

Prevalence of Myopia in Schoolchildren in Ejina: The Gobi Desert Children Eye Study

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PURPOSE. To determine the prevalence and associations of myopia in schoolchildren in provincial Western China.

METHODS. In the school-based observational cross-sectional Gobi Desert Children Eye Study, cycloplegic refractometry as part of a comprehensive ophthalmic examination was performed in all schools in the oasis region of Ejina. Out of 1911 eligible children, 1565 (81.9%) children with a mean age of 11.9 ± 3.5 years (range, 6–21 years) participated.

RESULTS. The mean refractive error in the worse eye was -1.38 ± 2.04 diopters (D) (median, -0.88 D; range, -13.00 to $+6.50$ D). In multivariate analysis, more myopic refractive errors were associated with older age ($P < 0.001$; regression coefficient B : -0.26 ; 95% confidence interval [CI]: -0.28 , -0.23), female sex ($P = 0.005$; B : -0.26 ; 95%CI: -0.43 , -0.08), more myopic paternal refractive errors ($P < 0.001$; B : 0.20 ; 95%CI: 0.14 , 0.27), more myopic maternal refractive errors ($P < 0.001$; B : 0.18 ; 95%CI: 0.12 , 0.24), and fewer hours spent outdoors ($P = 0.038$; B : 0.18 ; 95%CI: 0.01 , 0.35). The prevalence of myopia, defined as refractive errors (spherical equivalent) of ≤ -0.50 , ≤ -1.00 , and ≤ -6.00 D in the worse eye, was $60.0 \pm 1.2\%$, $48.0 \pm 1.3\%$, and $2.9 \pm 0.4\%$, respectively. The prevalence of high myopia (≤ -6.00 D) was $2.9 \pm 0.4\%$ in the whole study population, and it was $9.9 \pm 3.0\%$ in 17-year-olds. It was not associated with time spent outdoors ($P = 0.66$).

CONCLUSIONS. Even in Western China, prevalence of myopia in schoolchildren is high. As in East China, low and medium myopia was associated with less time spent outdoors. High myopia was not significantly associated with outdoors time. Compared with the myopia prevalence in elderly Chinese populations, the relatively high myopia prevalence in schoolchildren in China predicts a marked increase in vision-threatening high myopia in future elderly populations in China.

Keywords: myopia, refractive error, myopic shift

Refractive error is one of the most common ocular disorders worldwide, and its undercorrection is the leading cause of visual impairment.^{1,2} Refractive error, particularly undercorrection of myopia, can also affect performance at school, can reduce employability and productivity, and may generally impair quality of life.² Myopic individuals, particularly highly myopic persons, are susceptible to other ocular abnormalities and diseases, namely, retinal detachment, myopic maculopathy, and glaucomatous optic neuropathy.^{2,3} Despite the importance of myopia, only relatively few school-based studies on the prevalence of myopia have been carried out in China.^{4–8} Furthermore, previous studies were mainly performed in metropolitan regions at the Pacific coast of mainland China, such as in Beijing and in Guangzhou. There is a paucity of data on the prevalence of refractive errors in schoolchildren in the vast West of China, where, as compared with East Chinese metropolitan regions, education intensity, social economic conditions, and climate are different. We therefore conducted

this study to examine the prevalence of myopia in West China. As study region we chose a city in an oasis in the middle of the Gobi Desert in Inner Mongolia. This city of Ejina has the advantage that due to its isolated location, exchange of the population with other regions is limited and the population is relatively stable.

METHODS

The Desert Gobi Children Eye Study was a cross-sectional, school-based study that was performed in the city oasis of Ejina.⁹ The study was conducted in accordance with the tenets of the Declaration of Helsinki. The Ethics Board of the Affiliated Hospital of Inner Mongolia Medical University Hohhot and the local Administration of the Education and School Board of Ejina approved the study, and informed written consent was obtained from the parents or guardians of all children. Ejina is located in the most western part of the Chinese province of Inner Mongolia

and is characterized by extremely arid conditions. The study region belongs to the north temperature climate zone with a mean annual precipitation of approximately 40 mm. Average minimum winter temperatures are close to -40°C , while summertime temperatures can reach 50°C .

