Clinical Ophthalmology

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ORIGINAL RESEARCH

The UCI EyeMobile Preschool Vision Screening Program: Refractive Error and Amblyopia Results from the 2019–2020 School Year

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Purpose: To introduce the University of California Irvine (UCI) EyeMobile for Children preschool vision screening program and describe the ophthalmic examination results of children who failed screening with the PlusoptiX S12C photoscreener during one school year.

Patients and Methods: Children aged 30–72 months were screened with the PlusoptiX using ROC mode 3 during the 2019–2020 school year. Children who failed screening were referred for comprehensive eye examination on the EyeMobile mobile clinic. Presence of amblyopia risk factors (ARFs), amblyopia, and refractive error was determined via retrospective review of records. Amblyopia was defined as unilateral if there was ≥ 2-line interocular difference in the best-corrected visual acuity (BCVA) and as bilateral if BCVA was < 20/50 for children < 4 years old and < 20/40 for children ≥ 4 years old. ARFs were defined using 2021 American Association for Pediatric Ophthalmology and Strabismus (AAPOS) instrument-based screening guidelines.

Results: 5226 children were screened during the study period. Of the 546 children who failed screening, 350 (64%) obtained consent and were examined. Mean age of examined children was 4.45 years. Amblyopia was found in 8% of examined children, with unilateral amblyopia seen in 79% of amblyopic subjects. Glasses were prescribed to 246 (70.3%) children. Of the 240 children who received cycloplegic examinations, 43% had hyperopia and 30% had myopia. The positive predictive value (PPV) of the PlusoptiX screening for ARFs in children who received cycloplegic examinations was 70.4%.

Conclusion: A significant proportion of Orange County preschoolers with refractive errors and amblyopia have unmet refractive correction needs. The PlusoptiX S12C photoscreener is an adequate screening device for the UCI EyeMobile for Children program, although modification of device referral criteria may lead to increased PPV. Further research is necessary to understand and overcome the barriers to childhood vision care in our community.

Keywords: vision screening, amblyopia, refractive error, amblyopia risk factor, child, plusoptix, photoscreener

Introduction

Amblyopia is the most common cause of vision loss in children, with a prevalence of approximately 2–4%.[1,2] Early detection and treatment of amblyopia is critically important, as this may lead to better visual outcomes and may increase the cost-effectiveness of treatment.[3] The implementation of national vision screening programs has decreased the burden of amblyopia in some countries.[4] Currently the US Preventive Services Task Force (USPSTF) recommends at least one vision screening for all children aged 3 to 5 years.[5]

As vision screening programs for young children are becoming commonplace, the use of automated screening devices to perform vision screening is on the rise. Devices such as photoscreeners and autorefractors may offer advantages over traditional methods using visual acuity as they are accurate, reliable, and have been validated.[3] Despite their proposed benefits, organizations may struggle to choose the best screening device for their program as there is conflicting data regarding the effectiveness of different automated screening devices.[6–9] In addition, the specific community needs and

Received: 1 August 2022
Accepted: 18 November 2022
Published: 20 December 2022

resources available vary among vision screening programs, so a screening method or device ideal for one program may not be best for another.

The University of California Irvine (UCI) EyeMobile for Children is a community vision screening program for preschoolers modeled after the University of California San Diego EyeMobile for Children program. The purpose of the program is to screen children 3 to 5 years of age attending preschools within Orange County for refractive errors and amblyopia risk factors, and then provide those who fail the screening with a comprehensive eye examination, glasses prescription, glasses, and referral for further follow-up if needed. All services are provided free of charge. In this report, we introduce the UCI EyeMobile for Children and evaluate the challenges and results of a community vision screening program using data from the 2019–2020 school year.

Materials and Methods

The UCI Institutional Review Board Committee waived the need for IRB approval on the determination that study activities did not constitute human subjects research (IRB#1152). The study was conducted in compliance with the United States Health Insurance Portability and Accountability Act (HIPAA) and adhered to the tenets of the Declaration of Helsinki. During the 2019–2020 school year, children aged 30 to 72 months from 37 Orange County preschools underwent vision screening at their schools. Students who were absent from the school on the dates screening took place, had not provided signed consent forms, or were already under the care of an eye care professional were excluded from screening.

Screening was performed by trained employees using the PlusoptiX S12C mobile photoscreener (PlusoptiX GmbH, Nuremberg, Germany). The PlusoptiX includes five receiver operating characteristic (ROC) modes for referral criteria with varying specificity and sensitivity levels determined by the manufacturer. Referral criteria for our program were based on ROC 3, corresponding to 85% sensitivity and 90% specificity per the manufacturer. Using ROC 3, children were referred if the device detected any of the following: hyperopia $\geq +3.50$D, myopia ≥ -3.00D, astigmatism ≥ 1.50D, anisometropia ≥ 1.00D. Parents of children who failed the vision screening were provided with an informed consent form for a free comprehensive eye examination. All children with signed consent forms were scheduled for an eye examination on the UCI EyeMobile.

