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ORIGINAL RESEARCH

Does Performing the Chinese Eye Exercises Help Protect Children's Vision? – New Evidence from Primary Schools in Rural Northwestern China

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Background: The high prevalence of myopia among school-age children in China has raised serious concerns about protecting Chinese students' vision. While the regular performance of the Chinese eye exercises has been adopted as a preventive approach in China since the mid-1960s, these exercises' effectiveness at protecting students' vision has remained largely unknown. This study attempts to provide new evidence of the impact of regularly performing the exercises on Chinese students' visual outcomes, based on a large-scale dataset.

Methods: A school-based survey was conducted among 9842 randomly selected students (fourth graders) from 252 primary schools in rural Northwestern China in 2012. To address potential estimation bias, we adopted both an instrumental variable (IV) approach and a bivariate-probit model to estimate the impacts on students' visual acuity and the incidences of visual impairment and myopia.

Results: Both IV and bivariate-probit estimates reveal a detrimental impact of regularly performing the Chinese eye exercises on students' vision. Compared with students who did not regularly perform the exercises, those who did were 6.2 percentage points more likely to have impaired vision and 7.6 percentage points more likely to be myopic. The estimates are robust to different estimation strategies, various specifications, and the majority of subsamples.

Conclusion: Under the assumption that the correct performance of the Chinese eye exercises would not undermine students' vision, our findings suggest that the commonly-observed incorrect performance of these exercises among Chinese students imposes non-trivial threats to their vision health.

Keywords: Chinese eye exercises, visual impairment, myopia, instrumental variables, bivariate-probit, primary school

Introduction

The high prevalence of myopia among school-age children has been a significant health concern in China. In 2018, approximately 36% of primary school students, 72% of middle school students, and 81% of high school students in China were near-sighted.[1] Not only is myopia itself an undesirable health outcome, but it may also undermine children's learning if proper vision correction measures (eg, wearing eyeglasses or surgery) are not adopted.[2,3] The rapidly rising myopia prevalence, which has reached epidemic levels among middle and high schoolers in recent decades,[4–7] has triggered renewed concerns about protecting Chinese students' vision.

The high myopia prevalence in China dated back to the early 1960s.[8] In reaction to this problem, the Chinese government adopted a preventive approach in the mid-1960s,

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promoting the regular performance of the Chinese eye exercises among primary and secondary school students.[8] The Chinese eye exercises, taking the form of self-massage of periocular acupoints, were developed based on principles of traditional Chinese Massage Therapy by Chinese medical professionals. These exercises were expected to protect one's vision by promoting blood circulation around the eyes, relaxing extraocular muscles, and reducing eye fatigue.[9] However, despite more than half a century's practice, whether these exercises are effective has remained largely unknown. While some studies reported that students who regularly performed the exercises were less likely to develop myopia,[10–12] others found little impact of performing these exercises.[13–16]

Two factors may help explain why previous studies have failed to reach a consensus. First, there may be estimation biases in previous findings. To our knowledge, there has been no large-scale randomized controlled trial (RCT) conducted to evaluate the effectiveness of the Chinese eye exercises (—there do exist a small number of small-scale RCTs,[9,17] but the external validity of these studies is questionable). Nor are large-scale RCTs still feasible after the Chinese eye exercises have become a daily ritual among Chinese students. In particular, the requirement that some students must be assigned to the control group and stop performing the exercises (perhaps for years) is considered unethical by education authorities.[17] Such an institutional setting creates room for unobserved confounding factors to contaminate previous estimates of these exercises' effectiveness. For example, students who care more about their vision may perform these exercises more regularly, perhaps also seeking additional measures (eg, reducing screen time) to protect their vision. If these factors' influences are not adequately accounted for in the analysis, the estimated effects of performing these exercises may be biased.

Second, even if RCTs are feasible, the Chinese eye exercises' actual effectiveness may be masked by students' incorrect performance. It has been discovered that many Chinese students failed to perform the exercises correctly (eg, failing to find the exact periocular acupoints and to exert accurate pressure), even though they have performed them daily for years.[18,19] Incorrect precision and rhythm of finger massage may reduce the exercises' effect;[18] finger pressure not exerted at the optimal level may even cause physical damage to the eyes;[20] insufficient attention paid to hand sanitation may also cause infection in the eyes.[19] Therefore, even if the Chinese eye exercises are effective when performed correctly, the commonly-observed incorrect performance among students may have prevented previous studies from detecting their actual effect.

These two factors render it difficult (if not entirely impossible) to evaluate the effectiveness of the Chinese eye exercises themselves. However, it is still possible to assess the effect of regularly performing these exercises on students' vision. The impact of performing the exercises is of great policy relevance: it is the combination of the effectiveness of the exercises themselves and the effect of students' performance (whether correct or not) that ultimately affects their vision. Since China has recently enacted its Comprehensive Plan to Prevent Myopia among School-age Children (2018–2030),[21] which stipulates that "all primary and secondary schools ought to organize their students to perform the Chinese eye exercises twice a day", how students' performance of these exercises impacts their vision merits empirical scrutiny. This study attempts to provide new causal estimates of this impact by analyzing a large dataset involving 9842 fourth graders from 252 primary schools in rural Northwestern China.

To address potential estimation bias, this study adopts an instrumental-variable (IV) approach, which has been widely used in economic research[22] and gained popularity in public health and medical studies in recent decades.[23–30] Specifically, we use an indicator of whether a school plays the official companion music to urge its students to perform the Chinese eye exercises as an IV for their eye-exercise performing frequency. A bivariate-probit model is also estimated to account for the binary nature of two outcome variables of interest, incidences of visual impairment (reduced uncorrected visual acuity) and myopia. Since the identification of a bivariate-probit model does not require extra IVs but instead relies on the nonlinear and recursive structure of the model, bivariate-probit estimates serve as a check for the validity of our IV estimates.

Data

Sampling

Our data were collected through a school-based survey project conducted in rural areas of two Northwestern provinces in China, Shaanxi and Gansu, in 2012, in collaboration between Stanford University and Shaanxi Normal University. These two provinces are relatively underdeveloped compared to other regions of China. Official statistics indicate that in 2012, rural households' per capita incomes in Shaanxi and Gansu were, respectively, 31.3%

and 46.3% lower than the national figure.[31] To conform with international medical and public health research standards, the study received ethical approval from the Stanford University Institutional Review Board (No. ISRCTN03252665). All necessary permissions were obtained from the Chinese government. The parents and participants were informed about the purpose of the study, and that it was conducted in accordance with the Declaration of Helsinki. All participating students and their legal guardians provided written consent to participate in the project.