The study included all three available schools in Ejina, which has a total population of 18,030 inhabitants (including 11,301 Han Chinese, 6209 Mongols, and 520 individuals from other minorities). The next settlement is located a distance of approximately 400 km away. The three schools in Ejina (Ejina primary school [911 students], Ejina middle school [765 students], and Minority school [235 students]) included in total 1911 children.

The ophthalmologic examination consisted of measurement of uncorrected visual acuity and best-corrected visual acuity, slit lamp-based examination of the anterior ocular segment by an ophthalmologist, tonometry (noncontact tonometer; Canon TX-F Full-Auto Tonometer; Canon Co., Tokyo, Japan), and assessment of ocular motility, binocularity, and presence of strabismus. Cycloplegia was achieved by instilling at least three drops of 1% cyclopentolate (Alcon, Fort Worth, TX, USA) before autorefractometry (ARK-900; Nidek, Tokyo, Japan) and fundus photography were carried out. For refractometry, each eye was measured at least three times. The spherical equivalent (SE) of the refractive error was defined as the spherical value of refractive error plus one-half of the cylindrical value. We additionally measured body height (using a stadiometer) and body weight, heart rate, and blood pressure (using an automatic blood pressure monitor [YE655A; YUYUE, Jiangsu, China]). Body mass index was calculated as the ratio of body weight (expressed in kilograms) divided by the square of body height (expressed in meters).

The parents of the children were interviewed using a standardized questionnaire including questions on the profession, level of education, income, and ethnic background of both parents; the birth weight, birth age, and type of birth of the children; and whether oxygen was supplied after birth. Glasses worn by the parents were measured as an estimate of their refractive errors. The parents were not refracted.

Myopia was defined as a spherical equivalent of refractive error of ≤ -0.50 , ≤ -1.00 , and ≤ -6.00 diopters (D), respectively, in the worse eye. The eye with higher absolute value of the refractive error was taken as the worse eye.

Statistical analysis was performed using SPSS for Windows (version 22.0; IBM-SPSS, Chicago, IL, USA). Prevalence was calculated as the number of participants with the particular type of refractive error in relation to the total number of examined children and is given as mean $\pm$ standard error; 95% confidence intervals (95% CI) are also included. The normal distribution of parameters was tested by the Kolmogorov-Smirnov test. In the case of not normally distributed parameters, the Mann-Whitney test was applied to examine the statistical significance of difference between unpaired groups. The χ^2 test was used to compare proportions. Linear regression analysis was applied to examine associations between refractive error and other parameters such as age and body height. Logistic regression was used to compare the prevalence of myopia between age, sex, ethnicity (Han versus minorities including Mongolian, Hui, Erwenke, Man, Tujia, and Tibetan), and school type (Han school versus minority school) groups. Odds ratios (OR) and their 95% confidence intervals (CI) are presented. *P* values represent results for two-sided tests, with values less than 0.05 considered statistically significant.

RESULTS

Out of 1911 children who were eligible for the study, 346 refused the examination, so the study eventually included 1565

(81.9%) children (801 [51.2%] boys) with a mean age of 11.9 ± 3.5 years (median: 11.7 years; range, 6–21 years). In terms of ethnicity, 1264 fathers (80.8%) of the students were Han, and 282 (18%), 14 (0.9%), 4 (0.3%), and 1 (0.1%) were Mongolian, Hui, Man, and Erwenke, respectively. Correspondingly, 1209 (77.3%), 335 (21.4%), 14 (0.9%), 3 (0.2%), 3 (0.2%), and 1 (0.1%) of the mothers were Han, Mongolian, Hui, Man, Tibetan, and Tujia, respectively. If either of the parents of a student was a member of a minority group, the student was considered to belong to this minority group. There were 1160 Han students and 405 students from minority groups (Table 1).

The mean spherical equivalent refractive error was -1.22 ± 1.90 D (median: -0.50 D, range, -13.00 to $+6.50$ D) for right eyes and -1.30 ± 1.92 D (median: -0.63 D; range, -12.75 to $+5.75$ D) for left eyes, or -1.38 ± 2.04 D (median -0.88 D, range, -13.00 to $+6.50$ D) for the worse eyes. Refractive errors were not normally distributed ($P < 0.001$).

