Prevalence of uncorrected refractive errors among school-age children in the School District of Philadelphia

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PURPOSE To determine the prevalence and severity of uncorrected refractive errors in school-age children attending Philadelphia public schools.

METHODS The Wills Eye Vision Screening Program for Children is a community-based pediatric vision screening program designed to detect and correct refractive errors and refer those with nonrefractive eye diseases for examination by a pediatric ophthalmologist. Between January 2014 and June 2016 the program screened 18,974 children in grades K-5 in Philadelphia public schools. Children who failed the vision screening were further examined by an on-site ophthalmologist or optometrist; children whose decreased visual acuity was not amenable to spectacle correction were referred to a pediatric ophthalmologist.

RESULTS Of the 18,974 children screened, 2,492 (13.1%) exhibited uncorrected refractive errors: 1,776 (9.4%) children had myopia, 459 (2.4%) had hyperopia, 1,484 (7.8%) had astigmatism, and 846 (4.5%) had anisometropia. Of the 2,492 with uncorrected refractive error, 368 children (14.8%) had more than one refractive error diagnosis. In stratifying refractive error diagnoses by severity, mild myopia (spherical equivalent of −0.50 D to < −3.00 D) was the most common diagnosis, present in 1,573 (8.3%) children.

CONCLUSIONS In this urban population 13.1% of school-age children exhibited uncorrected refractive errors. Blurred vision may create challenges for students in the classroom; school-based vision screening programs can provide an avenue to identify and correct refractive errors. (J AAPOS 2018;22:214-217)

Refractive error is the most common childhood ocular condition.[1] The prevalence of refractive error depends on the demographic and age composition of the study population and the way in which refractive error is measured and defined.[1-4] Recent large-scale studies suggest that there is an unmet need to correct refractive error in low-income children.[1,5] Children in urban populations have a 2.6 times greater risk of developing myopia than children in rural populations.[4] In addition, Medicaid-enrolled children and non-Hispanic white children were found to have greater odds than Hispanic or nonwhite children of receiving eye care and lenses.[6] Uncorrected refractive error increases a child's risk for visual, academic, and cognitive challenges.[3,7,8] Conducting vision screenings and correcting refractive error—particularly in low-income, inner-city, early school-age children—has the potential to improve their social functioning and academic performance.[9,10]

The Wills Eye Vision Screening Program for Children (WEVSPC), in partnership with the School District of Philadelphia (SDP), was initiated in 2014 to address disparities in pediatric ocular care. The WEVSPC conducts vision screenings for children in grades K-5 and provides eyeglasses at no charge to children with uncorrected

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This project was funded by the Deerbrook Charitable Trust and in part by The Foerderer Fund (AVL), and the Robison D. Harley, MD Endowed Chair in Pediatric Ophthalmology and Ocular Genetics (AVL). Visionworks provided eyeglasses at a low cost. The Deerbrook Charitable Trust and Visionworks had no role in study design; in the collection, analysis or interpretation of data; in the writing of the report; or in the decision to submit the article for publication.

Submitted September 23, 2017.

Revision accepted January 18, 2018.

Published online April 13, 2018.

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1091-8531/$36.00

https://doi.org/10.1016/j.jaapos.2018.01.011

refractive error. Children whose suboptimal visual acuity could not be corrected by eyeglasses were referred to a pediatric ophthalmologist. Children previously diagnosed with refractive error who had normal corrected visual acuity at the time of screening were not included in the data analysis. Children previously diagnosed with refractive error who had suboptimal corrected visual acuity at the time of screening were included in the data analysis. The aim of the current study was to assess the prevalence of uncorrected refractive errors, including myopia, hyperopia, astigmatism, and anisometropia, in a low socioeconomic inner-city population.

Subjects and Methods

The full design and methodology of the WEVSPC have been described in detail elsewhere.[11] The protocol was approved by the SDP as an extended screening in compliance with state requirements that every child receive a vision screening annually in school.[12] In accordance with the state mandate, parental consent is not required for school-based vision screening. The Wills Eye Hospital Institutional Review Board approved a retrospective chart review of the WEVSPC data and outcomes for the purpose of this study.[11] This study conformed to the requirements of the US Health Insurance Portability and Accountability Act of 1996.