The study sample was collected using a multi-stage, random-sampling procedure. First, a list of all primary schools in two prefectures in the study area, prefecture Y in Shaanxi and a neighboring prefecture, T, in Gansu, was compiled (—due to data sensitivity, we are not allowed to disclose the names of these prefectures). Eighteen (18) of the 19 counties in these two prefectures, 11 in prefecture Y and 7 in prefecture T, were included in the sampling framework (—one county from prefecture Y was excluded from the study due to its small population size). Based on the list of schools, we initially selected one school randomly from each township in the 18 counties. But for logistics reasons, we restricted the choice of schools to those with 50–150 enrolled students from among the initially selected schools—a total of 252 schools, 132 in prefecture Y and 120 in T, were selected. Finally, one 4th Grade class from each sampled school was randomly chosen as the participating class. These steps yielded a study sample involving 9842 students. The size of the analytical sample is somewhat smaller due to missing information.

Survey Instrument and Variable Construction

The survey collected two sets of information on sampled students. The first, on students' personal, family, and school characteristics, was collected through streamlined questionnaires filled out by sampled students and relevant teachers during class; guidance and supervision were provided by trained enumerators when needed.

The second set concerns students' vision outcomes. With assistance from a nursing team trained in the Zhongshan Ophthalmic Center of Sun Yat-sen University, the research team administered a vision test to each sampled student on a school day. Student's uncorrected visual acuity was measured by ETDRS (Early Treatment Diabetic Retinopathy Study) charts, the world-wide standard instrument for assessing visual acuity.[13,32] (The vision screening lasted around ten days, conducted by a total of 26 optometry teams. Each team consisted of three members, one optometrist, one nurse, and one staff assistant, all trained by trainers from Zhongshan Ophthalmic Center, Sun Yat-sen University. To ensure the reliability of screening results, children with uncorrected visual acuity ≤ 0.5 in either eye underwent cycloplegia with up to three drops of cyclopentolate 1% in each eye, after anesthesia with topical proparacaine hydrochloride 0.5%, to prevent inaccurate refraction. They 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.)

To facilitate empirical analysis, we used the vision test results to create three outcome variables. The first is a continuous variable reflecting students' uncorrected visual acuity (V_{acuity}). Since the ETDRS-chart screening results in a discontinuous, multi-valued variable, we converted the results into the *LogMAR* (Logarithm of the minimal angle of resolution) scale, the most commonly-used continuous vision measure in ophthalmological research.[13,32] Mathematically, *LogMAR* is the logarithm of the inverse of uncorrected visual acuity:

$$LogMAR = log_{10}\left(\frac{1}{V_{acuity}}\right) \qquad (1)$$

Higher values of *LogMAR* indicate worse visual acuity. Each increment of the value of *LogMAR* corresponds to approximately one line of visual acuity loss in the ETDRS chart.

While the continuous outcome, *LogMAR*, provides more variation in students' visual acuity for estimation, estimation results based on this variable are not very intuitive. Thus, we also examine two more intuitive outcomes, the incidences of visual impairment (reduced uncorrected visual acuity) and myopia. Following the standard practice in the literature,[32–35] we define visual impairment ($V_{impaired}$) as an indicator of whether one's uncorrected visual acuity in either eye is $\leq$ 0.5:

$$V_{impaired} = 1\left(\text{uncorrected}\,\mathrm{V}_{\text{acuity}} \leq 0.5\,\text{in either eye}\right) \qquad (2)$$

and define myopia (V_{myopia}) as an indicator of whether spherical equivalent reflect error of an eye is $\leq$ - 0.50 D when ocular accommodation is relaxed:[36]

$$V_{myopia} = 1\left(\begin{array}{l}\text{spherical equivalent reflective error}\\ \text{of an eye } \leq -0.5\,\text{D when ocular}\\ \text{accomodation is relexed}\end{array}\right) \quad (3)$$

Explanatory variables come from three levels: (1) student-level factors include gender, age, and eye-exercise performance status; (2) household-level factors include parental education, occupation (whether being a migrant worker), and household wealth (an index constructed by summing the values of 16 selected durable items, using the price information provided by the China Rural Household Survey Yearbook);[37] (3) school-level factors include student-teacher ratio and classmates' vision status. These variables are created from participants' answers to survey questions and are self-explanatory.

Sample Characteristics and Descriptive Patterns

Table 1 presents summary statistics of these variables for all sample students (4th graders) and separately by their eye-exercise performance status. The students were, on average, 10.1 years old; 52% of them are male. Their fathers and mothers had completed only 7.8 and 6.2 years of schooling, respectively. Migration had become much more active in the study area than a decade ago:[38] nearly half (45.4%) of fathers and one-fifth (18%) mothers were migrant workers at the time of the survey. Most families in the sample had a television (93%) and a washing machine (81%). In contrast, less than 6% of households owned air conditioners, and less than 15% owned cars.

Turning to sample students' vision outcomes, Table 1, column 1 indicates that approximately 21% of students had impaired vision. Somewhat counterintuitively, students who performed the Chinese eye exercises regularly (59.6% of the sample) were more likely to have impaired vision than those who did not (22.4% versus 19.4%, see columns 2 and 3). However, such a bivariate relationship does not necessarily imply causality from regular eye-exercise performance to worse visual outcomes, because this relationship is observed without netting out the influences of potential confounding factors. There are indeed statistically significant differences in family background characteristics between regular and non-regular eye-exercise performers (column 4). For example, regular performers came from relatively wealthier families. Their families may be able to afford more luxurious entertainment, especially electronic products (eg, video games), which may impose threats to their visual health through lengthened screen time. Regular eye-exercise performers also seem to be enrolled in better schools (eg, those with higher teacher-to-student ratios). It could be that their schools value students' academic performance more, setting higher learning objectives, thus imposing more burden on their visual health. Given these possibilities, a more credible relationship may emerge after potentially confounding factors have been appropriately controlled for. The next section is devoted to the development of an empirical framework for this purpose.

Empirical Method

Conceptually speaking, a student's vision outcome ($V_{outcome}$) is potentially affected by whether he/she performs the Chinese eye exercises regularly (P_{CEE}, =1 if yes and = 0 otherwise), as well as a set of factors **X** that vary at the personal, household, and school levels (discussed in Survey Instrument and Variable Construction), through a "vision health production function" f:

$$V_{outcome} = f(P_{CEE}, \mathbf{X}) \quad (4)$$

As noted above, there are three outcome variables of interest. The first, continuous outcome, defined in Equation 1, reflects students' uncorrected visual acuity ($logMAR$). The second and third are binary indicators of visual impairment ($V_{impaired}$) and myopia (V_{myopia}), defined respectively in Equations 2 and 3. Considering the different nature of these outcome variables, we adopt two different approaches to estimate Equation 4.

Instrumental-Variable Approach

To develop an estimable model for the uncorrected visual acuity, linearize Equation 4:

$$logMAR = \beta_0 + \beta_1 P_{CEE} + \mathbf{X}\beta_x + u \quad (5)$$

where an error term u is added to capture the influences of unobserved factors (eg, diligence in studying) and random disturbances. The parameter of primary interest, β_1, measures the causal effect of performing the Chinese eye exercises regularly on one's uncorrected visual acuity. If Equation 5 is well-specified, such that conditional on **X**, whether a student performs these exercises regularly (P_{CEE}) is uncorrelated with u, then β_1 can be consistently estimated by ordinary least squares (OLS) techniques.

