

Effect of a Randomized Interventional School-Based Vision Program on Academic Performance of Students in Grades 3 to 7

A Cluster Randomized Clinical Trial

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IMPORTANCE Uncorrected refractive error in school-aged children may affect learning.

OBJECTIVE To assess the effect of a school-based vision program on academic achievement among students in grades 3 to 7.

DESIGN, SETTING, AND PARTICIPANTS This cluster randomized clinical trial was conducted in Baltimore City Public Schools during school years from 2016 to 2019 among 2304 students in grades 3 to 7 who received eye examinations and eyeglasses.

INTERVENTION Participating schools were randomized 1:1 to receive eye examinations and eyeglasses during 1 of 3 school years (2016-2017, 2017-2018, and 2018-2019).

MAIN OUTCOMES AND MEASURES The primary outcome was 1-year intervention impact, measured by effect size (ES), defined as the difference in score on an academic test (i-Ready or Partnership for Assessment of Readiness for College and Careers tests on reading and mathematics) between intervention and control groups measured in SD units, comparing cohort 1 (intervention) with cohorts 2 and 3 (control) at the end of program year 1 and comparing cohort 2 (intervention) with cohort 3 (control) at the end of program year 2. The secondary outcome was 2-year intervention impact, comparing ES in cohort 1 (intervention) with cohort 3 (control) at the end of program year 2. Hierarchical linear modeling was used to assess the impact of the intervention. Analysis was performed on an intention-to-treat basis.

RESULTS Among the 2304 students included in the study, 1260 (54.7%) were girls, with a mean (SD) age of 9.4 (1.4) years. The analysis included 964 students (41 schools) in cohort 1, 775 students (41 schools) in cohort 2, and 565 students (38 schools) in cohort 3. There were 1789 Black students (77.6%), 388 Latinx students (16.8%), and 406 students in special education (17.6%). There was an overall 1-year positive impact (ES, 0.09; $P = .02$) as assessed by the i-Ready reading test during school year 2016-2017. Positive impact was also observed among female students (ES, 0.15; $P < .001$), those in special education (ES, 0.25; $P < .001$), and students who performed in the lowest quartile at baseline (ES, 0.28; $P < .001$) on i-Ready reading and among students in elementary grades on i-Ready mathematics (ES, 0.03; $P < .001$) during school year 2016-2017. The intervention did not show a sustained impact at 2 years or on Partnership for Assessment of Readiness for College and Careers testing.

CONCLUSIONS AND RELEVANCE Students in grades 3 to 7 who received eyeglasses through a school-based vision program achieved better reading scores. Students had improved academic achievement over 1 year; however, a sustained impact was not observed after 2 years.

TRIAL REGISTRATION The Registry of Efficacy and Effectiveness Studies Identifier: [1573.1v1](https://www.clinicaltrials.gov/ct2/show/study/NCT02711114)

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The magnitude of uncorrected visual impairment due to refractive error in school-age children is substantial; corrective eyeglasses provide a simple solution. Failing a vision screening test is often the first indication of abnormal vision, prompting referral to an eye care clinician.¹ However, only 5% to 50% of children who fail screening tests receive follow-up care.²⁻⁵ These rates are especially alarming in high-poverty neighborhoods, where vision problems are more than double the national average and students face greater difficulties with access to care.⁶⁻¹⁰ The advent of school-based vision programs (SBVPs) offers an opportunity to improve access to care by providing services, including provision of eyeglasses, directly in schools.

Because schools, among other entities, including families and faith-based groups, are responsible for children's academic success,¹¹ it is logical to engage them in addressing students' vision needs. Although SBVPs have demonstrated success in connecting children who fail vision screening tests with eye examinations,¹² to our knowledge, little is known about whether provision of eyeglasses as part of programs impacts academic success. Although previous studies have shown that provision of eyeglasses improved students' classroom behavior and the probability of passing academic tests in reading and mathematics, they were limited by study design, population, and setting.¹³⁻¹⁶ A clear demonstration of the academic impact of SBVPs has not been made in the United States, to our knowledge.

Vision for Baltimore (V4B) is a citywide SBVP for students attending Baltimore City elementary and middle schools. We aimed to assess the impact of V4B's school-based vision services, including provision of eyeglasses to students who needed them, on student academic achievement in English language arts (herein referred to as *reading*) and mathematics.

Methods

Study Design

This cluster randomized clinical trial was conducted in Baltimore City Public Schools during the school years (SYs) from 2016 to 2019 as part of a citywide SBVP. Institutional review board approval was obtained from Johns Hopkins University and Baltimore City Public Schools, and this study was conducted in accordance with Declaration of Helsinki tenets.¹⁷ The trial was registered at the Registry of Efficacy and Effectiveness Studies (1573.1v1) (trial protocol in [Supplement 1](#)).

Baltimore City Public Schools included 151 schools that serve prekindergarten through grade 8. There were 127 schools enrolled and randomized into the study after excluding 24 schools that did not meet study eligibility ([Figure 1](#)).

Cluster randomization was stratified based on charter school status, school type (elementary, middle, or prekindergarten through grade 8), previous participation by some students in the Baltimore Reading and Eye Disease Study (BREDS), a principal component score based on school-level sex, race/ethnicity, prior achievement, special education (SPED) status, English language learner status, eligibility for free and

Key Points

Question How do school-based vision programs affect academic performance among students needing eyeglasses?

Findings This cluster randomized clinical trial found that a school-based vision program improved students' reading scores over 1 year, especially girls, those in special education, and students in the lowest quartile at baseline. A sustained benefit was not observed over 2 years.