Examinations were performed by two pediatric optometrists. All children who received an eye examination also underwent autorefraction with the Retinomax K+3 Autorefractor (Righton, Tokyo, Japan) before and after cycloplegia. Comprehensive examination included visual acuity using the HOTV vision chart, pupillary examination, Titmus stereoacuity test, ocular motility, cover test with fixation at distance (20 feet) and near (40 cm), fixation preference test, cycloplegic refraction, anterior segment examination using the slitlamp, and fundus examination using the binocular indirect ophthalmoscope. Children received cycloplegia at the discretion of the examining optometrist.

A retrospective review of de-identified records of children who were examined during the 2019–2020 school year was performed. Hyperopia and myopia were calculated as spherical equivalent (SE). SE was calculated as the sum of the spherical plus half the cylindrical error. Amblyopia was defined as unilateral if there was a $\geq$ 2-line difference in the best corrected visual acuity (BCVA) between the eyes with the presence of an ARF, and bilateral if the BCVA in each eye was < 20/50 for children < 4 years old, < 20/40 for children 4 to 5 years old, and < 20/30 for children older than 5 years with the presence of an amblyopia risk factor (ARF). Presence of ARFs was determined using 2021 American Association of Pediatric Ophthalmology and Strabismus (AAPOS) age-based referral criteria guidelines for instrument-based screening.[10] Referral criteria for all children include anisometropia >1.25 D and hyperopia >4.0 D; for children aged 31–48 months, astigmatism >3.0 D and myopia <-3.0 D were used as thresholds; for children >49 months of age, astigmatism >1.75 D and myopia <-2 D were used instead. Criteria were applied to cycloplegic retinoscopy data when available.

Results

A total of 5226 children were screened during the 2019–2020 school year. 10.4% (546/5226) children failed the photoscreening and were referred for further evaluation. 64.1% (350/546) of referred children arrived for their appointment with parental consent and were examined by an optometrist. The remaining 196 children did not receive examinations due to parental decline or no-show. The mean age of examined children was 4.45 years. A total of 246 children (70.3% of examined children) were prescribed glasses for the first time and received a free pair of spectacles. 68.6% (240/350) of children were dilated at the discretion of the optometrist and underwent cycloplegic examinations. Right eye refractive error results for children given a full cycloplegic

examination are presented in Table 1. Hyperopia (SE ≥ 0.50 D) was found in 43% of children who received the gold-standard examination, 30% had myopia (SE ≤ −0.50 D), and 27% had emmetropia (SE between −0.50 D and +0.50 D). Astigmatism (cylinder ≥ 0.5D) was seen in 100% of children with myopia, and 81% of myopic children had astigmatism ≥ 1.5 D. Astigmatism was observed in 77% of hyperopic children and 75% of anisometropic children. Overall, there were 28 children with amblyopia, 22 unilateral and 6 bilateral, corresponding to 8% of the examined population. Of the amblyopic children, 43% were hyperopic and 36% were myopic. Astigmatism ≥ 1.5D was found in 64% of amblyopic children. Refractive error data for children with unilateral amblyopia is presented in Table 2.

Of the children who underwent cycloplegia, 169 (70.4%) were found to have at least 1 amblyopia risk factor (ARF). Astigmatism was the most common risk factor detected, representing 66% of all refractive ARFs, followed by hyperopia (20%), anisometropia (9%), and myopia (5%). One child was found to have an intermittent exotropia of 10 prism diopters, and media opacity was not seen in any examined children. Among children who did not undergo cycloplegia, 51 were found to have at least one ARF using dry retinoscopy data, corresponding to a positive predictive value of 46.4% for the device screening for ARFs in the undilated group. 85% (186/220) of children with at least 1 ARF were prescribed glasses while 46% (60/130) of children without ARFs received glasses. Refractive error results from children without ARFs who were also prescribed glasses are presented in Table 3.

The average age of children who received cycloplegic examinations was 52.4 [95% CI: 51.5–53.3] months while the average age of children who were not dilated was 55.6 [95% CI: 54.5–56.5] months. There was no statistically significant difference in detecting ARFs between the two optometrists. Optometrist 1 prescribed glasses to 67.3% of children (142/211), while optometrist 2 prescribed glasses to 74.8% of children (104/139). The difference in prescribing pattern was not statistically significant (p = 0.0528). The positive predictive value of the PlusoptiX photoscreener using ROC 3 referral criteria in detecting ARFs in patients who received cycloplegic examinations was 70.4%. The positive predictive value of the device screening for need for glasses was 70.3%.

