Visual impairment in rural and migrant Chinese school-going children: prevalence, severity, correction and associations

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ABSTRACT

Purpose To describe changes in the prevalence of visual impairment and glasses ownership with age and as associated with income and population density for visual impairment among rural and urban migrant Chinese students.

Design Meta-analysis of 12 cross-sectional, school-based studies conducted between 2012 and 2017.

Setting Rural and urban migrant schools in seven Chinese provinces.

Participants A total of 83 273 rural and urban migrant Chinese students aged 6–17 years.

Results Prevalence of visual impairment (uncorrected visual acuity ≤6/12 in either eye) rose from 19.0% at age 6 to 66.9% at 17, with the overall age-adjusted prevalence higher for girls (35.8%) than for boys (30.1%, p<0.001). The rate of glasses ownership among students who needed them increased from 13.0% at age 6 to 63.9% (p<0.001) at 17 and was significantly higher for girls (37.0%) than boys (34.7%, p<0.001). The unmet need for glasses as a proportion of the student population peaked in junior high school (31.8%). A 1% increase in per capita gross domestic product was associated with a 4.45% rise in uncorrected visual acuity (R^2=0.057, p=0.020). Population density was significantly associated with glasses ownership among children (R^2=0.359, p=0.012). A 1% population density increase was associated with an increase in the glasses ownership rate of 6.83%.

Conclusion Efforts are needed to improve vision screening coverage in China's schools, particularly junior high schools, as this is when many rural children leave school and glasses coverage is lowest.

INTRODUCTION

Visual impairment is the most common disability to affect school-aged children in the developing world, comprising half of all disabilities among young people.[1] Common but untreated causes of visual impairment can lead to a variety of broader problems. For instance, research has shown that children with untreated visual impairment have reduced school performance.[2 3] Such poor academic performance may limit further educational attainment and limit future career prospects and lifetime earnings.[4] The WHO estimates the potential global loss of productivity due to visual impairment to be hundreds of billions of US dollars annually.[5]

Population-based studies have shown that the large majority of visual impairment (visual acuity [VA] ≤6/12 in either eye) among school children is due to uncorrected refractive error.[6 7] Visual acuity (VA)has been widely used as a proxy measure for refractive error in children in previous studies[8–10] and is useful for estimating the prevalence of myopia in large populations that undergo vision screening when refraction is not feasible.[11]

China is the world's most populous country, with an economy that has been growing steadily for over 30 years. Despite this growth, China's large rural and urban migrant communities continue to lag behind in key areas, such as academic achievement.[12 13] Nearly two-thirds of China's population holds a rural residence permit (*hukou*), and nearly half live in rural areas. Due to regulations related to the hukou system, a large share of the population continues to be educated in rural settings.[14] In addition, owing to rapid development and urbanisation over the past 40 years, some 288 million rural citizens have migrated to urban areas[15–17] for employment opportunities and higher wages.[18 19] In many cases, these workers have brought their families, increasing the number of migrant children to more than 20 million.[20] These migrant children often do not have access to urban public schools and, instead, must attend lower quality, privately run migrant schools.[21]

Although data on visual impairment, uncorrected VA, refractive error and prescription glasses ownership among children and adolescents in rural China have been reported in various epidemiologic studies,[11 22–27] knowledge of China's rural visual impairment problem is incomplete. Large studies with representative samples have examined visual impairment, uncorrected VA and refractive error in both rural and urban China.[11] To the best of our knowledge, however, there have been no large or systematic comparisons of county income with rates of uncorrected VA and glasses ownership. Similarly, although some studies have examined the associations between population density and uncorrected VA,[11] none has assessed the relationship between population density and glasses ownership rates. Both of these metrics have significant policy implications, as they affect both the sustainability and most effective distribution mechanisms of potential vision interventions. As such, increased knowledge about VA relative to these variables would be beneficial for planning rural healthcare policy and allocating resources.

