Clinical Ophthalmology

Dovepress

open access to scientific and medical research

Open Access Full Text Article

ORIGINAL RESEARCH

UCI EyeMobile Exam Findings from School Children Following on-Site Screening

John D Hong[1], Elliot H Choi[1], Susie Suh[1], Joseph H Bui[1], Annabelle M Storch[1], Kimberly R Walker[1], Kourosh Shahraki[1], Carolina Yanez[1], Diana Torres[1], Jennifer Espinoza[1], Iliana Molina[2,*], Donny W Suh[1,*]

[1]Gavin Herbert Eye Institute, Department of Ophthalmology, University of California, Irvine, CA, USA; [2]Shiley Eye Institute, Department of Ophthalmology, University of California, San Diego, CA, USA

*These authors contributed equally to this work

Correspondence: Donny W Suh, Gavin Herbert Eye Institute, Department of Ophthalmology, University of California, Irvine, 850 Health Sciences Road, Irvine, CA, 92697, USA, Tel +1 949 824-4122, Email donnys@hs.uci.edu; Iliana Molina, Shiley Eye Institute, Department of Ophthalmology, University of California, San Diego, 9415 Campus Point Dr, San Diego, CA, 92037, USA, Tel +1 858 822-2585, Email imolina@health.ucsd.edu

Purpose: Uncorrected refractive errors (REs) and amblyopia can lead to visual impairment with deleterious effects on quality of life and academic performance. Early detection and treatment by community vision care programs, such as the UCI EyeMobile for Children, can aid in addressing preventable vision loss.

Methods: A total of 5074 children between the ages of 3 and 10 years were screened at 153 locations, including preschools, head start programs, and elementary schools within Orange County (OC), California (CA). Subsequently, 1024 children presented for comprehensive eye examinations. A retrospective analysis of all examined children was conducted, determining the frequency and severity of REs and amblyopia and the spectacle prescription rate by age. Propensity score matching analysis evaluated the effect of median household income on RE and amblyopia frequency.

Results: Among those who failed initial screening and were subsequently examined, significant rates of REs and amblyopia were detected: myopia (24.4%), hyperopia (35.4%), astigmatism (71.8%), anisometropia (8.9%), amblyopia (7.0%), and amblyopia risk (14.4%). A majority (65.0%) of those examined received prescription spectacles from UCI EyeMobile, with around a third requiring a new or updated prescription. The frequency of REs and amblyopia and the spectacle prescription rate were uniform across OC congressional districts. Myopia and amblyopia risk was positively and negatively associated with household income, respectively.

Conclusion: The UCI EyeMobile for Children serves as a vital vision care program, providing free vision screening, comprehensive eye examinations, and spectacles. A significant number of children required examination, and a high frequency of REs and amblyopia were detected in examined children, with subsequent provision of prescription spectacles to most children.

Keywords: pediatrics, refractive error, amblyopia, spectacles, mobile clinic, screening

Introduction

Visual impairment in children due to uncorrected refractive errors (REs) is increasing globally.[1–4] REs often proceed uncorrected since they commonly go unnoticed in children. Uncorrected REs can contribute to poor academic performance and reduced quality of life.[5] REs can also contribute the risk of amblyopia, a well-known cause of preventable lifelong vision loss in children.[6] In the US, the rate of amblyopia is roughly 2% in children under 6 years old.[7,8] Early detection and treatment of REs and amblyopia lead to better visual outcomes and high quality of life using less costly interventions.[9]

The US Preventative Services Task Force recommends at least one vision screening for children between 3 and 5 years old.[10] However, due to socioeconomic disparities in pediatric vision care, many children are often undiagnosed and untreated for their ocular conditions, resulting in devastating and lifelong impaired vision.[11] The University of California Irvine (UCI) EyeMobile for Children provides free vision care services as a mobile clinic, conveniently relocating

Received: 27 January 2024
Accepted: 30 April 2024
Published: 6 June 2024

directly at schools and educational programs throughout Orange County (OC), California (CA). UCI EyeMobile administers free vision screening, comprehensive eye examinations, and prescription spectacles. In this study, we analyzed clinical eye examination data from the 2022–2023 school year, evaluating the frequency and severity of REs and amblyopia, as well as trends with community socioeconomic data.

Methods

Patients and Data Collection

The UCI Institutional Review Board (IRB) Committee provided an exemption from IRB approval as the study was not categorized as human subject research (IRB #1152). The study strictly adhered to Health Insurance Portability and Accountability Act guidelines and the World Medical Association Declaration of Helsinki. For the 2022–2023 academic school year, vision screenings for children between the ages of 3 and 10 were performed in 153 locations, consisting of preschools, head start programs, and elementary schools throughout OC. Notably, schools throughout OC were offered the services UCI EyeMobile vision screening program, and 153 requested for the EyeMobile service. Children absent during screening and/or without parental informed consent for examination were excluded from the study.

Screening

Emmetropia, hyperopia, and myopia was based on spherical equivalent (SE), calculated as sphere plus half cylinder. Retinoscopy data was used if available. Hyperopia was defined as SE ≥ +0.50 D, myopia as SE ≤ –0.50 D, and emmetropia as –0.50 D < SE < +0.50 D.[12,13] Astigmatism was defined as cylinder ≤ –0.50 D.[12,14] Anisometropia was determined to be an interocular difference in SE ≥ 1.00 D.[15]

Initial screening was performed by trained staff members using the Retinomax K-Plus 3 Autorefractor (Righton, Tokyo, Japan). Children were then referred for a free comprehensive eye examination in the UCI EyeMobile clinic upon meeting the referral criteria established by a prior Retinomax-based EyeMobile screening study.[12,16] The Retinomax exam referral criteria applied is as follows: sphere ≥ +1.75 diopters (D) or sphere ≤ –3.25 D, cylinder ≤ –1.50 D, or interocular difference with Δsphere ≥1.50 D or with Δcylinder ≥1.00 D.[12,16,17] Eye examinations were performed upon receipt of parental informed consent. Children who passed the autorefractor vision screening but required new spectacles with their current prescription were fitted for new frames.

Comprehensive Eye Examination

Children received a comprehensive eye examination from one of three pediatric optometrists at the UCI EyeMobile clinic. Uncorrected and best corrected visual acuity (UCVA and BCVA) testing were done using different visual acuity (VA) charts depending on child age, cooperation, or intellectual capability: the Lea symbol chart, HOTV matching chart, or Snellen chart. VA was calculated as the logarithm of the minimum angle of resolution (logMAR), or negative log of the VA score.