Between January 2014 and June 2016, 45 elementary schools were chosen by a SDP liaison in collaboration with school nurses based on vision screening needs, taking into consideration school nurse shortages and vision screening conducted by other programs.[13] All schools were in low-income areas of Philadelphia where the principals and nurses had requested assistance to comply with the state mandate. Vision screenings occurred on school premises in classrooms, auditoriums, and libraries during school hours and were conducted by trained Wills Eye Hospital staff members, including an ophthalmologist or optometrist, optician, project manager, and vision screeners. The vision screening was uniformly conducted at each grade level, with all children in each grade screened. The vision screening, as mandated by the state, consisted of near and distance visual acuity, stereopsis, and color vision testing.

Visual acuity charts (Snellen Charts, Kindergarten Eye Charts, Lea Symbols Charts, or ClearCharts [ClearChart 2 Digital Acuity System, Reichert Technologies, Depew, NY]) and Rosenbaum pocket vision cards (Graham-Field, Atlanta, GA) were used at standard distance. The chart chosen for a given child was based on his or her compliance and understanding as determined by the vision screener. An ophthalmologist or optometrist was present on site to examine all children who failed distance or near visual acuity screening, were unable to complete the screening, or were noted to have an ocular abnormality by the vision screeners. Subjective manifest refraction was performed on all children seen by the ophthalmologist or optometrist using a portable phoropter (Phoropter 11625, Reichert Scientific Instruments, Buffalo, NY).

Any child who had a visual acuity difference of at least 2 lines between eyes was considered a screen failure.[12,14] Monocular distance and binocular near visual acuity failure thresholds were defined based on the grade and reading level of the child. Children in grades K-1 with visual acuity worse than 20/40 in either eye failed vision screening regardless of age. Children in grades 2-5 failed the vision screening if their visual acuity was worse than 20/30 in either eye regardless of age.[14,15] Eyeglasses were prescribed for hyperopia $> +2.00$ D, cylinder $> +1.00$ D, and myopia > -0.50 D, if the visual acuity improved in a fashion consistent with expectations for that refraction. If the visual acuity remained below the pass criteria using subjective manifest refraction or if any ocular pathology was seen or suspected by the ophthalmologist or optometrist, a referral was made to a pediatric ophthalmologist. Children diagnosed with refractive error at either the on-site screening or through a referral appointment by a Wills Eye Hospital pediatric ophthalmologist are included in the current analysis. We defined refractive error as any refractive error causing suboptimal visual acuity for which eyeglasses were prescribed, based on the above criteria. Children previously diagnosed with refractive error who had normal corrected visual acuity at the time of screening were not included in the data analysis. Children previously diagnosed with refractive error who had suboptimal corrected visual acuity at the time of screening were included in the data analysis.

Statistical Analysis

Refractive error was analyzed in the plus cylinder form. Myopia and hyperopia were calculated as spherical equivalents (SE), equaling the sum of the sphere plus half the cylinder power. Severity was categorized based on published literature and investigator consensus as follows: mild myopia (SE from -0.50 D to < -3.00 D), moderate myopia (SE from -3.00 D to -6.00 D), high myopia (SE < -6.00 D), mild hyperopia (SE from $+0.50$ D to $+2.00$ D), moderate hyperopia (SE from $> +2.00$ D to $+5.00$ D), and high hyperopia (SE $> +5.00$ D).[16-20] Anisometropia was defined based on published literature and investigator consensus as ≥ 1.00 D interocular difference of spherical or cylindrical error.[21,22] Number of diagnoses for each child corresponded to diagnoses of myopia, hyperopia, or astigmatism in either eye (eg, if a child had myopia in one eye, hyperopia in the other eye, and astigmatism in either or both eyes, that child would have three diagnoses).

We calculated prevalence values for myopia, hyperopia, astigmatism, and anisometropia for the eyes with worse SE refractive error for these children and stratified the results by age. Differences between sexes were evaluated using a χ^2 test. A P value of <0.05 was considered statistically significant. Data analyses were performed with R version 3.2.2 (R Foundation for Statistical Computing, Vienna, Austria).

Results

Of the 18,974 children screened during the study period, 2,492 (13.1%) exhibited uncorrected refractive errors. Of the 18,974 children screened, 18,839 underwent subjective manifest refraction on site, and 135 children underwent a cycloplegic examination at Wills Eye Hospital to rule out nonrefractive ocular conditions. The median age of children with uncorrected refractive error was 8 years; 48.5% were

girls. Of the 18,974 children, 1,776 (9.4%) had myopia; 459 (2.4%), hyperopia; and 1,484 (7.8%), astigmatism.

