Annual Incidences and Progressions of Myopia and High Myopia in Chinese Schoolchildren Based on a 5-Year Cohort Study

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PURPOSE. To determine the annual incidences and rates of progression of myopia and high myopia in Chinese schoolchildren from grade 1 to grade 6 and explore the possible cause-specific risk factors for myopia.

METHODS. From 11 randomly selected primary schools in Anyang city, central China, 2835 grade 1 students were examined with annual follow ups for 5 years. Students were invited to undergo a comprehensive examination, including cycloplegic autorefriction, ocular biometry, and standardized questionnaires.

RESULTS. The mean spherical equivalent refraction decreased substantially from +0.94 ± 1.03 diopter (D) in grade 1 to −1.37 ± 0.28 D in grade 6, with rapid annual myopic shifts, especially for students in grades 3 through 6 (−0.51 to −0.59 D). The prevalence of myopia increased substantially, with the yearly incidence of myopia increasing from 7.8% in grade 1 and 2 to 25.3% in grades 5 and 6, and the incidence of high myopia increased from 0.1% to 1.0%. The 5-year incidence of myopia was lowest among children who has a baseline spherical equivalent refraction of greater than +2.00 D (4.4%), and increased to nearly 92.0% among children whose baseline spherical equivalent refraction was 0.00 to −0.50 D. The incidence of myopia was higher in children who had less hyperopic baseline refraction, two myopic parents, longer axial length, deeper anterior chamber, higher axial length–corneal radius of curvature ratio, and thinner lenses.

CONCLUSIONS. Both the annual incidence and progression rates of myopia and high myopia were high in Chinese schoolchildren, especially after grade 3. Hyperopic refraction of children should be monitored before primary school as hyperopia reserve to prevent the onset of myopia and high myopia.

Keywords: incidence of myopia, hyperopia reserve, schoolchildren

With the rapid increase in its prevalence over the past few decades, myopia has become a major global public health problem worldwide.1,2 Although myopia can be corrected by spectacles or contact lens, high or pathologic myopia can lead to permanent visual impairment and even blindness.3,4 High or pathologic myopia is associated with an increased risk of irreversible blinding conditions,5,6 leading to a heavy cost burden on individuals and communities.

The prevalence of myopia has been reported to be high among East and Southeast Asian schoolchildren and young adults.7 As reported in our previous studies, myopia affects 67.3% of grade 7 children and 83.2% of university students in central China.7,8 In South Korea, an even higher prevalence of 96.5% was found in 19-year-old male conscripts.9 There have been several cross-sectional studies of prevalence of myopia in school-aged children,10–13 but few longitudinal studies on the incidence and progression of myopia in China. Wang et al.14 reported annual incidence of myopia to be 20% from grade 1 to grade 6 and to be 30% from grade 7 to grade 9. However, this study did not perform cycloplegic refraction, which decreased the accuracy in evaluating the refractive status of children.17 A 6-year follow-up of the Sydney Myopia Study revealed a mean annual incidence of myopia of 2.2% in the younger cohort among 1765 children with a mean age of 6.7 years at baseline.16 The Northern Ireland Childhood Errors of Refraction (NICE) reported that the 6-year cumulative median change in spherical equivalent refraction (SER) was −1.38 diopter (D) in 6- to 7-year-old children.19 However, neither of these studies performed
Annual Incidences and Progressions of Myopia

Methods

Study Design and Sample

The Anyang Childhood Eye Study (ACES) was a school-based cohort study aiming to determine the annual rate of incidence, progression, and risk factors for myopia among Chinese children in urban areas of Anyang city, central China. The study methodologies have been reported in detail previously. In brief, we recruited 3112 grade 1 students from 11 randomly selected primary schools from February to May 2012. 2893 (93%) students were examined. They were followed annually for 5 years from February to May.

All children gave their written informed consent form signed by their parents or guardians, as well as verbal assent from each child. The study adhered to the tenets of the Declaration of Helsinki. Ethics committee approval was obtained from the Institutional Review Board of Beijing Tongren Hospital, Capital Medical University.

