Prevalence, Incidence, and Progression of Myopia of School Children in Hong Kong

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BACKGROUND. Myopia is the most common ocular disorder. All myopes must endure the physical and financial burden of spectacles and/or contact lenses throughout their lives. The need for optical correction in young myopes has affected career choices and social activities. Persons with a high degree of myopia, particularly those with degenerative or pathologic changes, also have a higher chance of the development of permanent visual impairment or blindness from macular degeneration, retinal detachment, glaucoma, and cataract.1–6 These myopia-related conditions also tend to occur at an earlier age than other common blinding disorders, such as diabetic retinopathy and age-related macular degeneration. The National Eye Institute7 has estimated that costs of refractive eye examinations amount to $1 billion annually, with another $1.5 billion spent on eyeglasses each year. Therefore, it is important to focus research on these age groups. To date, no large-scale studies have been performed to address the prevalence, incidence, and severity of myopia in children of Hong Kong. However, we know Hong Kong children share most of the common features among other East Asian countries—namely, ethnic Chinese living in highly congested environments with competitive lifestyles and heavy schoolwork. We sought to examine these important epidemiologic parameters and compare them with the published data. Prevention and healthcare planning for our next generation will be much facilitated when this important information is known. The study also has a component to investigate the risk factors of myopia and its progression, such as parental history of myopia, visual tasks, and astigmatism. We are in the process of finalizing the data analysis of this part of the study in preparation for another report.

METHODS

Study Population and Sampling

A school-based prevalence survey on myopia was conducted in Hong Kong from September 1998 to August 2000. Approval from the Ethics Committee of The Chinese University of Hong Kong was granted before the study commenced, and all ophthalmic examinations followed the guidelines of the Declaration of Helsinki. All children aged 6 to 15 residing in Hong Kong must attend school by local law. The study population included primary schools children, grades 1 to 6. There were 797 primary schools throughout the 19 school districts in Hong Kong with the exclusion of international schools and special schools for handicapped children. We randomly selected one primary school from each of the 19 school districts in Hong Kong. Invitation letters were sent to the school principal detailing the study objectives and procedures. When a selected school refused to participate, another school in the same district was selected randomly. Four of the 19 invited schools declined our invitation. Another four schools from the respective districts were invited, and they all agreed to participate in the study. From each school, two to three classes were randomly selected.

RESULTS. A total of 7560 children of mean age 9.33 (95% confidence interval [CI] = 9.11–9.45; range, 5–16) participated in the study. Mean spherical equivalent refraction (SER) was −0.35 D (SD = 11.56; range, −13.13 to +14.25 D). Myopia (SER ≤−0.50 D) was the most common refractive error and was found in 36.71% ± 2.87% (SD) of children. Prevalence of myopia correlated positively with older age. Children aged 11 years were almost 15 times more likely to have myopia than were children younger than 7 years (Odds ratio [OR] = 14.81; 95% CI = 14.17–15.48). Incidence of myopia was 144.1 ± 2.31 (SD) per 1000 primary school children per annum. Increasing age was correlated with increased incidence of myopia, with highest risk in children ages 11 years (OR = 2.27; 95% CI = 2.11–2.44). The average annual change in SER for children with myopia (SER ≤−0.50 D) was −0.65 D (SD = 3.44) compared with −0.29 D (SD = 2.96) for those who were not myopic at the beginning of the study (P < 0.001).