However, P_{CEE} can be correlated with the error term u (thus being "endogenous"), for two reasons. First, there

Table 1 Summary Statistics, by Eye-Exercise Performance Frequency

	(1)	(2)	(3)	(4)
	Full Sample	**Students Performing Eye Exercises Regularly**	**Students Not Performing Eye Exercises Regularly**	**Difference = (2) – (3)**
A.Visual outcomes				
Uncorrected visual acuity (raw)	0.730 (0.275)	0.721 (0.277)	0.745 (0.271)	−0.024*** [0.006]
LogMAR (defined in Equation 1)	0.188 (0.251)	0.195 (0.250)	0.179 (0.252)	0.016*** [0.005]
Vision impairment ($V_{impaired}$, defined in Equation 2)	0.212 (0.409)	0.224 (0.417)	0.194 (0.396)	0.030*** [0.008]
Myopia (V_{myopia}, defined in Equation 3)	0.154 (0.361)	0.167 (0.373)	0.133 (0.340)	0.034*** [0.008]
B.Student/family characteristics				
Male (dummy, =1 if yes)	0.524 (0.499)	0.515 (0.500)	0.536 (0.499)	−0.021** [0.010]
Age (years)	10.062 (1.044)	10.065 (1.009)	10.060 (1.093)	0.005 [0.216]
Father's education (years)	7.824 (3.321)	7.838 (3.446)	7.802 (3.127)	0.036 [0.069]
Mother's education (years)	6.232 (3.966)	6.250 (4.119)	6.205 (3.730)	0.045 [0.082]
Father is a migrant worker (dummy, =1 if yes)	0.454 (0.498)	0.440 (0.496)	0.476 (0.500)	−0.036*** [0.010]
Mother is a migrant worker (dummy, =1 if yes)	0.183 (0.387)	0.172 (0.377)	0.200 (0.400)	−0.029*** [0.008]
Household wealth (RMB, in log)	9.652 (0.973)	9.771 (1.019)	9.481 (0.873)	0.290*** [0.021]
C.School/teacher characteristics				
Teacher-student ratio	0.075 (0.036)	0.078 (0.035)	0.071 (0.037)	0.007*** [0.001]
Proportion of classmates with eyeglasses	0.032 (0.036)	0.033 (0.037)	0.031 (0.035)	0.002** [0.001]
School playing eye-exercise music (dummy, =1 if yes)	0.779 (0.415)	0.923 (0.267)	0.562 (0.496)	0.360*** [0.008]
N	9737	5805	3932	

Notes: Source: Author's survey. 1. Columns 1–3 report means and standard deviations (in parentheses) of variables; column 4 reports *t*-test results for differences in means between columns 2 and 3 (standard errors in brackets). 2. One US dollar = 6.81 RMB in 2012. 3. ***p<0.01, **p<0.05.

may exist unobserved factors that affect a student's eye-exercise performing status and visual outcomes simultaneously, causing omitted-variable bias in the OLS estimate of β_1. In particular, students who care more about their vision health may perform eye exercises more regularly and adopt some other measures (eg, reducing screen time) to protect their vision. Failing to control for these additional vision-protecting measures is likely to cause an upward bias in OLS estimates of β_1. Second, there may be reverse causality from students' vision outcomes to their eye-exercise performing status. For example, some students, noticing their visual acuity is falling, may start to perform eye exercises more frequently. Such a reverse causality, triggered by one's response to his/her worsening eyesight, will lead to a downward bias in the OLS estimate of β_1. Since these problems can bias the OLS estimate in opposite directions, the sign and magnitude of the ultimate bias are ambiguous in theory. Empirical methods that can address these issues are needed to obtain credible estimates of β_1.

In a cross-sectional observational setting, the standard approach to addressing the potential endogeneity in P_{CEE} is to find an instrument variable (IV) for it.[22–30] A valid IV should affect students' vision only through its impact on their eye-exercises performing status (P_{CEE}). More specifically, two conditions must hold for a valid IV: (a) being *exogenous*, ie, uncorrelated with the error term u; (b) being *relevant*, ie, strongly correlated with P_{CEE}, conditional on $\mathbf{X}$.[22–30] In the context of this study, a natural candidate IV is an indicator of whether a school plays the official music for performing the Chinese eye exercises (M_{CEE}) during class breaks, to remind its students that "it is time for eye exercises." Whether a school plays the music at the scheduled time is arguably out of a student's control (thus being *exogenous*). Moreover, while the music may induce many students to perform the exercises at school (who would otherwise do something else) during class breaks)), it is unlikely to affect students' vision outcomes directly. With this IV at hand, Equation 5 can be estimated, along with the following first-stage equation,

$$V_{impaired} = \alpha_0 + \alpha_1 M_{CEE} + \mathbf{X}\alpha_x + v \tag{6}$$

in a two-stage least-squares (2SLS) framework.[22–30]

However, one potential concern is that M_{CEE} may affect students' vision not only through their eye-exercise performance but also through some unobserved channels. For example, schools that play the official eye-exercise music may pay more attention to students' vision health and adopt some measures not recorded in the data (eg, providing more frequent vision check-ups) to protect their vision. To help address this concern, we control for the proportion of one's classmates who wear eyeglasses in the model. The rationale is: if schools adopted additional (unobserved) measures to protect student vision, the effects of these measures are presumably "absorbed" by one's classmates' vision outcomes. The inclusion of this variable also helps to control for students' motivation to protect their vision—seeing many classmates wearing eyeglasses may induce a student to feel an urgent need to protect his/her own vision. The inclusion of other school characteristics such as teacher-to-student ratio is also helpful because a higher teacher-to-student ratio usually implies more teachers' attention paid to students' vision health and their eye-exercise performing status.

Bivariate-Probit Approach

To further examine the impact of performing the Chinese eye exercises regularly on the incidence of visual impairment, we replace the outcome variable in Equation 5 with an indicator of whether a student's uncorrected visual acuity is $\leq$ 0.5 in either eye ($V_{impaired}$):

$$V_{impaired} = \gamma_0 + \gamma_1 P_{CEE} + \mathbf{X}\gamma_x + \varepsilon \tag{7}$$

Although the binary outcome variable in Equation 7 suggests a probit/logit specification, it is informative to estimate a linear probability model first and compare results with the continuous-outcome model. The linear probability model's primary limitation is that its predicted values may not lie within the unit interval, which renders the interpretation of these predicted values as "fitted probabilities" problematic. (Another, relatively minor problem is the inherited heteroscedasticity, which can be handled by estimating White's (1980)[39] robust standard errors). Yet if all predicted values lie within the unit interval, the linear probability model has the advantage that the coefficient γ_1 can be directly interpreted as the "partial effect" of performing the Chinese eye exercises regularly on one's likelihood of having impaired vision. When estimating a linear probability model, potential endogeneity in P_{CEE} can also be addressed by the IV approach discussed above—the same first-stage regression, Equation 6, would be estimated along with Equation 7 using 2SLS.

