Secular Trends of Reduced Visual Acuity From 1985 to 2010 and Disease Burden Projection for 2020 and 2030 Among Primary and Secondary School Students in China

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IMPORTANCE Understanding the burden and trends of reduced visual acuity (VA), a proxy measure for myopia, is essential to guide future health care and clinical management in China.

OBJECTIVES To describe the secular trends from 1985 to 2010, correlate the prevalence of reduced VA among children and adolescents with population density, and project the burden of reduced VA in China in 2020 and 2030.

DESIGN The National Survey on the Constitution and Health of Chinese Students conducted from 1985 to 2010, including 6 repeated surveys with a 3-stage clustering sampling strategy.

SETTING Mainland China.

PARTICIPANTS Primary and secondary school students 7 to 18 years of age were randomly selected from 30 of 31 mainland provinces, excluding Tibet.

MAIN OUTCOMES AND MEASURES Unaided distance VA was measured using a retroilluminated logMAR chart with tumbling-E optotypes. World Population Prospects data (the 2012 revision from the Population Division of the Department of Economic and Social Affairs of the United Nations) were used to project the number of people affected by reduced VA in 2020 and 2030.

RESULTS This analysis included 725 423, 142 655, 206 601, 219 663, 215 308 students in 1985, 1991, 1995, 2000, 2005, and 2010, respectively. The overall prevalence of reduced VA was 28.6% (95% CI, 28.4%-28.7%) in 1985, 38.6% (95% CI, 38.3%-38.8%) in 1991, 41.0% (95% CI, 40.8%-41.2%) in 1995, 38.5% (95% CI, 38.3%-38.7%) in 2000, 49.5% (95% CI, 49.3%-49.7%) in 2005, and 56.8% (95% CI, 56.6%-57.0%) in 2010. Girls were more susceptible than boys to having reduced VA (odds ratio, 1.38 [95% CI, 1.35-1.40]), and reduced VA was more prevalent in urban areas than in rural areas (odds ratio, 1.84 [95% CI, 1.81-1.87]). Reduced VA was not significantly associated with population density (P = .11). The projected numbers of cases with reduced VA are about 152.4 million (95% CI, 151.9-152.9 million) in 2020, increasing to 180.4 million (95% CI, 179.8-181.2 million) in 2030 among students who are 7 to 18 years of age in mainland China.

CONCLUSIONS AND RELEVANCE There was an increasing trend of reduced VA in both urban and rural areas from 1985 to 2010 in China. Although reduced unaided distance VA is not equal to visual impairment, these summary data are helpful in designing strategies for eye care and health services in China, which may also have public health implications for other developing countries whose economies are growing rapidly.

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Myopia is an important but often underestimated health problem associated with a great socioeconomic burden and various vision-threatening ocular complications. Recent epidemiologic studies have demonstrated that the prevalence of myopia has reached epidemic levels in some urban Asian communities. For example, the prevalence of myopia among teenagers has been reported to be about 81% in Singapore, 86% in Taiwan, 96% in Seoul, Korea, and 95% in Shanghai, China.

Unaided visual acuity (VA) has been widely used as a proxy measure for myopia in children in previous studies and has achieved a satisfactory sensitivity and specificity profile for myopia screening. For example, a myopia screening test in Singapore found that using a referral criterion of VA worse than or equal to 0.28 logMAR in at least one eye achieved a sensitivity of 72% (95% CI, 68%-76%) and a specificity of 97% (95% CI, 95%-98%). Similarly, myopia was found to have the highest sensitivity and specificity of any of the refractive errors for detection using VA (97.8% and 97.1%, respectively) in Australian school children. Among Chinese children in Guangzhou, the rates of reduced VA were closely correlated with the prevalence of myopia measured by cycloplegic autorefraction reported in a population-based study of the same year, with a correlation coefficient of 0.992. These results indicate that VA data may be useful for predicting the prevalence of myopia in large populations undergoing myopia screening examinations because cycloplegic refraction is not feasible.