Procedures

Students who enrolled in the ACES underwent a comprehensive, standardized examination at both baseline and follow-up. After corneal anesthesia with 1 drop of topical anesthetic agent (Alcaine; Alcon, Fort Worth, TX), cyclopia was induced by two drops of 1% cyclopentolate (Alcon) and 1 drop of tropicamide (Mydrin P; Santen, Osaka, Japan) with an interval of 5 minutes between drops. Thirty minutes after tropicamide, cyclopia was considered adequate if the pupillary light reflex was absent or pupil size was more than 6.0 mm. Otherwise, a third drop of cyclopentolate was administered. Cycloplegic refraction was measured for three repeated measurements by an autorefractor (HRK7000 A, Huvitz, Gunpo, South Korea). Ocular biometric components, including AL, lens thickness, and anterior chamber depth (ACD), were measured by the Lenstar LS900 (Haag-Streit, Koeniz, Switzerland) for five repeated measurements with average data used for analysis. An interviewer-administered questionnaire was filled by parents. Information requested included parental myopia, age of myopia onset (if applicable), and time outdoors and near work activities (hours per day) of children after school hours.

Definitions

SER was defined as the sum of spherical power and half of the cylinder. Myopia was defined as a SER of −0.5 D or less, hyperopia as a SER of +0.5 D or greater, and emmetropia as a SER between −0.5 D and 0.5 D. High myopia was defined as a SER of −6.00 D or less. The annual incidence rate of myopia was defined as the proportion of subjects who were not myopic in the preceding year and who subsequently developed myopia during the follow-up. The annual progression of myopia was defined as the change in cycloplegic SER between the measurements acquired in the previous year and the measurements taken during the annual follow-up period. The anterior corneal radius of curvature (CR, in mm) was defined as the average of the greatest and least anterior corneal radii of curvature. The AL/CR ratio was defined as the AL divided by the CR.

Statistical Methods

All examination data were entered independently twice into a database using EpiData software 3.1 (The EpiData Association, Odense, Denmark) by two trained data entry clerks. All analyses were conducted using SPSS software (Version 20.0; SPSS, Inc., Chicago, IL). All data were presented as mean ± standard deviation or percentages. Only right eyes were included for data analyses, because the cycloplegic SER for the right and left eyes were highly correlated at baseline (Spearman correlation coefficient = 0.838). Independent t-tests and analyses of variance were used to compare normally continuous data as appropriate and the χ² test was used for the categorized data. Multivariate logistic regression models were performed to explore factors associated with incident myopia, using individual incident myopia as the dependent variable and various baseline characteristics as covariates and adjusting for age and gender where appropriate. To investigate the predictive ability of risk factors for incident myopia, receiver-operating characteristic curves were plotted to calculate area under the curve. The hazard ratios of having myopia for children with different hyperopic refractions were analyzed by taking those with a baseline SER of more than +2.00 D as a reference group. A two-sided P value of less than 0.05 was considered statistically significant.

Results

At baseline, 3112 students in grade 1 in school year 2012 were eligible to participate in the ACES, of whom 2835 (91.1%) had complete cycloplegic refraction measurement. Baseline demographic and ocular biometry parameters are included in Table 1. The mean age of the 2835 children was 7.2 ± 0.3 years, with 57.9% boys. Students were followed annually for 5 years (until 2017), at which time graduation of all children occurred. A total of 2553 children (90.1%) were reexamined in the first follow-up visit, 2533 (89.3%) in the second follow-up visit, 2479 (87.4%) in the third follow-up visit, 2362 (83.3%) in the fourth follow-up visit, and 2048...
Table 1. Baseline Characteristics of the 2835 Participants

