Effect of providing free glasses on children's educational outcomes in China: The "Seeing is Learning" cluster-randomized controlled trial

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Abstract

Objective: To study for the first time using a clinical trial the effect of free glasses on academic performance in rural Chinese children, among whom uncorrected myopia is the leading cause of visual impairment.

Design: Cluster-randomized, investigator-masked, controlled trial carried out in the 2012-2013 school year.

Setting: Primary schools (n=252) randomly selected on a population basis in two prefectures in western China.

Participants: Among 19,934 children in grades 4 and 5 randomly selected for visual acuity screening, 3177 (15.9%, mean age 10.5 years) had visual acuity < 6/12 in either eye without glasses correctable to > 6/12 with glasses, and were eligible for allocation. Among these, 3052 (96.0%) completed the study.

Interventions: Children were randomized by school (84 schools per arm) to one of three interventions at the beginning of the school year: free glasses provided in class, vouchers for free glasses at a local facility or glasses prescriptions only (Control group).

Main Outcome: Main study outcome was year-end score on a specially-designed mathematics test, adjusted for baseline score, expressed in units of standard deviation (SD).

Results: Among 3177 eligible children, 1036 (32.6%), 988 (31.1%) and 1153 (36.3%) were randomized to Control, Voucher and Free Glasses respectively. All eligible children would benefit from glasses, but only 15% had them at baseline. Intention-to-treat analyses were performed on all 1002 (96.8%), 946 (95.9%) and 1104 (95.8%) children completing final testing in Control, Voucher and Free Glasses groups. Effect on test score was 0.11 SD (95% Confidence Interval [CI] 0.01 to 0.21, p = 0.03) comparing the Free Glasses and Control groups. Adjusted effect of providing free glasses (0.10 SD, 95% CI 0.01 to 0.20; p = 0.04) was greater than parental education (0.03, 95% CI -0.03 to 0.10) or family wealth (0.002, 95% CI -0.07 to 0.07). Closeout glasses wear was 41% (observed), 68% (self-reported) in the Free Glasses group.

Conclusions: Providing free glasses improves children's performance on mathematics testing to a statistically significant degree, despite imperfect compliance. Myopia is common and rarely corrected in this setting.

Introduction

Poor vision is the most common impairment affecting school-aged children in the developing world, comprising 48% of all disability among children aged 5 to 9 years in the India census of 2001.[1] The leading and most easily-remedied cause of visual impairment (visual acuity<6/18) among children is refractive error, affecting 12.8 million children between 5 and 15 years, half of whom live in China.[2] Spectacles provide a safe and inexpensive treatment.   Several studies report that children with uncorrected refractive errors have lower scores on a variety of motor and cognitive tests,[3-6] and that improvements in reading may occur when vision problems are corrected.[6-7]

However, the relationship between academic achievement and refractive error may be complex. Hyperopia (far-sightedness), causing difficulty in seeing close objects, is more likely to cause reading problems, and is the focus of many studies of refractive error and school performance.[5-6] Myopia (near-sightedness) causes difficulty in seeing distant objects, and is more common in school-aged children, particularly in Asia.[8-10] Myopia is responsible for > 90% of poor vision among children in China.[8-9] Prevalence of myopia may exceed 60% in rural areas,[9, 11] 80% in ethnically Chinese urban populations,[12] and two-thirds or more of rural Chinese children with myopia are without accurate correction.[13] The high prevalence of myopia among Chinese children appears to be due in part to high levels of near work related to school, and limited time spent outdoors.[14] Barriers to accessing refractive care include cost and poor quality of available glasses and lack of knowledge about

myopia and the benefits of its correction.[15]

It also appears that higher scholastic attainment is associated with myopia risk.[14] Thus, the directionality of cause and effect between myopia and school performance is unclear. Myopia will not cause near reading difficulties except in extreme cases, but could prevent clearly seeing material on a blackboard. A recent review of school vision screening practices found no randomized trials examining the impact of correcting myopia on school performance.[16] Trials are needed due to the scope of the myopia problem, because the effect of myopia on classroom learning is not well understood, and because only this study design can clarify any causal association between correcting myopia and school outcomes.