Meaning School-based vision programs may help children improve academic performance by providing eye examinations and eyeglasses.

reduced-price meals, and whether the school had more than 25% Latinx students. Schools in each stratum were allocated with a 1:1:1 ratio into 1 of 3 study cohorts using block randomization. Cohorts 1, 2, and 3 received V4B interventions in the first (SY 2016-2017), second (SY 2017-2018), and third (SY 2018-2019) program years, respectively.

Intervention and Implementation

Vision for Baltimore services included vision screenings, eye examinations, and eyeglasses, if needed. Screenings were conducted for all students.¹² Students who failed the screening test were provided a 2-sided consent form offering an eye examination and research participation. Signed parental consent was required for eye examinations; after providing consent for the examination, parents could opt out of participating in the research via a check box on the consent form.

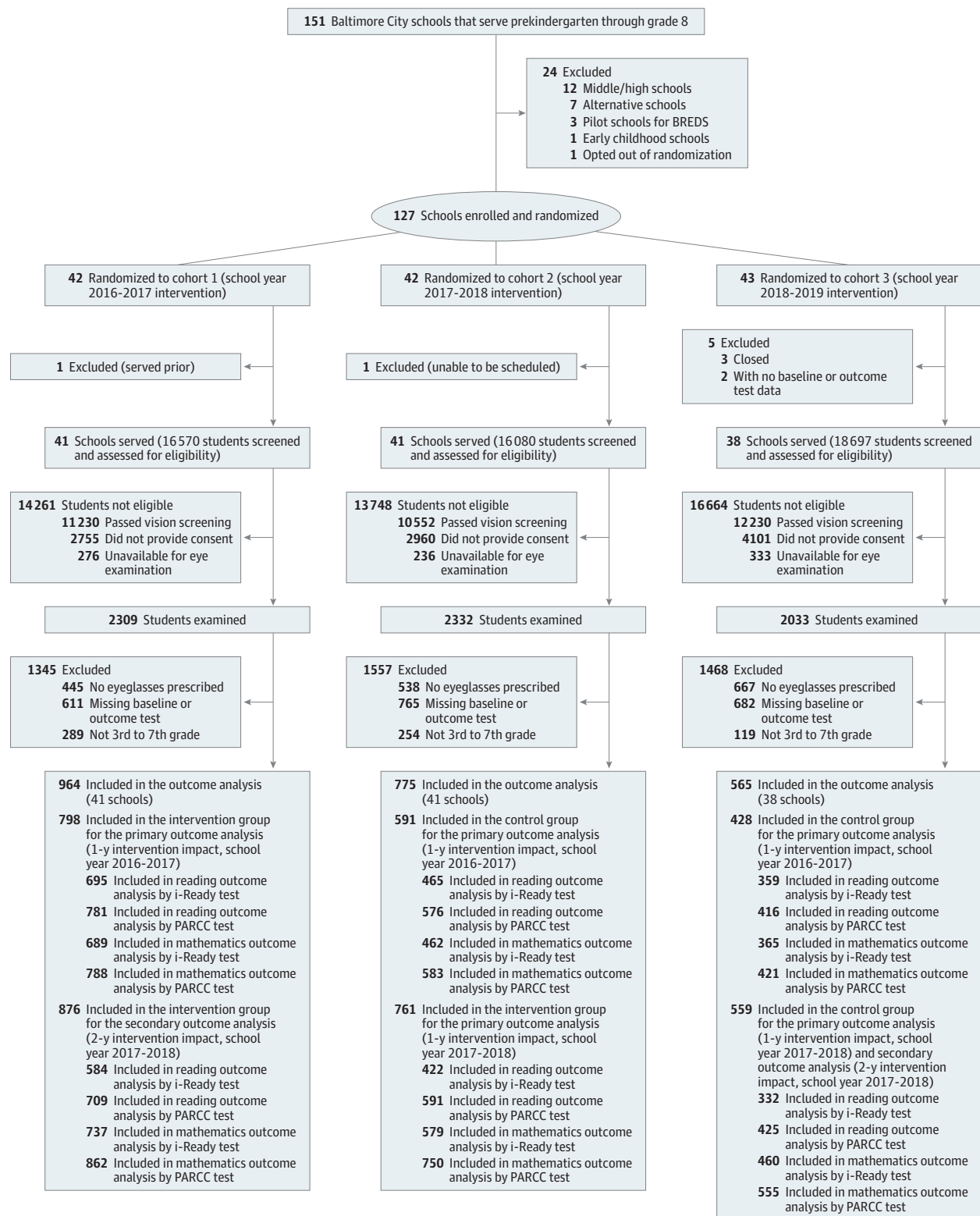
A mobile eye clinic from Vision To Learn, a project partner, visited each school. Eye examinations were conducted by licensed optometrists after parents provided consent. Students who needed eyeglasses selected frames at the examination. Eyeglasses were manufactured by Warby Parker and dispensed to students at school approximately 2 to 4 weeks after the examination. Students were provided replacement eyeglasses as needed within 1 year of their prescription. The costs of the eyeglasses were covered by the program. Vision for Baltimore staff provided implementation support to schools throughout the study.