Next, refraction testing was done using the Retinomax autorefractor, phoropter, and retinoscopy with and without cycloplegia, administered at the discretion of the examining optometrist. All children had received a non-cycloplegic refraction measurement using the Retinomax autorefractor and retinoscopy. Cycloplegia was attained using a drop of phenylephrine (2.5%) and tropicamide (1%), followed by cycloplegic refraction assessment 30 minutes after induction of dilation.[18] The examination also included: pupillary reflex test, ocular motility exam, Titmus stereoacuity test, color vision test using the Good-Lite ColorCheck Complete Vision Screener, and cover test with distance (20 feet) and near (40 cm) fixation. The anterior segment and fundus examinations were performed by slit lamp and binocular indirect ophthalmoscopy, respectively. Strabismus, upon detection, was evaluated by prism and alternate cover test. An updated spectacle prescription and a new pair of spectacles were provided if BCVA was 20/40 or worse.

Diagnosis of amblyopia or detection of amblyogenic risk factors (ARFs) was done by the optometrist at the time of examination under cycloplegic assessment. Unilateral amblyopia was defined as an interocular difference in BCVA of ≥2 lines on LEA, HOTV, or Snellen VA chart, or failure to initiate or maintain fixation with one eye, with at least one amblyogenic risk factor (ARF).[19] Bilateral amblyopia was determined if both eyes have a BCVA logMAR >0.40 for children under 4 years old, a BCVA logMAR >0.30 for children between 4 and 5 years old, and a BCVA logMAR ≥0.2 for children over 5 years old, with presence of at least one ARF in each eye.[12,19] The detection of ARFs using the Retinomax autorefractor was based on the 2021 American Association of Pediatric Ophthalmology and Strabismus age-based referral guidelines on instrument-based vision screening.[20] ARFs were defined by the following thresholds: myopia < –3.00 D or astigmatism < –3.00 D for 3–4 year-olds, myopia < –2.00 D or astigmatism ≤ –1.75 D for ≥4 year-olds, and across all ages, strabismus >8 prism diopters, anisometropia >1.25 D, or hyperopia > +4.00 D. Referral to Ophthalmology was recommended upon diagnosis of amblyopia.

Data Analysis

Following the 2022–2023 academic school year, a retrospective cross-sectional analysis of all examination records was conducted. The severity of RE, based on absolute SE for myopia or hyperopia and based on absolute cylinder for astigmatism, was categorized as follows: mild (0.50 to 1.75 D), moderate (2.00 to 3.75 D), moderately severe (4.00 to 5.75 D), severe (≥6.00 D).[12] Children were grouped by logMAR value from sharp to low VA: <0.2, 0.3 to 0.4, 0.5 to 0.6, and >0.7.[12] UCVA and BCVA were stratified by sharpness of vision and by age. The frequency of REs was stratified by severity and by age. The frequency of REs and its severity was also determined for children with either amblyopia or at risk of amblyopia. The distribution of children from sharp to low VA and mild to severe RE was fitted to an exponential curve to quantitatively determine the overall VA or RE severity in a group, whether a greater proportion had more severe condition (shallower curve with lower k) or milder condition (steeper curve with higher k).

Children were stratified by school zip code, then further grouped by congressional district based on their school zip code, using redistricting data from the California Senate Office of Demographics.[21] Using the US Census Bureau and Internal Revenue Service database, the median household income (MHI) by zip code was obtained.[22,23] MHI by zip code was divided by the overall MHI of OC to group children by their relative MHI above (>1) or below (<1) the county median. Associations of MHI with REs or amblyopia were evaluated by propensity score matching (PSM) analysis to adjust for heterogeneity in gender, age, and ethnicity between groups.

Results were reported as the mean with standard error. GraphPad Prism 10.0 was used for exponential or Gaussian distribution fit analysis. Statistical analyses were performed using several Python packages: pandas, numpy, scipy, and statistics. The MatchIt package in R was used for the PSM analysis.

Results

Demographics

Study population demographics can be found in Table 1. During the 2022–2023 school year, a total of 5074 students were screened by the UCI EyeMobile program. Subsequently, 28.1% (1425 students) failed the screening and were referred for a comprehensive eye examination. Of those screened, 4.5% (230 students) were fitted for new frames, and 0.2% (11 students) passed screening with previously provided EyeMobile spectacles. Unable to be screened by Retinomax autorefractor were 65 students due to underlying ocular conditions. These students were promptly recommended referral to ophthalmology by the supervising optometrist. A majority self-reported their ethnicity as Hispanic (55.8%) with the second and third largest groups self-reporting as Caucasian (17.9%) and Asian (16.4%), respectively. Nearly a third (34.4%) of students reported Spanish as their first and preferred language. Following screening, 1024 students presented to the EyeMobile clinic for eye examination. Subsequently, 158 students were fitted for new frames. A total of 553 students underwent complete cycloplegic refraction examination.

Visual Acuity

Uncorrected and corrected visual acuity (VA) measurements along with the rate of spectacle prescriptions were organized by age in Table 2. The majority (65.5%, 671/1024) of examined children were between 3 and 5 years old. Both distance and near UCVA showed an exponential distribution of VA severity, from more children with high VA (logMAR < 0.2) to fewer children with low VA (logMAR > 0.7). Upon correction, the distribution was nearly twice as steep with a greater proportion of children with higher VA (k = 1.08 and 1.90, before and after correction) as expected. The exponential

Table 1 Study Population Demographics

	Sample Size (%)
Mean Age ± SD	6.34 ± 2.84
Screened Total	5074
Pass	3343 (65.9)
Refer	1425 (28.1)
FFF	230 (4.5)
Unable	65 (1.3)
EM glasses	11 (0.2)
Ethnicity	
Caucasian	910 (17.9)
Hispanic	2831 (55.8)
Asian	834 (16.4)
African American	148 (2.9)
Middle Eastern	351 (6.9)
Preferred Language	
English	3328 (65.6)
Spanish	1746 (34.4)
Gender	
Male	2575 (50.7)
Female	2499 (49.3)

Notes: Retinomax-based referral criteria for subsequent examination was applied during screening.
Abbreviations: FFF, fitted for frames; EM, EyeMobile.