We carried out a cluster-randomized, factorial-design, controlled trial in rural western China to evaluate the effect of teaching about the value of glasses and providing free spectacles on rates of glasses wear and school performance. Cluster randomization was used because of the difficulty of assigning children to different interventions at one school. The study hypotheses were: Education promoting glasses wear aimed at school-going children with correctable refractive error, their teachers and parents, and providing such children with free spectacles, will increase children's glasses wear (intermediary hypothesis) and improve their academic performance (main hypothesis).

Methods

The protocol for this study was approved in full by Institutional Review Boards at Stanford University (Palo Alto, USA) and the Zhongshan Ophthalmic Center (Guangzhou, China). Permission was received from local Boards of Education in each region, and the principals of all schools. The principles of the Declaration of Helsinki were followed throughout.

Setting

The study was carried out in two nearby areas of western China. Tianshui prefecture is a poor area[17] in one of China's poorest provinces,[18] Gansu. Yulin prefecture is a relatively well-to-do area[19] in middle-income[18] Shaanxi province.

Sampling and eligibility criteria

A list of all 435 primary schools in the two prefectures was obtained from local education bureaus, and those having < 50 or > 150 students in the 4th and 5th grade together (19% of the sample frame) were eliminated for logistical reasons (Screening at the larger schools could not be reliably completed in a day, which would have interfered with the screening schedule, while smaller schools would be expected to have < 10 children requiring glasses, below our power requirements). One school from each township in the sample was randomly selected, and within each school, one class was randomly chosen in each of the 4th and 5th grades (likely age range 9-12 years). All children at the 252 selected schools meeting the following criteria were eligible:

- Uncorrected (without glasses) visual acuity <= 6/12 in either eye

- Refractive error meeting cutoffs shown to be associated with significantly greater improvement in visual acuity when corrected: [20]

  - Myopia <= -0.75 diopters (D)

  - Hyperopia >= +2.00 D or

  - Astigmatism (Non-spherical refractive error) >= 1.00 D

- Visual acuity could be improved to > 6/12 in both eyes with glasses

Questionnaires

At baseline (September 2012, beginning of the school year), enumerators administered questionnaires to children concerning their age, sex, glasses wear, awareness of their refractive status, belief that wearing glasses harms vision (a common misapprehension in China[13, 21]), boarding at school and parental migration and education. A parental questionnaire asked about ownership of 13 selected items as an index of family wealth. Mathematics teachers were asked to state whether the blackboard (potentially not clearly seen by myopic children) was used for all, most, about half, little or none of teaching.

Visual acuity Assessment

Children underwent baseline visual acuity screening at school by a nurse and trained assistant. Visual acuity was tested separately for each eye without refraction at 4 meters using Early Treatment Diabetic Retinopathy Study charts[22] (Precision Vision, La Salle, IL, USA) in a well-lighted, indoor area. These charts are preferred in vision research because of regular progression in letter size and uniform spacing between lines. The measured visual acuity is based on the precise number of letters read, and thus more accurate and repeatable than with Snellen charts employed in routine clinical practice.

If the orientation of at least four of five optotypes on the 6/60 line was correctly identified, children were examined on the 6/30 line, 6/15 and then line by line to 6/3. Visual acuity for an eye was defined as the lowest line on which 4 of 5 optotypes were read correctly. If the top line could not be read at 4 meters, the subject was tested as above at 1 meter, and the measured visual acuity was divided by 4.

Refraction (Measurement of glasses power)

Children with uncorrected visual acuity <= 6/12 in either eye underwent cycloplegia (pupil dilation) with up to three drops each of cyclopentolate 1% and proparacaine hydrochloride 0.5%, to prevent accommodation (focusing at near) and inaccurate refraction. Children then underwent automated refraction (Topcon KR 8900, Tokyo, Japan) with subjective refinement by a local refractionist, previously trained by experienced optometrists from Zhongshan Ophthalmic Center.