China is the world's most populous country and has had a booming economy for the past few decades. Although data on the refractive errors and visual impairment of children and adolescents in China have been reported in various epidemiologic studies, and considering the huge economic and health-related disparities seen in the different parts of the country, these sporadic estimates do not reflect the whole picture of the nationwide burden and trends. In addition, variations in methodological issues, such as using different sampling strategies and refraction methods, may also make it difficult to compare the results among these individual studies. Population-based studies have also shown that more than 90% of the cases of poor vision among school children in China are due to uncorrected refractive error, almost exclusively myopia. Therefore, a systematic nationwide surveillance of the Chinese population based on unaided VA measurements is a useful approach for understanding the secular trends of reduced VA in different parts of China and could further provide an early warning of an epidemic of myopia in this world's most populous country. In addition, to our knowledge, there have been no studies that have systematically compared the burden of this condition across areas with different population densities, which, from a public health perspective, would be important for planning health care policy and allocating appropriate resources.

The objectives of this effort are (1) to estimate the secular trends of reduced VA in Chinese children and adolescents 7 to 18 years of age on a national level from 1985 to 2010, (2) to correlate the prevalence of reduced VA among children and adolescents with population density, and (3) to project the burden of reduced VA among children and adolescents 7 to 18 years of age in 2020 and 2030 in mainland China.

### Methods

#### Study Population and Sampling Strategy

The National Survey on the Constitution and Health of Chinese Students (NSCHCS), conducted once every 5 years since 1985, is a series of multistage, cross-sectional, nationwide surveys aimed at estimating the nationwide and area-specific burdens of common health problems of children and adolescents 7 to 18 years of age in mainland China. We performed the analysis using data obtained from previous surveys conducted in 1985, 1991, 1995, 2000, 2005, and 2010. The study methods of the NSCHCS have been described elsewhere. In brief, all study participants were primary and secondary school students 7 to 18 years of age who were randomly selected from 30 of 31 mainland provinces, excluding Tibet (the only province where Han Chinese do not constitute an ethnic majority). Each province was treated as a cluster, and province-wide samples of students were selected by the local institutes of school health during a 3-stage clustering process.

In the first sampling stage, the study participants in each province were classified by sex and region (urban vs rural), and each of the 4 groups consisted of equal numbers of individuals from 3 classes based on socioeconomic status (ie, upper, middle, or lower class). These classes were defined using 5 indices created in 1985: the regional gross domestic product, the total yearly income per capita, the average food consumption per capita, the natural growth rate of the population, and the regional social-welfare index.

During the second sampling stage, 3 urban and 3 rural residential areas were randomly selected. Several primary and secondary schools were randomly selected from a list compiled by each area's educational committee. During the third sampling stage, a list of students from grade 1 to grade 12 was compiled, and 2 or 3 classes (depending on their size) from each grade were randomly selected. The sampling strategies were the same in all of the surveys at different time points. All of the study participants lived in their local areas for at least 1 year and were Han Chinese; this ethnic group comprises 92.7% of the nationwide population in China. This analysis included 725,423, 142,655, 206,601, 219,663, 234,377, and 215,308 students in 1985, 1991, 1995, 2000, 2005, and 2010, respectively.

Our study was approved by the ethics committee of the Medical College of Soochow University in Suzhou, Jiangsu, China, and followed the tenets of the Declaration of Helsinki. Oral informed consent was obtained from all parents after the nature of the study was explained to them.

#### VA Measurements

Certified optometrists measured the unaided distance VA for both eyes of students using a retroilluminated logMAR chart with tumbling-E optotypes (Precision Vision) in rooms with an illumination of approximately 500 lux. During the examination, study participants were required to indicate the direction of the E optotype within 5 seconds. Visual acuity measurements began at a distance of 5 m, with the fourth line from the bottom (6/6), using a staircase protocol. If 4 of the 5 optotypes were identified, it was considered as a correct response. The VA
of the eye was determined by the lowest line read correctly. If the top line was not read correctly, the study participant was advanced to 2.5 or 1 m. Visual acuity examinations were performed using a uniform protocol throughout the surveys at different time points. Because of limited resources, presenting VA and best-corrected VA were not measured. Reduced VA was defined as worse than 6/6. Mildly reduced VA was defined as worse than 6/9 but greater than or equal to 6/6, moderately reduced VA was defined as less than 6/18 but greater than or equal to 6/9, and severely reduced VA was defined as less than or equal to 6/18.