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To address these limitations in the extant literature, this paper examines a large school-based sample of rural and urban migrant students aged 6–17 years, spanning seven provinces. The objectives of this study were to (a) examine the age- and gender-stratified prevalence of visual impairment; (b) estimate the age- and gender-specific rate of glasses ownership among children who need refractive correction; (c) describe the unmet need for glasses among all school children; and (d) examine the extent to which county-level income and population density can explain provincial-level variation in visual impairment and/or glasses ownership rates.

METHODS

Ethical clearance

The protocol of this study was approved by institutional review boards at Stanford University (Protocols 24847, 28343, 28385). Permission was received from local boards of education in each setting and from the principals of each school, and at least one parent provided consent for his or her child to participate in this study. The principles of the Declaration of Helsinki were upheld throughout this study.

Sample selection

The data analysed in this study were drawn from 12 cross-sectional, school-based surveys conducted between 2012 and 2017, which covered 50 counties in 7 Chinese provinces: Shaanxi, Gansu, Henan, Shanghai, Jiangsu, Guangdong and Yunnan. These provinces reflected five different geographical regions: Northwestern, Southwestern, Central, Eastern and Southeastern China, and the complete database included 83 273 primary and secondary students in both rural and urban migrant communities (table 1).

The sample selection protocol was nearly identical across all included studies. In all studies, we followed the same four-step process. First, we obtained a list of all counties in the study region. Second, we obtained a list of all primary schools from the bureau of education in each county. Third, we randomly selected a school from each township in each sample county (with the exception of Cohorts 9–11 in Shaanxi province and Cohort 12 in Gansu, where all primary schools were enrolled, rather than one per township). Finally, within each school, one class was randomly selected from the target grade levels for participation in the survey (with the exception of secondary school students, in which all Grades 7 and 8 classes were included in the sample). The resulting sample included 12 cohorts that ranged in age from 6–17 years.

Data collection

Data collection followed a two-part survey protocol for both primary and secondary schools. First, a VA assessment was carried out for all sampled children. Due to the scarcity of local optometrists, we trained teachers, nurses and enumerators to conduct VA testing (described below) and then provided the study team with a list of visually impaired students. Second, at the time of VA testing, we administered a simple questionnaire to all sampled children to collect information on age, gender and self-reported ownership of glasses. Data on county-level per capita gross domestic product (GDP) and population density were collected from China's National Statistical Yearbooks.[28–31]

Measurement of visual acuity

Children underwent VA screening at school by trained teachers, nurses and enumerators. VA was tested separately for each eye with and without existing glasses (if available) at 4 m using an Early Treatment Diabetic Retinopathy Study (ETDRS) chart[32] (Precision Vision, La Salle, Illinois, USA) in a well-lit, indoor area. 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, the 6/15 line and then line by line to 6/3. VA for an eye was defined as the lowest line on which four of five optotypes were read correctly. If the top line could not be read at 4 m, the subject was tested as above at 1 m, and the measured VA was divided by 4. Following the Refractive Error Studies in Children (RESC) protocol, we defined visual impairment as uncorrected VA of ≤6/12 in either eye.

The teachers, nurses and enumerators underwent formal vision screening training by teachers from China's top vision training programme from Zhongshan Ophthalmic Centre (ZOC), Guangzhou, China. All staff members underwent 1 week of supervised practical training in their home county, during which time each staff member screened hundreds of children from local schools and underwent practical instruction in glasses dispensing. A consultant from the Brien Holden Vision Institute (BHVI) provided management training, including inventory control and recordkeeping.

