Incidence and Progression of Myopia in Singaporean School Children

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Purpose. To determine the incidence and progression rates of myopia in young Singaporean children.

Methods. A prospective cohort study, the Singapore Cohort Study of the Risk Factors for Myopia (SCORM), was conducted in two schools in Singapore (1999–2002). Children aged 7 to 9 years (n = 981) were followed up over a 3-year period. Cycloplegic autorefraction and biometry parameter measures were performed annually, according to the same protocol.

Results. The 3-year cumulative incidence rates were 47.7% (95% confidence interval [CI]: 42.2–53.3), 38.4% (95% CI: 31.4–45.4), and 32.4% (95% CI: 21.8–43.1) for 7-, 8-, and 9-year-old children, respectively. The 3-year cumulative incidence rates were higher in Chinese (49.5% vs. 27.2%) and in 7-year-old compared with 9-year-old children at baseline (47.7% vs. 32.4%), though the latter relationship was of borderline significance after adjustment for race, gender, amount of reading (books/week), and parental myopia (P = 0.057). Premyopic children with greater axial lengths, vitreous chamber depths, and thinner lenses were more prone to the development of myopia, after controlling for age, gender, race, reading, and parental myopia. The 3-year mean cumulative myopia progression rates were −2.40 D (95% CI: −2.57 to −2.22) in 7-year-old myopic children, −1.97 (95% CI: −2.16 to −1.78) in 8-year-olds, and −1.71 (95% CI: −1.98 to −1.44) in 9-year-olds.

Conclusions. Both the incidence and progression rates of myopia are high in Singaporean children. (*Invest Ophthalmol Vis Sci.* 2005;46:51–57) DOI:10.1167/iovs.04-0565

Myopia is the most common refractive error and is easily correctable with optical devices. The public health impact of myopia, however, should not be underestimated, because myopia is associated with potentially blinding conditions, such as myopic neovascular macular degeneration, and because of the considerable economic impact of optometry visits, contact lenses, spectacles, and refractive surgery.[1–3] In urban East Asian cities, there are reports of "epidemics" of myopia that do not appear to abate.[4]

The age of onset of myopia is frequently between 5 and 15 years of age, and it is one of the most common childhood ocular diseases.[5] Several surveys depicting myopia prevalence rates have been conducted over the past few decades, but there are few longitudinal studies. Although longitudinal refractive error data from adults are readily available, few cohort studies have evaluated the incidence and progression of myopia in children.[6,7] The prevalence rates of myopia (defined as spherical equivalent [SE] of at least −0.5 D) in the multicenter Refractive Error Study in Children (RESC), conducted in children aged 5 to 15 years, were 7.4% in India, 4.0% in South Africa, and <3% in Nepal.[8–10] In a longitudinal study of children (n = 4662) aged 5 to 12 years in Shunyi, China, the cumulative incidence rate of myopia (SE at least −0.5 D) was 14.1% over a 28.5-month period and the mean progression rate was −0.42 D over the same period.[11] No ocular biometry data were available. In a 12-month longitudinal study conducted in Hong Kong, the annual incidence rate of myopia (SE at least −0.5 D) was 14.4% in children aged 5 to 16 years.[12] Other data on the progression rates of myopia in children have been derived primarily from volunteers in the control arm of randomized clinical trials of interventions to retard the progression of myopia, such as the U.S.-based Correction of Myopia Evaluation Trial (COMET; mean annual progression, −0.59 D per year in 6- to 9-year-olds) and the Houston Myopia Control Study (mean annual progression, −0.34 D per year in 6- to 15-year-olds).[13,14] In a randomized clinical trial evaluating the efficacy of rigid gas-permeable contact lenses in Singapore, the rate of progression of myopia was −0.63 D per year in the control arm.[15]

In this study, we sought to describe the incidence and progression rates of myopia in a school-based cohort and the variations of these rates with age, gender, and race in young Singaporean children.

Methods

Population

The recruitment of subjects in the Singapore Cohort Study of the Risk Factors of Myopia (SCORM) and the examination procedures have been described previously.[16,17] All children aged 7 to 9 years from two schools in the eastern and northern parts of the island of Singapore were invited to participate in SCORM. Children with serious medical disorders, such as leukemia, or chronic eye disorders, such as congenital cataract, were excluded. All 1621 children in grades 1 to 3 were invited, 1019 (62.9%) of which participated in the baseline examination visit. There were 528 7-year-olds, 325 8-year-olds, and 166 9-year-olds, with 737 Chinese, 229 Malaysians, and 53 Indians. Thereafter, yearly follow-up visits were scheduled. Informed written consent was obtained after the nature of the study was explained to parents.

Procedures

The tenets of the Declaration of Helsinki were observed, and approval was granted by the Singapore Eye Research Institute Ethics Committee. Similar procedures were performed at the annual school visits. In brief, cycloplegia was induced in each eye by the instillation of 3 drops of 1%

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cyclopentolate 5 minutes apart. At least 30 minutes after the last drop, five consecutive refraction and keratometry readings were obtained with one of two calibrated autokeratorefractometers (model RK5; Canon, Inc. Ltd., Tochigiken, Japan). Contact ultrasound biometry measurements were performed with one of two biometry machines (Echoscan model US-800, probe frequency of 10 mHz; Nidek Co., Ltd., Tokyo, Japan), after 1 drop of 0.5% proparacaine was administered. The average of six measurements was taken if the standard deviation was <0.12 mm. If the standard deviation of the six measurements was ≥0.12 mm, the data were not included, and the measurements were repeated until the standard deviation was <0.12 mm.