<table>
<thead>
<tr>
<th>Variable</th>
<th>All (n = 2835)</th>
<th>Boys (n = 1641)</th>
<th>Girls (n = 1194)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD), y</td>
<td>7.15 (0.28)</td>
<td>7.17 (0.41)</td>
<td>7.13 (0.38)</td>
<td>.003</td>
</tr>
<tr>
<td>SE, mean (SD), D</td>
<td>0.94 (1.03)</td>
<td>0.91 (0.99)</td>
<td>0.98 (1.09)</td>
<td>.094</td>
</tr>
<tr>
<td>AL, mean (SD), mm</td>
<td>22.72 (0.76)</td>
<td>22.95 (0.70)</td>
<td>22.39 (0.71)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>ACD, mean (SD), mm</td>
<td>2.89 (0.24)</td>
<td>2.94 (0.23)</td>
<td>2.83 (0.24)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>LT, mean (SD), mm</td>
<td>3.61 (0.19)</td>
<td>3.60 (0.18)</td>
<td>3.64 (0.20)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>CR, mean (SD), mm</td>
<td>7.79 (0.25)</td>
<td>7.86 (0.25)</td>
<td>7.71 (0.24)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>AL/CR, mean (SD),</td>
<td>2.92 (0.07)</td>
<td>2.92 (0.07)</td>
<td>2.91 (0.08)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Height, mean (SD), cm</td>
<td>123.54 (5.30)</td>
<td>124.20 (5.12)</td>
<td>122.64 (5.41)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Weight, mean (SD), kg</td>
<td>24.64 (4.81)</td>
<td>25.27 (4.90)</td>
<td>23.78 (4.54)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Parental Myopia n (%)</td>
<td></td>
<td></td>
<td></td>
<td>.062</td>
</tr>
<tr>
<td>None</td>
<td>1874 (66.1)</td>
<td>1106 (67.4)</td>
<td>768 (64.3)</td>
<td></td>
</tr>
<tr>
<td>One</td>
<td>754 (26.6)</td>
<td>430 (26.2)</td>
<td>324 (27.1)</td>
<td></td>
</tr>
<tr>
<td>Both</td>
<td>207 (7.3)</td>
<td>105 (6.4)</td>
<td>102 (8.5)</td>
<td></td>
</tr>
</tbody>
</table>

P value shows the comparisons between boys and girls.

Figure 1 shows mean SERs for each school year. The mean SER decreased substantially from 0.94 ± 1.03 D in grades 1 and 2 to 0.50 ± 0.50 D (95% CI, 0.49–0.51 D), and grades 5 and 6 (0.50 ± 0.50 D) (Table 2). Girls had greater annual myopic shifts than boys (P < 0.001) for the third and succeeding follow-up visits. Myopes had greater annual myopic shifts than nonmyopes (P < 0.001) for the follow-up visits (Table 2).

Table 4 shows the annual incidence of myopia and high myopia by gender. These increased with higher grade: from 7.8% (95% confidence interval [CI], 6.8%–8.9%) in grades 1 and 2 to 13.9 (12.4%–15.3%) in grades 2 and 3, 18.6 (16.9%–20.4%) in grades 3 and 4, 20.6 (18.5%–22.7%) in grades 4 and 5, and 25.3 (22.7%–27.9%) in grades 5 and 6. The annual incidence for high myopia was no more than 1% for the primary school students.

Figure 2 shows the 5-year cumulative incidence of myopia. The more hyperopic at baseline, that is, a greater “hyperopia reserve,” the less likely myopia was to develop. Incidence rate of myopia was lowest among children whose baseline SER was +0.94 D (4.4%; 95% CI, 0.9%–7.9%), and increased to nearly 50% among children whose baseline SER was +1.50 D. The cumulative incidence of myopia varied according to different baseline demographic and ocular biometry parameters in nonmyopic students. Girls had significantly greater odds for cumulative incidence of myopia (odds ratio [OR], 1.7; 95% CI, 1.4–2.1) than boys (P < 0.001). Compared with children without a myopic parent, the ORs for cumulative incidences of myopia were 1.6 (95% CI, 1.3–2.0; P < 0.001) for children with one myopic parent and 2.9 (95% CI, 1.8–4.6; P < 0.001) with two myopic parents. In our multivariate logistic regression analysis controlling for age, gender, myopic parents, time outdoors, near work, higher AL/CRs, longer ALs, deeper anterior chambers, lens thickness, and corneal curvature of radius, the following were associated with higher risk of cumulative incidence of myopia: female gender (OR, 3.1; 95% CI, 2.3–4.3; P < 0.001), more myopic parents (OR, 1.4;
Girls