Randomization and Interventions (Figure 1)

This was a cluster-randomized, factorial-design, controlled trial, with schools as the clusters. In October 2012, after the baseline survey and vision screening but prior to refraction, eligible children were randomized by school to receive one of three interventions:

- Free spectacles based on the child's measured refractive power dispensed at school by the study optometrist. A letter informing the parents about the free glasses program and including the child's prescription was sent to parents. (Free Glasses group, 84 schools);

- Vouchers bearing the child's name, school name and glasses prescription, exchangeable for free glasses at the local county hospital (distance from children's township: range 1-105 km, median 30 km). Parents were responsible for paying transportation costs. Vouchers could not be

exchanged or sold, and students were required to produce school identification to redeem them. Children whose families did not redeem their vouchers received free glasses at study closeout, though this was not previously announced. (Voucher group, 84 schools); or

- A glasses prescription and letter to the parents informing them of the refractive status of their child, with free glasses provided only at closeout, though this was not previously announced. (Control group, 84 schools).

Within each group, schools were randomized to receive an educational intervention promoting spectacle wear (Education group) in October 2012, or no education. There were six groups of 42 schools in this 3X2 factorial design (Figure 1). Schools were stratified by five variables, information on which was collected during the baseline survey and screening: county; the total number of students in grade 4 and in grade 5; and the number of students failing vision screening in grade 4 and in grade 5. Within each stratum, a school was randomly assigned to one of the 6 treatment arms. Stratification and random assignment were carried at a central location (Stanford University, Stanford, USA) using R software (R Foundation for Statistical Computing, Vienna, Austria).

Participants (students, parents and teachers) and enumerators were not informed of either the overall design of the study or the explicit treatment arm assignment. Participants were told only that this was a study of vision care among rural, school-aged children. As described above, only one school was selected in each township, minimizing the possibility of cross-arm communication and contamination.

Educational Intervention

Children at Education group schools watched a 10-minute documentary-style video and were given a booklet of cartoons, followed by a classroom discussion led by study personnel. All children in the selected classes, regardless of vision status, participated. These materials showed children experiencing the benefits of glasses and teachers explaining that glasses do not harm vision. Teachers and parents viewed a presentation at school on the safety and benefits of glasses, accompanied by a brochure with similar information, and posters with similar content were hung in classrooms. All materials delivered to children, teachers and parents were designed to convey the same set of messages: Myopia is common in China; glasses provide the safest and most effective treatment of myopia for children; and wearing glasses does not harm children's eyes. Study personnel returned in December 2012 to reinforce these messages, which were based on previous research in rural China.[13, 21, 23]

Outcome Assessment: Mathematics Test and Glasses wear

Separate mathematics tests appropriate for 4th and 5th grade children were administered on printed paper by research personnel at baseline and closeout (May-June 2013: end of the school year). Questions were selected with assistance of local educators from items developed for the Trends in International Mathematics and Science Study (TIMSS, http://timss.bc.edu/home/pdf/TP_About.pdf). The exam was timed (25 minutes) and proctored by two study enumerators at each school. Mathematics was chosen for testing to reduce the effect of home learning on performance, and better focus on classroom learning. At closeout, spectacle wear was assessed through unannounced direct examinations. Children also described their own spectacle wear as "always," "only for studying" or "usually not worn". Study personnel were masked to group assignment.

Sample size

Using Optimal Design software,[24] a sample size of 252 schools with a minimum 10 students per school conferred 90% power, with alpha=0.05, intraclass correlation (ICC)=0.15 and explained variation by covariates (R^2)=0.50, to detect a difference of 0.20 standard deviations (SD) in endline math score between intervention arms and the control group.

Statistical Methods (Analysis performed by XM, MEM, SC)

Baseline and endline math score were standardized for each grade separately to give a mean of 0 and SD of 1 among Control group children at baseline. Baseline wear of glasses was defined as having glasses at school. Family wealth was calculated by summing the value, as reported in the China Rural Household Survey Yearbook (Department of Rural Surveys, National Bureau of Statistics of China, 2013), of items on the list of 13 owned by the family. Refractive power was defined throughout as the spherical equivalent, spherical power plus half the cylindrical power.

