Near-Work Activity, Night-lights, and Myopia in the Singapore-China Study

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Objective: To investigate the relationship among near-work activity, night-lights, and myopia in schoolchildren in Singapore and Xiamen, China.

Methods: The refractive error and ocular dimensions of 957 Chinese schoolchildren aged 7 to 9 years in Singapore and Xiamen, China, were determined using cycloplegic autorefraction and A-scan ultrasound biomicroscopy. Information on near-work activity (number of books read per week, reading in hours per day) and night-light use before age 2 years was obtained.

Results: The prevalence rate of myopia was 36.7% (95% confidence interval [CI], 33.0%-40.3%) in Singapore and 18.5% (95% CI, 14.0%-23.1%) in Xiamen, China. The crude odds ratio (OR) of higher myopia (at least –3.0 dioptries) for children who read more than 2 books per week was 3.50 (95% CI, 2.15-5.70). In a multivariate logistic regression model, the OR of higher myopia for children who read more was 2.81 (95% CI, 1.69-4.69), adjusted for age, night-light use, parental myopia, and country, whereas there was no association between night-light use before age 2 years and higher myopia (OR, 1.54; 95% CI, 0.92-2.58), after controlling for age, books read per week, parental myopia, and country.

Main Outcome Measures: The ORs of higher myopia for children who read more and children who are exposed to night-lights before age 2 years.

Conclusions: Reading (number of books per week) may be associated with higher myopia in Chinese schoolchildren. However, night-light use does not seem to be related to higher myopia.

Arch Ophthalmol. 2002;120:620-627

In certain Asian cities with competitive educational systems, the prevalence of myopia has risen to alarmingly high rates. There has been a long-standing debate of the role of nature vs nurture in myopia pathogenesis. Near-work activity and night-time lighting have been identified in previous studies as possible environmental risk factors for myopia. Evidence from animal experiments indicated that disruptions of the dark-light cycle may disturb the emmetropization mechanism. Night-lights suppress the amplitude of diurnal cycling of dopaminergic activity, resulting in an augmentation of eye growth. However, there are different results from epidemiologic studies of night-lights and myopia. Chick experiments have illustrated that poor retinal images of reading may lead to aberrant eye growth and myopia. Correlations between educational level or academic achievement and myopia have been found; however, past cross-sectional studies of near-work activity and myopia were often conducted in select populations, and detailed measures of near-work activity, such as time spent reading, may not be available.

Few studies have evaluated the prevalence rates of myopia in different populations using similar methods, protocols, and equipment. One of our hypotheses is that any differences in the prevalence rates of myopia in studies of different populations with similar ethnic background and using identical methods may be attributed primarily to environmental influences such as near-work activity. To our knowledge, there are few epidemiologic studies that have simultaneously evaluated both the role of near-work activity and night-lights in the development of myopia.

We aimed to determine the association among near-work activity, night-lights, and myopia in Chinese schoolchildren in Singapore and Xiamen, China. Our comparative study was conducted in Singapore and Xiamen (previously called Amoy) in Southeast China. Most Chi-
PARTICIPANTS AND METHODS

The initial cross-sectional results of a multicenter Singapore-Xiamen concurrent cohort study are reported herein. Chinese children in an eastern school (grades 1 and 2) and a northern school (grades 1-3) in Singapore and Chinese children in 2 city (grade 2) and 2 countryside schools (grade 2) in Xiamen were invited to join the study. Children with chronic medical disorders, such as hypothyroidism, syndrome-associated myopia conditions, or allergy to eye-drops, or those who were treated with other modalities to prevent myopia, were excluded. There were 1005 children from Singapore who agreed to join the study, and only Chinese children (n=729) were enrolled in the Singapore-Xiamen concurrent cohort study. In Xiamen, 369 Chinese children joined the study; thus, there was a total of 1098 Chinese children. The participation rates in Singapore and Xiamen were 62.8% and 91.0%, respectively. The proportion of Singapore children who reported shortsightedness before the school eye examination was 27.3% for those who participated compared with 26.8% for those who did not. The results of a preliminary study conducted in Xiamen in 1998 have been reported elsewhere. Informed consent was obtained from parents after the nature of the study was explained, and the conduct of the study followed the tenets of the Declaration of Helsinki. Approval was obtained from the ethics committee, Singapore National Eye Center, and the ethics committee, Xiamen Eye Institute.