To further account for the binary nature of $V_{impaired}$, while simultaneously addressing potential endogeneity in P_{CEE}, we adopt a bivariate-probit approach.[22,40] Based on a latent-variable specification, the bivariate-probit model in our context is of the form:

$$V_{impaired}^{*} = \eta_0 + \eta_1 P_{CEE} + \mathbf{X}_v \eta_v + \varepsilon_v, V_{impaired} = 1 \; if \; V_{impaired}^{*} > 0 \quad (8)$$

$$P_{CEE}^{*} = \delta_0 + \mathbf{X}_p \delta_p + \varepsilon_p, \; P_{CEE} = 1 \; if \; P_{CEE}^{*} > 0 \quad (9)$$

where $V_{impaired}^{*}$ and P_{CEE}^{*} are the latent variables determining the observed values of $V_{impaired}$ and P_{CEE}, respectively; the error terms, ε_v and ε_p, are assumed to follow a bivariate normal distribution:

$$\begin{pmatrix} \varepsilon_v \\ \varepsilon_p \end{pmatrix} | \mathbf{X}_v, \mathbf{X}_p \Bigg) \tilde{} \; Normal \left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \rho \\ \rho & 1 \end{pmatrix} \right] \quad (10)$$

A desirable feature of the bivariate-probit model is that parameter identification can be achieved by maximum likelihood estimation (MLE), without special attention paid to the endogenous nature of P_{CEE}—the recursive structure of the model (Equations 8 and 9) and the assumed bivariate-normal distribution of the error terms suffice for parameter identification.[27,35] This feature also suggests that we can use bivariate-probit estimates to assess the validity of 2SLS estimates.

To see how the parameters may be identified without relying on IVs, consider first one of the four conditional probabilities of being myopic given the values of P_{CEE} that enters the log-likelihood function: $\text{Prob}(V_{impaired} = 1, P_{CEE} = 1) = \text{Prob}(V_{impaired} = 1 | P_{CEE} = 1) \times \text{Prob}(P_{CEE} = 1)$.

Given the setup of Equations 8–10, the marginal probability of $P_{CEE} = 1$ is $\Phi(\delta_0 + \mathbf{X}_p \delta_p)$, whereas the conditional probability of $V_{impaired} = 1$ given $P_{CEE} = 1$ is $\text{Prob}(V_{impaired} = 1 | P_{CEE} = 1) = \Phi(\eta_0 + \eta_1 \times 1 + \mathbf{X}_v \eta_v) / \Phi(\delta_0 + \mathbf{X}_p \delta_p)$.

Thus, the product returns the bivariate-normal probability $\Phi_{bivariate}(\eta_0 + \eta_1 + \mathbf{X}_v \eta_v, \delta_0 + \mathbf{X}_p \delta_p, \rho)$. The other three terms in the log-likelihood function can be similarly derived. More specifically, we have, for all four combinations:

$$\begin{aligned} &\text{Prob}(V_{impaired} = 1, P_{CEE} = 1) = \Phi[\eta_0 + \eta_1 + \mathbf{X}_v \eta_v, \delta_0 + \mathbf{X}_p \delta_p, \rho], \\ &\text{Prob}(V_{impaired} = 1, P_{CEE} = 0) = \Phi[\eta_0 + \mathbf{X}_v \eta_v, -(\delta_0 + \mathbf{X}_p \delta_p), -\rho], \\ &\text{Prob}(V_{impaired} = 0, P_{CEE} = 1) = \Phi[-(\eta_0 + \eta_1 + \mathbf{X}_v \eta_v), \delta_0 + \mathbf{X}_p \delta_p, -\rho], \\ &\text{Prob}(V_{impaired} = 0, P_{CEE} = 0) = \Phi[-(\eta_0 + \mathbf{X}_v \eta_v), -(\delta_0 + \mathbf{X}_p \delta_p), \rho] \end{aligned} \quad (11)$$

The log-likelihood for this model is, then,

$$lnL = \sum_{i=1}^{n} ln\Phi\left[q_{p,i}\left(\eta_0 + \eta_1 \times P_{CEE} + \mathbf{X}_p \eta_p\right), q_{c,i}(\delta_0 + \mathbf{X}_p \delta_p), q_{p,i} q_{c,i} \rho\right] \quad (11)$$

where $q_{p,i} = 2(V_{impaired_i} - 1)$ and $q_{c,i} = 2(P_{CEEi} - 1)$. The parameters in lnL can be estimated by MLE.

The model for the third outcome, myopia incidence (V_{myopia}), can be similarly developed and estimated. For comparison purposes, results from both the linear probability model and the bivariate-probit model will be presented below. All estimations were performed in Stata 14, with standard errors adjusted to allow for within-school clustering.

Results

Table 2 presents our main results of estimating the impacts of regularly performing the Chinese eye exercises on students' uncorrected visual acuity (columns 1 and 2), their likelihood of having impaired vision (columns 3–5), and that of being myopic (columns 6–8). Consistent with the findings of many previous studies,[13–16] OLS regressions (columns 1, 3 and 6) reveal essentially no impact of performing the Chinese eye exercises regularly on any of the three outcomes. In contrast, 2SLS estimates (columns 2, 4 and 7) suggest that regularly performing these exercises indeed exerted some detrimental effects. (The differences between the OLS and 2SLS estimates of β_1 are also statistically significant: for visual impairment, for example, a Standard Hausman-Durbin-Wu test yields an F-statistic of 13.19, with a p-value of 0.003). More specifically, other things being equal, compared with students who did not perform the exercises regularly, those who did on average scored 0.033 points higher on the *logMAR* scale (column 2), which translated into a 6.2 percentage-point higher likelihood of having impaired vision (column 4) and a 7.6 percentage-point higher chance of being myopic (column 7) among regular eye-exercise performers (—to capture more clearly whether regular performance of the Chinese eye exercises causes myopia, we dropped observations with high myopia (spherical equivalent refractive error ≤ −6 D) and positive spherical equivalent reflective error in the models for myopia).