All analyses were performed using Stata 12.0 (StataCorp, College Station, TX), calculating robust standard errors to adjust for clustering by school.[25] Randomization groups were compared by intention-to-treat using multiple linear regression, with endline math score as main outcome for the main hypothesis, and intervention arms and baseline math score as covariates. Other baseline variables were investigated as predictors for math score, with the final model including intervention arms and variables associated with baseline math score at $p \leq 0.20$. For the intermediary hypothesis regarding glasses wear, primary outcome was observed wear at closeout, and secondary outcome was self-reported wear ("only for studying" or "always",

compared to "mostly not worn"). For intention to treat analyses with wear as outcome, generalized linear models with Poisson regression were used to estimate the relative risk for intervention arms adjusting for baseline wear and other covariates. One-way analysis of variance was used to estimate the intra-class correlation coefficient as a measure of clustering of endline math score and glasses wear within school. Children with missing data were excluded from analysis.

Results

Among 19,934 children screened at 252 selected schools, 4839 (24.3%) failed visual acuity screening and were randomized (Figure 1). A total of 3177 (65.4%) children in 251 schools were eligible for allocation (visual acuity improving with refraction; one school was excluded because there were no children at that school that met the inclusion criteria) (Table 1). The Voucher group had lower baseline math scores compared with the Control and Free Glasses groups. Tables 1 and 2 show the distribution of various factors between groups at baseline. Figure 2 shows the distribution of refractive power among children allocated in the trial.

Intention-to-treat analyses were performed on all 1002 (96.8%), 946 (95.9%) and 1104 (95.8%) children completing final testing in Control, Voucher and Free Glasses groups in 250 schools (one school was excluded because there were no children at that school providing follow-up data). (Figure 1) Among 123 missing children, 26 (21%) were at home the day of follow-up, 90 (73%) had transferred to other schools, and 7 (6%) had withdrawn from school. Children with follow-up did not differ in any baseline variables compared to those without (data not shown).

Table 3 gives the baseline, endline and change in the mathematics score by study group. Intention-to-treat analyses showed a significant difference in endline score adjusted for baseline score of 0.11 SD (95% CI 0.01 to 0.21; P=0.03) for the Free Glasses group and 0.04 SD (95% CI -0.05 to 0.14; P=0.36) for the Voucher group compared to Control. Unadjusted intraclass correlation coefficient for endline math score was 0.12, adjusted for baseline scores it was 0.08.

In intention-to-treat models adjusting for baseline math score, membership in the Free Glasses group, younger age, residence in Shaanxi and parental education were significantly associated with higher endline math score. Membership in the Voucher group, sex, refractive error, family wealth, boarding at school and parental migration for work were unassociated with endline score. (Table 4) In the full multiple model, baseline score, membership in the Free Glasses group (0.10 SD, 95% CI 0.01 to 0.20; P=0.04), younger age and residence in Shaanxi remained associated with endline score. (Table 4)

In a post-hoc exploratory analysis stratifying by classroom black board use, effect size was larger for children in classrooms where blackboards were utilized more regularly: Among 146 (5.1%) children in classrooms where the blackboard was used for all teaching, the Free Glasses group scored 0.52 SD (95% CI 0.16 to 0.89, P=0.01) higher than controls; in 904 (31.3%) children using the blackboard for most or all teaching, the Free Glasses group scored 0.23SD (95% CI 0.04 to 0.42, P = 0.02) higher; for 1992 (68.9%) children using the blackboard half or more of the time the difference was 0.15 SD (0.03 to 0.26, P = 0.01) and for 899 (31.1%) children receiving little or no blackboard teaching, the difference was -0.003 (95% CI -0.16 to 0.16, P=0.97).

Table 5 shows baseline and endline observed and self-reported spectacle wear among children in the trial. Only 15% of these children needing glasses were wearing them at baseline. Both providing free glasses and vouchers increased spectacle wear compared to controls, as measured by both observed and self-reported wear. Endline

glasses wear was 41% (observed), 68% (self-reported) in the Free Glasses group and 26% (observed), 37% (self-reported) among Controls. The educational intervention increased self-reported but not observed wear (Table 5). No interaction was found between the Glasses and Education interventions on either outcome (data not shown).