REFRACTIVE ERROR MEASUREMENTS

The children were examined in November 1999 in Singapore and in April 2000 in Xiamen. A group of investigators from Singapore supervised the eye examination team in April 2000 in Xiamen. The same protocol, measurement techniques, and equipment were used in Singapore and Xiamen. All equipment in Singapore and Xiamen were calibrated at the beginning of the study. Corrected and uncorrected distance visual acuity was measured in the right and left eyes using logMAR charts following a standard protocol. After instillation of 0.5% proparacaine hydrochloride, 3 drops of 1% cyclopentolate hydrochloride were instilled 5 minutes apart. At least 30 minutes after the last drop, an autokeratorefractometer (Canon RK 5; Canon Inc Ltd, Tochigiken, Japan) was used to obtain 5 consecutive refractions and corneal curvature measurements in 2 meridia, each 90° apart. Ultrasound biometry measurements (best average of 6 values) were performed using a biometry unit (Nidek Echocan model US-800; Nidek Co Ltd, Tokyo, Japan; probe frequency of 10 MHz). Before the procedure, the corneas were anesthetized with 1 drop of 0.5% proparacaine. All refractive error and biometry measurements were performed by personnel who had no knowledge of risk factor information obtained from the questionnaire (M.-Z.Z., Z.-F.F., and M.-H.F.).

QUESTIONNAIRE

Parents in both Singapore and Xiamen completed an 8-page questionnaire. This questionnaire was translated into Chinese because a large proportion of parents in Xiamen and Singapore could not read the written English language. Information on sociodemographic factors, such as father’s and mother’s completed level of education, was obtained. We asked about the number of hours of reading per day, number of books read per week, and a near-vision task index (adding 3 times reading, 2 times computer use, and 2 times video game use in hours per day). The intraclass correlation coefficient of the reliability of near-work activity was

RESULTS

There were 295 children from the eastern school and 376 children from the northern school in Singapore, 91 and 77 children from the 2 Xiamen city schools, and 68 and 50 children from the 2 Xiamen countryside schools. A total of 52.1% were boys, 47.9% were girls, and the age range was 7 to 9 years. The proportion of children of Hokkien dialect in Xiamen was 91.2% compared with 48.4% in Singapore. The proportion of children in Singapore (56.1%) and Xiamen (38.1%) who slept with night-lights before 2 years of age differs (P.<.001). Children in Xiamen spent an average of 8.71 (SD, 7.22) hours per week on outdoor activity compared with 3.34 (SD, 2.94) hours per week for Singapore children (P.<.001). A greater proportion of children in Xiamen performed eye exercises on a regular basis (98.2%) compared with Singapore children (11.0%).

The prevalence rate of myopia in Singapore was 2 times higher than Xiamen (36.7% vs 18.5%) (P.<.001), whereas the prevalence rate of higher myopia was 3 times higher (9.8% vs 2.5%) (P.<.001) (Table 2). The prevalence rate of myopia in boys was 29.9% (95% CI, 23.8%-36.8%) and 32.8% (95% CI, 28.4%-37.1%) in girls. The myopia rates were 37.4% (95% CI, 27.1%-43.8%) in 7-year-olds, 33.0% (95% CI, 28.1%-37.8%) in 8-year-olds, and 27.5% (95% CI, 21.7%-33.2%) in 9-year-olds. The prevalence rates of anisometropia were similar (P=.99), hyperopia was lower (P=.04), and astigmatism higher (P=.002) in Singapore compared with Xiamen children. The axial length and anterior chamber depth of the children (P.<.001 for all) were longer and lens thicker.

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Higher myopia was defined as myopia greater than –3.0 D, an arbitrary separation to distinguish degrees of myopia for analysis purposes in this study.

DATA ANALYSIS

The data on the right and left eyes were initially analyzed separately. However, because the correlation between the right and left eyes for SE was high (r=0.95), only the right eye data are presented. The prevalence rates and 95% CIs of refractive errors (myopia, anisometropia, hyperopia, and astigmatism) were reported. First, reading and night-light activity in Singapore and Xiamen were compared, followed by a comparison of activity in subjects with higher or absent myopia, lower myopia, and nonmyopia. Subjects with missing data for any of the main covariates of interest (books read per week, reading in hours per day, near-light use before age 2 years, and parental myopia) were excluded from all statistical analyses. Of the 1098 subjects, interview data were missing for 141 subjects, and analyses were therefore performed for 957 subjects. Multiple logistic regression analysis was conducted to examine the relationship between myopia (yes or no) or higher myopia (yes or no) and reading or night-lights, controlling for other factors. Multiple linear regression models were conducted with axial length as the response variable and the exposure as the main covariate, adjusting for other confounders. The interaction term (reading books per week and night-light use) was not statistically significant and therefore not included in multivariate models. Analyses were also conducted separately for each country. The P values quoted are 2-sided; they are considered statistically significant when values are below .05. Statistical analyses were conducted using the commercially available statistical software Stata, version 7.0.24

in Singapore children. The mean refractive error in Singapore was –0.49 D compared with +0.17 D in Xiamen (Figure 1), whereas the mean axial length in Singapore was 23.40 mm compared with 23.09 mm in Xiamen (Figure 2).