As part of our study protocol, students who failed the vision screening and whose VA could not be improved with glasses were referred to nearby partner hospitals for more advanced care. In

Table 1 Description of sample population

Cohort	Sample province	No. of sampled counties	No. of sampled schools	No. of sampled students	Age (median)	Age (IQR)	Boys (%)	Survey year
1	Shaanxi	11	132	9617	10	1	53.7	2012
2	Gansu	7	120	10 296	11	1	50.6	2012
3	Henan	5	23	7517	11	2	53.9	2013
4	Shanghai	4	66	2945	11	2	54.4	2014
5	Jiangsu	5	28	1451	11	1	57.4	2014
6	Guangdong	4	88	6474	11	1	53.6	2014
7	Yunnan	5	50	3747	10	1	50.2	2014
8	Shaanxi	3	36	2217	13	1	52.1	2013
9	Shaanxi	1	14	4554	14	2	52.1	2015
10	Shaanxi	2	34	13 749	13	6	51.7	2016
11	Shaanxi	3	109	12 707	12	3	53.2	2014–2017
12	Gansu	3	279	7999	13	2	52.9	2014–2017
Total		53	979	83 273	12	3	52.4	

Although the number of sampled counties is 53, our sample includes students in only 50 distinct counties. Some surveys/datasets included previously sampled counties to survey students in different grades.

addition to providing the child's teachers at the school with referral information, the research team also sent a formal notification letter with detailed referral instructions to the child's parents to make sure they were also notified. In addition, a random subsample of children participating in our studies were re-screened by an ophthalmic professional from Zhongshan Ophthalmic Centre (ZOC), among the top vision training programmes in China. These professionals replicated the screening conducted by trained members of the research team and compared their findings, without detecting any inconsistencies or erroneous results.

Statistical methods

We performed our analyses in per-protocol fashion in Stata 16 (StataCorp, College Station, Texas, USA). To achieve Objectives 1, 2 and 3, we used descriptive analyses to examine the age- and gender-stratified prevalence of visual impairment, to estimate the age- and gender-specific rates of glasses ownership among children who needed refractive correction, and to examine the unmet need for glasses among all school children. To achieve Objective 4, we used linear regressions to assess the extent to which income and population density could explain county-level variation in visual impairment and glasses ownership rates.

RESULTS

Figure 1 and online appendix table 1 show the age- and gender-specific prevalence of vision impairment. The overall prevalence of uncorrected VA was 32.8% (27 315/83 273), increasing from 19.0% at age 6 to 66.9% at 17. The prevalence among girls across all ages (14 119/39 428=35.8%) was significantly higher than that for boys (13 196/43 845=30.1%, p<0.001).

In total, 35.9% (9799/27 315) of children who needed glasses had them, with a steadily increasing rate of ownership from 13.0% (3/23) at age 6 to 63.9% (921/1441) at 17 (figure 1, online appendix table 1). The overall prevalence of glasses ownership in girls (5223/14 119=37.0%) was higher than that in boys (4576/13 196=34.7%, p<0.001).

An unmet need for glasses increases steadily through primary school and peaks during junior high school, when over one-third of junior high students who need glasses do not own them (figure 2). This unmet need decreases from about 31.8% of students in junior high school to approximately 23.2% in senior high school. Over 21.0% of rural students have vision that could be corrected with glasses but do not own them.

The prevalence of uncorrected VA was positively and significantly associated with income and was twice as high in the richest five counties (642/2593=24.8%) compared with that in the poorest five counties (960/8297=11.6%, p<0.001) (figure 3). An additional 1% of per capita GDP change was associated with an increase in uncorrected VA of 4.45% (R^2=0.057, p=0.020); however, no association was found between glasses ownership among children who needed them and per capita GDP (coefficient=0.024, p=0.095).

The prevalence of uncorrected VA was not associated with population density (p=0.586). There was, however, a positive and significant relationship between glasses ownership among children who needed them and population density (figure 4). Ownership was 22.6% (414/1833) in the five least-dense counties vs 25.6% (257/1005) in the five most-dense counties. An additional 1% of population density change was associated with an increase in the glasses ownership rate of 6.83% (R^2=0.359, p=0.012).