Discussion

Principal Findings

Intention-to-treat analysis in this trial found a statistically significant impact on

math test scores among children randomized to receive free glasses. This effect size is

the equivalent of approximately half a semester of additional learning, based on the

report of Hill et al[26] that average annual gains for students between 4th and 5th grades

was 0.4SD. It should be acknowledged that this effect size was smaller than the 0.2

SD specified in our sample size calculations, and smaller than the difference between

the Voucher and Free Glasses groups at baseline (0.14 SD). The choice of 0.2 SD in

our sample size calculations was based on our experience with previous trials in this

region, and was not meant as a cutoff for a meaningful effect. We adjusted for

baseline differences between groups in all our calculations.   Membership in the Free

Glasses group had a greater effect on math test scores than either parental education

or family wealth, and was similar to the effect of residence in middle-income Shaanxi

compared to much poorer Gansu. The fact that effect size increased with increasing

classroom blackboard use (a post-hoc analysis) adds biological plausibility, as

reliance on blackboards created greater distance vision demands for myopic children.

The voucher intervention was explored because vouchers are logistically easier to

implement than school-based distribution glasses distribution. We speculate no

significant effect on test scores was found in the Voucher group due the combined

influence of slightly lower rates of spectacle wear in the Voucher versus Free group,

and slightly shorter opportunity for glasses wear to affect learning in the Voucher

group due to the logistics of securing spectacles (though 85% of families did redeem their vouchers in the first three weeks after receiving them).

We observed a statistically-significant impact of providing spectacles on academic performance even though compliance with wear was imperfect. New approaches to encourage glasses use may further increase academic benefits. We are studying teacher incentives to promote glasses use in the classroom in a separate trial.

Strengths and limitations of the study

Strengths of this study include population-based sampling, a randomized controlled design and high participation and follow-up rates, all of which increase confidence in the findings. However, all schools were in rural northwest China, which limits external validity with reference to other populations. Other weaknesses include the fact that masking of subjects was not practical. Compliance with glasses was imperfect, and day-to-day spectacle use was not assessed, making it difficult to accurately identify children with the most regular wear to gauge effect size among them.

Two of our inclusion criteria, enrolling children already wearing glasses (n=477, 15.0%) and those with poor vision in only one eye (n=385, 12.1%), might have decreased effect size. Children already wearing glasses were included (and re-refracted) in view of reports of poor glasses quality in rural China.[27] Excluding these groups did not change our results (data not shown).

Comparison with other studies

We searched the PubMed database in January 2014 for articles in any language

published since 1970, using the terms "correction" cross-indexed with "refractive error" and "myopia"; "school," "educational" and "academic"; and "impact," "outcomes" and "performance." Some uncontrolled studies have reported lower achievement scores among children with uncorrected, mostly hyperopic, refractive error,[3-6] though a Singapore study of predominantly myopic children found no association between distance VA and later academic performance.[28] We found no randomized trials addressing the impact of correcting refractive error on school performance, nor did a recent systematic review.[16]

A recent, unpublished review of randomized trials with educational outcomes in primary schools in the developing world (McEwan PJ. Improving Learning in Primary Schools of Developing Countries: A Meta-Analysis of Randomized Experiments. http://academics.wellesley.edu/Economics/mcewan/PDF/meta.pdf, accessed 17 January 2014) listed 60 health-related trials, including 22 of de-worming, with a mean effect size of 0.013 SD, and 38 of nutritional or micronutrient supplementation, with a mean effect size of 0.035 SD. It appears the effect size on education outcomes of spectacle provision in this study compares favorably with that of other health-related interventions.