The near-work and other lifestyle activities of children with higher myopia, lower myopia, and no myopia were compared (Table 3). The ORs of myopia were 1.71 (95% CI, 1.28-2.27) for children who read more than 2 books per week, 1.83 (95% CI, 1.32-2.54) for children who read more than 2 hours per day, and 1.70 (95% CI, 1.29-2.25) for children who spent more than 8 hours per day quantified by the near-vision task index. The ORs for higher myopia for children who read more than 2 books per week, read more than 2 hours per day, or spent more than 8 hours per day (measured by the near-vision task index) were 3.50 (95% CI, 2.15-5.70), 2.93 (95% CI, 1.44-5.98), and 2.14 (95% CI, 1.29-3.55), respectively. The OR of myopia for children who used the computer regularly was 1.80 (95% CI, 1.36-2.37) and the OR of higher myopia was 2.77 (95% CI, 1.66-4.61). Furthermore, the ORs of myopia and higher myopia for children who attend additional reading classes were 1.61 (95% CI, 1.22-2.13) and 2.44 (95% CI, 1.46-4.07), respectively. A dose-response relationship between the number of parents with myopia and the severity of myopia (nonmyopia vs lower myopia vs higher myopia) was noted (P<.001). A higher proportion of children with higher myopia (11.2%) slept with light from the adjacent room or window or with night-lights (9.9%) compared with children who slept in the dark (5.7%), although the relationship was of borderline significance (P=.05). The ORs of myopia and higher myopia for children who were exposed to lighting at night were 1.18 (95% CI, 0.90-1.55) and 1.73 (95% CI, 1.05-2.83), respectively. Myopic children spent less time on outdoor activities (P=.03).

The 2 final multiple logistic regression models of myopia (present or absent) or higher myopia (present or absent) as the dependent variables and major risk factors as the main covariates, controlling for other confounders, are presented in Table 4. The OR of myopia for children who read more than 2 books per week, adjusted for age, near-light use, parental myopia, and country was 1.43 (95% CI, 1.05-1.94), whereas the OR of higher myopia was 2.81 (95% CI, 1.69-4.69), after adjustment for the same factors. The OR of myopia for children with 1 or more parents who are myopic, adjusted for age, near-light use, books per week, and country, was 2.40 (95% CI, 1.72-3.34), and the multivariate-adjusted OR of higher myopia for children with parents who are
myopic was 2.67 (95% CI, 1.38-5.17). The adjusted ORs of myopia and higher myopia for children exposed to any kind of night-lights before age 2 years were 1.04 (95% CI, 0.78-1.39) and 1.54 (95% CI, 0.92-2.58), respectively, controlling for age, books per week, parental myopia, and country. In the examination of other near-work variables in multiple logistic regression models, the relationships among reading in hours per day, hours measured by the near-vision task index, additional reading classes, music classes, regular computer use, and myopia were also investigated.