The results of the associated first-stage regression (Table 3, column 1) reveal no sign of the IV, M_{CEE}, being a weak IV.[36] The F-statistic from testing its predictive power in the first-stage regression is 75.13, much higher than the commonly-adopted threshold of 10,[22,41,42] lending strong support to the "relevance" of this IV. Since our IV models are just-identified, without another suitable IV, we cannot perform standard over-identification tests for "exogeneity" of the IV;[22] we did,

Table 2 Estimated Impacts of Regularly Performing the Chinese Eye Exercises on 4th Graders' Visual Outcomes

Outcome Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
	Uncorrected Visual Acuity (*LogMAR*)		**Visual Impairment ($V_{impaired}$)**			**Myopia (V_{myopia})**		
Estimator	**OLS**	**2SLS**	**OLS**	**2SLS**	**Bivariate Probit**	**OLS**	**2SLS**	**Bivariate Probit**
Reported Estimates	**Coef.**	**Coef.**	**Coef.**	**Coef.**	**APE**	**Coef.**	**Coef.**	**APE**
Performed eye exercises regularly (P_{CEE})	−0.005 (0.008)	0.033** (0.015)	−0.006 (0.011)	0.062*** (0.023)	0.079* (0.043)	−0.006 (0.009)	0.076*** (0.020)	0.051 (0.114)
Male (dummy, =1 if yes)	−0.028*** (0.006)	−0.027*** (0.006)	−0.032*** (0.010)	−0.032*** (0.010)	−0.021*** (0.005)	−0.029*** (0.009)	−0.028*** (0.009)	−0.019*** (0.007)
Father's education (years)	−0.001 (0.001)	−0.001 (0.001)	−0.001 (0.001)	−0.001 (0.001)	0.000 (0.001)	0.000 (0.001)	0.000 (0.001)	0.000 (0.001)
Mother's education (years)	0.001* (0.001)	0.001 (0.001)	0.001 (0.001)	0.001 (0.001)	0.001 (0.001)	0.001 (0.001)	0.000 (0.001)	0.000 (0.001)
Father is a migrant worker (dummy, =1 if yes)	0.005 (0.006)	0.004 (0.006)	0.021** (0.009)	0.018* (0.009)	0.011** (0.005)	0.019** (0.008)	0.017** (0.008)	0.012** (0.006)
Mother is a migrant worker (dummy, = 1 if yes)	−0.005 (0.008)	−0.012 (0.008)	−0.022** (0.011)	−0.036*** (0.011)	−0.017** (0.007)	−0.018* (0.010)	−0.032*** (0.010)	−0.015* (0.008)
Household wealth (RMB, in log)	0.004 (0.003)	0.008** (0.004)	0.010* (0.005)	0.020*** (0.005)	0.007** (0.003)	0.008 (0.005)	0.019*** (0.005)	0.005* (0.003)
Teacher-student ratio	0.171 (0.106)	0.275** (0.110)	0.047 (0.173)	0.405** (0.195)	0.035 (0.096)	0.071 (0.171)	0.357** (0.176)	0.038 (0.091)
Proportion of classmates with eyeglasses	0.398*** (0.143)	0.902*** (0.136)	0.689*** (0.213)	1.478*** (0.227)	0.304*** (0.085)	0.608*** (0.199)	1.355*** (0.226)	0.267*** (0.095)
Constant	0.222*** (0.038)	0.056 (0.035)	0.230*** (0.062)	−0.078 (0.054)		0.178*** (0.058)	−0.131*** (0.048)	
Log (likelihood)					−8734.322			−7401.669
N	8813	8673	8772	8632	8772	8330	8197	8197
R^2(Pseudo R^2)	0.053	0.024	0.056	0.027	0.164	0.062	0.027	0.182

Notes: Source: Author's survey. 1. The 2SLS models (columns 2, 4 and 7) use the indicator of whether a school plays the official eye-exercise music during class breaks (M_{CEE}) as an instrumental variable for the indicator of whether a student performed the Chinese eye exercises regularly (P_{CEE}). 2. Columns 6–8 exclude observations with "high myopia" (spherical equivalent refractive error ≤ −6 D)[33] or with spherical equivalent refractive error > 0. 3. Robust standard errors in parentheses, adjusted for intra-school clustering. 4. APE (average partial effects) is defined as the sample average of the individual partial effect estimated for each of the observations.[22] 5. ***p<0.01, **p<0.05, *p<0.1.

however, perform a series of other checks (discussed in the next section).

One potential concern is that the IV/2SLS estimates based on a linear probability model (Table 2, columns 4 and 7) may not fully reflect changes in incidences of visual impairment and myopia because the predicted values from these models may fall outside the unit interval, losing the interpretation as "predicted probabilities". Yet this concern is negligible in our case because no observation's predicted value lies outside the unit interval for "visual impairment" (column 4) and only 38 observations (out of 8197) have predicted values lying outside the unit interval for "myopia" (column 7); estimates obtained after dropping these observations remained very similar (which are not reported but made available upon request).

To account for the binary nature of $V_{impaired}$ and V_{myopia} formally, we estimated bivariate-probit models. Since the estimated coefficients of bivariate-probit models (Table 4,

Table 3 First-Stage Regression Results

Outcome Variables	(1)	(2)
	Whether Performed the Chinese Eye Exercises Regularly	
Estimator	**OLS**	**Bivariate Probit**
Reported Parameters	**Coef.**	**Coef.**
IV: School plays official eye-exercise music (M_{CEE})	0.272*** (0.050)	
Male (dummy, =1 if yes)	−0.023*** (0.009)	−0.086*** (0.031)
Father's education (years)	0.003** (0.001)	0.012** (0.005)
Mother's education (years)	−0.000 (0.001)	0.003 (0.004)
Father is a migrant worker (dummy, =1 if yes)	−0.010 (0.012)	−0.012 (0.032)
Mother is a migrant worker (dummy, =1 if yes)	−0.016 (0.013)	−0.078* (0.041)
Household wealth index (RMB, in log)	0.015** (0.006)	0.046*** (0.018)
Teacher-student ratio	−0.122 (0.512)	−0.152 (0.622)
Proportion of classmates wearing eyeglasses	−0.459 (0.600)	−0.725 (0.543)
Constant	0.248* (0.139)	−0.204 (0.214)
N R^2(Pseudo R^2)	8673 0.337	8772 0.126

Notes: Source: Author's survey. 1. The F-statistic of testing the null hypothesis that the coefficient of the instrument variable (M_{CEE}) in column 1 is zero (ie H_0: $\alpha_1 = 0$) is 75.13 (P-value = 0.0000). 2. One US dollar = 6.81 RMB in 2012. 3. Robust standard errors in parentheses, adjusted for intra-school clustering. 4. ***p<0.01, **p<0.05, *p<0.1.