Conclusions and policy implications

Myopia is common among rural Chinese children, and increases with age.[14] Even in these relatively young children, one in six (15.9%) had poor vision due to refractive error. Only 15% of these children needing glasses had them, and the number using glasses could be nearly doubled by providing them free compared to giving a

prescription (Table 4). Data from our baseline survey showed that the median price paid for glasses among children owning them was approximately USD60. This represents nearly half the monthly income for rural families in China of USD130 in 2012.[29] While cost is a very significant barrier for families in obtaining glasses, high-quality spectacles can be purchased in bulk for < USD5, which would make them affordable for government programs. In fact, a pilot program has now started in Shaanxi Province to provide free glasses to children as a result of this project, with the possibility of expansion province-wide if successful.

China's rural health insurance system (the New Cooperative Medical Scheme) covered 96% of rural dwellers by 2011,[30] and has begun experimenting in limited areas with providing free glasses.   Results of our trial suggest this inexpensive intervention may be effective in improving academic performance among rural children, and that wider coverage under the New Cooperative Medical Scheme may be warranted. As an important reason for non-wear of glasses in China is the widespread perception that spectacle wear can harm children's vision,[13, 31] we will present data in a separate manuscript on the effect of providing glasses on one-year change in uncorrected visual acuity.

What this paper adds

➢   What is already known on this subject:

• It appears children with uncorrected hyperopia (far-sightedness) have lower test scores,[3-6] and that their reading improves with refractive correction,[8-9] but the

impact on classroom learning of myopia (near-sightedness), the leading cause of vision impairment in school-aged children, is not well understood.

- Higher scholastic achievement may increase myopia risk,[15] so the direction of cause and effect between myopia and school attainment is not clear.

- Randomized trials are needed to assess the impact of myopia on academic achievement, and to determine the direction of any cause and effect, but no published trials exist.

➢ What this study adds:

- Using intention-to-treat analysis in a clinical trial, children randomized to receive spectacles over a school year had statistically significantly higher scores than control children on a study-specific mathematics test.

- Effect size increased with increasing blackboard use during teaching, which is biologically plausible due to greater distance vision demands of the blackboard on myopic children.

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Date integrity: All of the authors had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Transparency: Dr Nathan Congdon (the manuscript's guarantor) affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained

Data analysis: Mirjam Meltzer, Xiaochen Ma and Saskia Le Cessie conducted and are responsible for the data analysis.

Data sharing: The full dataset and statistical code are available at www.stanford.edu/REAP with open access The presented data are anonymized and risk of identification is low.

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Figure legends

Figure 1: Enrollment and progress of children through the study

Figure 2: Distribution of spherical equivalent refractive error in the more myopic eye among rural children with uncorrected visual acuity <= 6/12 in at least one eye recruited into the trial

Table 1. Baseline characteristics of 3177 children with correctable refractive error allocated in the trial, by group assignment with regard to the free spectacle intervention.

Characteristics	Control Group n=1036*	Voucher Group n=988*	Free Glasses Group n=1153*	Missing Data (%)
Individual level				
Age (years)	10.5 (1.1)	10.5 (1.1)	10.4 (1.1)	3 (0.09)
Male sex	517 (49.9)	474 (48.0)	563 (48.8)	0 (0)
Wearing glasses at baseline†	144 (13.9)	138 (14.0)	181 (15.7)	0 (0)
Gansu residence (%)	397 (38.3)	356 (36.0)	405 (35.1)	0 (0)
Refractive error				
<-2 D	410 (39.6)	374 (37.9)	431 (37.4)	
>=-2 – -0.5 D	560 (54.1)	547 (55.4)	665 (57.7)	2 (0.06)
>=-0.5 – 0.5D	18 (1.7)	17 (1.7)	10 (0.9)	
>=0.5 D	47 (4.5)	49 (5.0)	47 (4.1)	
Uncorrected visual acuity < 6/18, better-seeing eye	602 (58.1)	525 (53.1)	686 (59.5)	0 (0)
Baseline standardized mathematics score (SD)	0.22 (1.01)	0.14 (0.98)	0.28 (0.98)	1 (0.03)
One or both parents with >= 12 years of education	211 (20.5)	174 (17.8)	259 (22.8)	32 (1.01)
Family wealth:				
Bottom tercile	317 (32.4)	338 (36.0)	355 (31.9)	
Middle tercile	356 (36.4)	313 (33.3)	342 (30.7)	145 (4.56)
Top tercile	306 (31.3)	289 (30.7)	416 (37.4)	
Boarding at school	235 (22.7)	183 (18.5)	286 (24.8)	3 (0.09)
Both parents out-migrated for work	112 (10.9)	100 (10.2)	105 (9.2)	30 (0.9)
Blackboard use in class:				
Little or none	266 (26.5)	248 (26.2)	442 (40.0)	
Half of the time	422 (42.1)	383 (40.4)	347 (31.4)	123 (3.9)
Most or all	315 (31.4)	316 (33.4)	315 (28.5)	
Cluster level				
Grade level (Mean number/cluster (SD)):				
4th grade	5.0 (3.4)	4.6 (3.7)	5.5 (4.8)	0 (0)
5th grade	7.3 (4.5)	7.3 (4.8)	8.3 (5.3)	
Uncorrected visual acuity < 6/18, better-seeing eye (Mean number/cluster (SD))	7.2 (4.7)	6.3 (5.0)	8.2 (6.1)	0 (0)