The incidence rates were higher in children who had less
myopic shifts in grades 3 and 4 (–0.59 D), and in grades 4 and
5 (–0.51 D), and in grades 5 and 6 (–0.56 D). The yearly
incidence rates of myopia increased from 7.8% in the first
year (grades 1–2) to 25.3% in the fifth year (grades 5–6).
The incidence rates were higher in children who had less
baseline refractions, two myopic parents, longer AL, deeper
anterior chambers, higher AL/CR ratios, and thinner lenses.

Epidemiological studies reporting similar issues among
primary school students with annual changes are lack-
ing, with the exception of one in Guangzhou, China.
As acknowledged by its authors, that study overestimated
myopia owing to the use of noncycloplegic autorefraction.
Our study demonstrated the mean annual rates of change
in SER were more than –0.50 D per year after grade 3, with
the fastest change of –0.59 D in the third year (grades 3–4).
Consistent with the CLEERE, we found that annual progress-
sion was faster than for boys. Therefore, it is highly impor-
tant to implement interventions on preventing the develop-
ment of myopia among primary school students, especially
for students before grade 3. The low development of myopia
in the first 2 to 3 years of primary schools indicates that
there is a 3-year window to apply school-based measures to
slow the onset of myopia before large numbers of children
become myopic.

In another follow-up study conducted in Western China,
the mean progression of myopia was –2.21 D over 5 years
with an annual myopia progression rate of –0.43 D, which
was similar to the mean progression of –0.46 D in our study.
In Shanghai children, the average 2-year myopia progression
rates were much higher at –0.91 D for grade 1, –0.91 D for
grade 2, and –1.11 D for grade 3. Two studies from about
20 years ago found lower annual myopia progression rate
than ours: a study in Shunyi District (–0.17 D per year in
children aged 5–13 years) and a Hong Kong study (–0.32
D per year in children aged 7–12 years). The higher myopia
progression rate in the recent studies may be associated with
the development of intensive mass education systems and
exposure to rapid urbanization.

The mean myopia progression rates in Chinese children
were higher than for studies in Australian primary school
children (–0.16 D), white Northern Irish schoolchildren
(–0.38 D), and children from the Collaborative Longitudi-
nal Evaluation of Ethnicity and Refractive Error Study (–0.38
D), but lower than reported in the Singapore Cohort Study
of the Risk Factors for Myopia Singapore (–0.80 D in 7-year-
olds, –0.66 D in 8-year-olds, and –0.57 D in 9-year-olds).

### Table 2. Annual Change of SER in Primary School Students

<table>
<thead>
<tr>
<th>Variable</th>
<th>All</th>
<th>Myopes</th>
<th>Nonmyopes</th>
</tr>
</thead>
<tbody>
<tr>
<td>All 1–2 y</td>
<td>-0.33 (-0.35, -0.30)</td>
<td>-0.69 (-0.85, -0.53)</td>
<td>-0.30 (-0.32, -0.28)</td>
</tr>
<tr>
<td>2–3 y</td>
<td>-0.45 (-0.47, -0.43)</td>
<td>-0.90 (-0.98, -0.83)</td>
<td>-0.38 (-0.40, -0.36)</td>
</tr>
<tr>
<td>3–4 y</td>
<td>-0.59 (-0.61, -0.57)</td>
<td>-0.97 (-1.00, -0.93)</td>
<td>-0.47 (-0.50, -0.45)</td>
</tr>
<tr>
<td>4–5 y</td>
<td>-0.51 (-0.54, -0.49)</td>
<td>-0.76 (-0.80, -0.73)</td>
<td>-0.37 (-0.39, -0.34)</td>
</tr>
<tr>
<td>5–6 y</td>
<td>-0.56 (-0.59, -0.54)</td>
<td>-0.73 (-0.77, -0.70)</td>
<td>-0.41 (-0.44, -0.38)</td>
</tr>
</tbody>
</table>