Measurements and Outcomes

Academic Performance and Demographic Data

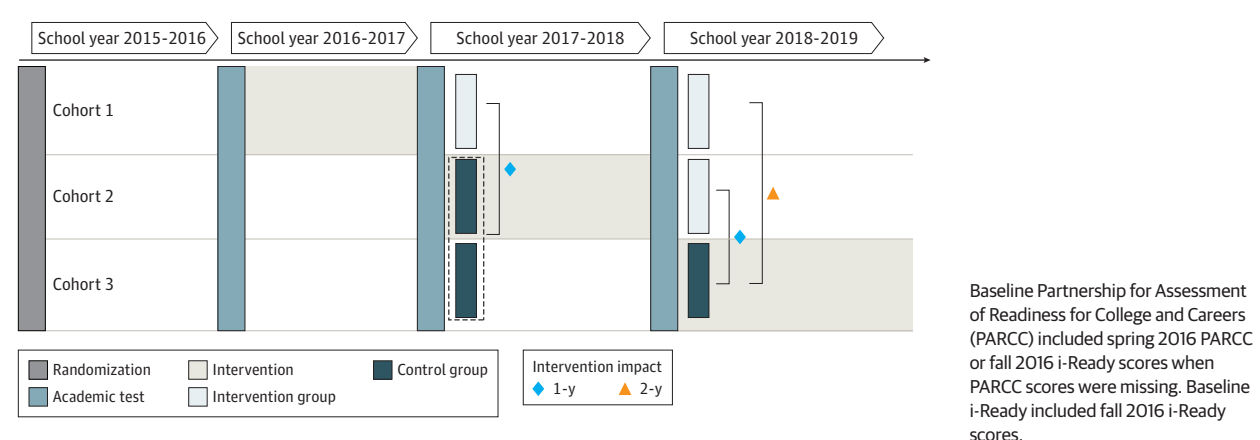
The academic testing outcomes were reading and mathematics scores on the i-Ready test and the Partnership for Assessment of Readiness for College and Careers (PARCC) test. i-Ready, a standardized test given 3 times per year for students in grades 1 through 8, monitors academic progress in reading and mathematics. PARCC, a Maryland state-mandated test, is administered each spring to students in grades 3 through 8. Data on individual student test scores for SY 2015-2016 through SY 2017-2018, student demographic characteristics, and education status, including birthdate, grade, sex, race, ethnicity, SPED status, and English language learner status, were obtained from Baltimore City Public Schools.

Figure 1. Vision for Baltimore Participant Flow Diagram



BREDs indicates Baltimore Reading and Eye Disease Study; PARCC, Partnership for Assessment of Readiness for College and Careers.

Figure 2. Randomization, Intervention, and Control Groups



Eye Examination Data

Presenting visual acuity was measured monocularly using an electronic acuity testing monitor (20/20 Vision; Canela Software) located 2.4 m from the examination chair. Students were tested with correction if wearing eyeglasses. Presenting visual acuity was the smallest line with at least 3 optotypes identified. Children underwent noncycloplegic autorefractometry (RC-5000 Advanced Auto Refractor; Tomey Corporation) measurement followed by noncycloplegic manifest refraction.

Refractive error was determined based on the final lens prescription in the eye with better presenting visual acuity and was categorized as hyperopia (at least 0.50-diopter [D] spherical equivalent [SE]), myopia (at least -0.50-D SE), and emmetropia (between -0.50-D and 0.50-D SE). Astigmatism was defined as 1.00 D-cylindrical power or greater.

Outcome Measures

Program effect size (ES) was defined as the difference in score on a particular academic test between the intervention and control groups, measured in SD units. The primary study outcome was the 1-year intervention impact, measured by ES, comparing cohort 1 (intervention) with cohorts 2 and 3 (control) at the end of the first program year (SY 2016-2017) and comparing cohort 2 (intervention) with cohort 3 (control) at the end of the second program year (SY 2017-2018). The secondary outcome was the 2-year intervention impact, measured by comparing cohort 1 (intervention) with cohort 3 (control) at the end of the second program year (SY 2017-2018) (Figure 2).

Student Participants and Eligibility

Students were included in the analytic sample if they failed the vision screening test, completed the eye examination, and opted into the study. Students were excluded for any of the following: (1) eyeglasses were not prescribed, (2) they had no baseline standardized test scores prior to program implementation or postintervention scores on any test, and (3) they were not in grades 3 to 7 when they received the intervention.

Statistical Analysis

Analysis was performed on an intention-to-treat basis. Grade levels were categorized as elementary school (grades 3-5) and middle school (grades 6 and 7). Students with the lowest 25% baseline performance on each test were defined as students who performed in the lowest quartile (SPLQ) at baseline. The school attrition rate, defined as the number of schools in a cohort at the time of outcome divided by the number of schools assigned to cohort at baseline, was used to assess the loss of entire schools from the analytic sample due to closure or not having results for a specific test. We used the baseline performance at randomization to avoid any sample contamination between randomization and time-lagged baseline. Hierarchical linear modeling was used to assess the impact of the V4B intervention on academic performance. Students were nested within schools in which they received the intervention. The models analyzed program effects on each academic test outcome separately, controlling for grade level and baseline achievement at student level, as well as stratifying variables used in randomization at the school level. Hierarchical linear modeling was used to examine intervention effects for various student subgroups (sex, grade level, SPED status, and baseline achievement) by including interaction terms in the model. The Hedges g ES¹⁸ and 95% CIs and 99% CIs¹⁹ were calculated. Given the large number of comparisons tested in the analyses of differential treatment effects, multiple comparison corrections were applied using the Bonferroni procedure. A 2-sided $P < .05$ was considered statistically significant. All analyses were conducted using R statistical software, version 4.0.0 (R Group for Statistical Computing)²⁰ and the lmer package.²¹

Results

Baseline Characteristics

School Characteristics

Forty-two schools were randomized to cohorts 1 and 2, and 43 schools were randomized to cohort 3 (Figure 1). The analytic sample included 120 schools; school-level characteristics are