Table 2 Uncorrected and Corrected Visual Acuity of Each Eye by Age Group

Age (Total Subjects)	3 (n = 169)	4 (n = 398)	5 (n = 104)	6–10 (n = 353)	Total (n = 1024)
Mean Age ± SD (Median)	3.64 ± 0.25 (3)	4.52 ± 0.27 (4)	5.36 ± 0.29 (5)	8.47 ± 1.49 (8)	5.76 ± 2.15 (4)
Spectacles Rate	88/169 (52.0%)	242/398 (61.0%)	73/104 (70.0%)	266/353 (75.0%)	669/1024 (65.0%)
Uncorrected Distance Visual Acuity (logMAR) by Eye					
< 0.2 (20/30)	152/280 (54.3%)	382/678 (56.3%)	76/160 (47.5%)	268/427 (62.8%)	878/1545 (56.8%)
0.3 to 0.4 (20/40 to 20/50)	81/280 (28.9%)	171/678 (25.2%)	47/160 (29.4%)	66/427 (15.5%)	365/1545 (23.6%)
0.5 to 0.6 (20/63 to 20/80)	34/280 (12.1%)	77/678 (11.4%)	24/160 (15.0%)	37/427 (8.7%)	172/1545 (11.1%)
> 0.7 (20/100)	13/280 (4.6%)	48/678 (7.1%)	13/160 (8.1%)	56/427 (13.1%)	130/1545 (8.4%)
Uncorrected Near Visual Acuity (logMAR) by Eye					
< 0.2 (20/30)	144/266 (54.1%)	392/664 (59.0%)	78/164 (47.6%)	290/428 (67.8%)	904/1522 (59.4%)
0.3 to 0.4 (20/40 to 20/50)	68/266 (25.6%)	168/664 (25.3%)	54/164 (32.9%)	86/428 (20.1%)	376/1522 (24.7%)
0.5 to 0.6 (20/63 to 20/80)	24/266 (9.0%)	53/664 (8.0%)	18/164 (11.0%)	17/428 (4.0%)	112/1522 (7.4%)
> 0.7 (20/100)	30/266 (11.3%)	51/664 (7.7%)	14/164 (8.5%)	35/428 (8.2%)	130/1522 (8.5%)
Best Corrected Distance Visual Acuity with Spectacles (logMAR) by Eye					
< 0.2 (20/30)	64/91 (70.3%)	210/292 (71.9%)	83/96 (86.5%)	286/318 (89.9%)	643/797 (80.7%)
0.3 to 0.4 (20/40 to 20/50)	23/91 (25.3%)	54/292 (18.5%)	9/96 (9.4%)	27/318 (8.5%)	113/797 (14.2%)
0.5 to 0.6 (20/63 to 20/80)	2/91 (2.2%)	4/292 (1.4%)	3/96 (3.1%)	0/318 (0.0%)	9/797 (1.1%)
> 0.7 (20/100)	2/91 (2.2%)	24/292 (8.2%)	1/96 (1.0%)	5/318 (1.6%)	32/797 (4.0%)

Notes: Retinomax exam referral criteria during screening were applied and results are from children who subsequent underwent comprehensive examination.

distribution and changes in steepness after correction were similar across age groups. Notably, even with correction, about 14% of children with spectacles still had moderately poor VA (logMAR between 0.3 and 0.4) and around 5% had very poor VA (logMAR > 0.5), highlighting the need for routine examinations to update prescriptions. The majority

(65.0%, 669/1024) of examined children required spectacles as follows: 322 continued with their current EyeMobile prescription frames, 158 were fitted for new frames, 112 did not possess any frames and received new prescription spectacles, and 77 received updated prescription spectacles for logMAR ≥0.3.

Refraction

In Table 3, across all children with sphere and cylinder measurements for each eye, the ratio of emmetropia, myopia, and hyperopia was about 2:1:2, respectively. The rate of hyperopia decreased linearly with age (4.3% / age group), while myopia increased linearly (6.6% / age group). A large majority (71.8%) of all children had astigmatism. An exponential distribution of subjects was observed going from mild to severe myopia, hyperopia, or astigmatism (k = 1.52, 1.30, and 0.30, respectively). The distribution was significantly shallower for astigmatism, indicating a higher overall severity of astigmatism as compared to myopia or hyperopia. The high astigmatism rate (≥70%) and shallow exponential distribution of astigmatism severity was seen across age groups. Myopes and hyperopes had higher rates of astigmatism at around 90% and 80%, respectively.

Anisometropia appears to affect nearly a tenth of all children examined, with the rate increasing with age. The frequency of an interocular spherical difference ≥1.00 D was higher than an interocular cylindrical difference ≥1.00 D; however, mean oculus dexter and sinister (OD, OS) cylinder were both high at −1.44 ± 0.18 and −1.58 ± 0.17, respectively. Anisometropes had higher rates of myopia, hyperopia, and astigmatism than the total examined group. About half of anisometropes with myopia or hyperopia also had astigmatism (44.0% or 54.7%, respectively).

Table 3 Frequency and Severity of Refractive Errors by Age Group

Age (Total Eyes)	3 (n = 294)	4 (n = 704)	5 (n = 174)	6–10 (n = 510)	Total (n = 1682)
Emmetropia	130 (44.2%)	288 (40.9%)	66 (37.9%)	192 (37.6%)	676 (40.2%)
Myopia (|SE|, D)	44 (15.0%)	142 (20.2%)	52 (29.9%)	172 (33.7%)	410 (24.4%)
0.50 to 1.75	40 (90.9%)	114 (80.3%)	46 (88.5%)	104 (60.5%)	304 (74.1%)
2.00 to 3.75	2 (4.5%)	20 (14.1%)	2 (3.8%)	48 (27.9%)	72 (17.6%)
4.00 to 5.75	2 (4.5%)	4 (2.8%)	4 (7.7%)	14 (8.1%)	24 (5.9%)
≥ 6.00	0 (0.0%)	4 (2.8%)	0 (0.0%)	6 (3.5%)	10 (2.4%)
with Astigmatism	43 (97.7%)	134 (94.4%)	45 (86.5%)	145 (84.3%)	367 (89.5%)
Hyperopia (|SE|, D)	120 (40.8%)	274 (38.9%)	56 (32.2%)	146 (28.6%)	596 (35.4%)
0.50 to 1.75	86 (71.7%)	204 (74.5%)	42 (75.0%)	104 (71.2%)	436 (73.2%)
2.00 to 3.75	32 (26.7%)	54 (19.7%)	6 (10.7%)	26 (17.8%)	118 (19.8%)
4.00 to 5.75	2 (1.7%)	16 (5.8%)	6 (10.7%)	10 (6.8%)	34 (5.7%)
≥ 6.00	0 (0.0%)	0 (0.0%)	2 (3.6%)	6 (4.1%)	8 (1.3%)
with Astigmatism	97 (80.8%)	215 (78.5%)	59 (105.4%)	115 (78.8%)	486 (81.5%)
Astigmatism (|Cyl|, D)	208 (70.7%)	502 (71.3%)	143 (82.2%)	354 (69.4%)	1207 (71.8%)
0.50 to 1.75	119 (57.2%)	276 (55.0%)	69 (48.3%)	216 (61.0%)	680 (56.3%)
2.00 to 3.75	76 (36.5%)	187 (37.3%)	65 (45.5%)	111 (31.4%)	439 (36.4%)
4.00 to 5.75	13 (6.2%)	36 (7.2%)	9 (6.3%)	24 (6.8%)	82 (6.8%)
≥ 6.00	0 (0.0%)	3 (0.6%)	0 (0.0%)	3 (0.8%)	6 (0.5%)
Anisometropia (|ΔSE| ≥ 1.0 D)	10/147 (6.8%)	29/352 (8.2%)	7/87 (8.0%)	29/255 (11.4%)	75/841 (8.9%)
Sph ≥ 1.0 D	9 (90.0%)	26 (89.7%)	4 (57.1%)	24 (82.8%)	63 (84.0%)
Cyl ≥ 1.0 D	5 (50.0%)	7 (24.1%)	4 (57.1%)	12 (41.4%)	28 (37.3%)
with Myopia	6 (60.0%)	14 (48.3%)	3 (42.9%)	15 (51.7%)	38 (50.7%)
with Hyperopia	6 (60.0%)	20 (69.0%)	5 (71.4%)	17 (58.6%)	48 (64.0%)
with Astigmatism	9 (90.0%)	23 (79.3%)	7 (100.0%)	24 (82.8%)	63 (84.0%)
with Myopia & Astigmatism	6 (60.0%)	12 (41.4%)	3 (42.9%)	12 (41.4%)	33 (44.0%)
with Hyperopia & Astigmatism	5 (50.0%)	16 (55.2%)	5 (71.4%)	15 (51.7%)	41 (54.7%)