In univariate analysis, girls as compared with boys were significantly more myopic (-1.48 ± 2.01 vs. -1.28 ± 2.01 D; $P = 0.02$). Refractive error decreased significantly, that is, became more myopic, with older age (correlation coefficient $r = -0.43$; $P < 0.001$), higher diastolic blood pressure ($r = -0.22$; $P < 0.001$) and higher systolic blood pressure ($r = -0.30$; $P < 0.001$), lower pulse ($r = 0.10$; $P < 0.001$), higher body weight ($r = -0.37$; $P < 0.001$), taller body height ($r = -0.41$; $P < 0.001$) and higher body mass index ($r = -0.25$; $P < 0.001$), non-Han ethnicity of father ($P = 0.001$) and mother ($P < 0.001$), higher refractive error of father ($r = 0.16$; $P < 0.001$) and mother ($r = 0.14$; $P < 0.001$), and higher number of hours spent indoors ($r = -0.14$; $P < 0.001$). Refractive error was not significantly associated with intraocular pressure ($P = 0.14$).

The multivariate analysis included all parameters that were significantly associated with refractive error in univariate analysis. Due to collinearity, we first dropped body weight (variance inflation factor [IF]: 53.7), body height (IF: 23.6), and systolic blood pressure (IF: 2.2). We then dropped those parameters that were no longer significantly associated with refractive error: pulse ($P = 0.82$), paternal ethnicity ($P = 0.38$), maternal ethnicity ($P = 0.52$), and body mass index ($P = 0.24$).

In the final model, more myopic refractive errors were significantly associated with older age ($P < 0.001$), female sex ($P = 0.005$), more myopic refractive error of the father ($P < 0.001$) and mother ($P < 0.001$), and less hours spent outdoors after school ($P = 0.038$) (Table 2).

Overall, the prevalence of myopia increased significantly (all $P \leq 0.001$) with age (Figs. 1, 2). The prevalence of myopia defined as refractive error ≤ -0.50 , ≤ -1.00 , and ≤ -6.00 D in the worse eye was $60.0 \pm 1.2\%$, $48.0 \pm 1.3\%$, and $2.9 \pm 0.4\%$, respectively. In multivariate logistic regression analysis, presence of myopia (defined as myopic refractive error of ≤ -1.00 D in the worse eye) was significantly associated with older age ($P < 0.001$), female sex ($P = 0.001$), more myopic refractive error of the father ($P = 0.002$) and mother ($P < 0.001$), and less hours spent outdoors after school ($P = 0.04$) (Table 3).

The overall prevalence of high myopia defined as refractive error ≤ -6.00 D was $2.9 \pm 0.4\%$ (95%CI: 2.1, 3.7) (or 45 out of 1565 study participants). It increased from $3.4 \pm 1.5\%$ in 11-year-olds to $9.9 \pm 3.0\%$ in teenagers aged 18+ years (Fig. 2). In multivariate logistic regression analysis, presence of high myopia (defined as myopic refractive error of ≤ -6.00 D in the worse eye) was significantly associated with older age ($P < 0.001$; OR: 1.37; 95%CI: 1.23, 1.52) and more myopic refractive error of the mother ($P < 0.001$; OR: 0.74; 95%CI: 0.64, 0.85). The mean number of hours daily spent outdoors did not differ significantly between the highly myopic group and the nonhighly myopic group (0.93 ± 1.32 hours versus 0.88 ± 1.23 hours; $P = 0.94$). Correspondingly, the prevalence of high myopia was not significantly ($P = 0.66$) associated with the

TABLE 1. Demographic Characteristics of the Participants of the Gobi Desert Children Eye Study