Table 1. Baseline Student-Level Characteristics by Outcome Measure Period

Characteristic	1-y Intervention impact, Students, No. (%) ^a				2-y Intervention impact on SY 2017-2018, Students, No. (%) ^a	
	SY 2016-2017		SY 2017-2018		Intervention, cohort 1 (n = 876)	Control, cohort 3 (n = 559)
	Intervention, cohort 1 (n = 798)	Control, cohorts 2 and 3 (n = 1019)	Intervention, cohort 2 (n = 761)	Control, cohort 3 (n = 559)		
Race/ethnicity^b						
Black	624 (78.2)	792 (77.7)	576 (75.7)	443 (79.2)	685 (78.2)	443 (79.2)
White	131 (16.4)	200 (19.6)	162 (21.3)	105 (18.8)	146 (16.7)	105 (18.8)
Latinx	122 (15.3)	178 (17.5)	136 (17.9)	97 (17.4)	143 (16.3)	97 (17.4)
Asian	17 (2.1)	10 (1.0)	8 (1.1)	2 (0.4)	20 (2.3)	2 (0.4)
Female	423 (53.0)	596 (58.5)	430 (56.5)	318 (56.9)	461 (52.6)	318 (56.9)
English language learner	63 (7.9)	78 (7.7)	64 (8.4)	56 (10.0)	77 (8.8)	56 (10.0)
Special education	145 (18.2)	172 (16.9)	128 (16.8)	103 (18.4)	154 (17.6)	103 (18.4)
Eye examination findings						
Wearing eyeglasses at baseline	34 (4.3)	33 (3.2)	2 (0.3)	42 (7.5)	34 (3.9)	42 (7.5)
Refractive error						
Emmetropia	198 (24.8)	231 (22.7)	212 (27.9)	101 (18.1)	227 (25.9)	101 (18.1)
Hyperopia	101 (12.7)	109 (10.7)	96 (12.6)	60 (10.7)	129 (14.7)	60 (10.7)
Myopia	499 (62.5)	679 (66.6)	453 (59.5)	398 (71.2)	520 (59.4)	398 (71.2)
Astigmatism	321 (40.2)	364 (35.7)	276 (36.3)	222 (39.7)	372 (42.5)	222 (39.7)

Abbreviation: SY, school year.

^a The numbers of students in each intervention and control group reflected all students who were included in at least 1 academic test outcome analysis; the numbers may differ from the baseline academic equivalence estimates

(eTable 5 in Supplement 2).

^b Race/ethnicity was not mutually exclusive, and students may have self-classified as more than 1 race/ethnicity. Percentages may sum to more than 100%.

shown in eTable 1 in Supplement 2. The overall school attrition rate ranged from 6.3% (8 of 127) to 23.5% (20 of 85). The differential attrition rates between intervention and control schools ranged between 1.8% (23.3% [10 of 43] for the control group compared with 21.4% [9 of 42] for the intervention group) and 11.6% (14.0% [6 of 43] for the control group compared with 2.4% [1 of 42] for the intervention group), depending on the outcome analyzed (eTable 2 in Supplement 2).

Student Characteristics

The analytic sample included 2304 students (1044 boys [45.3%] and 1260 girls [54.7%]; mean [SD] age of 9.4 [1.4] years; retention rate by cohort presented in eTable 3 in Supplement 2) who were mostly Black (1789 [77.6%]), Latinx (388 [16.8%]), and White (432 [18.8%]), with some students self-identifying as more than 1 race/ethnicity. A total of 406 students (17.6%) were in SPED, and 204 (8.9%) were English language learners. No statistically significant demographic differences were observed between cohorts (eTable 4 in Supplement 2). Baseline student characteristics by intervention outcome period are presented in Table 1. Students in the intervention and control groups had baseline standardized scores that were less than 0.25 SDs apart, a standard cutoff in education for comparable groups (eTable 5 in Supplement 2).

Overall Intervention Impact on Academic Outcomes

The primary and secondary outcome measures are shown in Table 2. At 1 year, there was a positive impact on the i-Ready reading score (ES, 0.09; P = .02) during SY 2016-2017. A similar positive impact on i-Ready reading scores was observed

during SY 2017-2018 (ES, 0.12; P = .09) and with PARCC test scores during SY 2016-2017 and 2017-2018 (SY 2016-2017: ES, 0.04; P = .31; SY 2017-2018: ES, 0.04; P = .59), although these were not statistically significant. For the 1-year mathematics intervention impact, no positive impact was observed during SY 2016-2017. A positive impact was found with both i-Ready and PARCC during SY 2017-2018 (i-Ready: ES, 0.09; P = .07; PARCC: ES, 0.10; P = .11), although neither was statistically significant.

At 2 years, a positive intervention impact was observed on i-Ready reading scores (ES, 0.08; P = .23) and mathematics scores (ES, 0.08; P = .20); however, these were not statistically significant. No impact was seen on PARCC reading scores (ES, -0.04; P = .46) or mathematics scores (ES, 0.00; P = .95).

Intervention Impact on Academic Outcomes by Student Characteristics

One-year and 2-year intervention impacts were analyzed by sex, grade level, SPED status, and baseline achievement (Table 3). After application of the Bonferroni correction, a statistically significant positive 1-year intervention impact was observed with the reading i-Ready score for girls (ES, 0.15; P < .001) but not for boys (ES, 0.01; P = .48).

For the 1-year intervention impact on i-Ready mathematics, a statistically significant impact was observed in elementary school grades (ES, 0.03; P < .001) but not middle school grades (ES, -0.21; P ≥ .99) during SY 2016-2017 (Table 3). No statistically significant outcome was found in SY 2017-2018 with 2-year intervention impact or with PARCC outcomes by grade level.