### Table 1. Lifestyle Habits of Children in the Singapore-China Study

<table>
<thead>
<tr>
<th>Habit</th>
<th>Total (n = 957)</th>
<th>Singapore (n = 671)</th>
<th>Xiamen (n = 286)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Books read per week</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>2.3 (2.2)</td>
<td>2.6 (2.2)</td>
<td>1.6 (1.9)</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td>Median (range)</td>
<td>2.0 (0-20.0)</td>
<td>2.0 (0-20.0)</td>
<td>1.0 (0-20.0)</td>
<td></td>
</tr>
<tr>
<td>Reading, h/d</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>2.5 (1.3)</td>
<td>2.7 (1.3)</td>
<td>1.9 (1.1)</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td>Median (range)</td>
<td>2.0 (0-8.0)</td>
<td>2.4 (0-8.0)</td>
<td>1.7 (0-7.7)</td>
<td></td>
</tr>
<tr>
<td>Near-vision task index, h/d</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>8.9 (4.8)</td>
<td>10.1 (4.7)</td>
<td>6.0 (3.5)</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td>Median (range)</td>
<td>8.0 (0.9-34.0)</td>
<td>9.6 (1.2-34.0)</td>
<td>6.0 (0.9-23.1)</td>
<td></td>
</tr>
<tr>
<td>Computer games, No. (%)</td>
<td></td>
<td></td>
<td></td>
<td>&lt;.001†</td>
</tr>
<tr>
<td>No</td>
<td>518 (54.1)</td>
<td>259 (38.6)</td>
<td>259 (90.6)</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>439 (45.9)</td>
<td>416 (61.4)</td>
<td>27 (9.4)</td>
<td></td>
</tr>
<tr>
<td>Night-light use before 2 years of age, No. (%)</td>
<td></td>
<td></td>
<td></td>
<td>&lt;.001†</td>
</tr>
<tr>
<td>In the dark</td>
<td>472 (49.3)</td>
<td>295 (43.9)</td>
<td>177 (61.9)</td>
<td></td>
</tr>
<tr>
<td>Light from adjacent room or window</td>
<td>134 (14.0)</td>
<td>120 (17.9)</td>
<td>14 (4.9)</td>
<td></td>
</tr>
<tr>
<td>Night-light</td>
<td>283 (29.6)</td>
<td>201 (30.0)</td>
<td>82 (28.7)</td>
<td>&lt;.001†</td>
</tr>
<tr>
<td>Room light</td>
<td>68 (7.1)</td>
<td>55 (8.2)</td>
<td>13 (4.5)</td>
<td></td>
</tr>
<tr>
<td>No. of parents with myopia, No. (%)</td>
<td></td>
<td></td>
<td></td>
<td>&lt;.001†</td>
</tr>
<tr>
<td>0</td>
<td>416 (43.5)</td>
<td>196 (29.2)</td>
<td>220 (76.9)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>334 (34.9)</td>
<td>288 (42.9)</td>
<td>46 (16.1)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>207 (21.6)</td>
<td>187 (27.9)</td>
<td>20 (7.0)</td>
<td></td>
</tr>
</tbody>
</table>

*Based on rank sum test. †Based on χ² test.

### Table 2. Prevalence Rates of Refractive Errors and Distribution of Biometry Measures of Chinese Children in the Singapore-China Study

<table>
<thead>
<tr>
<th>Variable</th>
<th>Total (n = 957)</th>
<th>Singapore (n = 671)</th>
<th>Xiamen (n = 286)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prevalence rate, % (95% CI)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Myopia (SE &lt; -0.5 D)</td>
<td>31.2 (23.3 to 34.2)</td>
<td>36.7 (33.0 to 40.3)</td>
<td>18.5 (14.0 to 23.1)</td>
<td>&lt;.001†</td>
</tr>
<tr>
<td>Anisometropia (≥1.0 D SE difference)</td>
<td>4.2 (2.9 to 5.4)</td>
<td>4.2 (2.7 to 5.7)</td>
<td>4.2 (1.9 to 6.5)</td>
<td>.99†</td>
</tr>
<tr>
<td>Hyperopia (SE ≥2.0 D)</td>
<td>0.8 (0.3 to 1.4)</td>
<td>0.4 (0.1 to 1.0)</td>
<td>1.7 (0.2 to 3.3)</td>
<td>.04†</td>
</tr>
<tr>
<td>Astigmatism (cylinder ≥1.0 D)</td>
<td>18.3 (15.8 to 20.7)</td>
<td>20.9 (17.8 to 23.9)</td>
<td>12.2 (8.4 to 16.1)</td>
<td>.002†</td>
</tr>
<tr>
<td>Refractive error, D</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>-0.29 (1.54)</td>
<td>-0.49 (1.64)</td>
<td>+0.17 (1.18)</td>
<td></td>
</tr>
<tr>
<td>Median (range)</td>
<td>+0.18 (~5.40 to 6.55)</td>
<td>+0.03 (~6.03 to 3.31)</td>
<td>+0.38 (~3.83 to 6.55)</td>
<td>&lt;.001‡</td>
</tr>
<tr>
<td>Axial length, mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>23.31 (0.93)</td>
<td>23.40 (0.96)</td>
<td>23.09 (0.80)</td>
<td></td>
</tr>
<tr>
<td>Median (range)</td>
<td>22.32 (21.36 to 27.22)</td>
<td>23.30 (21.42 to 27.22)</td>
<td>23.07 (21.17 to 25.42)</td>
<td>&lt;.001†</td>
</tr>
<tr>
<td>Anterior chamber depth, mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>3.62 (0.28)</td>
<td>3.65 (0.28)</td>
<td>3.54 (0.27)</td>
<td></td>
</tr>
<tr>
<td>Median (range)</td>
<td>3.64 (2.95 to 4.41)</td>
<td>3.67 (2.95 to 4.41)</td>
<td>3.57 (2.92 to 4.26)</td>
<td>&lt;.001†</td>
</tr>
<tr>
<td>Lens thickness, mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>3.45 (0.18)</td>
<td>3.46 (0.18)</td>
<td>3.41 (0.18)</td>
<td></td>
</tr>
<tr>
<td>Median (range)</td>
<td>3.43 (3.02 to 4.21)</td>
<td>3.45 (3.07 to 4.21)</td>
<td>3.40 (2.90 to 3.92)</td>
<td>&lt;.001†</td>
</tr>
<tr>
<td>Vitreous chamber depth, mm</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>16.25 (0.87)</td>
<td>16.30 (0.91)</td>
<td>16.14 (0.77)</td>
<td></td>
</tr>
<tr>
<td>Median (range)</td>
<td>16.16 (14.43 to 19.60)</td>
<td>16.19 (14.43 to 19.60)</td>
<td>16.07 (14.37 to 18.45)</td>
<td>.07†</td>
</tr>
<tr>
<td>Average corneal curvature radius, mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean (SD)</td>
<td>7.75 (0.25)</td>
<td>7.74 (0.24)</td>
<td>7.79 (0.25)</td>
<td></td>
</tr>
<tr>
<td>Median (range)</td>
<td>7.76 (7.15 to 8.60)</td>
<td>7.74 (7.11 to 8.60)</td>
<td>7.80 (7.16 to 8.42)</td>
<td>.003‡</td>
</tr>
</tbody>
</table>