Age, y	Sex, <i>n</i> (%)		Ethnicity, <i>n</i> (%)		
	<i>n</i> (%)	Boys	Girls	Han	Mongolian and Other Ethnicities
6	1 (0.1)	0 (0.0)	1 (100.0)	0 (0.0)	1 (100.0)
7	110 (7.0)	50 (45.5)	60 (54.5)	71 (64.5)	39 (35.5)
8	149 (9.5)	73 (49.0)	76 (51.0)	104 (69.8)	45 (30.2)
9	147 (9.4)	70 (47.6)	77 (52.4)	100 (68.0)	47 (32.0)
10	153 (9.8)	92 (60.1)	61 (39.9)	127 (83.0)	26 (17.0)
11	118 (7.5)	58 (49.2)	60 (50.8)	91 (77.1)	27 (22.9)
12	148 (9.5)	69 (46.6)	79 (53.4)	99 (66.9)	49 (33.1)
13	132 (8.4)	61 (46.2)	71 (53.8)	87 (65.9)	45 (34.1)
14	134 (8.6)	73 (54.5)	61 (45.5)	103 (76.9)	31 (23.1)
15	120 (7.7)	66 (55.0)	54 (45.0)	83 (69.2)	37 (30.8)
16	120 (7.7)	69 (57.5)	51 (42.5)	90 (75.0)	30 (25.0)
17	80 (5.1)	42 (52.5)	38 (47.5)	67 (83.8)	13 (16.3)
18	100 (6.4)	50 (50.0)	50 (50.0)	89 (89.0)	11 (11.0)
19	43 (2.7)	23 (53.5)	20 (46.5)	39 (90.7)	4 (9.3)
20	7 (0.4)	2 (28.6)	5 (71.4)	7 (100.0)	0 (0.0)
21	3 (0.2)	3 (100.0)	0 (0.0)	3 (100.0)	0 (0.0)
Total	1565 (100.0)	801 (51.2)	764 (48.8)	1160 (74.1)	405 (25.9)

number of hours spent outdoors in the multivariate model including age and maternal myopic refractive error. However, the statistical power to detect a significant difference was also limited; it is estimated that a sample size of 4000 participants would be needed to correctly reject the null hypothesis when it is false.

DISCUSSION

Our population-based study in Western China confirms previous studies from the Pacific rim indicating that the prevalence of myopia in general and that of high myopia in particular are relatively high in the young generation in China. Prevalences of myopia in the young generation, with figures similar to or even higher than those in our study, have been reported for the far more developed urban and suburban regions at the Pacific rim of Eastern China.^{4,5,8,10–15} These studies agree with findings from other countries such as Singapore and Taiwan of high prevalences of myopia in the young generation.^{16–18} These figures on the prevalence of myopia in the young generation contrast with data on the prevalence of myopia in the elderly generation, which was examined in population-based studies such as the Beijing Eye Study. In the latter, with a study population aged 40+ years, the prevalence of myopia defined as a myopic refractive error of <-1.0 D was 16.9% (95%CI: 15.8, 18.0), while the 17-year-old teenagers in our study had a myopia prevalence of 71.3% (95%CI: 62.3, 80.3).¹⁰ In a similar manner, the prevalence of high myopia (refractive error <-6 D) was 2.6% (95%CI: 2.2,

3.1) in the elderly population of the Beijing Eye Study and was 9.9% (95%CI: 4.0, 15.8) in the 17-year-olds in our study. Although it is difficult to draw conclusions from comparisons of myopia prevalence figures for study populations, as studies differ in location, age, examination methods, ethnicity, and other parameters, accumulating data suggest that the young generation in China, both at the Pacific rim and in Western China, have experienced a marked myopic shift in their refractive errors. While such large increases in the prevalence of myopia have not been observed in Western countries, studies by Vitale et al. and others^{19–22} have nonetheless reported modest increases in the prevalence of myopia.

Taking into account that the prevalence of myopia increases with age, the prevalence of myopia in general and of high myopia in particular will further increase in the schoolchildren of our study as they get older.^{4–8,10–15} This has important clinical and public health implications since high myopia is associated with vision-threatening disorders such as myopic maculopathy and myopic chronic open-angle glaucoma.^{3,23,24} Myopic maculopathy is already now one of the most important causes for visual field defects and visual impairment in East Asia.^{17,25,26}

The results of our study can be compared with the findings obtained in previous investigations performed in different regions of China at different times. The data reveal an increase in the prevalence of myopia with a higher degree of urbanization and a more recent date of examination. In 1998, the Refractive Error Study in Children was conducted in the rural Shunyi district northeast of Beijing on 5884 randomly selected children aged 5 to 15 years.⁴ With an overall