### Table 3. Prevalence of Myopia in Primary School Students

<table>
<thead>
<tr>
<th>Variable</th>
<th>All</th>
<th>Boys</th>
<th>Girls</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year level</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 y</td>
<td>6.6 (5.6–7.5)</td>
<td>6.9 (5.7–8.2)</td>
<td>6.0 (4.7–7.4)</td>
<td>.596</td>
</tr>
<tr>
<td>2 y</td>
<td>15.7 (12.4–15.0)</td>
<td>15.4 (11.7–15.1)</td>
<td>14.1 (12.1–16.1)</td>
<td>.827</td>
</tr>
<tr>
<td>3 y</td>
<td>25.2 (23.6–26.8)</td>
<td>24.2 (22.0–26.3)</td>
<td>26.5 (24.0–29.0)</td>
<td>.073</td>
</tr>
<tr>
<td>4 y</td>
<td>38.2 (36.4–40.1)</td>
<td>35.7 (33.3–38.1)</td>
<td>41.5 (38.6–44.3)</td>
<td>.903</td>
</tr>
<tr>
<td>5 y</td>
<td>50.2 (48.2–52.1)</td>
<td>60.2 (43.6–48.8)</td>
<td>55.3 (52.4–58.3)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>6 y</td>
<td>61.5 (59.4–63.6)</td>
<td>56.1 (53.2–59.0)</td>
<td>67.9 (64.9–70.9)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

P values were used to compare the prevalence of myopia
for boys and girls.

95% CI, 1.1–1.8; P = 0.004), higher AL/CRs (OR, 2.3; 95%
CI, 1.8–2.9; P < 0.001), longer ALs (OR, 1.7; 95% CI, 1.3–
2.4; P = 0.001), and deeper anterior chambers (OR, 1.3; 95%
CI, 1.02–1.5; P = 0.035). The following were not associated
with cumulative incidence of myopia: age (P = 0.57), time
outdoors (P = 0.56), near work (P = 0.48), lens thickness (P
= 0.27), or CR (P = 0.23).

Figure 4 shows the receiver operating curve from univari-
ate logistic regressions. The strongest single predictor of
incident myopia was baseline SER with an area under the
curve of 0.82 (95% CI, 0.80–0.84), followed by AL/CR (0.72;
0.70–0.75) and ACD (0.64; 0.61–0.67). The single factors of
gender, parental myopia, AL, CR, and lens thickness had an
area under the curve of less than 0.60. Slight improvements
in prediction were provided by the model combining baseline
SER, gender, and parental myopia (0.84; 0.82–0.85); the
addition of AL/CR and ACD made no improvement.

### DISCUSSION

The mean SER decreased from 0.94 ± 1.03 D among students
in grade 1 to –1.37 ± 2.08 D in grade 6, with rapid annual
myopic shifts in grades 3 and 4 (–0.59 D), in grades 4 and
5 (–0.51 D), and in grades 5 and 6 (–0.56 D). The yearly
incidence rates of myopia increased from 7.8% in the first
year (grades 1–2) to 25.3% in the fifth year (grades 5–6).
The incidence rates were higher in children who had less
Progression rates are higher in East Asia than elsewhere, which is consistent with the higher prevalence of myopia reported in East Asians.