*CI indicates confidence interval; SE, spherical equivalent; and D, diopters. †Based on χ² test. ‡Based on rank sum test.
myopia or higher myopia did not remain. Similarly, there was no association between outdoor activity and myopia or higher myopia, after controlling for other factors. No interaction between reading books per week and night-light use before 2 years of age was noted. Similar results were found when data from Singapore and Xiamen were separately analyzed.

Table 5 gives the axial lengths of children with different characteristics. Children who read more than 2 books per week ($P<.001$), spent more than 2 hours reading per day ($P=.04$), reported more than 8 hours as defined by the near-vision task index ($P=.02$), and used the computer regularly ($P<.001$) had longer eyeballs. Children exposed to lighting at night before 2 years of age (light from adjacent room or night-lights or rooms lights) had longer eyeballs than children who slept in the dark ($P=.02$). In multiple linear regression models, the relationship between books read per week and axial length remained after adjusting for age, night-light use, parental myopia, and country ($P=.002$). However, the relationships among reading (0.41), the near-vision task index (0.82), computer use (0.68), and axial length did not remain after controlling for similar factors. When children from Singapore and Xiamen were analyzed separately, similar results were present. Axial length was weakly associated with lighting at night before 2 years of age, after controlling for age, books read per week, parental myopia, and country ($P=.03$).

In this multicenter study of Chinese children in Singapore and Xiamen, reading quantified by books per week was associated with myopia and early-onset myopia. There were positive associations between reading in hours per day, hours measured by the near-vision task index, computer use, and higher myopia; however, these relationships did not remain after adjusting for other factors. Night-light exposures before age 2 years and at other ages were not related with higher myopia after controlling for other factors. The prevalence rates of myopia and astigmatism in Singapore were also higher than Xiamen, China, in a multicenter study of Chinese children involving the same group of investigators and using identical methods.

This unique epidemiologic study conducted in 2 different populations with a similar genetic background includes detailed information on near-work and night-light habits of schoolchildren of similar ages in Singapore and Xiamen, China. Both cycloplegic refraction measures and detailed evaluation of ocular components of the refractive state were made. Another advantage of this multicenter study is that there may be an increased variation in exposure activity (near-work or night-light activity). Efforts were made to decrease biases with the use of identical definitions, protocols, measurement techniques, and instruments in both countries. We noted that one potential limitation of the study is that other factors not measured and controlled for, such as climate, pollution, or diet, may be different in the 2 countries and may contribute to the differences in myopia prevalence rates. On the other hand, there are few studies that have measured these factors (such as climate), and there is little evidence that they contribute to myopia.

In multicenter, population-based studies25-27 of refractive error in children aged 5 to 15 years using similar methods in China, Chile, and Nepal, the prevalence rates of myopia were 16.2%, 5.8%, and 0.3%, respectively. In our study, the prevalence rate of myopia in children of similar ethnic origin in Singapore (36.7%) was twice that in Xiamen (18.5%). We noted that the average eyeball length of children in Singapore was 0.6 mm longer than Xiamen children, suggesting axial myopia. Because the study protocol methods are identical and children in both countries have similar hereditary predispositions, environmental factors are likely to contribute to the differences in the prevalence rates. Identifying primary preventive strategies is an important goal because primary prevention may eventually lead to a reduction in the prevalence rates of myopia. Singapore is an urbanized and a rapidly developing financial country with a highly competitive education system, whereas Xiamen is less urbanized and the schooling system is not so demanding. Previously hypothesized risk factors for myopia that may be associated with urbanization, including near-work activity and night-light use, may explain the differences in myopia prevalence rates.