Notes:Retinomax exam referral criteria during screening were applied and results are from children who subsequent underwent comprehensive examination.

Amblyopia

Of the 1024 children examined, nearly a fifth (21.7%) or 225 children were diagnosed with or at risk of amblyopia (Table 4). Amblyopia due to RE was diagnosed in 73 children (7.1%, 73/1024). Only 2 children were diagnosed with amblyopia due to strabismus. This could be due to strabismus being more apparent compared to other ocular conditions, leading to more prompt medical intervention prior to preventative screening or examination.

For the amblyopia group, including those diagnosed with or at risk of amblyopia, the rate of myopia (29.3%) was slightly higher than that of total examined children (24.4%). The distribution of myopia severity in the amblyopia group (k = 2.17), however, skewed slightly more toward mild condition than that of the total examined group (k = 1.52). Furthermore, the rate of hyperopia (50.7%) in the amblyopia group was higher than that of all children examined (35.4%). The distribution of hyperopia in the amblyopia group (k = 0.64) skewed more toward moderate-to-severe conditions in contrast to that of the total examined group (k = 1.30). The rate of astigmatism (94.0%) in the amblyopia group was significantly higher than that of all children examined (71.8%). Additionally, the distribution of disease

Table 4 Frequency and Severity of Refractive Errors in Amblyopia Population

	Sample Size (%)
Amblyopia Risk & Dx	N = 225 (21.7%)
Risk	149 (14.4%)
Refractive Error	73 (7.0%)
Strabismus	2 (0.0%)
Mean Age ± SD (Median)	5.39 ± 1.83 (4)
Myopia (|SE|, D)	132/450 (29.3%)
0.50 to 1.75	108 (81.8%)
2.00 to 3.75	16 (12.1%)
4.00 to 5.75	2 (1.5%)
≥ 6.00	6 (4.5%)
with Astigmatism	131 (99.2%)
Hyperopia (|SE|, D)	228/450 (50.7%)
0.50 to 1.75	132 (57.9%)
2.00 to 3.75	64 (28.1%)
4.00 to 5.75	24 (10.5%)
≥ 6.00	8 (3.5%)
with Astigmatism	225 (98.7%)
Astigmatism (|Cyl|, D)	423/450 (94.0%)
0.50 to 1.75	103 (24.3%)
2.00 to 3.75	246 (58.2%)
4.00 to 5.75	69 (16.3%)
≥ 6.00	5 (1.2%)
Anisometropia (|ΔSE| ≥ 1.0 D)	39/225 (17.3%)
Sph ≥ 1.0	36 (92.3%)
Cyl ≥ 1.0	14 (35.9%)
with Myopia	12 (30.8%)
with Hyperopia	30 (76.9%)
with Astigmatism	35 (89.7%)
with Myopia & Astigmatism	12 (30.8%)
with Hyperopia & Astigmatism	26 (66.7%)

Notes:Amblyopia diagnosis and risk of amblyopia was determined by an optometrist during comprehensive examination under cycloplegia. Examined subjects were those who failed the screening where the Retinomax exam referral criteria was applied. AAPOS guidelines for thresholds defining ARFs were applied in detecting ARFs using the Retinomax autorefractor under cycloplegia.

severity changed from the exponential distribution of the total examined group to a Gaussian distribution centered at moderate severity, reflecting a major shift away from mild condition and toward moderate and severe condition.

The rate of anisometropia nearly doubled in the amblyopia group as compared to the total examined group (17.3% vs 8.9%). The frequency of an interocular spherical difference ≥1.00 D was again higher than the interocular cylindrical difference ≥1.00 D; however, mean cylinder OD and OS were both high at −1.41 ± 0.21 and −2.04 ± 0.25, respectively. Anisometropes in the amblyopia group had lower rates of myopia as compared to all anisometropes (30.8% vs 50.7%) but higher rates of hyperopia (76.9% vs 64.0%). They also had significantly high rates of astigmatism comparable to that of all anisometropes (89.7% vs 84.0%). Anisometropes in the amblyopia group with astigmatism had lower rates of myopia as compared to all anisometropes (30.8% vs 44.0%) but higher rates of hyperopia (66.7% vs 54.7%).