Table 2. 1-Year and 2-Year Intervention Impact on Academic Outcomes for All Students^a

Outcome period, subject, and test	Schools, No.	Students, No.	Academic outcome test scores						
			Control	Intervention	Mean difference (SE)	Effect size ^b	P value	95% CI	99% CI
1-y Intervention impact									
SY 2016-2017									
Reading									
i-Ready	107	1519	513.71	518.78	5.07 (2.11)	0.09	.02 ^c	0.01 to 0.17	-0.01 to 0.19
PARCC	118	1773	697.53	698.92	1.39 (1.37)	0.04	.31	-0.04 to 0.12	-0.06 to 0.14
Mathematics									
i-Ready	106	1516	448.24	448.15	-0.09 (1.23)	0.00	.94	-0.10 to 0.10	-0.13 to 0.13
PARCC	119	1792	728.53	728.57	0.04 (1.21)	0.00	.97	-0.19 to 0.19	-0.25 to 0.25
SY 2017-2018									
Reading									
i-Ready	65	754	532.27	540.12	7.85 (4.56)	0.12	.09	-0.02 to 0.26	-0.06 to 0.30
PARCC	78	1016	701.99	703.22	1.23 (2.24)	0.04	.59	-0.10 to 0.18	-0.15 to 0.23
Mathematics									
i-Ready	66	1039	449.86	453.36	3.50 (1.87)	0.09	.07	-0.01 to 0.19	-0.04 to 0.22
PARCC	79	1305	731.64	734.76	3.12 (1.91)	0.10	.11	-0.02 to 0.22	-0.06 to 0.26
2-y Intervention impact									
SY 2017-2018									
Reading									
i-Ready	67	916	529.64	534.49	4.85 (4.01)	0.08	.23	-0.05 to 0.22	-0.09 to 0.25
PARCC	78	1134	698.83	697.54	-1.29 (1.75)	-0.04	.46	-0.14 to 0.06	-0.18 to 0.10
Mathematics									
i-Ready	69	1197	449.51	452.45	2.94 (2.29)	0.08	.20	-0.04 to 0.20	-0.08 to 0.24
PARCC	79	1417	724.19	724.32	0.13 (2.09)	0.00	.95	-0.11 to 0.11	-0.15 to 0.15

Abbreviations: PARCC, Partnership for Assessment of Readiness for College and Careers; SY, school year.

^a The models adjusted for student grade level (3-7), prior achievement (testing scores), and blocking variables used in randomization (charter school status, school type, pilot study participation, school proportion of low-income and Black students, and whether the school served more than 25% Latinx students). Effect size estimates presented are model-adjusted estimates. The

analytic sample included 120 schools. Different analyses had different numbers of students and school samples owing to the availability of baseline and postintervention tests.

^b The difference in score on a particular academic test between the intervention and control groups measured in SD units.

^c Statistically significant at 2-sided $P < .05$ level.

A positive 1-year intervention impact on reading by i-Ready score during SY 2016-2017 was found for SPED students (ES, 0.25; $P < .001$) but not for non-SPED students (ES, 0.06; $P = .48$) (Table 3). Similarly, for SPLQ at baseline, there was a positive 1-year intervention impact on reading by i-Ready score during SY 2016-2017 (ES, 0.28; $P < .001$). Such an impact was not observed for their counterparts with higher baseline achievement (ES, 0.03; $P = .48$). No statistically significant impact was observed by SPED or baseline achievement status with other 1-year or 2-year intervention outcomes.

Discussion

In this citywide, cluster randomized clinical study conducted in Baltimore, Maryland, students receiving SBVP interventions with eyeglasses achieved better scores than controls on i-Ready reading assessments over 1 year. Our findings highlighted that students with certain characteristics benefited more from the intervention. Over the course of 1 year,

girls, SPED students, and those with SPLQ at baseline obtained higher scores on i-Ready reading, while students in elementary school grades achieved higher scores on i-Ready mathematics. The improved students' academic achievements seen in the first year were not sustained at 2 years. Vision for Baltimore demonstrated success in identifying and correcting vision deficits for students in Baltimore, many of whom may have never previously accessed vision care.²²

When evaluating the impact of an intervention, which for this study was provision of eyeglasses, on academic achievement, a 0.09 ES in reading is considered medium by benchmark standards; the 0.25 ES in some of our subgroup analyses would be considered large.²³ The ESs are noteworthy by education standards given the randomized design and study size.²³ It is important to compare the demonstrated benefit of school-based vision care with ES for widely used educational interventions.²⁴⁻²⁶ The overall ES of 0.09 in this study is larger than that for other common interventions, with the exception of tutoring (eFigure in Supplement 2). The effects for SPED students (ES, 0.25) and those with SPLQ at baseline (ES, 0.28)

Table 3. 1-Year and 2-Year Intervention Impacts on Academic Outcomes by Student Characteristics