The Guangzhou study reported a high annual myopia incidence of 20.0% to 30.0% throughout primary school.\textsuperscript{16} However, in our study, the incidence rate of myopia was only 7.8% in the first year (grades 1–2), and increased to more than 20% in the fourth and fifth years (grades 4–6). Noncycloplegic refraction was used in the Guangzhou study; as mentioned elsewhere in this article, noncycloplegic refraction overestimates the myopic status and hence the rates of myopia. At present, to obtain the prevalence of myopia among children, the China's National Health Commission have carried out the strategy of school screening. However, although the prevalence of myopia will be overestimated, the use of noncycloplegic refraction for school screening is quite appropriate, because it has the desirable property of identifying all myopes. In addition, the survey was conducted in metropolitan Guangzhou, compared with our study in Anyang, where the socioeconomic status is similar to the national average. Studies have suggested that myopia prevalence is associated with socioeconomic status.\textsuperscript{36,39} In the present study, the annual incidence of myopia was similar to those conducted in Chongqing City,\textsuperscript{31} Hong Kong,\textsuperscript{40} and Singapore,\textsuperscript{22} but higher than in Australia\textsuperscript{18} and Northern Ireland.\textsuperscript{19} Annual incidence of myopia was 10.6% among Chongqing school-aged children aged 6 to 15 years,\textsuperscript{31} was
Table 5. Associations between 5-Year Cumulative Incidence of Myopia and Baseline Demographic and Ocular Biometry Parameters

<table>
<thead>
<tr>
<th>Baseline Characteristics</th>
<th>5-Year Cumulative Incidence, n, % (95% CI)</th>
<th>OR (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boys</td>
<td>530 54.2 (51.1–57.4)</td>
<td>Reference</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Girls</td>
<td>510 66.7 (63.3–70.0)</td>
<td>1.69 (1.39, 2.06)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td><strong>Parental myopia</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0 parents</td>
<td>681 55.8 (53.0–58.6)</td>
<td>Reference</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>1 parent</td>
<td>277 66.6 (62.0–71.1)</td>
<td>1.58 (1.25, 2.00)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>2 parents</td>
<td>82 78.1 (70.1–86.1)</td>
<td>2.85 (1.76, 4.62)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td><strong>SER (D)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; +1.50</td>
<td>55 16.4 (12.4–20.3)</td>
<td>Reference</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>&gt; +1.00 to ≤ +1.50</td>
<td>247 49.3 (44.9–53.7)</td>
<td>5.49 (3.87, 7.73)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>&gt; +0.50 to ≤ +1.00</td>
<td>425 75.6 (72.1–79.2)</td>
<td>18.99 (13.23, 27.25)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>&gt; −0.50 to ≤ +0.50</td>
<td>313 91.3 (88.2–94.3)</td>
<td>65.79 (40.45, 107.01)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td><strong>AL (mm)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First tertile (&lt;22.36)</td>
<td>285 50.6 (46.5–54.8)</td>
<td>Reference</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Second tertile (22.36–22.97)</td>
<td>347 59.4 (55.4–63.4)</td>
<td>1.83 (1.42, 2.34)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Third tertile (&gt;22.97)</td>
<td>383 68.3 (64.4–72.1)</td>
<td>3.27 (2.49, 4.31)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td><strong>CR (mm)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First tertile (&lt;7.69)</td>
<td>371 65.2 (61.3–69.1)</td>
<td>Reference</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Second tertile (7.69–7.90)</td>
<td>331 58.1 (54.0–62.1)</td>
<td>0.80 (0.63, 1.02)</td>
<td>.076</td>
</tr>
<tr>
<td>Third tertile (&gt;7.90)</td>
<td>256 55.0 (50.9–59.1)</td>
<td>0.75 (0.59, 0.96)</td>
<td>.024</td>
</tr>
<tr>
<td><strong>Lens thickness (mm)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First tertile (&lt;3.54)</td>
<td>366 68.2 (64.2–72.1)</td>
<td>Reference</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Second tertile (3.54–3.69)</td>
<td>346 60.4 (56.4–64.4)</td>
<td>0.71 (0.56, 0.92)</td>
<td>.008</td>
</tr>
<tr>
<td>Third tertile (&gt;3.69)</td>
<td>268 50.0 (45.8–56.4)</td>
<td>0.44 (0.34, 0.56)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td><strong>ACD (mm)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First tertile (&lt;2.78)</td>
<td>251 45.1 (40.9–49.2)</td>
<td>Reference</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Second tertile (2.78–2.97)</td>
<td>358 61.1 (57.1–65.1)</td>
<td>2.32 (1.81, 2.97)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Third tertile (&gt;2.97)</td>
<td>395 72.2 (68.5–76.0)</td>
<td>4.16 (3.18, 5.45)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td><strong>AL/CR ratio</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First tertile (&lt;0.88)</td>
<td>206 36.6 (32.6–40.6)</td>
<td>Reference</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Second tertile (0.88–2.93)</td>
<td>343 62.7 (58.6–66.8)</td>
<td>3.24 (2.52, 4.17)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Third tertile (&gt;2.93)</td>
<td>460 77.9 (74.6–81.3)</td>
<td>7.52 (5.73, 9.88)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Boldface indicates statistical significance (P < 0.05).