CONCLUSIONS. The results show that the prevalence and progression of myopia in Hong Kong children was much higher than those previously reported in Western countries. The long-term socioeconomic impact of these findings warrants further studies. (Invest Ophthalmol Vis Sci. 2004;45:1071–1075) DOI: 10.1167/iovs.03-1151

Myopia is the most common ocular disorder. All myopes must endure the physical and financial burden of spectacles and/or contact lenses throughout their lives. The need for optical correction in young myopes has affected career choices and social activities. Persons with a high degree of myopia, particularly those with degenerative or pathologic changes, also have a higher chance of the development of permanent visual impairment or blindness from macular degeneration, retinal detachment, glaucoma, and cataract.1–6 These myopia-related conditions also tend to occur at an earlier age than other common blinding disorders, such as diabetic retinopathy and age-related macular degeneration. The National Eye Institute7 has estimated that costs of refractive eye examinations amount to $1 billion annually, with another $1.5 billion spent on eyeglasses each year. Therefore, it is important to focus research on these age groups. To date, no large-scale studies have been performed to address the prevalence, incidence, and severity of myopia in children of Hong Kong. However, we know Hong Kong children share most of the common features among other East Asian countries—namely, ethnic Chinese living in highly congested environments with competitive lifestyles and heavy schoolwork. We sought to examine these important epidemiologic parameters and compare them with the published data. Prevention and healthcare planning for our next generation will be much facilitated when this important information is known. The study also has a component to investigate the risk factors of myopia and its progression, such as parental history of myopia, visual tasks, and astigmatism. We are in the process of finalizing the data analysis of this part of the study in preparation for another report.

METHODS
Table 1. Prevalence of Emmetropia and Different Types of Refractive Errors in Primary School Children of Hong Kong

<table>
<thead>
<tr>
<th></th>
<th>Boys (n = 3817)</th>
<th>Girls (n = 3743)</th>
<th>All (n = 7560)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emmetropia</td>
<td>% (SD)</td>
<td>% (SD)</td>
<td>% (SD)</td>
</tr>
<tr>
<td>(&gt;−0.50 D and &lt;± 2.00 D SER)</td>
<td>60.1 (2.9)</td>
<td>58.4 (2.9)</td>
<td>59.3 (2.9)</td>
</tr>
<tr>
<td>Hyperopia (≥ +2.00 D SER)</td>
<td>3.9 (1.2)</td>
<td>4.2 (1.2)</td>
<td>4.0 (1.2)</td>
</tr>
<tr>
<td>Myopia (≤ −0.50 D SER)</td>
<td>36.0 (2.9)</td>
<td>37.4 (2.9)</td>
<td>36.7 (2.9)</td>
</tr>
<tr>
<td>Astigmatism (≥ −1.00 cylinder)</td>
<td>19.4 (0.7)</td>
<td>16.7 (0.6)</td>
<td>18.1 (0.4)</td>
</tr>
<tr>
<td>Anisometropia (SER difference ≥ 1.00 D)</td>
<td>8.6 (0.5)</td>
<td>9.7 (0.5)</td>
<td>9.2 (0.3)</td>
</tr>
</tbody>
</table>

Table 2. Refractive Error among Primary School Children of Hong Kong

<table>
<thead>
<tr>
<th>Subjects (n)</th>
<th>Prevalence (%)</th>
<th>Odds Ratio</th>
<th>95% CI</th>
<th>Myopia</th>
<th>Refractive Error (SER)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td>Female</td>
<td>3743</td>
<td>37.4</td>
<td>Reference</td>
<td>Reference</td>
<td>−0.29</td>
</tr>
<tr>
<td>Male</td>
<td>3817</td>
<td>36.0</td>
<td>0.96</td>
<td>0.939–0.976</td>
<td>−0.36</td>
</tr>
<tr>
<td>Age (y)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Below 7</td>
<td>1035</td>
<td>17.0</td>
<td>Reference</td>
<td>Reference</td>
<td>0.67 D</td>
</tr>
<tr>
<td>7</td>
<td>1194</td>
<td>28.9</td>
<td>2.55</td>
<td>2.44–2.67</td>
<td>0.44 D</td>
</tr>
<tr>
<td>8</td>
<td>1210</td>
<td>37.5</td>
<td>4.31</td>
<td>4.12–4.50</td>
<td>0.00 D</td>
</tr>
<tr>
<td>9</td>
<td>1134</td>
<td>43.1</td>
<td>7.12</td>
<td>6.82–7.45</td>
<td>−0.34 D</td>
</tr>
<tr>
<td>10</td>
<td>1267</td>
<td>48.2</td>
<td>9.11</td>
<td>8.72–9.51</td>
<td>−0.77 D</td>
</tr>
<tr>
<td>≥11</td>
<td>1720</td>
<td>53.1</td>
<td>14.81</td>
<td>14.17–15.48</td>
<td>−1.26 D</td>
</tr>
</tbody>
</table>