Table 4 Coefficient Estimates of Bivariate-Probit Models

Outcome Variables	(1)	(2)
	Visual Impairment ($V_{impaered}$)	Myopia (V_{myopia})
Reported Estimates	**Coefficient**	**Coefficient**
Performed eye exercises regularly (P_{CEE})	0.514* (0.304)	0.396 (0.944)
Male (dummy, =1 if yes)	−0.098*** (0.033)	−0.112** (0.049)
Father's education (years)	−0.005 (0.005)	−0.001 (0.006)
Mother's education (years)	0.004 (0.004)	0.003 (0.005)
Father is a migrant worker (dummy, =1 if yes)	0.079** (0.032)	0.096*** (0.037)
Mother is a migrant worker (dummy, =1 if yes)	−0.075* (0.045)	−0.085 (0.057)
Household wealth (RMB, in log)	0.024 (0.018)	0.024 (0.024)
Teacher-student ratio	0.292 (0.604)	0.444 (0.681)
Proportion of classmates with eyeglasses	2.285*** (0.529)	2.318*** (0.581)
Constant	−1.026*** (0.240)	−1.183*** (0.434)
$\hat{\rho}$	−0.324* (0.197)	−0.264 (0.593)
N	8772	8197
Pseudo R^2	0.164	0.182

Notes: Source: Author's survey. 1. One US dollar = 6.81 RMB in 2012. 2. ***p<0.01, **p<0.05, *p<0.1.

columns 1 and 2) are not directly interpretable as marginal/partial effects, we reported the average partial effect (APE)—ie, the sample average of individual partial effects of the sample observations, evaluated at their observed values—for each explanatory variable in columns 5 and 8 of Table 2, for comparison and interpretation purposes. These APEs are comparable to their 2SLS counterparts reported in columns 4 and 7 of Table 2, although less statistically significant. In particular, the APEs suggest that, compared with students who did not regularly perform the Chinese eye exercises, those who did were 7.9 percentage points more likely to have impaired vision (column 5) and 5.1 percentage points more likely to develop myopia (column 8).

Note also that even though a (marginally) significant estimate of ρ (Table 4, column 1) suggests endogeneity of P_{CEE} (—which echoes the results of the Hausman-Durbin-Wu test for the linear models for *logMAR*), identification of the parameters and APEs in the bivariate-probit models rely only on the models' recursive structure (Equations 8–9) and the assumed bivariate-normal distribution of the error terms (Equation 10), but not on the extra variation provided by the IV.[22,40] Since the bivariate-probit and 2SLS models exploit different sources of variation to achieve identification, the similarity between their estimates lends strong support to the validity of our chosen IV and the 2SLS estimates. Thus, we base most of the discussions below on IV/2SLS estimates.

All the results discussed above point to a detrimental effect of regularly performing the Chinese eye exercises on students' vision. Under the presumption that these exercises can effectively protect children's vision health (or at least will not impose significant threats to it) when performed correctly, the adverse effects we found are likely due to students' incorrect performance of the exercises. While our data lack sufficient information to estimate the prevalence of incorrect performance among our sample students, the incorrect performance of the Chinese eye exercises is quite possible in a low-income rural setting, where many teachers may not even know how to perform these exercises correctly.

Discussion

Even though the similarity in the results of the linear probability model and the bivariate-probit model lends strong support to our findings, these two models may have omitted the same set of confounding factors, thereby biasing the two sets of estimates in the same direction. This section, therefore, performs additional checks for the robustness of our findings.

At the individual level, the most probable confounder is students' diligence in studying—spending long hours studying may harm their vision. To help control for diligence, we added students' standardized math test scores (the only achievement test scores available to us) as an additional covariate in the models. While this variable is not a direct measure of students' diligence, it presumably captures the influence of diligence to some extent because diligent students are likely to score higher on achievement tests. The updated results, reported in columns 1, 4 and 7 of Table 5, indicate that while students' math test scores help predict their vision outcomes, the inclusion of this variable hardly changed the estimated impacts of regularly performing the Chinese eye exercises. Using one's classmates' average math test scores (Table 5, columns 2, 5 and 8) to absorb the influences of the "classroom academic atmosphere" also led to no notable changes in the estimates.

At the school level, the primary threat comes from the possibility that the IV used, M_{CEE}, may affect students' vision not only through their eye-exercise performing status but also through other unobserved factors. For example, schools that play the official eye-exercise music may

Table 5 Robustness Checks

Outcome Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**
	Visual Acuity (*LogMAR*)			**Visual Impairment ($V_{impaired}$)**			**Myopia (V_{myopia})**		
Estimator	**2SLS**			**2SLS**			**2SLS**		
Performed eye exercises regularly (P_{CEE})	0.034** (0.015)	0.035** (0.015)	0.033** (0.015)	0.063*** (0.023)	0.065*** (0.023)	0.064*** (0.022)	0.077*** (0.019)	0.081*** (0.020)	0.076*** (0.019)
Standardized math score	0.004 (0.003)			0.010* (0.005)			0.021*** (0.005)		
Classmates' average standardized math score		0.017* (0.010)			0.028* (0.016)			0.044*** (0.014)	
School organized vision screening			−0.001 (0.009)			−0.006 (0.013)			−0.001 (0.011)
Constant	0.058* (0.035)	0.060* (0.035)	0.056 (0.035)	−0.073 (0.054)	−0.071 (0.054)	−0.077 (0.055)	−0.121** (0.048)	−0.121** (0.048)	−0.131*** (0.049)
Other control variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	8672	8672	8673	8631	8631	8632	8196	8196	8197
R^2	0.024	0.025	0.024	0.027	0.027	0.027	0.030	0.029	0.027

Notes: Source: Author's survey. 1. "Other control variables" include a male dummy, parents' years of schooling, parents' migration status (dummies), family wealth, teacher-to-student ratio, and the proportion of classmates wearing eyeglasses. 2. Robust standard errors in parentheses, adjusted for intra-school clustering. 3. ***p<0.01, **p<0.05, *p<0.1.

Table 6 Heterogeneity Analysis

Outcome Variables		(1)	(2)	(3)	(4)
		Performing Eye Exercises Regularly (P_{CEE})	**Visual Acuity (*LogMAR*)**	**Visual Impairment ($V_{impaired}$)**	**Myopia (V_{myopia})**
Estimator			**2SLS**	**2SLS**	**2SLS**
Subsamples defined by different values of:					
Gender	Boys [N = 5099]	0.587	0.031*	0.045	0.052**
		[0.492]	(0.018)	(0.028)	(0.024)
	Girls [N = 4638]	0.607	0.036**	0.077***	0.095***
		[0.489]	(0.018)	(0.029)	(0.024)
Father's education	≥ 9 years [N = 5282]	0.600	0.024	0.054*	0.055**
		[0.490]	(0.018)	(0.029)	(0.025)
	< 9 years [N = 4455]	0.592	0.039**	0.068**	0.097***
		[0.492]	(0.018)	(0.027)	(0.025)
Mother's education	> 6 years [N = 3565]	0.616	0.010	0.051	0.070**
		[0.486]	(0.021)	(0.035)	(0.030)
	≤ 6 years [N = 6172]	0.585	0.040***	0.058***	0.071***
		[0.493]	(0.015)	(0.022)	(0.020)
Is father a migrant worker?	Yes [N = 4395]	0.577	0.038**	0.071***	0.059**
		[0.494]	(0.017)	(0.026)	(0.023)
	No [N = 5276]	0.613	0.026	0.048*	0.082***
		[0.487]	(0.017)	(0.027)	(0.024)
Is mother a migrant worker?	Yes [N = 1761]	0.557	0.022	0.074*	0.078**
		[0.497]	(0.027)	(0.040)	(0.032)
	No [N = 7854]	0.605	0.036**	0.061***	0.075***
		[0.489]	(0.015)	(0.023)	(0.020)
Household wealth	> median [N = 4955]	0.650	0.033	0.057*	0.076***
		[0.477]	(0.021)	(0.032)	(0.027)
	≤ median [N = 4782]	0.540	0.033**	0.062**	0.070***
		[0.498]	(0.017)	(0.026)	(0.023)

