author Contributions: Drs Varma and Jiang had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.
Concept and design: Jiang.
Acquisition, analysis, or interpretation of data: All authors.
Drafting of the manuscript: Jiang.
Critical revision of the manuscript for important intellectual content: All authors.
Statistical analysis: Tarczy-Hornoch, Jiang.
Administrative, technical, or material support: Varma.
Supervision: Jiang.

Conflict of Interest Disclosures: All authors have completed and submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest and none were reported.

Funding/Support: This study was supported by grants EY025313 (Dr Jiang, principal investigator) and EY14472 (Dr Varma, principal investigator) from the National Eye Institute, Bethesda, Maryland, and unrestricted grants from Research to Prevent Blindness, New York, New York.

Role of the Funder/Sponsor: These funding organizations had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Additional Contributions: We recognize and acknowledge the significance of the data from the Baltimore Pediatric Eye Disease study, which was led by David S. Friedman, MD, MPH, PhD (Wilmer Eye Institute of Johns Hopkins University School of Medicine), Joanne Katz, MS, BSc (Department of International Health, Johns Hopkins Bloomberg School of Public Health), and James M. Tielsch PhD, MHSc (Department of Global Health, Milken Institute School of Public Health, George Washington University). No compensation was provided for their contributions.

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