Of the 2,492 children with uncorrected refractive errors, 1,776 (71.3%) had myopia; 459 (18.4%), hyperopia; and 1,484 (59.6%), astigmatism (eTable 1). Median and mean myopia was −1.25 D and −1.64 D. Median and mean hyperopia was +1.56 D and +1.13 D. Median and mean astigmatism was 1.75 D and 1.97 D. Of the children with uncorrected refractive error, a total of 1,292 (51.8%) children had one refractive error diagnosis, 338 (13.6%) children had two diagnoses, and 30 (1.2%) children had three diagnoses (eTable 2). A total of 846 (33.9%) children exhibited anisometropia of ≥1.00 D. There was no significant difference in the prevalence of uncorrected refractive errors on the basis of sex.

Mild myopia and low astigmatism were the most prevalent categorizations, present in 1,573 (63.1%) and 1,241 (49.8%), respectively, of the 2,492 children with uncorrected refractive error. In order of decreasing prevalence, diagnoses of anisometropia (33.9%), mild hyperopia (13.7%), high astigmatism (9.8%), moderate myopia (7.4%), moderate hyperopia (4.3%), high myopia (0.7%), and high hyperopia (0.4%) followed. Detailed refractive error results by age and severity are presented in eFigure 1.

Discussion

Pennsylvania mandates that all children receive annual school-based vision screening; however, nursing shortages in Philadelphia have made this goal difficult to achieve.[23] Partnering with an academic eye center such as Wills Eye Hospital has allowed schools to provide children with eye screenings as well as free eyeglasses to correct refractive error. Between January 2014 and June 2015, 1,015 (77%) children with refractive error received free eyeglasses.[11]

The WEVSPC screened 18,974 school-age children for near and distance visual acuity, stereopsis, and color vision, examined 2,942 children who failed the screening, and provided eyeglasses according to measured prescriptions. These schools had a 49% African American population, of which almost 90% of students were from low-income families.[24] African American children are less likely to have a diagnosed eye condition than non-Hispanic white children.[5,25] Conversely, children from higher income families are more likely to be diagnosed with eye conditions.[25]

Although few studies report on the severity of myopia and hyperopia in elementary school children, we found mild myopia to be the most common uncorrected refractive error in our study population. Rates of low astigmatism, anisometropia, mild hyperopia, high astigmatism, moderate myopia, and moderate hyperopia were also substantial, whereas the rates of high myopia and high hyperopia were very low.

The finding that 13.1% of children had uncorrected refractive errors is consistent with the published data for this age group with regard to uncorrected visual impairment.[25,26] The Medical Expenditure Panel Surveys have documented that 1.3% of children report having a diagnosed refractive error.[25] The difference indicates that our screened population may have had a particularly high prevalence of uncorrected refractive disorders. However, it is expected that a vision screening program would find a higher incidence of refractive error than a general medical survey due to the more rigorous nature of the screening.

Effectively diagnosing and correcting refractive error is paramount in improving children's learning in school. A 12-year retrospective study demonstrated that, similar to the WEVSPC, a van-based model for vision screening is an effective way to reach low-income children by directly bringing services to elementary schools within the community.[9] Another study of 1,037 children from 372 elementary schools found that hyperopic children have decreased reading performance, specifically in the fluency of reading. Correction of this refractive error led to increased reading speed and speed of word recognition.[27] In a study conducted in western China, 3,177 myopic fourth and fifth graders were randomized to either receive a prescription for eyeglasses, a voucher for free eyeglasses, or free eyeglasses provided in the class. The results showed that the provision of free eyeglasses during class improved children's mathematic testing to a statistically significant degree.[28] These last two studies indicate that providing eyeglasses to children with uncorrected refractive errors can improve their academic performance.

The current study has several limitations. Race/ethnicity were not evaluated because of confidentiality restraints from the SDP, which limits the generalizability of our results. Cycloplegic refractions were only performed in the children who were referred to Wills Eye Hospital, which limited the accuracy of our refractive error measurements in the schools. Visual acuity testing is subjective and may be difficult to assess, especially in younger children.[29] Additionally, the visual acuity chart used for a given child was based on their age and comprehension as determined by the vision screener. Consequently, nonuniform eye charts were used for different age groups. Pennsylvania requires that every child receives a vision screening annually in school. As a result, children with refractive error may have been identified and given vision correction prior to the WEVSPC. Older children, who underwent many previous school vision screenings, may be more likely than younger children to have had vision correction and received eyeglasses by an eye care provider. This may have contributed to the low prevalence of uncorrected refractive error in older children.