Notes: Source: Author's survey. 1. Column 1 reports means and standard deviations of the indicator of whether a student performed the Chinese eye exercises regularly (P_{CEE}) ; columns 2–4 report estimated coefficients and standard errors, adjusted for intra-school clustering . 2. ***p<0.01, **p<0.05, *p<0.1.

also adopt some measures not recorded in the data (eg, providing vision check-ups more frequently) to protect students' vision. To assess how this may affect our estimation results, we included an indicator of whether a school had organized vision check-ups before the survey in all the models (Table 5, columns 3, 6 and 9). Again, this did not notably alter our estimates.

Another concern is that schools playing official eye-exercise music care more about students' overall development. Thus, they pay attention to both students' visual health and their academic performance. These schools' higher learning objectives may impose a heavy learning burden on their students, introducing more threats to their vision health. Yet this concern has been addressed by the inclusion of classmates' average math test scores as an additional control (Table 5, columns 2, 5 and 8).

Finally, we explored potential heterogeneity in the effects of performing the Chinese eye exercises regularly. Table 6, reporting estimates for various subsamples defined based on the values of students' family background characteristics, reveals that the majority of the estimated effects are comparable to those for the full sample (Table 2), in terms of both direction and magnitude. There are some differences in the estimates across groups, eg, between boys and girls and across the levels of parental education, but the differences are, in general, not statistically significant.

Both IV/2SLS and bivariate-probit models discussed above reveal that regularly performing the Chinese eye exercises negatively affects students' vision. The estimates remain robust to different model specifications and subsamples. While our study lacks the power to assess the effectiveness of the Chinese eye exercises themselves, under the assumption that correctly performing these exercises would not undermine students' visual health, our findings suggest that the commonly-observed incorrect performance of these exercises among Chinese students may be the culprit of the detrimental effects we found.

Despite the considerable efforts devoted to addressing potential confounding effects, our study still has several limitations. First, as already mentioned at the outset, our study is not a randomized controlled trial, which leaves room for estimation bias. On a more positive note, this study's observational nature introduces minimal distortions to students' behavior, helping to strengthen its external validity. Given the institutional setting in which large-scale RCTs would encounter ethical concerns, more observational studies that employ sound identification strategies should be conducted to provide more insights into the effect of (performing) the Chinese eye exercises. We hope that the present study has provided a useful example in this direction.

Second, the key explanatory variable in our study, whether a student performed the Chinese eye exercises frequently, is measured in a relatively crude way. In particular, the actual frequency of students' performance (eg, once a day or twice a week) is not available in the data; only the self-reported relative frequency is recorded. Future studies may benefit from constructing more specific and detailed measures that capture students' eye-exercise performance more accurately.

Third, although the size of our sample is large, the entire sample came from rural schools located in two Northwestern provinces of China. Differences in students' general health status, school activities, family background, and lifestyle between the study area and other parts of China may prevent us from generalizing our findings to other regions. Large-scale studies conducted in other areas of China are likely to be fruitful in deepening our understanding of the effectiveness of performing the Chinese eye exercises.

Despite these limitations, however, we believe that our study provides new and useful information to inform policy. In particular, while our OLS estimates are consistent with many previous findings, our IV/2SLS estimates discovered adverse effects that have not been found in previous studies. These adverse effects, at least, suggest a pressing need to investigate the prevalence of incorrect performance among Chinese students and to devise measures to correct their performance.

Conclusion

The Chinese eye exercises have been performed by Chinese students for more than half a century. Yet, as few systematic evaluations have been conducted, whether (performing) these exercises can effectively protect students' vision has been largely unknown. This study, adopting an instrumental-variable approach and a bivariate-probit approach, found that regularly performing the Chinese eye exercises exerts a detrimental impact on students' vision acuity. Our IV/2SLS estimates suggest that, compared with students who did not regularly perform these exercises, those who did are 6.2 percentage points more likely to have impaired vision and 7.6 percentage points more likely to be myopic; our bivariate-probit models yielded comparable estimates. Under the presumption that the Chinese eye exercises themselves are effective at protecting children's vision (or at least they will not impose significant threats to children's vision health) when performed correctly, the adverse effects we found are likely driven by students' incorrect performance of the exercises. A policy implication follows immediately: schools in China should try hard to correct students' performance of the Chinese eye exercises. For example, more guidance and instructions on how to correctly perform these exercises, as well as closer supervision on students' performance, should be provided.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Disclosure

The authors report no conflicts of interest for this work.