Subject and test	1-y Intervention impact ^a										2-y Intervention impact on SY 2017-2018 ^a				
	SY 2016-2017					SY 2017-2018					Mean difference, Score	Effect size ^b	P value	95% CI	99% CI
	Mean difference, Score	Effect size ^b	P value	95% CI	99% CI	Mean difference, Score	Effect size ^b	P value	95% CI	99% CI					
Sex															
Female															
Reading															
i-Ready	8.73	0.15 ^c	<.001	0.06 to 0.24	0.03 to 0.27	5.44	0.09	≥.99	-12.62 to 12.80	-16.61 to 16.80	6.39	0.10	≥.99	-14.02 to 14.22	-18.46 to 18.66
PARCC	2.44	0.08	≥.99	-11.22 to 11.38	-14.77 to 14.93	1.02	0.03	≥.99	-4.21 to 4.27	-5.54 to 5.60	-0.18	-0.01	≥.99	-1.42 to 1.40	-1.87 to 1.85
Mathematics															
i-Ready	1.03	0.03	≥.99	-4.21 to 4.27	-5.54 to 5.60	1.62	0.04	≥.99	-5.61 to 5.69	-7.39 to 7.47	2.22	0.06	≥.99	-8.41 to 8.53	-11.08 to 11.20
PARCC	0.55	0.02	≥.99	-2.80 to 2.84	-3.69 to 3.73	4.07	0.13	≥.99	-18.23 to 18.49	-24.00 to 24.26	3.30	0.11	.96	-3.80 to 4.02	-5.03 to 5.25
Male															
Reading															
i-Ready	0.36	0.01	.48	-0.02 to 0.04	-0.03 to 0.05	9.00	0.14	≥.99	-19.63 to 19.91	-25.85 to 26.13	2.31	0.04	≥.99	-5.61 to 5.69	-7.39 to 7.47
PARCC	0.76	0.02	≥.99	-2.80 to 2.84	-3.69 to 3.73	1.19	0.04	≥.99	-5.61 to 5.69	-7.39 to 7.47	-2.02	-0.06	≥.99	-8.53 to 8.41	-11.20 to 11.08
Mathematics															
i-Ready	-1.52	-0.05	≥.99	-7.11 to 7.01	-9.33 to 9.23	5.29	0.14	≥.99	-19.63 to 19.91	-25.85 to 26.13	3.70	0.10	≥.99	-14.02 to 14.22	-18.46 to 18.66
PARCC	-0.56	-0.02	≥.99	-2.84 to 2.80	-3.73 to 3.69	1.66	0.05	≥.99	-7.01 to 7.11	-9.23 to 9.33	-3.67	-0.12	≥.99	-17.07 to 16.83	-22.40 to 22.16
Grade level															
Elementary grades															
Reading															
i-Ready	6.14	0.11	.48	-0.19 to 0.41	-0.28 to 0.50	8.40	0.13	≥.99	-18.23 to 18.49	-24.00 to 24.26	6.75	0.11	≥.99	-15.43 to 15.65	-20.31 to 20.53
PARCC	1.86	0.06	≥.99	-8.41 to 8.53	-11.08 to 11.20	1.01	0.03	≥.99	-4.21 to 4.27	-5.54 to 5.60	0.17	0.01	≥.99	-1.40 to 1.42	-1.85 to 1.87
Mathematics															
i-Ready	1.11	0.03 ^c	<.001	0.01 to 0.05	0.01 to 0.05	3.54	0.09	≥.99	-12.62 to 12.80	-16.62 to 16.80	4.38	0.12	≥.99	-16.83 to 17.07	-22.16 to 22.40
PARCC	0.17	0.01	≥.99	-1.40 to 1.42	-1.85 to 1.87	5.57	0.18	.96	-6.22 to 6.58	-8.23 to 8.59	1.13	0.04	≥.99	-5.61 to 5.69	-7.39 to 7.47
Middle grades															
Reading															
i-Ready	-0.59	-0.01	.48	-0.04 to 0.02	-0.05 to 0.03	4.88	0.08	≥.99	-11.22 to 11.38	-14.77 to 14.93	1.33	0.02	≥.99	-2.80 to 2.84	-3.69 to 3.73
PARCC	0.97	0.03	≥.99	-4.21 to 4.27	-5.54 to 5.60	1.18	0.03	≥.99	-4.21 to 4.27	-5.54 to 5.60	-2.51	-0.08	≥.99	-11.38 to 11.22	-14.93 to 14.77
Mathematics															
i-Ready	-6.91	-0.21	≥.99	-29.87 to 29.45	-39.19 to 38.77	2.97	0.08	≥.99	-11.22 to 11.38	-14.77 to 14.93	1.56	0.04	≥.99	-5.61 to 5.69	-7.39 to 7.47
PARCC	-0.44	-0.01	≥.99	-1.42 to 1.40	-1.87 to 1.85	1.01	0.03	≥.99	-4.21 to 4.27	-5.54 to 5.60	-0.76	-0.02	≥.99	-2.84 to 2.80	-3.73 to 3.69

(continued)

Table 3. 1-Year and 2-Year Intervention Impacts on Academic Outcomes by Student Characteristics (continued)