TABLE 2. Multivariate Analysis of the Associations of Refractive Error in the Gobi Desert Children Eye Study

Parameter	<i>P</i> Value	Regression Coefficient <i>B</i>	95% Confidence Interval
Age, y	<0.001	−0.26	−0.28, −0.23
Sex, boys vs. girls	0.005	−0.26	−0.43, −0.08
Paternal refractive error, diopters	<0.001	0.20	0.14, 0.27
Maternal refractive error, diopters	<0.001	0.18	0.12, 0.24
Hours spent outdoors after school	0.038	0.18	0.01, 0.35

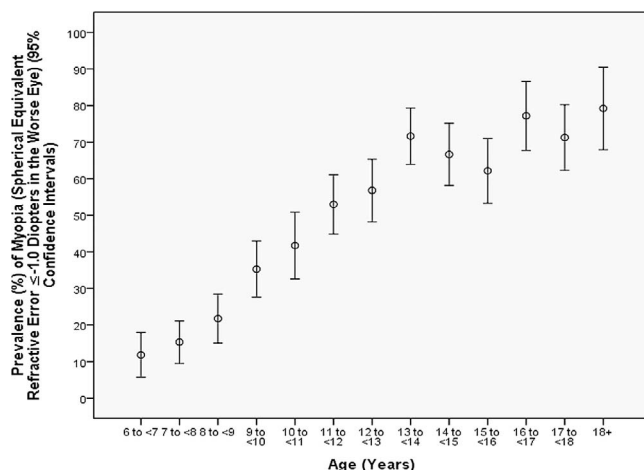


FIGURE 1. Graph showing the prevalence (%) of myopia (defined as spherical equivalent refractive error ≤ -1.0 diopters in the worse eye) in the Gobi Desert Children Eye Study. The error bars show the range of the 95% confidence intervals.

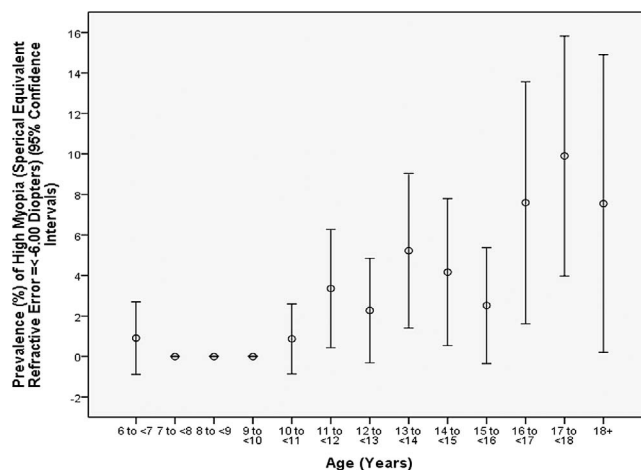


FIGURE 2. Graph showing the prevalence (%) of high myopia (defined as spherical equivalent refractive error ≤ -6.0 diopters in the worse eye) in the Gobi Desert Children Eye Study. The error bars show the range of the 95% confidence intervals.

prevalence of myopia of 16.7%, myopia was mostly absent in the 5-year-old children, and its prevalence increased to 36.7% in boys and to 55.0% in girls by the age of 15 years. Examining 4364 children aged 5 to 15 years in Guangzhou in the year 2004, He and coworkers⁵ found a prevalence of myopia of 3.3% in children aged 5 years and of 73.1% in children aged 15 years. In a study from Hong Kong on 7560 children aged 5 to 16 years in 2004, myopia defined as refractive error ≤ -0.50 D was found in $36.7 \pm 2.9\%$ of the children.⁶ In 2005, a similar study was carried out in the southern rural county of Yangxi on 2454 children with an age of 13 to 17 years.¹¹ Prevalence of myopia increased from 36.8% in the 13-year-old children to 53.9% in the 17-year-old teenagers. In 2010, Pi and colleagues¹² published the results of a population-based refractive error study in the metropolis of Chongqing in West China. Prevalence of myopia increased from 0.42% in 6-year-old children to 27.1% in 15-year-old teenagers. The Beijing Childhood Eye Study carried out in 2008 examined 15,066 school students aged from 7 to 18 and revealed a prevalence of myopia overall of $64.9 \pm 0.4\%$.⁸ Our finding of a high prevalence of myopia in the 18-year-old group agrees with a recent study from South Korea, in which a 19-year-old male population from Seoul had a myopia prevalence of 96.5%.²⁷ Our study also agrees with a recent cross-sectional study on 5083 students from Donghua University in Shanghai.¹⁵ Mean refractive error was -4.1 D, and 95.5% of the students were myopic (< -0.50 D), 19.5% were highly myopic (< -6.0 D), and only 3.3% of the individuals were emmetropic (-0.5 to $+0.5$ D). The tendency toward a higher prevalence of myopia in the younger generation in China has also been demonstrated in a recent investigation by Xiang and colleagues,¹³ who showed that the prevalence of myopia was significantly higher in Chinese children than in their parents. All these studies, including investigations assessing differences in refractive error between parents and their children, agree on the considerable increase in the prevalence of myopia.²⁸