D = diopter SE = spherical equivalent refractive error

*Data are means (SD) or numbers (%) unless otherwise stated.

† Defined as having glasses at school at baseline, having previously been told to bring them to school

Table 2 Baseline characteristics of children with correctable refractive error allocated in the trial, by group assignment with regard to the educational intervention.

Characteristic	Education on Importance of Glasses n=1648*	No Education n=1529*	Missing Data (%)
Individual level			
Age (years)	10.5 (1.1)	10.5 (1.1)	3 (0.09)
Male sex	794 (48.2)	760 (49.7)	0 (0)
Gansu residence	603 (38.0)	525 (35.7)	0 (0)
Wearing glasses at baseline†	221 (13.4)	242 (15.8)	0 (0)
Aware of having refractive error at baseline	736 (45.0)	728 (47.8)	20 (0.63)
Believes wearing glasses harms vision	686 (41.6)	591 (38.7)	0 (0)
Refractive error			
<-2 D	630 (38.3)	585 (38.3)	
>=-2 – -0.5 D	913 (55.5)	859 (56.2)	2 (0.06)
>=-0.5 – 0.5D	27 (1.6)	18 (1.2)	
>=0.5 D	76 (4.6)	67 (4.4)	
Uncorrected visual acuity < 6/18, better-seeing eye	936 (56.8)	877 (57.4)	0 (0)
One or both parents with >= 12 years of education	335 (20.5)	309 (20.4)	32 (1.01)
Family wealth:			
Bottom tercile	535 (34.0)	475 (32.6)	145 (4.56)
Middle tercile	537 (34.1)	474 (32.6)	
Top tercile	504 (32.0)	507 (34.8)	
Boarding at school	379 (23.0)	325 (21.3)	3 (0.09)
Both parents out-migrated for work	165 (10.1)	152 (10.0)	30 (0.94)
Cluster level			
Grade level (Mean number/cluster (SD)):			
4th grade	5.3 (4.1)	4.8 (3.9)	0 (0)
5th grade	7.8 (4.9)	7.5 (4.9)	
Uncorrected visual acuity < 6/18, better-seeing eye (Mean number/cluster (SD))	7.4 (5.5)	7.0 (5.2)	0 (0)

D diopter   spherical equivalent refractive error

*Data are means (SD) or numbers (%) unless otherwise stated.

† Defined as having glasses at school at baseline, having previously been told to bring them to school

Table 3. **Effect of treatment arms on endline standardized mathematics score controlling for baseline score (Bold type indicates comparisons for which the 95% Confidence Interval for effect size does not cross zero)**