Ocular Disorder Frequency by Congressional District

The rates of RE and amblyopia for each OC congressional district are shown in Table 5. The rates of myopia, hyperopia, astigmatism, anisometropia, amblyopia, and spectacle prescriptions showed high consistency between districts 40, 45, 46, and 47. These rates and distribution of condition severity were occasionally divergent in districts 38 and 49, likely due to

Table 5 Frequency and Severity of Refractive Errors and Amblyopia in Each Congressional District

Congressional District	38	40	45	46	47	49
Total Subjects	51	194	757	569	286	43
Mean Age ± SD (Median)	7.20 ± 2.20 (7)	4.88 ± 1.57 (4)	6.08 ± 2.22 (5)	5.80 ± 2.14 (4)	6.68 ± 2.37 (6)	4.25 ± 0.48 (4)
Spectacles Rate	40/51 (78.0%)	108/194 (56.0%)	512/757 (68.0%)	365/569 (64.0%)	203/286 (71.0%)	16/43 (37.0%)
Amblyopia Risk & Dx	9 (17.6%)	36 (18.6%)	162 (21.4%)	128 (22.5%)	73 (25.5%)	7 (16.3%)
Risk	5 (9.8%)	21 (10.8%)	108 (14.3%)	95 (16.7%)	43 (15%)	5 (11.6%)
Refractive Error	4 (7.8%)	14 (7.2%)	52 (6.9%)	33 (5.8%)	30 (10.5%)	2 (4.7%)
Strabismus	0 (0.0%)	0 (0.0%)	1 (0.1%)	1 (0.2%)	0 (0.0%)	0 (0.0%)
Total Eyes Measured	60	326	1208	970	448	76
Myopia (SE, D)	18 (30.0%)	70 (21.5%)	296 (24.5%)	220 (22.7%)	132 (29.5%)	14 (18.4%)
−1.75 to −0.50	14 (77.8%)	60 (85.7%)	218 (73.6%)	164 (74.5%)	104 (78.8%)	14 (100.0%)
−3.75 to −2.00	4 (22.2%)	8 (11.4%)	50 (16.9%)	36 (16.4%)	18 (13.6%)	0 (0.0%)
−5.75 to −4.00	0 (0.0%)	2 (2.9%)	22 (7.4%)	12 (5.5%)	6 (4.5%)	0 (0.0%)
≤ −6.00	0 (0.0%)	0 (0.0%)	6 (2.0%)	8 (3.6%)	4 (3.0%)	0 (0.0%)
with Astigmatism	14 (77.8%)	66 (94.3%)	258 (87.2%)	199 (90.5%)	119 (90.2%)	12 (85.7%)
Hyperopia (SE, D)	24 (40.0%)	104 (31.9%)	428 (35.4%)	356 (36.7%)	164 (36.6%)	30 (39.5%)
+0.50 to +1.75	16 (66.7%)	88 (84.6%)	292 (68.2%)	256 (71.9%)	122 (74.4%)	24 (80.0%)
+2.00 to +3.75	2 (8.3%)	12 (11.5%)	100 (23.4%)	78 (21.9%)	32 (19.5%)	4 (13.3%)
+4.00 to +5.75	6 (25.0%)	4 (3.8%)	28 (6.5%)	18 (5.1%)	8 (4.9%)	2 (6.7%)
≥ +6.00	0 (0.0%)	0 (0.0%)	8 (1.9%)	4 (1.1%)	2 (1.2%)	0 (0.0%)
with Astigmatism	19 (79.2%)	76 (73.1%)	369 (86.2%)	296 (83.1%)	126 (76.8%)	17 (56.7%)
Astigmatism (Cyl, D)	44 (73.3%)	216 (66.3%)	883 (73.1%)	708 (73.0%)	319 (71.2%)	42 (55.3%)
−1.75 to −0.50	20 (45.5%)	115 (53.2%)	515 (58.3%)	409 (57.8%)	166 (52.0%)	21 (50.0%)
−3.75 to −2.00	18 (40.9%)	83 (38.4%)	300 (34.0%)	236 (33.3%)	122 (38.2%)	18 (42.9%)
−5.75 to −4.00	6 (13.6%)	17 (7.9%)	65 (7.4%)	60 (8.5%)	29 (9.1%)	2 (4.8%)
≤ −6.00	0 (0.0%)	1 (0.5%)	3 (0.3%)	3 (0.4%)	2 (0.6%)	1 (2.4%)
Anisometropia	3/30 (10.0%)	15/163 (9.2%)	57/604 (9.4%)	40/485 (8.2%)	20/224 (8.9%)	4/38 (10.5%)
Sph ≥ 1.0	3 (100.0%)	11 (73.3%)	48 (84.2%)	33 (82.5%)	18 (90.0%)	4 (100.0%)
Cyl ≥ 1.0	0 (0.0%)	6 (40.0%)	21 (36.8%)	15 (37.5%)	7 (35.0%)	2 (50.0%)
with Myopia	2 (66.7%)	6 (40.0%)	30 (52.6%)	18 (45.0%)	11 (55.0%)	2 (50.0%)
with Hyperopia	1 (33.3%)	11 (73.3%)	35 (61.4%)	26 (65.0%)	13 (65.0%)	3 (75.0%)
with Astigmatism	0 (0.0%)	13 (86.7%)	48 (84.2%)	36 (90.0%)	16 (80.0%)	3 (75.0%)
with Myopia & Astigmatism	0 (0.0%)	6 (40.0%)	25 (43.9%)	17 (42.5%)	10 (50.0%)	2 (50.0%)
with Hyperopia & Astigmatism	0 (0.0%)	9 (60.0%)	31 (54.4%)	23 (57.5%)	10 (50.0%)	2 (50.0%)

Notes: Retinomax exam referral criteria during screening were applied and results are from children who subsequent underwent comprehensive examination. Amblyopia diagnosis and risk of amblyopia was determined by an optometrist during comprehensive examination with cycloplegic assessment. AAPOS guidelines for thresholds defining ARFs were applied in detecting ARFs using the Retinomax autorefractor under cycloplegia.

sampling error from smaller sample sizes (51 and 43, respectively, vs ≥200). Despite the potential sampling error, district 49 showed lower rates in 4 out of 5 ocular disorders compared to other districts.

Associations of Ocular Disorders and Socioeconomic Factors

PSM analysis showed a significantly higher amblyopia risk rate (Below: 38/195 vs Above: 16/195; p-value: 0.0021) in children from MHI below the median (Table 6). Conversely, myopia rate (Below: 29/195 vs Above: 47/195; p-value: 0.0298) was significantly higher in children from MHI above the median. No significant differences were found with hyperopia or astigmatism. Anisometropia, or amblyopia due to refraction or strabismus also had no significant difference.

Discussion

The UCI EyeMobile for Children serves as an important community vision care program, offering free vision screenings, eye exams, and prescription spectacles, directly at schools eliminate obstacles in accessibility and affordability. The program's efforts led to the identification of a considerable number of children with RE and amblyopia. The beneficial impact of the UCI EyeMobile program on addressing uncorrected RE and amblyopia in OC has also been observed in other EyeMobile programs in other counties.[16,18,24] All OC school districts are offered the UCI EyeMobile vision screening program, and 153 schools responded with request for our services. Most of these schools are in zip codes with an MHI below the average for OC (Figure 1), with 126 schools below and 27 above. Many of the 126 schools were clustered in zip codes with MHI 25–40% below the average. The demand for our services appears to be far greater by schools in relatively socioeconomically disadvantaged areas of OC. These results underscore the importance of our program, particularly for the underserved, likely through the removal of barriers of accessibility and affordability.