Data are estimates of coefficient and standard error of a multivariate model; age and sex are covariates in the model.

* Coefficient, estimate of coefficient.
A positive correlation between the prevalence of myopia and age was evident, with more than half of the children (54.52%) older than 11 years being myopic. Compared with children younger than 7 years, the average refractive errors for all other age groups were significantly more myopic (all \( P < 0.0001 \); Table 2). Boys on average had more myopic refractive error than girls, but the difference was insignificant (\( P = 0.9397 \)). In multivariate models controlling for age and gender, increasing age was associated with increased risk of having myopia (Table 2). Children aged 11 years were almost 15 times more likely to have myopia than those younger than 7 years (\( OR = 14.81; 95% CI = 14.17-15.48 \)). Boys had a lower odds ratio of having myopia than girls (\( OR = 0.96; 95% CI = 0.94-0.98 \)). The prevalence of anisometropia was 9.2% ± 0.3% (range, 1.00 to 9.25 D). The prevalence of emmetropia, hypermetropia, and myopia are shown in Table 1. Myopia was the most common type of refractive error. It was found in 36.71% ± 2.87% (SD) of the children. The average refractive error of these myopic eyes was −2.33 D (SD = 9.62 D). Mild myopia (−0.50 to −2.99 D) was found in 26.27% of children, moderate myopia (−3.00 to −5.99 D) in 9.47%, and severe myopia (≤−6.00 D) in 1.19%. Astigmatism was the second most common refractive error, present in 18.1% ± 0.4% (range, −1.00 to −5.75 D) of the study subjects. The frequency of anisometropia was 9.2% ± 0.3% (range, 1.00–9.25 D).

**Incidence of Myopia and Myopic Progression**

Another part of the study is a 1-year longitudinal cohort study. Among the children who participated at the beginning of the study, 6443 were invited. One school, which moved to another district and included new students from the new district, was excluded from this part of the study. There were no statistically significant differences in the SER and axial length between participants at this school and other schools (\( P = 0.283 \) and 0.348, respectively). The final eligible study pool was 5885 children, among whom 4973 were successfully reexamined 1 year later. The response rate was 84.5%. There was no statistically significant difference in baseline SER between the participants and nonparticipants (\( P = 0.136 \)). Of the 3149 children who were not myopic at the initial examination, 454 were myopic in the second examination. The incidence of myopia was therefore 144.1 ± 2.31 per 1000 primary school children per annum. Incidences of individual gender and age groups are shown in Figure 1. Highest incidences were found in 10-year-old boys and 11-year-old girls, with annual incidence of 199.5 and 275.6 per 1000, respectively. Multivariate analysis showed that boys had a lower incidence of myopia than girls (OR = 0.86; 95% CI = 0.83–0.88). Increasing age was positively correlated with increased incidence of myopia, with highest risks in children aged 10 and 11 (OR = 1.93 and 2.27, respectively; Table 3).