As in previous studies, factors associated with myopia in our study were older age, parental myopia, and time spent outdoors.^{29–31} Interestingly, the prevalence of high myopia (refractive error ≤ -6.00 and ≤ -8 D) was not significantly associated with the time spent outdoors in our study. Future investigations are needed to address the question whether or not the development of high myopia is related to lifestyle,

given the limited statistical power to address this question in the current study resulting from the relatively small sample size. This would have clinical and practical importance, since prolonging time spent outdoors by children has been considered to be a protective measure against the development of myopia in general.

Interestingly, prevalence of myopia and myopia refractive error was not significantly associated with the parental ethnicity (Han Chinese versus Mongolian or other minorities) after adjusting for age, sex, parental refractive error, and time spent outdoors (Tables 2, 3). One may suggest that the ethnic background, as compared to lifestyle of the children, parental myopia, and sex, played a minor role in the development of myopia. This observation fits with the results of a recent multicenter genetic study in which 24 new loci associated with refractive error were identified and in which a 10-fold increased risk of myopia for those individuals carrying the highest number of risk alleles was shown, but in which the genetic variants explained only 3.4% of the phenotypic variation in refractive error.³² These findings emphasize the importance of nongenetic factors in the development of myopia.

Potential limitations of our study should be mentioned. First, as in any population-based study, nonparticipation might have induced a selection bias. In our study, the response rate of 81.9% of eligible children participating was comparable with that in other population-based studies. In addition, our study included all children in a specific area, which due to its geographic location did not overlap with neighboring areas. Second, the population of the oasis city of Ejina in West China is not representative of China as a whole. Living and other conditions in our study region, however, are similar to those in other regions of the Far West of China, so the results of our investigation may have predictive value for other Western Chinese provinces. Third, we did not measure axial length, which would have complemented our data on refractive status measured under cycloplegic conditions. Fourth, because our study had a relatively large sample size overall, statistically significant associations do not necessarily signify practically important correlations. In addition to low P values, however, the odds ratios in the multivariate analysis of the associations between the prevalence of myopia and other parameters were considerably different from 1.0 (Table 3). These data suggest

TABLE 3. Multivariate Analysis of the Associations of the Prevalence of Myopia (Defined as Myopic Refractive Error of ≤ -1.00 D in the Worse Eye) in the Gobi Desert Children Eye Study

Parameter	P Value	Odds Ratio	95% Confidence Interval
Age, y	<0.001	1.34	1.29, 1.39
Sex, boys vs. girls	0.001	1.51	1.19, 1.90
Paternal refractive error, diopters	0.002	0.87	0.79, 0.95
Maternal refractive error, diopters	<0.001	0.85	0.79, 0.92
Hours spent outdoors after school	0.04	0.80	0.64, 0.99

that in addition to being statistically significant, the associations have practical meaning.

In conclusion, even in Western China, the prevalence of myopia in schoolchildren is relatively high. As in Eastern China, low and medium myopia was associated with less time spent outdoors. High myopia was not significantly associated with outdoors time. Compared with the myopia prevalence in elderly Chinese populations, the relatively high myopia prevalence in schoolchildren overall in China predicts a marked increase in vision-threatening high myopia in the elderly populations in China in the future.

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