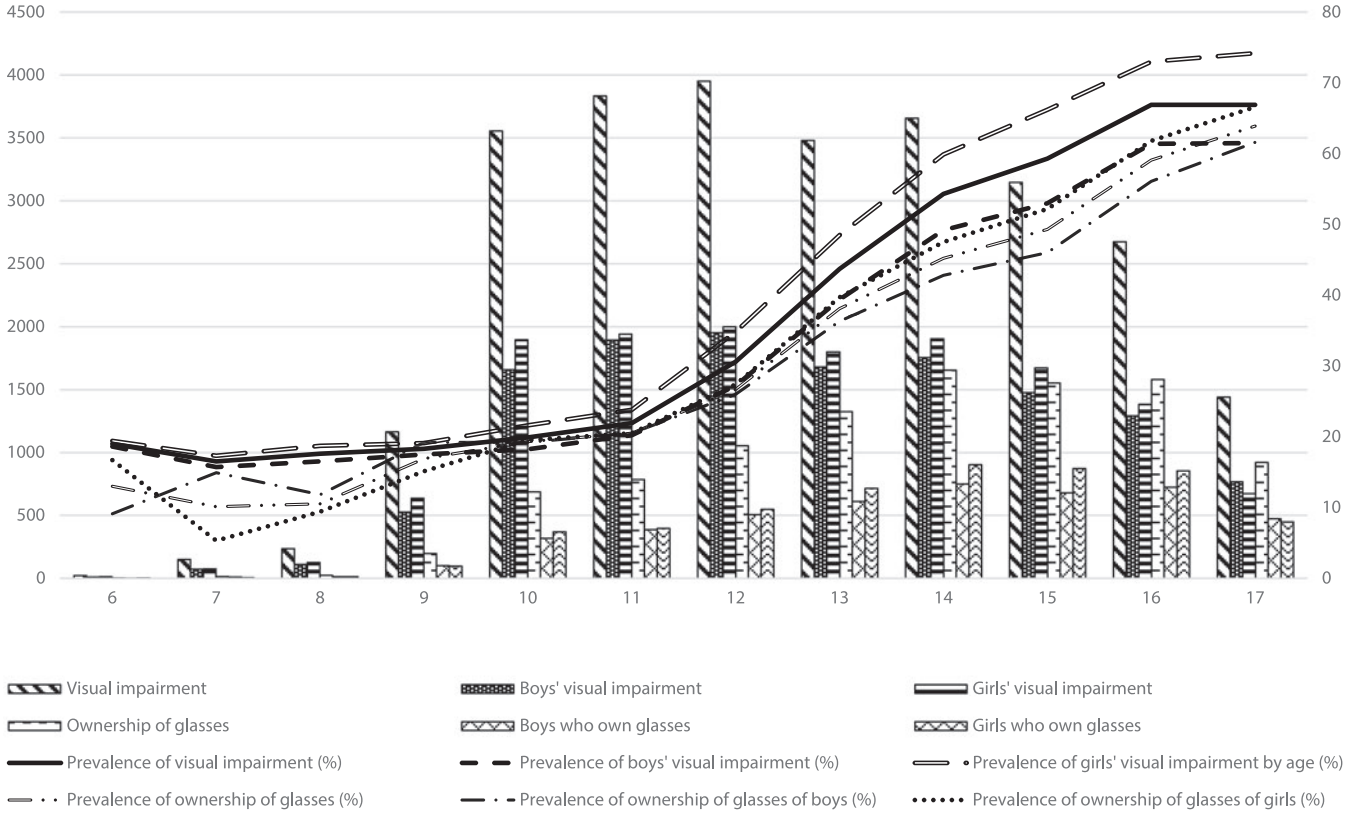

Figure 1 Age-specific prevalence of vision impairment and spectacle ownership by gender.

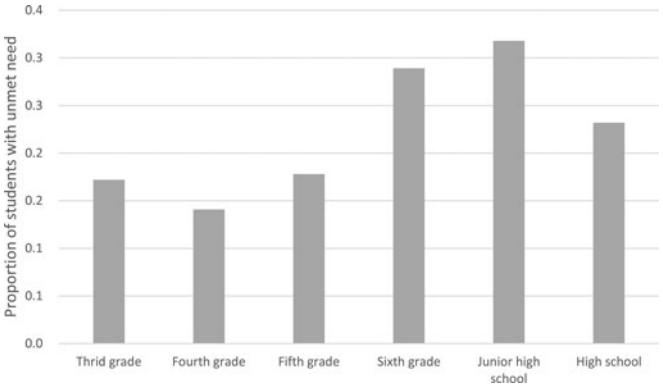

Figure 2 Unmet need for glasses across grade cohorts. Unmet need for glasses in each cohort is calculated as the percentage of students who need but do not own glasses.