There is little information about the role of near-work activity in past epidemiologic studies; the measures...
of near-work activity were crude, and often educational level or occupational status was used as a surrogate measure of near-work activity.\textsuperscript{17,18} In contrast, there were several indexes of reading or near-work activity (reading books per week, reading in hours per day, near-vision task index) in this multicenter study. Possible advantages of our study include a wide variation in reading activity, with Singapore children reading more on the average and children from Xiamen reading less. In certain population groups, such as medical students, the reading habits are rather uniform, and the lack of variation of the risk factor may lead to results that tend toward the null. We found

\begin{table}
\centering
\caption{Lifestyle Behavior of Children With Higher Myopia, Lower Myopia, and Nonmyopia in the Singapore-China Study*}
\begin{tabular}{lcccccc}
\hline
 & HM & LM & NM & & & \\
(n = 73) & (n = 226) & (n = 658) & & & \\
\hline
Books read per week
Mean (SD) & 3.6 (2.6) & 2.6 (2.3) & 2.1 (2.0) & & & \\
Mean (range) & 3.0 (0.0-10.0) & 2.0 (0.0-20.0) & 2.0 (0.0-20.0) & & & \\
Reading, h/d
Mean (SD) & 2.8 (1.1) & 2.5 (1.1) & 2.4 (1.3) & & & \\
Median (range) & 2.7 (0.6-5.6) & 2.2 (0.0-6.5) & 2.0 (0.0-8.0) & & & \\
Near-vision task index, h/d
Mean (SD) & 10.3 (4.1) & 9.1 (4.5) & 8.7 (4.9) & & & \\
Median (range) & 10.1 (1.8-23.4) & 8.4 (0.0-34.0) & 7.2 (1.2-30.1) & & & \\
Computer use, No. (%)
No & 23 (4.4) & 109 (21.1) & 386 (74.5) & & & \\
Yes & 50 (11.4) & 117 (26.6) & 272 (62.0) & & & \\
Night-light use before 2 years of age, No. (%)
In the dark & 27 (5.7) & 112 (23.7) & 333 (70.6) & & & \\
Light from adjacent room or window & 15 (11.2) & 39 (29.1) & 80 (59.7) & & & \\
Night-light & 28 (9.9) & 62 (21.9) & 193 (68.2) & & & \\
Room light & 3 (4.4) & 13 (19.1) & 52 (76.5) & & & \\
No. of parents with myopia, No. (%)
0 & 13 (3.1) & 66 (15.9) & 337 (81.0) & & & \\
1 & 27 (8.1) & 92 (27.5) & 215 (64.4) & & & \\
2 & 33 (15.9) & 68 (32.9) & 106 (51.2) & & & \\
\hline
*Higher myopia (HM) is defined as a spherical equivalent (SE) $\leq-3.0$ diopters (D); lower myopia (LM), SE $>-3.0$ D $\leq-0.5$ D; and nonmyopia (NM), SE $>-0.5$ D.
†Based on analysis of variance.
‡Based on $\chi^2$ test.
\end{tabular}
\end{table}

\begin{table}
\centering
\caption{Multiple Logistic Regression Models of Multivariate Adjusted Odds Ratios of Myopia and Higher Myopia for Children With Different Risk Factors*}
\begin{tabular}{lcccccc}
\hline
Variable & No. & Adjusted OR for Myopia (95\% CI) & P Value & Adjusted OR for Higher Myopia (95\% CI) & P Value & \\
\hline
Books read per week
$\leq$2 & 657 & 1.00 (Referent) & 1.00 (Referent) & & & \\
$>2$ & 300 & 1.43 (1.05-1.94) & <.001 & 2.81 (1.69-4.69) & <.001 & \\
Age, y
7 & 363 & 1.00 (Referent) & 1.00 (Referent) & & & \\
8 & 361 & 1.52 (1.08-2.13) & .02 & 1.74 (1.00-3.00) & .05 & \\
$\geq$9 & 233 & 1.97 (1.25-3.10) & .003 & 1.20 (0.50-2.84) & .68 & \\
Night-light use before 2 years of age
In the dark & 472 & 1.00 (Referent) & 1.00 (Referent) & & & \\
Light from adjacent room or window & 154 & 1.36 (0.69-2.08) & .15 & 1.95 (0.97-4.69) & .06 & \\
Night-light & 283 & 1.03 (0.73-1.44) & .58 & 1.64 (0.92-2.91) & .09 & \\
Room light & 68 & 0.59 (0.32-1.11) & .10 & 0.58 (0.17-2.03) & .39 & \\
No. of parents with myopia
0 & 416 & 1.00 (Referent) & 1.00 (Referent) & & & \\
1 & 334 & 2.05 (1.43-2.94) & <.001 & 2.06 (1.00-4.25) & .05 & \\
2 & 207 & 3.44 (2.30-5.13) & <.001 & 3.83 (1.86-7.91) & <.001 & \\
Country
Singapore & 671 & 1.00 (Referent) & 1.00 (Referent) & & & \\
Xiamen & 286 & 0.47 (0.31-0.73) & .001 & 0.44 (0.18-1.11) & .08 & \\
\hline
*Myopia is defined as a spherical equivalent (SE) of at least $-0.5$ diopters (D); higher myopia, SE $<-0.3$ D. OR indicates odds ratio; CI, confidence interval.
\end{tabular}
\end{table}
logic studies have shown that night-lights were posi-
monkeys: ambient night-light use did not appear to in-
ing, and hyperopia. Different results were seen in infant
ness) caused shallow anterior chambers, corneal flatten-
tinuous illumination of chicks (fewer than 4 hours of dark-
normal refractive error development in young children.\(^2\)