Finally, it is vital to keep in mind that the current study applies to screening in low-income schools for children not already in eyeglasses and thus is not comparable to epidemiology of the general pediatric population. Future studies should evaluate the relationship between uncorrected refractive error prevalence and race/ethnicity, household income level, and insurance status. A better understanding of which subpopulations exhibit a higher prevalence of uncorrected refractive error will help focus vision screening

efforts on those who are most vulnerable. Additionally, longitudinal studies assessing refractive errors are needed to better evaluate how refractive error changes over time during childhood.

Acknowledgments

The authors acknowledge the strong support received from the School District of Philadelphia, including Superintendent, William R. Hite, EdD, Karyn Lynch, Chief, Office of Student Support Services, Tracey Williams, Director, Office of Student Health Services, Angela Rice, MBA, Philadelphia School District Liaison with Wills Eye, and the teachers and school nurses, without whom this work would not have been possible.

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eTable 1. Uncorrected refractive error in worse eyes of the examined population categorized by age

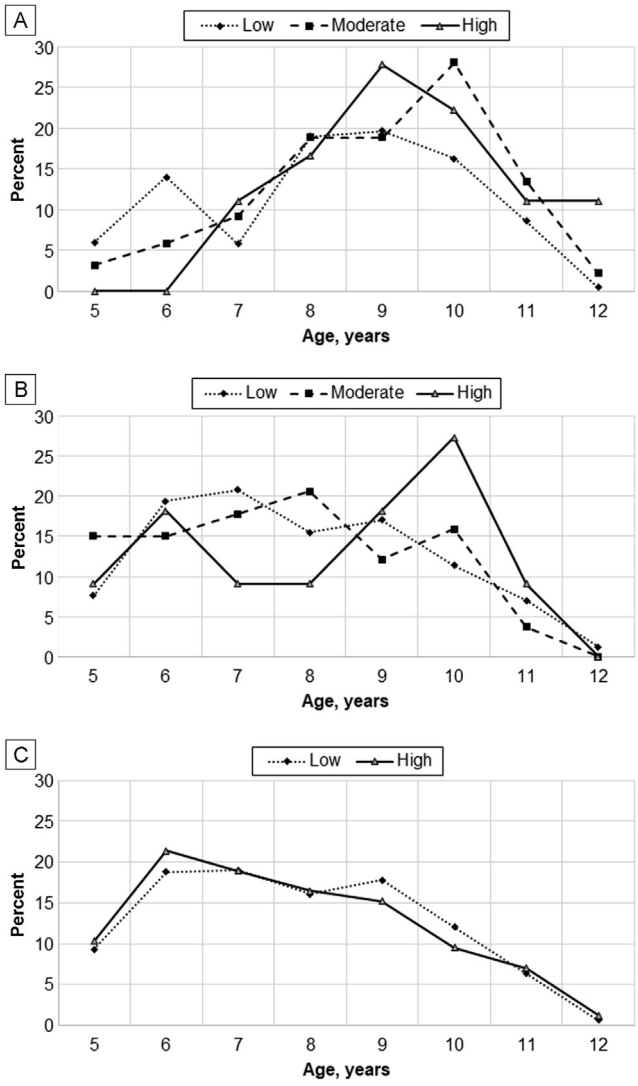
		Age, years								
		5	6	7	8	9	10	11	12	Total
Diagnoses by category, n (%)[a]	SE	173 (6.9)	380 (15.2)	419 (16.8)	446 (17.9)	461 (18.5)	389 (15.6)	201 (8.1)	23 (0.9)	N = 2492
Hyperopia										
Low	0.50-1.99	26 (15.0)	66 (17.4)	71 (16.9)	53 (11.9)	58 (12.6)	39 (10.0)	24 (11.9)	4 (17.4)	341 (13.7)
Moderate	2.00-4.99	16 (9.2)	16 (4.2)	19 (4.5)	22 (4.9)	13 (2.8)	17 (4.4)	4 (2.0)	0 (0.0)	107 (4.3)
High	≥5.00	1 (0.6)	2 (0.5)	1 (0.2)	1 (0.2)	2 (0.4)	3 (0.8)	1 (0.5)	0 (0.0)	11 (0.4)
Total (≥+0.50)		43 (24.9)	84 (22.1)	91 (21.7)	76 (17.0)	73 (15.8)	59 (15.2)	29 (14.4)	4 (17.4)	459 (18.4)
Myopia										
Low	0.50-2.99	94 (54.3)	221 (58.2)	249 (59.4)	299 (67.0)	310 (67.2)	256 (65.8)	136 (67.7)	8 (34.8)	1573 (63.1)
Moderate	3.00-5.99	6 (3.5)	11 (2.9)	17 (4.1)	35 (7.8)	35 (7.6)	52 (13.4)	25 (12.4)	4 (17.4)	185 (7.4)
High	≥6.00	0	0	2 (0.5)	3 (0.7)	5 (1.1)	4 (1.0)	2 (1.0)	2 (8.7)	18 (0.7)
Total	(≤−0.50)	100 (57.8)	232 (61.1)	268 (64.0)	337 (75.6)	350 (75.9)	312 (80.2)	163 (81.1)	14 (60.9)	1776 (71.3)
Astigmatism										
Low	1.00-2.75	116 (67.1)	233 (61.3)	236 (56.3)	200 (44.8)	221 (47.9)	149 (38.3)	78 (38.8)	8 (34.8)	1241 (49.8)
High	≥3.00	25 (14.5)	52 (13.7)	46 (11.0)	40 (9.0)	37 (8.0)	23 (5.9)	17 (8.5)	3 (13.0)	243 (9.8)
Total	(DC ≥1.00)	141 (81.5)	285 (75.0)	282 (67.3)	240 (53.8)	258 (56.0)	172 (44.2)	95 (47.3)	11 (47.8)	1484 (59.6)
Anisometropia										
Spherical	(≥1.0)	39 (22.5)	3 (0.8)	2 (0.5)	2 (0.4)	83 (18.0)	67 (17.2)	39 (19.4)	4 (17.4)	479 (19.2)
Cylindrical	(≥1.0)	32 (18.5)	62 (16.3)	65 (15.5)	61 (13.7)	73 (15.8)	42 (10.8)	31 (15.4)	1 (4.3)	367 (14.7)