Table 1 Refractive Error in the Right Eyes of Examined Children (N, %)

	Age			
	3 Years (N = 54)	4 Years (N = 150)	5 Years (N = 36)	Total (N = 240)
Hyperopia (SE ≥ +0.50)	30 (56%)	59 (39%)	13 (36%)	102 (43%)
Emmetropia (−0.5 < SE < +0.5)	15 (28%)	39 (26%)	11 (31%)	65 (27%)
Myopia (SE ≤ −0.50)	9 (17%)	52 (35%)	12 (33%)	73 (30%)
Astigmatism				
0.5–1.25	18 (33%)	37 (25%)	7 (19%)	62 (26%)
1.5–3.75	26 (48%)	74 (49%)	19 (53%)	119 (50%)
≥ 4	2 (4%)	10 (7%)	2 (6%)	14 (6%)

Abbreviation: SE, spherical equivalent.

Table 2 Refractive Error in Children with Unilateral Amblyopia (N, %) Categorized by the Better-Seeing Eye and the Amblyopic Eye

Refractive Error	Better Eye (N=22)	Amblyopic Eye (N = 22)
Hyperopia (SE ≥ +0.50)	9 (41%)	7 (32%)
Myopia (SE ≤ −0.50)	3 (14%)	5 (23%)
Astigmatism		
0.5–1.25	6 (27%)	6 (27%)
1.5–3.75	8 (36%)	11 (50%)
≥ 4	1 (5%)	1 (5%)

Abbreviation: SE, spherical equivalent.

Table 3 Refractive Error Results of Children Without Amblyopia Risk Factors Who Received Glasses (N,%)

Refractive Error	Worse Eye (N=60)
Hyperopia (SE ≥ +0.50)	25 (42%)
Myopia (SE ≤ −0.50)	12 (20%)
Astigmatism	
0.5–1.00	17 (28%)
1.25–1.5	27 (45%)
≥ 1.75	0 (0%)

Abbreviation: SE, spherical equivalent.

Discussion

Vision screening programs for young children provide an incredibly important service as they facilitate the early detection and treatment of amblyopia, which can lead to better treatment outcomes and even prevent blindness.[11–13] In addition, screening programs can detect uncorrected refractive error in children, which can have a devastating impact on childhood development. Studies have shown that children with visual impairment caused by refractive error can be misdiagnosed with learning disabilities or autism.[14–16] Pediatric vision screening programs run by the University of California Los Angeles (UCLA) and the University of California San Diego (UCSD) have had positive results in addressing uncorrected refractive error and amblyopia in Los Angeles County and San Diego County, respectively.[17,18] This report is the first introduction of the UCI EyeMobile for Children program and describes the results and challenges faced during one year of implementation.

Our program screened 5226 preschool children with the PlusoptiX S12C photoscreener using ROC 3 referral criteria during the 2019–2020 school year, examined 350 children who failed the screening, and prescribed free glasses to 70.3% of examined children. The prevalence of amblyopia and amblyopia risk factors in our examined population was 8% and 63%, respectively. Astigmatism was the most common refractive risk factor in our examined population, a finding shared with the UCLA screening program during their first year of implementation.[19] Our calculated positive predictive value (PPV) for the PlusoptiX in screening for ARFs was 70.4%, which is lower than some reported values; however, a wide range of PPVs have been described in the literature, from 19%[20] to 100%.[21] A 2019 meta-analysis evaluating the accuracy of Spot and PlusoptiX photoscreeners from 21 published studies determined the PPV of the PlusoptiX to be 65.3% in children younger than 7 years old.[22] One study reported a PPV of 76% for the PlusoptiX screening for ARFs, although this was studied in children aged 8.6–15.6 years, significantly older than the population served by our program.[23] Recent studies evaluating use of the PlusoptiX in vision screening programs for young children similar to ours have reported PPVs of 69%,[24] 43%,[18] 42%,[25] and 53%[26] for the detection of ARFs.