The regular use of spectacles during near-work activity may
ing accomplished in a certain period.\(^2\) Because parents of-
ten actively participate in the purchase of books, they may
place more aware of the number of books their child reads.
In contrast, time-based near-work measures, such as reading
hours per day or near-vision task index, may be in-
accurate because the child may not be actively reading dur-
the entire documented period. The parent may find it
difficult to recall the exact amount of time a child reads
in a usual day to the nearest half hour. A possible limita-
tion of our study is that information on whether the chil-
dren actively participate in the purchase of books, and near-
work activity (quantified as books read per week) is a detailed
of the amount of read-

Although we observed that both the frequency of night-
time lighting and myopia prevalence rates were higher in Singapore compared with Xiamen, we cannot
conclude that there is a positive relationship from this
observation alone. This is because other factors, such as
ear-work activity, may contribute to the higher preva-
ence rates of myopia in Singapore. Further analysis of
combined data from Singapore and Xiamen revealed that
ight-lights were not significantly related to myopia or
higher myopia (at least \(-3.0 \text{ D}\)), after controlling for sev-
eral factors. There are several explanations for the nega-
tive associations. The stronger effects of reading on myo-
China children may “mask” any small effect of
ight-lights. The quantification of night-lights using the
questionnaire method may be crude and of limited value,
resulting in risk estimates that tend toward the null. Ques-
tions on nighttime lighting used in our study were simi-
lar to those used in the 3 US studies.\(^1,14,15\) Estimates of
ight-light use, however, are often not perfectly mea-
sed by questionnaires, and further studies with pro-
spective measures of night-light use using light meters
in a large group of infants may be needed. As observed
by Smith and coworkers,\(^11\) perhaps patients in tertiary
eye centers may exhibit this relationship since the over-
all prevalence rate of refractive errors is higher than the
normal population.\(^3\) In contrast, school-based studies do
not seem to show an association.\(^14,15\) Alternatively, it is
possible that no true relationship between night-lights
and myopia exists; our study has a power of more than
90% to determine the effects of night-lights on myopia.
Another possible reason is that gene-environment inter-
action exists and the effect of night-lights on myopia in
Chinese children may be different from white children.
In this unique epidemiologic study conducted in chil-
dren of similar ages and ethnic origin in 2 different coun-
tries, near-work activity (quantified as books read per
week) may be linked to myopia. However, our data sug-
gest that it is unlikely that lighting at night predicts myo-
pia in Chinese children.

### Table 5. Axial Lengths in Children With Different Risk Factors in the Singapore-China Study

<table>
<thead>
<tr>
<th>Variable</th>
<th>No.</th>
<th>Mean (SD) Axial Length, mm</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Books read per week ≤2</td>
<td>657</td>
<td>23.22 (0.85)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>&gt;2</td>
<td>300</td>
<td>23.51 (1.05)</td>
<td></td>
</tr>
<tr>
<td>Reading, h/d ≤2</td>
<td>267</td>
<td>23.17 (0.89)</td>
<td>.004</td>
</tr>
<tr>
<td>&gt;2</td>
<td>690</td>
<td>23.36 (0.94)</td>
<td></td>
</tr>
<tr>
<td>Near-vision task index, h/d ≤8</td>
<td>470</td>
<td>23.24 (0.96)</td>
<td>.02</td>
</tr>
<tr>
<td>&gt;8</td>
<td>475</td>
<td>23.38 (0.96)</td>
<td></td>
</tr>
<tr>
<td>Computer games No</td>
<td>518</td>
<td>23.22 (0.89)</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>439</td>
<td>23.42 (0.96)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Night-light use before 2 years</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In the dark</td>
<td>472</td>
<td>23.22 (0.87)</td>
<td></td>
</tr>
<tr>
<td>Light from adjacent room or window</td>
<td>134</td>
<td>23.44 (0.95)</td>
<td>.02</td>
</tr>
<tr>
<td>Night-light</td>
<td>283</td>
<td>23.38 (0.98)</td>
<td></td>
</tr>
<tr>
<td>Room light</td>
<td>68</td>
<td>23.41 (1.03)</td>
<td></td>
</tr>
<tr>
<td>No. of parents with myopia 0</td>
<td>416</td>
<td>23.13 (0.81)</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>334</td>
<td>23.36 (0.94)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>207</td>
<td>23.60 (1.05)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