Early detection and treatment of REs and amblyopia helps prevent blindness and results in better vision outcomes.[25] The Investing in Vision study conducted by PricewaterhouseCoopers showed an estimated benefit of $4 for each $1 spent towards vision care.[26] Through our program, every child requiring spectacles was provided with new or updated prescription spectacles free-of-charge. The majority (65%) of children examined required spectacles, and a third (33.9%) required a new or updated prescription from the EyeMobile clinic.

Among examined children, the rates of myopia increased as hyperopia decreased with age; however, this increase in myopia was faster than the decrease in hyperopia. This observation could be due to a variety of factors, including decreased outdoor time and increased screen time during prior school years engaging in remote learning and lockdown procedures in response to COVID pandemic.[27,28] Further investigation comparing myopia rates observed through the UCI EyeMobile service before, during, and after school lockdown measures is ongoing. The rate of anisometropia also increased with age, which was observed in a prior study showing increasing anisometropia frequency with higher educational stage.[29]

The rates of myopia, hyperopia, and astigmatism (24.4%, 35.4%, and 71.8%, respectively) among examined children who failed initial vision screening were expectedly higher than national averages (4–9%, 13–21%, and 15–28%, respectively).[7] However, after accounting for all 5074 subjects screened in this study, these rates were estimated to be

Table 6 PSM Analysis of Association Between MHI and Refractive Errors or Amblyopia

Condition	Median Household Income (n = 195)		
	Above (n, %)	Below (n, %)	χ^2 value (p value)
Myopia	47 (24.1)	29 (14.9)	4.723 (0.0298)
Hyperopia	64 (32.8)	78 (40.0)	1.872 (0.1713)
Astigmatism	118 (60.5)	126 (64.6)	0.536 (0.4639)
Anisometropia	15 (7.7)	13 (6.7)	0.0385 (0.8445)
Amblyopia Risk	16 (8.2)	38 (19.5)	9.479 (0.0021)
Amblyopia Refractive Error	10 (5.1)	9 (4.6)	0 (1)
Amblyopia Strabismus	0 (0.0)	1 (0.5)	0 (1)

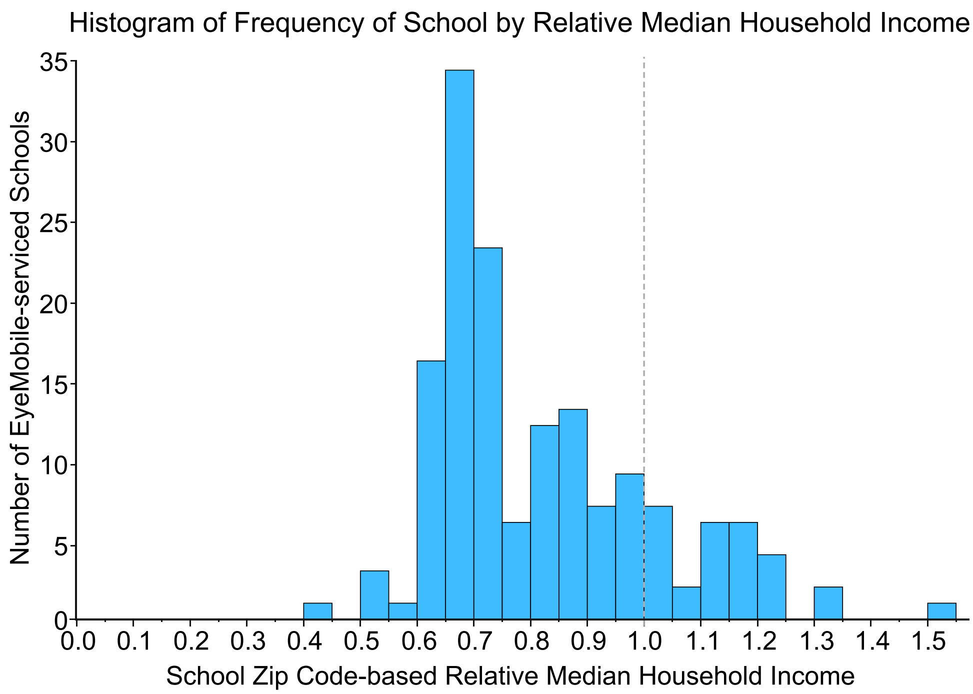

Figure 1 Histogram of frequency of EyeMobile-serviced schools by relative MHI. A total of 126 schools were in zip codes below the average MHI for OC, while 27 were above. The distribution of schools concentrates at a relative MHI of around 0.6–0.75.

6.8%, 10.0%, and 20.2%, respectively, which then do align more closely with national averages. The rate of amblyopia diagnosis (7.3%) and amblyopia risk (14.6%) after accounting for all subjects became 2.0% and 4.1%, respectively, with the diagnostic rate aligning more closely to the national average (2.0%) and that found in other studies.[7,30–32] The combined rate of amblyopia diagnosis and risk being 6.1% highlights the importance of early detection. Given these estimated rates upon considering all subjects are similar to national averages, the significant number of children requiring new or updated prescription spectacles suggest the potential positive impact of mobile community vision care programs for children across the US.

Among those with amblyopia, the rate and severity of hyperopia was much greater than that of the total examined group. The higher hyperopia rate could be thought to be associated with amblyopia group having a larger proportion of children from younger age groups; however, the average age of the amblyopia group (5.39 ± 1.83) was not significantly different from the total group (5.82 ± 2.15). Notably, nearly all children (94%) in the amblyopia group had astigmatism; furthermore, their astigmatism tended to be significantly more severe than that of the total examined group. The link between higher rates and severity of hyperopia and astigmatism could be associated with genetic or developmental dispositions in early life that increase the likelihood of amblyopia. This association, however, requires further investigation.[33]

Across congressional districts, the frequency of REs appeared largely uniform across districts with notable exceptions of districts 38 and 49, likely due to sampling error. The uniformity indicates the need for EyeMobile services across all OC districts. Since children do not often receive regular eye exams even with health insurance, the uniformity is unsurprising. PSM analysis revealed associations of MHI to frequency of REs and amblyopia. Higher income was significantly associated with myopia, aligning with the better-established association of higher education with myopia, while lower income was significantly associated with amblyopia risk.[36]