Several studies have reported the potential of the PlusoptiX to over refer, due to its lower specificity compared to other photoscreening devices.[20,27–29] However, we are willing to accept a lower specificity and PPV in our vision screening program to better address the specific needs of our community. Our community is both ethnically and economically diverse, and many children are either uninsured, underinsured, or living in poverty. Our program may be a child's only opportunity to interact with a healthcare system, thus we are willing to accept lower PPV and specificity at the cost of over referral. Though our screening device may have room for improvement based on our data, our calculated PPV still falls within the range of previously reported values for the PlusoptiX. As the estimated prevalence of ARFs is much higher than the prevalence of amblyopia (15–20% vs 2–4%), a majority of children with ARFs do not develop amblyopia.[1,30,31] Thus, programs that screen for ARFs to detect decreased vision and amblyopia must carefully determine referral criteria in order to minimize the number of over referrals. We will consider modifying the device referral criteria for our program as other studies have demonstrated this may lead to increased specificity and PPV.[29] Overall, we determine the PlusoptiX S12C to be an adequate vision screening device for our program.

There are several limitations to this evaluation. A major limitation is due to the retrospective nature of the study. As we were unable to provide comprehensive eye examinations for all screened children, some children with refractive error, amblyopia, or ARFs may have passed vision screening. These "false negatives" were not included in our analysis and therefore we were unable to calculate sensitivity, specificity, or negative predictive value for the device, rendering our

evaluation of device effectiveness incomplete and limiting the generalizability of our results. For a more comprehensive evaluation of photoscreener effectiveness in our population, an additional study in which all screened children receive examinations is warranted. Another limitation was that not all referred children underwent a comprehensive examination with cycloplegic retinoscopy. Using dry retinoscopy data from children who were not dilated, we calculated a much lower device PPV of 46.4%; however, we expect this to underestimate the true PPV of the photoscreener as AAPOS ARF criteria for refractive error should be confirmed with cycloplegic examination.

While vision screening programs like the UCI EyeMobile for Children provide a vital service for ensuring quality childhood vision care, their operation can be complex and challenging. One challenge our program experienced during the 2019–2020 school year was the inability to provide comprehensive cycloplegic examinations to all referred children. 31.4% of referred children did not undergo cycloplegia, substantially higher than the 12% reported by the UCLA program during the 2012–2013 school year.[19] One possible explanation for this discrepancy is that a portion of our examinations were conducted during the COVID-19 pandemic, and in an effort to reduce visit times for parents and children, dilated examinations were avoided if possible. Our data showed that older patients were less frequently dilated than younger patients, possibly because they were more cooperative with distance fixation during the exam. Nevertheless, there is potential for refractive error or retinal pathology to go undiagnosed in referred children and our program is working to increase cycloplegic examination rates.

Another issue that our program hopes to address is the examination rate for children who fail screening. 36.9% of referred children failed to arrive or did not obtain parental consent for their examination, which is comparable to the 35% no-show rate reported by the UCLA program.[19] The 196 children who were referred but not examined corresponds to 3.7% of the total population screened by our program, thus the prevalence of refractive error and ARFs in our population may be higher than reported here. Studies have identified several barriers to childhood vision care, including lack of community awareness of the importance of vision care, limited availability of convenient eye appointments, and high economic costs of corrective lenses.[32–34] The UCI EyeMobile for Children overcomes financial barriers faced by parents/guardians by providing eye examinations, glasses, and referrals completely free of charge. Our program seeks to alleviate parental burden and address the inconvenience of appointments by visiting children while they are in school and examining them aboard our mobile clinic. Lack of parental awareness and understanding of the importance of vision care is an additional barrier which may be contributing to our suboptimal examination rate. We hope to remedy this issue by incorporating more community education and outreach efforts into our program.

Conclusion

The importance of childhood vision care cannot be overstated, and vision screening programs like the UCI EyeMobile for Children are essential for identifying and treating visual disorders such as amblyopia and refractive error in at-risk children. Using the PlusoptiX S12C photoscreener with ROC 3 referral criteria, our program identified a significant proportion of Orange County preschool children with refractive errors and amblyopia who were living with unmet needs for refractive correction. While the PlusoptiX adequately meets the vision screening needs of our program, modification of device referral criteria may improve its effectiveness. More research is needed to better understand barriers to pediatric vision care and to guide the development of programs which overcome these barriers and address the specific needs of our community.

Abbreviations

ARF, amblyopia risk factor; UCI, University of California Irvine.

Acknowledgments

The authors wish to thank Iliana Molina and Jennifer Espinoza for their dedication to the UCI EyeMobile for Children program and for their assistance in data processing. The authors also wish to thank Angele Nalbandian for her assistance with manuscript editing and preparation.

The abstract of this paper was presented at the 2022 Association for Research in Vision and Ophthalmology Annual Meeting as a poster presentation with interim findings. The poster's abstract was published in the "2022 Abstract Issue" of *Investigative Ophthalmology & Visual Science*: https://iovs.arvojournals.org/article.aspx?articleid=2779774.

Disclosure

The authors report no conflicts of interest in this work.

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