### Statistical Analysis
The prevalence of reduced VA was estimated for the overall sample and then stratified by age, sex, and area (urban vs rural) in different study years. Data of the latest survey in 2010 were used to estimate the cross-sectional associations.

### Table. Prevalence of Reduced Visual Acuity in the National Survey on the Constitution and Health of Chinese Students

<table>
<thead>
<tr>
<th>Classification</th>
<th>1985</th>
<th>1991</th>
<th>1995</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>Total</td>
<td>% (95% CI)</td>
</tr>
<tr>
<td><strong>All</strong></td>
<td>207,128</td>
<td>725,423</td>
<td>28.6 (28.4-28.7)</td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>109,861</td>
<td>353,436</td>
<td>31.1 (30.9-31.2)</td>
</tr>
<tr>
<td>Male</td>
<td>97,267</td>
<td>371,987</td>
<td>26.1 (26.0-26.3)</td>
</tr>
<tr>
<td><strong>Area</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>140,271</td>
<td>376,715</td>
<td>37.2 (37.1-37.4)</td>
</tr>
<tr>
<td>Rural</td>
<td>66,857</td>
<td>348,708</td>
<td>19.2 (19.0-19.3)</td>
</tr>
</tbody>
</table>

* Reduced visual acuity was defined as worse than 6/6.
between reduced VA and population density. Census-based data on population density were retrieved from the Chinese government website (http://www.stats.gov.cn/). A simple linear regression model was constructed to evaluate the association between reduced VA and population density for each province. To project the cases with reduced VA for 2020 and 2030, a logistic regression model was established to estimate the nationwide prevalence for each yearly increase in age for boys and girls: logit \( P \) = \( \beta_0 + \beta_1 \times \text{age} + \beta_2 \times \text{sex} + \beta_3 \times \text{year} \). The estimated population structures of mainland China in 2020 and 2030 were obtained from World Population Prospects data (the 2012 revision from the Population Division of the Department of Economic and Social Affairs of the United Nations [http://esa.un.org/unpd/wpp/unpp/panel_indicators.htm]). The estimated prevalence of reduced VA was used to calculate the total number of individuals with reduced VA in 2020 and in 2030 by multiplying the age-specific estimated prevalence rates found in the World Population Prospects data.

## Results

The Table shows the prevalence of reduced VA stratified by sex and area (urban vs rural). The overall prevalence of reduced VA was 28.6% (95% CI, 28.4%-28.7%) in 1985, 38.6% (95% CI, 38.3%-38.8%) in 1991, 41.0% (95% CI, 40.8%-41.2%) in 1995, 38.5% (95% CI, 38.3%-38.7%) in 2000, 49.5% (95% CI, 49.3%-49.7%) in 2005, and 56.8% (95% CI, 56.6%-57.0%) in 2010. In all surveys at different time points, girls were more susceptible than boys to having reduced VA (all \( P < .001 \)). Reduced VA was more prevalent in urban areas than in rural areas (all \( P < .001 \)). For example, in 2010, girls had a higher odds ratio of reduced VA than boys (odds ratio, 1.38 [95% CI, 1.35-1.40]), and the prevalence of reduced VA was also higher in urban areas than in rural ones (odds ratio, 1.84 [95% CI 1.81-1.87]).

Study participants were categorized into 4 age groups (7-9, 10-12, 13-15, and 16-18 years). Figure 1 shows the age-specific prevalence of reduced VA in different survey years. In general, there was an increasing trend of reduced VA in all age groups. For example, in 1985, the prevalence was only 8.3% (95% CI, 8.2%-8.4%), 16.6% (95% CI 16.4%-16.8%), 35.8% (95% CI, 35.5%-36.0%), and 50.8% (95% CI, 50.6%-51.1%) for children in the age groups of 7 to 9 years, 10 to 12 years, 13 to 15 years, and 16 to 18 years, respectively. In 2010, these figures were 31.8% (95% CI, 31.6%-32.0%), 47.9% (95% CI, 47.7%-48.1%), 67.5% (95% CI, 67.2%-67.8%), and 79.3% (95% CI, 79.0%-79.6%), respectively. Reduced VA was more prevalent among older children than among younger children in all surveys at different time points (\( P < .001 \)). In addition, there was an increasing trend of severely reduced VA over the past 25 years for all age groups (Figure 2). Figure 3 shows the correlation of the prevalence of reduced VA with population density in 2010. The relationship between population density and the prevalence of reduced VA was positive but did not reach statistical significance (regression coefficient = \( 3.6 \times 10^{-5} \); \( P = .11 \)).