DC, diopters of cylinder; *SE*, spherical equivalent in diopters.
[a]The denominator of each calculated percentage corresponds to the number of children with uncorrected refractive error in each age group.

eTable 2. Number of uncorrected refractive error diagnoses categorized by age

	Age, years								
	5	6	7	8	9	10	11	12	Total
Number of diagnoses, n (%)[a]	173 (6.9)	380 (15.2)	419 (16.8)	446 (17.9)	461 (18.5)	389 (15.6)	201 (8.1)	23 (0.9)	N = 2492
One									
Myopia	31 (17.9)	92 (24.2)	135 (32.2)	205 (46.0)	220 (47.7)	228 (58.6)	110 (54.7)	8 (34.8)	1029 (41.3)
Hyperopia	13 (7.5)	29 (7.6)	29 (6.9)	38 (8.5)	28 (6.1)	20 (5.1)	9 (4.5)	2 (8.7)	168 (6.7)
Astigmatism	12 (6.9)	19 (5.0)	23 (5.5)	14 (3.1)	16 (3.5)	6 (1.5)	5 (2.5)	0	95 (3.8)
Total	56 (32.4)	140 (36.8)	187 (44.6)	257 (57.6)	264 (57.3)	254 (65.3)	124 (61.7)	10 (43.5)	1292 (51.8)
Two									
Myopia and hyperopia	1 (0.6)	2 (0.5)	1 (0.2)	4 (0.9)	5 (1.1)	3 (0.8)	2 (1.0)	0	18 (0.7)
Astigmatism and myopia	18 (10.4)	42 (11.1)	47 (11.2)	39 (8.7)	44 (9.5)	31 (8.0)	17 (8.5)	1 (4.3)	239 (9.6)
Astigmatism and hyperopia	11 (6.4)	14 (3.7)	17 (4.1)	9 (2.0)	8 (1.7)	17 (4.4)	5 (2.5)	0	81 (3.3)
Total	30 (17.3)	58 (15.3)	65 (15.5)	52 (11.7)	57 (12.4)	51 (13.1)	24 (11.9)	1 (4.3)	338 (13.6)
Three									
Astigmatism, myopia, and hyperopia	3 (1.7)	4 (1.1)	4 (1.0)	4 (0.9)	4 (0.9)	7 (1.8)	4 (2.0)	0	30 (1.2)

[a]The denominator of each calculated percentage corresponds to the number of children with uncorrected refractive error in each age group.



eFIG 1. Relative frequency of uncorrected myopia (A), hyperopia (B), and astigmatism (C) by age and severity. Each data point represents the number of diagnoses of a severity of uncorrected myopia, hyperopia, or astigmatism within an age group divided by the number of diagnoses of all severities of the same uncorrected problem within an age group.