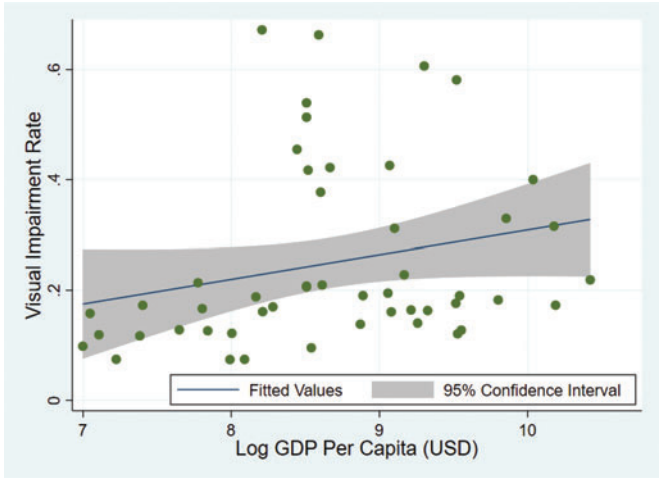

Figure 3 Association between visual impairment and county per capita GDP (from 50 counties in 7 provinces in China). As the relationship in this figure is exponential, we employ a log scale to simplify interpretation of the data.

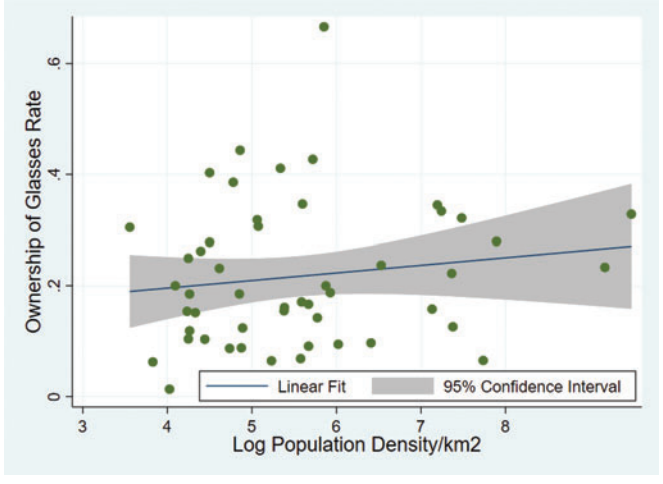

Figure 4 Association between glasses ownership and county population density (from 50 counties in 7 provinces in China). As the relationship in this figure is exponential, we employ a log scale to simplify interpretation of the data.

DISCUSSION

This unique, large database demonstrates the pervasive problem of lack of glasses among children who need them in rural and urban migrant Chinese communities. More than one in five (21.0%) students who attend rural and urban migrant schools have uncorrected vision problems. Even greater wealth (as measured by county GDP) did not appear to significantly improve glasses ownership rates, highlighting the need for targeted interventions to drive demand for glasses. Among those interventions that have been tested in clinical trials, the provision of free glasses,[2] especially when combined with teacher incentives,[33] is highly effective. Educational interventions alone, even when targeting children, teachers and families, appear to be less successful.[2 34]

This large dataset allows us to elucidate an important trend that has previously not been identified: The proportion of children in the population who need glasses but do not own them peaks in junior high school. This is because increases in myopia with age outstrip the rise in glasses ownership among older children. It is particularly important for policymakers to target this age group with strategies to increase glasses wear, as this is the level of schooling that determines entrance to high school (currently ≤50% admittance in many rural areas of China), without which entry to university is impossible. This crucial turning point in Chinese children's educational careers is also the time when the largest number leaves formal schooling. As improved glasses wear has been proven to enhance academic performance,[2 3] interventions tailored to this age group that promote the use of glasses could potentially boost academic outcomes for many rural and urban migrant junior high school children and help to keep them in school. An ongoing trial (SWISH, See Well to stay In ScHool[35]) is currently testing this hypothesis.