The projected numbers of children and adolescents 7 to 18 years of age with reduced VA in 2020 and 2030 are shown in Figure 4. For the year 2020, the projected number of cases with reduced VA will be about 152.4 million (95% CI, 151.9-152.9 million), increasing to 180.4 million (95% CI, 179.8-181.2 million) in 2030, with the largest number being adolescents 15 to 18 years of age. There may be more boys than girls affected by reduced VA in 2020 and 2030.

## Discussion

The NSCHCS showed that the nationwide burden of reduced VA, a proxy measure for myopia, had increased among children and adolescents from 1985 to 2010 in mainland China,

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The estimated prevalence of reduced VA was used to calculate the total number of individuals with reduced VA in 2020 and in 2030 by multiplying the age-specific estimated prevalence rates found in the World Population Prospects data.

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The estimated prevalence of reduced VA was used to calculate the total number of individuals with reduced VA in 2020 and in 2030 by multiplying the age-specific estimated prevalence rates found in the World Population Prospects data.
and this was accompanied by the rapid development in the economy in recent decades. The projected number of children and adolescents 7 to 18 years of age affected by reduced VA is approximately 152 million in 2020 and approximately 180 million in 2030. These data are helpful in designing strategies for eye care and health services in China, which may also have public health implications for other developing countries with rapid economic growth.

Although cycloplegic refraction was not measured owing to limited resources, the observed increasing trends over the past 25 years are largely due to the increasing prevalence of myopia, considering the validation of unaided VA as a predictor for myopia in previous studies. In China, visual impairment among school-aged children is commonly caused by uncorrected refractive errors, especially myopia. During China’s economic development and urbanization, numerous environmental exposures would have been changed, resulting in increasing myopia rates. However, the exact factors contributing to the increasing trend of reduced VA or myopia remain unclear. In other urban Asian communities, such as Singapore, the increasing prevalence of myopia among different generations was mainly due to intensive schooling that is associated with more time spent doing homework and less time spent outdoors. This may also be happening in mainland China, where the school system is becoming more and more competitive, with an emphasis in recent decades on early educational achievements and passing examinations.

For example, the college entrance examination in China is extremely competitive, and adolescents 16 to 18 years of age are usually at the preparation stage of this examination. They have to spend more time doing homework every day and less time playing outdoors, which results in a sedentary lifestyle. Ji et al reported that 84.6% of the senior high school students in China have little or no daily physical activity. In the past, these same type of students may have been exposed to less intensive schooling and were less likely to receive preschool education compared with their counterparts born later. In addition, with the development...
of information technology, children and adolescents are spending more and more time using modern digital products such as computers and smartphones, which may be harmful to their eyes. Ji et al25 reported that, in China, 34.3% of secondary school students spent 2 hours or more per day (and 13.5% spent ≥4 h/d) watching television, 21.2% of primary school students spent 2 hours or more per day (and 3.3% spent ≥4 h/d) playing electronic games, and 25.6% of senior high school students spent 2 hours or more per day (and 5.5% spent ≥4 h/d) on the Internet.

The major strength of our study is the availability of the nationwide data collected using this same study protocol over a time period of 25 years. Nevertheless, the major limitation of our study should be acknowledged. Cycloplegic refraction is the gold standard of measurement for myopia in children and adolescents and was not performed in the NSCHCS. Given that the link between VA and myopia is not definite, a VA of less than 6/6 in the best eye. Our definition of mildly and moderately reduced VA are not visual impairment in China and in other developing countries with rapid growing economies.

Conclusions

In conclusion, these summary data on reduced VA indicate the substantial nationwide burden of myopia among children and adolescents in China, and they provide information to help us understand the effect of the condition and design strategies for eye care and health services. Mainland China may be at an early stage of a myopia epidemic compared with other urban Asian communities. Therefore, myopia may warrant more attention in China and in other developing countries with rapidly growing economies.