Notably, our study modeled and expanded upon the analyses performed in the UCI EyeMobile study for the 2019–2020 school year. The earlier study details vision screening performed using the Plusoptix, which had a significantly lower exam referral rate of 10.4% (546/5226), while ours using the Retinomax had a rate of 28.0% (1425/5074).[17] The following is a comparison of refractive errors found during examination by the previous study and ours: emmetropia (27.1% vs 40.2%), hyperopia (42.5% vs 35.4%), myopia (30.4% vs 24.4%), and astigmatism (81.3% vs 71.8%). Our study found higher emmetropia and lower rates of refractive errors, likely due to the higher sensitivity of the Retinomax, with a tendency to over-refer for exams as shown by a recent comparative study of both devices.[37] However, in the same study as well as another study comparing the two devices, the Plusoptix consistently had significantly more children who were "unable" to be screened by the device, whereas the Retinomax had few to none.[24,37] The switch from the Plusoptix to the Retinomax for the UCI EyeMobile program had primarily to do with fewer "unables", ease-of-use and -training, and overall faster screening times. However, these advantages came at the cost of potential over-referral, but several studies have shown that repeated measurements increase the specificity of a Retinomax-screen and helps minimize over-referral.[38,39] In a future study, our program will explore the optimal measurement repetitions and stricter referral criteria thresholds to increase specificity while maintaining acceptable sensitivity.

There were several limitations to our study. Since our EyeMobile program is limited in resources, not every screened child received a comprehensive eye examination, and not every examined child underwent cycloplegic refraction. Another limitation is the drop-off from eye exam referrals (1425) to examined children (1024). Notably, the rate of no-show (28.1%) was improved from the initial study (36.9%) analyzing the 2019–2020 school year.[17] The remarkably low number of strabismic amblyopic subjects might be influenced by initial screening based principally on refraction, using the Retinomax device; therefore to better screen for strabismus, a recently developed and studied device, the Blinq vision scan with capabilities to detect even micro-strabismus, could be incorporated into our screening protocol.[40] Staff will also be trained and equipped to evaluate and screen for strabismus. Furthermore, the incongruity in sample sizes across districts was due to the ease of coordinating vision screening with schools in OC districts having an already well-established relationship with the UCI EyeMobile program. In future studies, the program will extend to more schools in OC districts with low sampling to improve the strength of our comparative analysis between districts, which might reveal distinct differences and needs. In our PSM analysis, the income of the family of the child could not be gathered as part of the scope of the vision care program; therefore, in future studies, metrics of socioeconomic factors related to vision care will be collected in formats, such as parent surveys assessing their experience with child vision care accessibility and affordability.

Conclusions

The UCI EyeMobile for Children provides a free and accessible vision care service for children, identifying and treating RE and amblyopia in children from participating schools throughout OC. The EyeMobile program screened over 5000 children and examined over 1000 children, finding high rates of REs and amblyopia, subsequently providing most examined children free spectacles. The higher frequency and severity of hyperopia and astigmatism unrelated to age seen in amblyopic children should be further explored. The positive and negative associations of household income with myopia and amblyopic risk, respectively, will be analyzed in future studies using socioeconomic data intrinsic to the household of each examined child. With greater adoption of EyeMobile services by more schools across OC, its impact will extend to more children and enrich future EyeMobile studies on pediatric ocular disorder rates observed through our mobile free eye clinic services and socioeconomic trends with these rates.

Abbreviations

UCI, University of California Irvine; OC, Orange County; CA, California; IRB, Institutional Review Board; RE, refractive error; OD, oculus dexter; OS, oculus sinister; VA, visual acuity; BCVA, best corrected visual acuity; UCVA, uncorrected visual acuity; logMAR, Logarithm of the Minimum Angle of Resolution; SE, spherical equivalent; D, diopters; MHI, median household income; PSM, propensity score matching.

Funding

This research was supported in part by National Institutes of Health Training Grants 1F30EY033659-01 and T32-GM08620 to J.D.H. The authors acknowledge support from the Gavin Herbert Eye Institute at the University of California, Irvine from an unrestricted grant from Research to Prevent Blindness.

Disclosure

The authors have no conflicts of interest to report for this article.