The increasing prevalence of uncorrected VA over time was positively and significantly associated with income, which is consistent with the existing literature.[36] This association is likely explained by the associations of income with 'near work' and outdoor activity. First, students with more affluent backgrounds spend more time with near work due to increased academic pressure associated with higher levels of affluence,[37] including studying and viewing screens, leaving less time available for outdoor activities.[36 38 39] Near work has been shown to be associated with a greater risk of myopia.[36 39] Second, students with more affluent backgrounds are likely to spend less time outdoors, which also is associated with the development of myopia.[36 38 39] Recent randomised controlled trials demonstrate a causal association between increased time outdoors and decreased incidence of myopia.[36 38]

The positive and statistically significant effect of population density on glasses ownership suggests that limited access to vision care may be a barrier to glasses ownership. Bai *et al*,[40] for instance, find that optometrists in rural China are rare, with one optometrist as serving more than 133 000 individuals on average. (In the United States, by comparison, the ratio is 1 optometrist for every 8682 individuals.[41]) Not only is the supply of optometrists low in China, but, as with other healthcare practitioners, they tend to cluster in high-population density urban areas. This underscores the importance for Chinese government programmes to target rural areas that have the lowest population densities with additional optometric services.

Although our data show that girls are more likely than boys in rural China to wear glasses, they also carry a significantly higher burden of vision impairment, due predominantly to uncorrected or undercorrected myopia. This phenomenon, which has been previously described,[23 24] may be the result of additional near

work and academic pressure among girls or of less time spent outdoors, as compared to boys, which recent trials[38 42] have shown can reduce the incidence of myopia.

This study has several strengths. First, the sample includes numerous large cohorts of rural and migrant students from across China, giving our findings a high degree of statistical precision and greater applicability to the country as a whole. Second, the sampling protocol and vision screening tests used in this study were uniform and standardised across all 12 cohorts and 50 counties, allowing easy comparability. More importantly, to our knowledge, this is the first study to systematically estimate the rates of glasses ownership across different age groups by gender and to examine whether county-level factors, such as income and population density, can account for provincial variation in uncorrected VA and rates of glasses ownership.

We acknowledge limitations to our research as well. First, our main outcome measure was uncorrected VA rather than refractive error. This decreases comparability with other studies in which all participants underwent refraction. Second, our estimates do not account for the accuracy of prescriptions among children who do own glasses. Finally, although these results may be broadly applicable to Chinese rural and urban migrant communities, they can be applied only to other countries and racial groups with caution.

Despite these limitations, we feel these results are valuable for China's policy planners, especially in view of the current national programme to manage childhood myopia.[43] Based on these findings, we suggest that China's health and education policymakers take steps to incorporate vision care into public health and education agendas, especially in rural schools. Specifically, universal vision screening should be integrated into the in-school physical examination plan currently required once every school year. Although the physical examination plan includes a vision component, available evidence suggests that vision screenings are implemented only sporadically in rural China and are of low quality.[44] Additional investment will be required to improve the accuracy and regularity of these screenings.

In addition, given that ownership of glasses is low among visually impaired students, even in relatively rich counties, the solution to vision problems cannot be solely income based. On the demand side, this includes eliminating common misunderstandings regarding vision care, especially that younger children should not wear glasses or that glasses harm their vision.[45 46] On the supply side, the emphasis should be on increasing access to high-quality, low-cost or free glasses, especially for children in the least-densely settled rural areas and those in junior high school.

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Competing interests NC is the Director of Research for Orbis International, a non-governmental organization that delivers children's refraction service among other services in China and other countries.

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