The disruption of light-dark cycles may influence
ueball shape, eye growth, and refractive error in animal
ments.\(^10,13,15\) Li and colleagues\(^13\) found that con-
tinuous illumination of chicks (fewer than 4 hours of dark-
ess) caused shallow anterior chambers, corneal flatten-
ing, and hyperopia. Different results were seen in infant
monkeys: ambient night-light use did not appear to in-
fuence normal emmetropization.\(^3\) Recent epidemi-
logic studies\(^13,15\) have shown that night-lights were posi-
tively associated with myopia in a study of 479 children
aged 2 to 16 years in a tertiary hospital. However, simi-
lar associations between night-lights and myopia were
not present in 2 other US studies.\(^1,14\) The reason for these
discrepancies is not clear and may include a lack of con-
trol of confounders such as parental myopia, varying
methods of refractive error measurements, and selection
bias among different population groups were chosen.
In our study, confounders such as near-work activity
and parental myopia were controlled for, and both
cycloplegic refraction and biometry ultrasound measure-
ments were conducted in school populations with high
rates of myopia similar to that of the study by Quinn and
colleagues.\(^11\) Chinese children may have different hab-
its than white children, and fewer Chinese children sleep
ight with night-lights or room lighting. In our pres-
ent study, there was a higher proportion of children ex-
posed to low doses of nighttime lighting via lights from
adjacent windows. This phenomenon may be more com-
mon in Asian cities such as Singapore and Xiamen, where
most children live in high-rise apartments in close prox-
imity to each other. Differences in results of the effects
of night-lights in white and Asian populations may be
attributed to the higher prevalence rate of low-dose night-
time lighting exposure and lower prevalence of high-
dose exposure in Asian populations. However, the exact
effects of varying doses of nighttime lighting exposure
are largely unknown.

## References

1. Quinn GE, Lin HC, Yip TT, et al. Chinese children may have different hab-
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Although we observed that both the frequency of nighttime lighting and myopia prevalence rates were higher in Singapore compared with Xiamen, we cannot conclude that there is a positive relationship from this observation alone. This is because other factors, such as near-work activity, may contribute to the higher prevalence rates of myopia in Singapore. Further analysis of combined data from Singapore and Xiamen revealed that night-lights were not significantly related to myopia or higher myopia (at least \(-3.0 \text{ D}\)), after controlling for several factors. There are several explanations for the negative associations. The stronger effects of reading on myopia in Chinese children may “mask” any small effect of night-lights. The quantification of night-lights using the questionnaire method may be crude and of limited value, resulting in risk estimates that tend toward the null. Questions on nighttime lighting used in our study were similar to those used in the 3 US studies.\(^1,14,15\) Estimates of night-light use, however, are often not perfectly measured by questionnaires, and further studies with prospective measures of night-light use using light meters in a large group of infants may be needed. As observed by Smith and coworkers,\(^11\) perhaps patients in tertiary eye centers may exhibit this relationship since the overall prevalence rate of refractive errors is higher than the normal population.\(^3\) In contrast, school-based studies do not seem to show an association.\(^14,15\) Alternatively, it is possible that no true relationship between night-lights and myopia exists; our study has a power of more than 90% to determine the effects of night-lights on myopia. Another possible reason is that gene-environment interaction exists and the effect of night-lights on myopia in Chinese children may be different from white children. In this unique epidemiologic study conducted in children of similar ages and ethnic origin in 2 different countries, near-work activity (quantified as books read per week) may be linked to myopia. However, our data suggest that it is unlikely that lighting at night predicts myopia in Chinese children.
Submitted for publication July 24, 2001; final revision received December 14, 2001; accepted January 10, 2002.
This study was funded by grant SERI/MG/97-04/0005 from the National Medical Research Council, Singapore.
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REFERENCES


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