Subject and test	1-y Intervention impact ^a										2-y Intervention impact on SY 2017-2018 ^a				
	SY 2016-2017					SY 2017-2018					Mean difference, Score	Effect size ^b	P value	95% CI	99% CI
	Mean difference, Score	Effect size ^b	P value	95% CI	99% CI	Mean difference, Score	Effect size ^b	P value	95% CI	99% CI					
Special education status															
Yes															
Reading															
i-Ready	13.87	0.25 ^c	<.001	0.10 to 0.40	0.06 to 0.44	15.41	0.24	≥.99	-33.66 to 34.14	-44.31 to 44.79	14.50	0.23	≥.99	-32.25 to 32.71	-42.46 to 42.92
PARCC	2.79	0.09	≥.99	-12.62 to 12.80	-16.62 to 16.80	-1.52	-0.04	≥.99	-5.69 to 5.61	-7.47 to 7.39	-1.07	-0.03	≥.99	-4.27 to 4.21	-5.60 to 5.54
Mathematics															
i-Ready	-0.79	-0.02	≥.99	-2.84 to 2.80	-3.73 to 3.69	1.83	0.05	≥.99	-7.01 to 7.11	-9.23 to 9.33	4.81	0.13	≥.99	-18.23 to 18.49	-24.00 to 24.26
PARCC	0.60	0.02	≥.99	-2.80 to 2.84	-3.69 to 3.73	4.62	0.15	≥.99	-21.04 to 21.34	-27.69 to 27.99	5.16	0.17	≥.99	-23.84 to 24.18	-31.39 to 31.73
No															
Reading															
i-Ready	3.32	0.06	.48	-0.10 to 0.22	-0.15 to 0.27	5.17	0.08	≥.99	-11.22 to 11.38	-14.77 to 14.93	2.41	0.04	≥.99	-5.61 to 5.69	-7.39 to 7.47
PARCC	1.48	0.05	≥.99	-7.01 to 7.11	-9.23 to 9.33	1.62	0.05	≥.99	-7.01 to 7.11	-9.23 to 9.33	-0.99	-0.03	≥.99	-4.27 to 4.21	-5.60 to 5.54
Mathematics															
i-Ready	0.06	0.00	≥.99	-0.56 to 0.56	-0.74 to 0.74	3.52	0.09	≥.99	-12.62 to 12.80	-16.62 to 16.80	2.49	0.07	≥.99	-9.82 to 9.96	-12.92 to 13.06
PARCC	-0.05	0.00	≥.99	-0.56 to 0.56	-0.74 to 0.74	2.70	0.09	≥.99	-12.62 to 12.80	-16.62 to 16.80	-1.00	-0.03	≥.99	-4.27 to 4.21	-5.60 to 5.54
Baseline achievement level															
Students in lowest quartile															
Reading															
i-Ready	15.54	0.28 ^c	<.001	0.11 to 0.45	0.06 to 0.50	7.88	0.12	≥.99	-16.83 to 17.07	-22.16 to 22.40	10.27	0.17	≥.99	-23.84 to 24.18	-31.39 to 31.73
PARCC	3.17	0.10	≥.99	-14.02 to 14.22	-18.46 to 18.66	0.25	0.01	≥.99	-1.40 to 1.42	-1.85 to 1.87	0.95	0.03	≥.99	-4.21 to 4.27	-5.54 to 5.60
Mathematics															
i-Ready	2.18	0.07	≥.99	-9.82 to 9.96	-12.92 to 13.06	2.46	0.06	≥.99	-8.41 to 8.53	-11.08 to 11.20	4.34	0.11	≥.99	-15.43 to 15.65	-20.31 to 20.53
PARCC	0.09	0.00	≥.99	-0.56 to 0.56	-0.74 to 0.74	6.31	0.20	≥.99	-28.05 to 28.45	-36.93 to 37.33	1.05	0.03	≥.99	-4.21 to 4.27	-5.54 to 5.60

(continued)

are comparable to those of tutoring for students performing below grade level, the most effective educational intervention known.²⁴ Although this analysis measured impact only on academic achievement, the educational implications can be more far reaching, including the potential impact on attendance and behavior.

For PARCC, reliability estimates range from 0.90 to 0.92 for reading and 0.91 to 0.94 for mathematics²⁷; for i-Ready, reliability estimates range from 0.85 to 0.86 for reading and 0.83 to 0.87 for mathematics.²⁸ The yearly spring to spring gains on standardized tests for the grades included ranged from 0.23

to 0.60 SDs. The ES seen with eyeglasses would be additive to these expected gains. Because learning gains narrow in higher grades, a 0.09 ES becomes even more impactful for older students.²³ We did not observe the same impact on PARCC testing as on i-Ready, which is designed to measure incremental changes more reliably than PARCC.

Our findings are supported by previous studies about SBVPs in elementary school populations. The i-Ready reading results (ES, 0.09) are similar to those of BREDs, a study that examined the impact of prescribing eyeglasses for low refractive error on individual reading assessments (ES, 0.16); how-

Table 3. 1-Year and 2-Year Intervention Impacts on Academic Outcomes by Student Characteristics (continued)

Subject and test	1-y Intervention impact ^a										2-y Intervention impact on SY 2017-2018 ^a				
	SY 2016-2017					SY 2017-2018									
	Mean difference, Score	Effect size ^b	P value	95% CI	99% CI	Mean difference, Score	Effect size ^b	P value	95% CI	99% CI	Mean difference, Score	Effect size ^b	P value	95% CI	99% CI
Students in 26th-100th percentile															
Reading															
i-Ready	1.50	0.03	.48	-0.05 to 0.11	-0.08 to 0.14	6.61	0.11	≥.99	-15.43 to 15.65	-20.31 to 20.53	2.44	0.04	≥.99	-5.61 to 5.69	-7.39 to 7.47
PARCC	1.18	0.04	≥.99	-5.61 to 5.69	-7.39 to 7.47	1.38	0.04	≥.99	-5.61 to 5.69	-7.39 to 7.47	-1.72	-0.05	≥.99	-7.11 to 7.01	-9.33 to 9.23
Mathematics															
i-Ready	-0.86	-0.03	≥.99	-4.27 to 4.21	-5.60 to 5.54	3.48	0.09	≥.99	-12.62 to 12.80	-16.62 to 16.80	2.41	0.06	≥.99	-8.41 to 8.53	-11.08 to 11.20
PARCC	0.05	0.00	≥.99	-0.56 to 0.56	-0.74 to 0.74	1.93	0.06	≥.99	-8.41 to 8.53	-11.08 to 11.20	-0.24	-0.01	≥.99	-1.42 to 1.40	-1.87 to 1.85

Abbreviations: PARCC, Partnership for Assessment of Readiness for College and Careers; SY, school year.