Intervention group	N	Mean baseline score (SD)	Mean endline score (SD)	Unadjusted change in score (95%CI)	Difference in endline score adjusted for baseline score¶ compared with Control group
TOTAL*	3052	0.22 (0.98)	0.34 (0.98)	**0.12 (0.08, 0.17)**	
Control	1002	0.23 (1.00)	0.30 (1.00)	0.06 (-0.004, 0.13)	(reference)
Voucher	946	0.13 (0.98)	0.28 (0.98)	**0.15 (0.08, 0.22)**	0.04 (-0.05,0.14)
Free Glasses	1104	0.29 (0.97)	0.44 (0.96)	**0.15 (0.07, 0.24)**	**0.11 (0.01,0.21)**
No education	1467	0.15 (1.00)	0.31 (1.01)	**0.15 (0.09, 0.22)**	(reference)
Education	1585	0.28 (0.96)	0.38 (0.96)	**0.09 (0.03, 0.16)**	-0.01 (-0.09,0.07)
Control No education	489	0.20 (1.04)	0.26 (1.06)	0.06 (-0.04, 0.16)	(reference)
Control + Education	513	0.26 (0.97)	0.33 (0.94)	0.07 (-0.03, 0.17)	0.03 (-0.12,0.18)
Voucher No education	472	0.08 (0.98)	0.29 (0.97)	**0.21 (0.12, 0.31)**	0.10 (-0.03,0.24)
Voucher + Education	474	0.18 (0.98)	0.27 (1.00)	0.09 (-0.02, 0.19)	0.02 (-0.12,0.16)
Free glasses No education	506	0.17 (0.99)	0.36 (1.00)	**0.19 (0.07, 0.31)**	0.12 (-0.03,0.27)
Free glasses + Education	598	0.38 (0.94)	0.50 (0.93)	**0.12 (0.01, 0.24)**	0.14 (-0.01.0.28)

* 2 students had missing data for the endline math score

SD= Standard deviation 95% CI = 95% Confidence Interval

¶ Linear regression using endline math score as dependent variable and adjusting for baseline math score

Table 4: Linear regression model of potential predictors of endline math score. (Bold type indicates comparisons for which the 95% Confidence Interval for effect size does not cross zero)

Characteristics	Model adjusted for baseline math score (n=3052)		Full model‡ (n=2891)	
	Regression coefficient* (95%CI)	P-value	Regression coefficient (95%CI)	P-value
Baseline standardized mathematics score (SD)	**0.59 (0.56,0.62)**	**<0.001**	**0.56 (0.53,0.59)**	**<0.001**
Intervention group (Control group as reference)				
Voucher Group	0.04 (-0.05,0.14)	0.36	0.03 (-0.06,0.13)	0.50
Free Glasses Group	**0.11 (0.01,0.21)**	**0.03**	**0.10 (0.01,0.20)**	**0.04**
Age (years)	**-0.14 (-0.17,-0.11)**	**<0.001**	**-0.14 (-0.17,-0.10)**	**<0.001**
Male sex	-0.01 (-0.07,0.04)	0.62		
Wearing glasses at baseline	0.05 (-0.03,0.13)	0.23		
Gansu residence	**-0.16 (-0.25,-0.08)**	**<0.001**	**-0.12 (-0.21,-0.03)**	**0.01**
Refractive error (>=-0.5D – 0.5D as reference)				
<-2 D	0.14 (-0.16,0.44)	0.35		
-2 D – -0.5 D	0.10 (-0.21,0.40)	0.53		
>=0.5 D	0.13 (-0.18,0.44)	0.41		
One or both parents with >= 12 years of education	**0.07 (0.004,0.13)**	**0.04**	0.03 (-0.03,0.10)	0.33
Family wealth (poorest tercile as reference)				
Middle tercile	0.05 (-0.02,0.12)	0.13	0.02 (-0.04,0.09)	0.50
Richest tercile	0.06 (-0.01,0.13)	0.08	0.002 (-0.07,0.07)	0.95
Boarding at school	0.05 (-0.03,0.14)	0.20	0.02 (-0.06,0.10)	0.59
Both parents out-migrated for work	0.01 (-0.08,0.11)	0.79		

* Except for the regression coefficient for baseline math score (simple regression), coefficients for the different variables are for multiple models with endline math score as dependent variable, adjusted for baseline math score

‡Including variables associated with endline math score p<0.20 in the model also including baseline math score

95% CI   95% Confidence interval, D diopter,   SD Standard deviation