References

1. Foster PJ, Jiang Y. Epidemiology of myopia. *Eye (Lond)*. 2014;28(2):202–208. doi:10.1038/eye.2013.280
2. Ma Y, Qu X, Zhu X, et al. Age-specific prevalence of visual impairment and refractive error in children aged 3-10 years in shanghai, China. *Invest Ophthalmol Vis Sci*. 2016;57(14):6188–6196. doi:10.1167/iovs.16-20243
3. Varma R, Tarczy-Hornoch K, Jiang X. Visual impairment in preschool children in the United States: demographic and geographic variations from 2015 to 2060. *JAMA Ophthalmol*. 2017;135(6):610–616. doi:10.1001/jamaophthalmol.2017.1021
4. Suh DW, Shahraki K. Vision screening claims for young children in the United States. *Pediatrics*. 2023;152(3). doi:10.1542/peds.2023-062804
5. Pirindhavellie GP, Yong AC, Mashige KP, Naidoo KS, Chan VF. The impact of spectacle correction on the well-being of children with vision impairment due to uncorrected refractive error: a systematic review. *BMC Public Health*. 2023;23(1):1575. doi:10.1186/s12889-023-16484-z
6. Sen S, Singh P, Saxena R. Management of amblyopia in pediatric patients: current insights. *Eye (Lond)*. 2022;36(1):44–56. doi:10.1038/s41433-021-01669-w
7. Ruderman M. Children's vision and eye health: a snapshot of current national issues. 1st Ed. (Chicago, IL: National Center for Children's Vision and Eye Health at Prevent Blindness). 2016.
8. Holmes JM, Clarke MP. Amblyopia. *Lancet*. 2006;367(9519):1343–1351. doi:10.1016/S0140-6736(06)68581-4
9. Silverstein E, Donahue SP. Preschool vision screening: where we have been and where we are going. *Am J Ophthalmol*. 2018;194:xviii–xxiii. doi:10.1016/j.ajo.2018.07.022
10. Uspst F, Grossman DC, Curry SJ, et al. Vision screening in children aged 6 months to 5 years: US preventive services task force recommendation statement. *JAMA*. 2017;318(9):836–844. doi:10.1001/jama.2017.11260
11. Antonio-Aguirre B, Ambrosino CM, Dai X, Collins ME. Addressing health disparities in pediatric eye care for school-age children: A call to action. *Transl Vis Sci Technol*. 2023;12(11):17. doi:10.1167/tvst.12.11.17
12. Hendler K, Mehravaran S, Lu X, Brown SI, Mondino BJ, Coleman AL. Refractive errors and amblyopia in the UCLA preschool vision program; first year results. *Am J Ophthalmol*. 2016;172:80–86. doi:10.1016/j.ajo.2016.09.010
13. Flitcroft DI, He M, Jonas JB, et al. IMI - defining and classifying myopia: a proposed set of standards for clinical and epidemiologic studies. *Invest Ophthalmol Vis Sci*. 2019;60(3):M20. doi:10.1167/iovs.18-25957
14. Villegas EA, Alcon E, Artal P. Minimum amount of astigmatism that should be corrected. *J Cataract Refract Surg*. 2014;40(1):13–19. doi:10.1016/j.jcrs.2013.09.010
15. Deng L, Gwiazda JE. Anisometropia in children from infancy to 15 years. *Invest Ophthalmol Vis Sci*. 2012;53(7):3782–3787. doi:10.1167/iovs.11-8727
16. Margines JB, Huang C, Young A, et al. Refractive errors and amblyopia among children screened by the UCLA preschool vision program in los angeles county. *Am J Ophthalmol*. 2020;210:78–85. doi:10.1016/j.ajo.2019.10.013
17. Hunter SC, He J, Han M, Suh DW. The UCI eyemobile preschool vision screening program: refractive error and amblyopia results from the 2019-2020 school year. *Clin Ophthalmol*. 2022;16:4249–4255. doi:10.2147/OPTH.S382899
18. Rohn MCH, O'Sullivan F, Brown SI, Hernandez E, Borooah S, Molina I. Pediatric eye care treatment rates and community compliance to a spectacle provision program in an underserved school district in san diego, CA. *Clin Ophthalmol*. 2023;17:1729–1737. doi:10.2147/OPTH.S409075
19. Wallace DK, Repka MX, Lee KA, et al. Amblyopia preferred practice pattern(R). *Ophthalmology*. 2018;125(1):1.
20. Arnold RW, Donahue SP, Silbert DI, et al. AAPOS uniform guidelines for instrument-based pediatric vision screen validation 2021. *J AAPOS*. 2022;26(1):1 e1–1 e6. doi:10.1016/j.jaapos.2021.09.009
21. Zip Code Directory. California senate office of demographics. Available from; https://sdmg.senate.ca.gov/zipcodedirectory. Accessed May 29, 2024.
22. Internal Revenue Service. IRS SOI tax stats - individual income tax statistics - ZIP code data. internal revenue service IRS. Available from; https://www.irs.gov/statistics/soi-tax-stats-individual-income-tax-statistics-zip-code-data-soi. Accessed May 29, 2024.
23. Orange County.*California*. US Census Bureau; 2023. https://www.census.gov/quickfacts/fact/table/orangecountycalifornia/PST045222.
24. Kinori M, Molina I, Hernandez EO, et al. The plusoptix photoscreener and the retinomax autorefractor as community-based screening devices for preschool children. *Curr Eye Res*. 2018;43(5):654–658. doi:10.1080/02713683.2018.1437453
25. Kirk VG, Clausen MM, Armitage MD, Arnold RW. Preverbal photoscreening for amblyogenic factors and outcomes in amblyopia treatment: early objective screening and visual acuities. *Arch Ophthalmol*. 2008;126(4):489–492. doi:10.1001/archopht.126.4.489
26. PricewaterhouseCoopers. Investing in vision – comparing the costs and benefits of eliminating avoidable blindness and visual impairment. 2013;1:1.
27. Li M, Xu L, Tan CS, et al. Systematic review and meta-analysis on the impact of COVID-19 pandemic-related lifestyle on myopia. *Asia Pac J Ophthalmol (Phila)*. 2022;11(5):470–480. doi:10.1097/APO.0000000000000559
28. Yang X, Fan Q, Zhang Y, et al. Changes in refractive error under COVID-19: a 3-year follow-up study. *Adv Ther*. 2022;39(6):2999–3010. doi:10.1007/s12325-022-02150-0
29. Nunes AF, Batista M, Monteiro P. Prevalence of anisometropia in children and adolescents. *F1000Res*. 2021;10:1101. doi:10.12688/f1000research.73657.4
30. Multi-ethnic Pediatric Eye Disease Study Group, MEPEDS. Prevalence of amblyopia and strabismus in African American and Hispanic children ages 6 to 72 months. *Ophthalmology*. 2008;115(7):1229–1236 e1221. doi:10.1016/j.ophtha.2007.08.001
31. Al-Salem KM, Saleem MS, Ereifej I, et al. Amblyopia screening for first and second-grade children in Jordan. *Int J Ophthalmol*. 2022;15(2):352–356. doi:10.18240/ijo.2022.02.24
32. Griffith JF, Wilson R, Cimino HC, Patthoff M, Martin DF, Traboulsi EI. The use of a mobile van for school vision screening: results of 63 841 evaluations. *Am J Ophthalmol*. 2016;163:108–114 e101. doi:10.1016/j.ajo.2015.11.026
33. Pascual M, Huang J, Maguire MG, et al. Risk factors for amblyopia in the vision in preschoolers study. *Ophthalmology*. 2014;121(3):622–629 e621. doi:10.1016/j.ophtha.2013.08.040

34. Killeen OJ, Choi H, Kannan NS, Asare AO, Stagg BC, Ehrlich JR. Association between health insurance and primary care vision testing among children and adolescents. *JAMA Ophthalmol*. 2023;141(9):909–911. doi:10.1001/jamaophthalmol.2023.3644
35. Lim DH, Han J, Chung TY, Kang S, Yim HW. Epidemiologic Survey Committee of the Korean ophthalmologic s. the high prevalence of myopia in Korean children with influence of parental refractive errors: the 2008-2012 Korean national health and nutrition examination survey. *PLoS One*. 2018;13(11):1.
36. Nitzan I, Bez M, Megreli J, et al. Socio-demographic disparities in amblyopia prevalence among 1.5 million adolescents. *Eur J Public Health*. 2021;31(6):1211–1217. doi:10.1093/eurpub/ckab111
37. Hunter SC, Suh DW, Molina I, Espinoza J. Automated screening devices for vision screening in preschool children: a comparison of the plusoptiX S12C photoscreener and retinomax K+3 autorefractor. *Frontiers in Ophthalmology*. 2022;1:2.
38. Kulp MT, Vision in Preschoolers Study G. Findings from the vision in preschoolers (VIP) Study. *Optom Vis Sci*. 2009;86(6):619–623.
39. Lowry EA, Lui R, Enanoria W, Keenan J, de Alba Campomanes AG. Repeat Retinomax screening changes positive predictive value. *J AAPOS*. 2014;18(1):45–49. doi:10.1016/j.jaapos.2013.11.004
40. Bosque LE, Yamarino CR, Salcedo N, et al. Evaluation of the blinq vision scanner for detection of amblyopia and strabismus. *J AAPOS*. 2021;25 (4):214–e217. doi:10.1016/j.jaapos.2021.02.011