ORs for each group were adjusted for potential confounding effects of age and gender.

14.4% among Hong Kong children aged 5 to 16 years,40 and was 14.2% among Singaporean children aged 7 to 9 years.22 However, the annual incidence of myopia was as low as 2.2% for both Australian children with a mean age of 6.7 ± 0.4 years and for Northern Ireland children aged 6 to 7 years.18,19

As with previous cohort studies, our findings showed that children who had more hyperopic baseline refractions, described by the term “hyperopia reserve,” were less likely to become myopic.41–43 Ma et al.32 found that approximately 9% of grade 1 students in Shanghai with more than 1.0 D hyperopia progressed to myopia after 2 years, whereas we found 36.1% progression in this grade. In addition, we found that 81.5% of children with a baseline SER of +1.00 D to greater than –0.5 D progressed to myopia after 5 years. Our study suggested that school-based health education and prevention programs could be targeted at the grade 1 students with baseline SER less than +1.00 D, aiming to prevent the development of myopia. Our cut-point of +1.00 D is slightly higher than the +0.75D determined in the CLEERE study in the United States.42

Consistent with previous cohort studies,31,22 we found that girls had a higher cumulative incidence of myopia than boys. This finding may be because of more time spend on near work and less time on outdoor activities, as reported by other studies.11,44 Consistent with the CLEERE study21 and the Orinda Longitudinal Study of Myopia,45 we found also that the risk for myopia onset was associated with parental
myopia. In SCORM, Saw et al.22 found that children with greater ALs and vitreous chamber depths and thinner lenses had higher incidence rates of myopia. In Chinese children, Wang et al.16 reported that an AL/CR ratio higher than the 75th percentile at baseline was the second strongest factor associated with incidence of myopia. However, some studies46,47 reported a lower sensitivity for AL/CR ratio than Wang et al. Thus, these relationships may be inconsistent between different ethnic groups and populations. These findings are largely consistent with our study. Therefore, some myopic biometry parameters are risk factors for myopia onset in children. As with previous cohort studies, our findings showed that baseline SER is the single best predictive factor for myopia onset.48 Adding gender and parental myopia improve the prediction. The further addition of AL/CR and ACD make little difference.

The strengths of our study included the standardized measurement of refractive errors using cycloplegia, a large sample size, and a 5-year longitudinal cohort. However, there are limitations in present study. The main limitation is that, despite efforts to maintain high follow-up rates, there were 27.8% missing data by the fifth, final follow-up visit. Students in grade 6 had intensive mass education pressure due to the unified junior high schools entrance examination soon, leading to lower level of participation. In addition, it might be considered that the overall incidence rates of myopia may be biased because this was a school-based investigation rather than a population-based cohort, but as the attendance rates of grade 1 students were greater than 99%.7 the children in our study are a fair representation of the Anyang population.

CONCLUSIONS

For children in Anyang city in Central China, we found an increasing incidence of myopia from 7.8% in grades 1 and 2 to 25.3% in grades 5 and 6. Mean SER decreased substantially from grade 1 to grade 6, with considerable annual myopic shifts for grades 3 and 4 (−0.59 D), grades 4 and 5 (−0.51 D), and grades 5 and 6 (−0.56 D). Yearly incidence of myopia and changes in SER were higher for girls than boys. We suggest implementing interventions to prevent myopia development throughout primary school, especially before grade 3. Hyperopic refraction of children should be monitored before primary school as hyperopia reserve to prevent the onset of myopia and high myopia, and thus reducing the potential for sight-threatening pathological changes later in life.

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