References

1. National Health Commission of the People's Republic of China. China will carry out more-targeted myopia intervention. Available from: http://www.nhc.gov.cn/xcs/s7847/201905/11c679a40eb3494cade977f65f1c3740.shtml. Accessed May 08, 2019. (In Chinese)
2. Ma X, Zhou Z, Yi H, et al. Effect of providing free glasses on children's educational outcomes in china: cluster randomized controlled trial. *BMJ*. 2014;349:g5740. doi:10.1136/bmj.g5740
3. Glewwe P, Park A, Zhao M. A better vision for development: eyeglasses and academic performance in rural primary schools in China. *J Dev Econ*. 2016;122(C):170–182. doi:10.1016/j.jdeveco.2016.05.007
4. Zhao J, Pan X, Sui R, et al. Refractive error study in children: results from Shunyi District, China. *Am J Ophthalmol*. 2000;129:427–435. PMID: 10764849. doi:10.1016/S0002-9394(99)00452-3
5. He M, Zheng Y, Xiang F. Prevalence of myopia in urban and rural children in mainland China. *Optom Vis Sci*. 2009;86:40–44. doi:10.1097/OPX.0b013e3181940719
6. Li Y, Liu J, Qi P. The increasing prevalence of myopia in junior high school students in the Haidian District of Beijing, China: a 10-year population-based survey. *BMC Ophthalmol*. 2017;17(1):88. doi:10.1186/s12886-017-0483-6
7. Chen M, Wu A, Zhang L, et al. The increasing prevalence of myopia and high myopia among high school students in Fenghua city, eastern China: a 15-year population-based survey. *BMC Ophthalmol*. 2018;18:159. doi:10.1186/s12886-018-0829-8
8. Ostberg O, Horie Y, Feng Y. On the merits of ancient Chinese eye acupressure practices. *Appl Ergon*. 1992;23:343–348. PMID: 15676881. doi:10.1016/0003-6870(92)90296-8
9. Zhao R, He X, Zhu J. Analysis on the evolution of students' eye exercises. *Shanghai J Prev Med*. 2009;21(05):214–217. (In Chinese).
10. Han X, Miao HL, Huang D. Investigation of junior school student myopia in high-altitude Tibetan areas in Qinghai Province. *Int Eye Sci*. 2014;14:913–915.
11. Kang MT, Li SM, Peng X, et al. Chinese eye exercises and myopia development in school age children: a nested case-control study. *Sci Rep*. 2016;6(1):1–8.
12. Wang L, Du M, Yi H, et al. Prevalence of and factors associated with myopia in Inner Mongolia medical students in China, a cross-sectional study. *BMC Ophthalmol*. 2017;17(1):52. doi:10.1186/s12886-017-0446-y
13. Yi H, Zhang L, Ma X, et al. Poor vision among China's rural primary school students: prevalence, correlates and consequences. *China Econ Rev*. 2016;33:247–262. doi:10.1016/j.chieco.2015.01.004
14. Lin Z, Vasudevan B, Jhanji V, et al. Eye exercises of acupoints: their impact on refractive error and visual symptoms in Chinese urban children. *BMC Complement Altern Med*. 2013;13(1):306. doi:10.1186/1472-6882-13-306
15. Lin Z, Vasudevan B, Fang SJ, et al. Eye exercises of acupoints: their impact on myopia and visual symptoms in Chinese rural children. *BMC Complement Altern Med*. 2016;16(1):349. doi:10.1186/s12906-016-1289-4
16. Wang H, Qian Y, Congdon N, Boswell M, Rozelle S, Ma X. Effect of Chinese eye exercises on change in visual acuity and eyeglasses wear among school-aged children in rural China: A propensity-score-matched cohort study. *BMC Complement Altern Med*. 2020;20(1):82. doi:10.1186/s12906-020-2878-9
17. Li S-M, Kang M-T, Peng -X-X, et al. Efficacy of Chinese eye exercises on reducing accommodative lag in school-aged children: A randomized controlled trial. *PLoS One*. 2015;10(3):e0117552. doi:10.1371/journal.pone.0117552
18. Xiong R, Liu Q. Investigation of incorrect performance of students' eye exercises. *Chin J School Health*. 2001;22(06):566. (In Chinese).
19. Zhao R, He X, Zhu J, Lu L, Zhang S. An analysis of beliefs and behaviors related to Chinese eye exercises among primary and secondary school teachers and students in Shanghai. *Chin J School Health*. 2012;33(03):270–272. (In Chinese).
20. Li M, Ren Z. The necessity of reforming Chinese eye exercises. *Chin J School Health*. 2003;24(05):547–548. (In Chinese).
21. Ministry of Education. Notice on distributing Comprehensive plan to prevent myopia among school-age children. Available from: http://www.moe.gov.cn/srcsite/A17/moe_943/s3285/201808/t20180830_346672.html. Accessed May 15, 2020. (In Chinese)
22. Greene W. *Econometric Analysis*. 8th ed. London: Pearson Education; 2018.
23. Greenland S. An introduction to instrumental variables for epidemiologists. *Int J Epidemiol*. 2000;29(4):722–729. doi:10.1093/ije/29.4.722
24. Hernán MA, Robins JM. Instruments for causal inference: an epidemiologist's dream? *Epidemiology*. 2006;17(4):360–372. doi:10.1097/01.ede.0000222409.00878.37
25. Martens EP, Pestman WR, de Boer A, Belitser SV, Klungel OH. Instrumental variables: applications and limitations. *Epidemiology*. 2006;17(3):260–267. doi:10.1097/01.ede.0000215160.88317.cb
26. Baiocchi M, Cheng J, Small DS. Instrumental variable methods for causal inference. *Stat Med*. 2014;33(13):2297–2340. doi:10.1002/sim.6128
27. Ertefaie A, Small DS, Flory JH, Hennessy S. A tutorial on the use of instrumental variables in pharmacoepidemiology. *Pharmacoepidemiol Drug Saf*. 2017;26(4):357–367. doi:10.1002/pds.4158
28. Lousdal ML. An introduction to instrumental variable assumptions, validation and estimation. *Emerg Themes Epidemiol*. 2018;15(1):1–7. doi:10.1186/s12982-018-0069-7
29. Moss HA, Melamed A, Wright JD. Measuring cause-and-effect relationships without randomized clinical trials: quasi-experimental methods for gynecologic oncology research. *Gynecol Oncol*. 2019;152(3):533–539.
30. Maciejewski ML, Brookhart MA. Using instrumental variables to address bias from unobserved confounders. *JAMA*. 2019;321(21):2124–2125. doi:10.1001/jama.2019.5646
31. National Bureau of Statistics of China. *China Statistical Yearbook*. Beijing: China Statistics Press; 2013. (In Chinese).
32. Camparini M, Cassinari P, Ferrigno L, et al. ETDRS-Fast: implementing psychophysical adaptive methods to standardized visual acuity measurement with ETDRS charts. *Invest Ophthalmol Vis Sci*. 2001;42(6):1226–1231.
33. Tong L, Saw SM, Tan D, et al. Sensitivity and specificity of visual acuity screening for refractive errors in school children. *Optom Vis Sci*. 2002;79(10):650–657. doi:10.1097/00006324-200210000-00011
34. He M, Zeng J, Liu Y, Xu J, Pokharel GP, Ellwein LB. Refractive error and visual impairment in urban children in southern China. *Invest Ophthalmol Vis Sci*. 2004;45(3):793–799. doi:10.1167/iovs.03-1051
35. Luo H-D. Defining myopia using refractive error and uncorrected logMAR visual acuity >0.3 from 1334 Singapore school children ages 7–9 years. *Br J Ophthalmol*. 2006;90(3):362–366. doi:10.1136/bjo.2005.079657
36. 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–M30. doi:10.1167/iovs.18-25957
37. National Bureau of Statistics of China. *China Rural Household Survey Yearbook*. Beijing: China Statistics Press; 2013. (In Chinese).
38. Chen Q. Relaxed population policy, family size and parental investments in children's education in rural Northwestern China. *Int J Educ Dev*. 2017;54(C):39–50. doi:10.1016/j.ijedudev.2017.03.009
39. White H. A heteroskedasticity-consistent covariance matrix estimator and a direct test for heteroskedasticity. *Econometrica*. 1980;48(4):817–838. doi:10.2307/1912934
40. Maddala GS. *Limited-Dependent and Qualitative Variables in Econometrics*. Cambridge: Cambridge University Press; 1983:123.
41. Bound J, Jaeger DA, Baker R. Problems with instrumental variables estimation when the correlation between the instrument and the endogenous explanatory variable is weak. *J Am Stat Assoc*. 1995;90:443–450.
42. Staiger D, Stock JH. Instrumental variables regression with weak instruments. *Econometrica*. 1997;65:557–586. doi:10.2307/2171753