The average rate of myopic progression as measured by cycloplegic autorefraction was −0.40 D per year (SD = 3.50 D). The average annual change in SER for children who were myopic (SER ≤−0.50 D) was −0.63 D (SD = 3.44 D) compared with −0.29 D (SD = 2.96 D) for those who were not myopic at the beginning of study. This difference was statistically significant (\( P < 0.001 \)). A higher degree of myopia at the beginning of the study was directly related to higher myopic progression (all \( P < 0.001 \), Table 4).
counterparts. Lin et al.14 also reported a lower prevalence and odds ratios of 0.96 (95% CI

Our results, however, were than 10 times that reported from the Middle East, and nearly
twice that in South America. 13,14 Our results, however, were

uni- and multidimensional study examining the prevalence and incidence of my-
opia in school children. Few epidemiologic studies addressing
similar issues had a comparable population size. Our children
were selected randomly from all over Hong Kong and were of

mean of 2.00 D and SER

$1.30$ to $1.44$ for those

Mean incidence rate per 1000 primary school children per an-
num.

To our knowledge, this is the largest cross-sectional and longi-
duital study examining the prevalence and incidence of my-
opia in school children. Few epidemiologic studies addressing

Our results showed that Hong Kong has one of the highest
prevalences of myopia in the world (Table 5). Taking into
account of the differences in myopic definition, study, and
measurement methodology and age group compositions, Hong
Kong still had a high percentage of myopic children. Our
prevalence was three times that of the United States, 12 more
than 10 times that reported from the Middle East, and nearly
twice that in South America. 13,14 Our results, however, were
comparable to our East Asian neighbors, such as Taiwan and
Singapore where Chinese population predominated. 15,16

A positive correlation between the prevalence of myopia and
age within the range from 5 to 11 years was found. Our
prevalence rates for children aged 7, 8, and 9 years (Table 2)
were highly comparable to those recently reported in Singa-
apore (27.6%, 34.6%, and 43.2%, respectively). 18 We found a
lower prevalence and incidence of myopia among boys, with
odds ratios of 0.96 (95% CI = 0.94–0.98) and 0.86 (95% CI = 0.83–0.88), respectively, compared with their age-matched
counterparts. Lin et al. 14 also reported a lower prevalence and

less myopic refractive error among boys in Taiwan. A Finnish
study 19 reported slower myopic progression in boys. One
possible explanation would be that girls tend to read and write
more, at least at primary school level. The subsequent increase
in near-work predispose them to myopia development. Further
studies are warranted to confirm such proposition.

Our 1-year cohort study found the incidence of myopia to be 144.1 per 1000 primary school children per annum, an
increase from a previous study in Hong Kong in which the
incidence was 118 per 1000 among children of age 6 to 17.
The cohort was much smaller, with 142 school children using
noncycloplegic refraction. 20 The average change in SER for
children who were myopic (SER ≤ −0.50 D) was −0.63 D (SD = 3.44 D) compared with −0.29 D (SD = 2.96 D) for those
who were not myopic at the beginning of study ($P < 0.001$). Similar
difference in favor of nonmyopes was previously re-
ported using noncycloplegic subjective refraction (−0.46 D vs.
−0.17 D, respectively). 20 A Singaporean study 21 in children
aged 6 to 12 reported the average annual change for children
with SER more than −2.00 D and SER −2.00 D or less to be
−0.56 and −0.65 D, respectively ($P < 0.0001$). Caution must
be exercised when interpreting results from this latter study,
because it recruited children participating in a clinical trial on
control of myopia progression, rather than children in the
general population. 22 Nonetheless, most reports so far support
the hypothesis that myopic children have a greater myopic
shift than do those without myopia. 22,23

Mean rates of childhood myopia progression among white
children in the United States 24,25 and the United Kingdom 27
were generally quoted in the range of −0.10 to −0.30 D per
year, much lower than rates reported by Asian studies. This
may be the result of the complex interaction between genetic
and environmental factors unique to Asian children, such as
genetic susceptibility, living in a congested environment, and
highly competitive education systems. Further studies compar-
ing children of different ethnicities living in identical environ-
ments with children of same ethnicity living in different envi-
ronments would help to explore the observed differences.