^a The models adjusted for student grade level (3-7), prior achievement (testing scores), and blocking variables used in randomization (charter school status, school type, pilot study participation, school proportion of low-income and Black students, and whether the school served more than 25% Latinx students). Effect size estimates presented are model-adjusted estimates.

^b The difference in score on a particular academic test between the intervention and control groups measured in SD units.

^c Statistically significant after Bonferroni correction at 2-sided $P < .001$ level, calculated by conducting a test to see if $\text{intervention} \times \text{interaction} = 0$ after running the relevant model. Multiple comparison corrections were applied to P values using the Bonferroni procedure. $P < .05$ was considered statistically significant.

ever, BREDS did not focus specifically on students who failed vision screening tests.²⁹ A review of the academic records of children in grades 1 through 5 in the Los Angeles Unified School District demonstrated a change in percentile ranking in mathematics and reading assessments from 1 year prior to 2 years after receiving eyeglasses.¹⁴ In another retrospective review of 349 students in kindergarten through grade 5 in the Philadelphia school district who received eyeglasses through a school-based program, students scoring in the satisfactory range at baseline were more likely to maintain scores during the same academic year; however, no benefit was noted for children performing in the inadequate or marginal category at baseline.¹³

To our knowledge, there has been 1 randomized study among students in the United States comparing screening alone vs screening plus eye examinations and eyeglasses that reported improved scores on Florida Comprehensive Achievement Tests¹⁶; however, substantial implementation challenges limit the interpretation of these results. A study among children in rural China also found positive effects on standardized mathematics tests of providing eyeglasses, yet with no assessment of reading performance.¹⁵ It is unclear why we did not observe the same benefit for mathematics across our study population, instead of only for students in elementary school grades on i-Ready. This finding may be associated with differences between the tests used in the United States and China or differences between rural Chinese students and an urban high-poverty population in Baltimore.

In subgroup analysis, we found a positive impact on i-Ready reading scores for students in SPED. A prior observa-

tional study explored the impact for students in SPED and reported that those receiving eyeglasses had significant improvements in classroom behavior; however, no standardized testing results were measured.³⁰ Students in SPED suspected of having a vision problem are recommended to have a baseline eye examination prior to placement.³¹ Efforts should be made to improve mechanisms to ensure that such students receive the recommended eye care. In contrast to the Philadelphia study,¹³ our subgroup analysis demonstrated a larger benefit for children with SPLQ at baseline. The reasons for this difference may be that we studied younger students and used different assessments.

Our study showed benefit at 1 year that was not sustained after 2 years. The reasons for this may be that students may wear eyeglasses less over time or that the refractive correction may no longer be sufficient. A similar decrease in impact over time has been reported previously,¹⁶ as has decreased use of eyeglasses with time.³² Collectively, these findings underscore that for SBVPs to maximize impact, they must not only provide eyeglasses but also ensure mechanisms for monitoring wear, replacement, and connection to community eye care clinicians for long-term care.³³

Strengths and Limitations

This study has several strengths and limitations. The research study was performed in the context of a real-world SBVP involving more than 30 000 students. The randomized clinical design enabled the evaluation of 1- and 2-year impacts on reading and mathematics using i-Ready and PARCC.

There may have been variations in vision screenings and examinations that would not have occurred in a clinical trial setting. Although students were measured for best-corrected visual acuity with refraction, their vision was not remeasured after they received eyeglasses. The refractive error findings and visual acuity change with eyeglasses in relation to academic outcomes will be reported separately. We observed a decrease in eyeglasses prescription rates over time; however, the impact on academic outcome assessments was expected to be minimal given the balanced student characteristics across cohorts.

Data on individual eyeglass wear compliance were not collected, limiting further explorations of other factors associated with academic outcomes. Because the program operated throughout the school year, students may have been wearing eyeglasses for varying lengths of time before benchmark assessments. However, we maintained extensive engagement with schools because previous research demonstrated the positive impact of teacher reminders on students consistently wearing their eyeglasses.³² It is also possible that students may have lost or broken their eyeglasses. The program had an active system in which replacements were provided on request, but we may have missed students who did not report lost or broken eyeglasses.

The research sample may not be representative of the demographic characteristics of all students who failed vision screening tests owing to school-level attrition and the number of individual students consenting to participate in research. Study implementation may have underestimated the interventional impact based on an intention-to-treat analysis

approach, as students were wearing eyeglasses for different durations depending on when they underwent eye examinations; it is also possible that not all students had received the intervention by the time they took standardized tests. There were 47.7% of students (1100) excluded from at least 1 outcome analysis owing to missing academic test data, largely associated with the approximately 30% student mobility rate in schools.³⁴ We do not know the diagnoses for SPED students; however, most were likely to have high-incidence disabilities, such as specific learning disability and speech or language impairment, because these are the most common diagnoses in which students would still participate in standardized testing.

Finally, we were unable to examine impacts for children below third grade because we did not have available pretest data. Evaluating program effects for this age group would be important given the considerable interest in improving reading for students in early elementary school grades.

Conclusions

Based on our analyses, there was a positive impact of an SBVP on academic performance in reading, with a larger observed program effect on female students, those in elementary grades, SPED, and SPLQ at baseline. The study provides evidence that eyeglasses not only help children see more clearly but achieve more academically. These findings have potential relevance for policymakers and stakeholders interested in school-based vision care.

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Concept and design: Neitzel, Wolf, Repka, Friedman, Collins.

Acquisition, analysis, or interpretation of data: All authors.

Drafting of the manuscript: Neitzel, Wolf, Guo, Shakarchi, Friedman, Collins.

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