Our study also had limitations. First, not all children in Hong
Kong were included in the sampling frame. Children studying
in international schools and special schools were excluded.
Thus, our study results reflect only the prevalence and inci-
dence of myopia in ethnic Chinese children studying at con-
ventional Chinese primary schools in Hong Kong. Second,
although we tried to improve the participation rate by con-
ducting all examinations in schools, holding prestudy educa-
tion seminars, and giving out information sheets to parents,
20% of all invited children still refused to participate. Third,
even though the present study was the largest of its kind, our
incidence and myopic progression rates were calculated based
on only 1 year of follow-up. A longer follow-up would provide
better knowledge on how incidence of myopia changes with

<table>
<thead>
<tr>
<th>Subjects ($n$)</th>
<th>Mean Incidence Rate*</th>
<th>Odds Ratio</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>2421</td>
<td>150.0</td>
<td>Reference</td>
</tr>
<tr>
<td>Male</td>
<td>2552</td>
<td>139.0</td>
<td>0.855</td>
</tr>
<tr>
<td>Age (y)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Below 7</td>
<td>650</td>
<td>106.2</td>
<td>Reference</td>
</tr>
<tr>
<td>7</td>
<td>886</td>
<td>131.3</td>
<td>1.30</td>
</tr>
<tr>
<td>8</td>
<td>985</td>
<td>148.4</td>
<td>1.44</td>
</tr>
<tr>
<td>9</td>
<td>1111</td>
<td>149.6</td>
<td>1.51</td>
</tr>
<tr>
<td>10</td>
<td>1090</td>
<td>197.7</td>
<td>1.93</td>
</tr>
<tr>
<td>≥11</td>
<td>251</td>
<td>209.4</td>
<td>2.27</td>
</tr>
</tbody>
</table>

Table 3. Risk of Myopia Development in the Cohort Study among Primary School Children of Hong Kong

<table>
<thead>
<tr>
<th>Sex</th>
<th>Mean Incidence Rate*</th>
<th>Odds Ratio</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>2421</td>
<td>150.0</td>
<td>Reference</td>
</tr>
<tr>
<td>Male</td>
<td>2552</td>
<td>139.0</td>
<td>0.855</td>
</tr>
</tbody>
</table>

Table 4. Annual Change in SER among Primary School Children of Hong Kong

<table>
<thead>
<tr>
<th>SER at Beginning of Cohort Study</th>
<th>Mean (D)</th>
<th>$^a$Coefficient</th>
<th>SE</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emmetropia ($&gt;−0.50$ to $&lt;2.00$ D)</td>
<td>$−0.29$ D</td>
<td>Reference</td>
<td>$0.36$</td>
<td>$&lt;0.001$</td>
</tr>
<tr>
<td>Low myopia ($&gt;−0.50$ to $&lt;2.99$ D)</td>
<td>$−0.63$ D</td>
<td>Reference</td>
<td>$0.22$</td>
<td>$&lt;0.001$</td>
</tr>
<tr>
<td>Moderate myopia ($&gt;3.00$ to $&lt;5.99$ D)</td>
<td>$−0.64$ D</td>
<td>Reference</td>
<td>$0.37$</td>
<td>$&lt;0.001$</td>
</tr>
<tr>
<td>High myopia ($&gt;6.00$ D)</td>
<td>$−0.71$ D</td>
<td>Reference</td>
<td>$0.44$</td>
<td>$&lt;0.001$</td>
</tr>
</tbody>
</table>

$^a$Coefficient, estimate of coefficient.
time, as well as the impact of a rapid growth spurt on the growth of the eyeball and progression of myopia.

In conclusion, Hong Kong has one of the highest prevalences of myopia in the world, and it is likely that both the rate and severity of myopia will increase over time. Similar epidemiologies are observed in our East Asian neighbors, creating important medical, social, and public health issues. With the availability of these basic epidemiologic parameters, we are now in a better position to explore the risk factors associated with myopia. Some postulations have already been made regarding the etiology of myopia—namely, increased near-work activity and intense schooling. More studies on the interaction between genetic and environmental factors are warranted.

References