Questionnaire Data

The parents completed a questionnaire at baseline. Risk-factor information collected included the number of books the child finished reading per week in the past year. We also asked whether either parent wore spectacles or contact lenses for short-sightedness.

Definitions and Statistical Methods

Spherical equivalent (SE) is defined as spherical power plus half negative cylinder power. Because the refractive error (Pearson correlation coefficient = 0.95) and axial length data (Pearson correlation coefficient = 0.94) from the right and left eyes were similar, only the results from the right eye are presented. Myopia was defined as SE of at least −0.5 D. Levels of myopia included low myopia, defined as SE ≤ −0.5 D and >−3 D; higher myopia, defined as SE ≤ −3 D and >−6 D; and high myopia, defined as SE at least −6.0 D.

The cumulative incidence rate of myopia is defined as the proportion of participants in whom myopia developed during the 3-year follow-up period who had myopia at the baseline visit. The age-, gender-, and race-specific cumulative incidence rate of myopia and 95% confidence intervals (CIs) were calculated. The multivariate adjusted odds ratios and 95% CIs of myopia were derived from multiple logistic regression models and the explanatory variables age, gender, race, amount of reading (books/week), and parental myopia were included.

Change in refraction was defined as the refraction at the baseline examination subtracted from that at the final examination, divided by the total duration of follow-up in years. Multiple linear regression models were constructed with changes in refraction as the dependent variable and age, gender, race, amount of reading, and parental myopia as covariates. Statistical analyses were conducted with commercially available software (SAS, ver. 8.2; SAS, Cary, NC).

Results

Incidence of Myopia

Overall, 842 children (82.6% of those with baseline examinations) were observed for the entire 3 years. There were no statistical differences in age, gender, and baseline refraction of children who remained in the study throughout the 3 years and children who were lost to follow-up. However, children who were lost to follow-up were less likely to be Chinese (54.6%) than were children who remained in the study throughout the 3 years (69.6%). There were 660 baseline nonmyopes and 321 baseline myopes with at least one follow-up visit. Of these, there were 569 baseline nonmyopes with 3-year follow-up visit data (Fig. 1). Table 1 depicts the cumulative incidence rates of myopia by age, race, and gender. The 3-year cumulative incidence rate was 47.7% (95% CI: 42.2–53.3) for 7-year-olds, 38.4% (95% CI: 31.4–45.4) for 8-year-olds, and 32.4% (95% CI: 21.8–43.1) for 9-year-olds. The yearly incidence rates of myopia are highest in the first year (21.6%) and lowest in the third (final) year (14.0%; *P* for trend = 0.003). After adjustment for age, gender, amount of reading (books/week) and parental myopia, the incidence rates of myopia were twice as high in Chinese as in non-Chinese ($P < 0.001$). The incidence rates of myopia were higher in children aged 7 years than in those aged 9 years at baseline, after adjustment for race, gender, amount of reading (books/week), and parental myopia, though this relationship was only of borderline significance ($P = 0.057$).

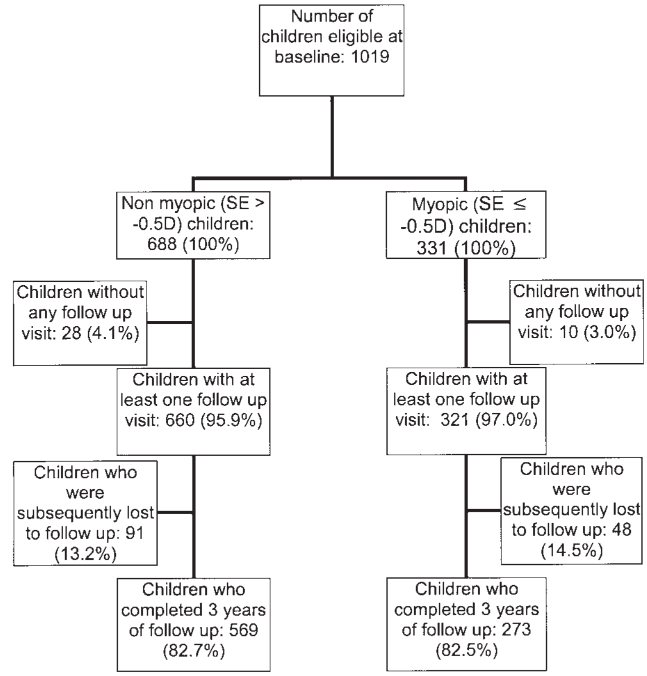

Figure 1. Follow-up status of eligible myopic and nonmyopic children.

The myopic and nonmyopic children at baseline were compared. The myopic children in the study had longer mean axial lengths (24.1 mm vs. 23.0 mm), deeper vitreous chambers (16.9 mm vs. 15.9 mm), thinner lenses (3.4 mm vs. 3.5 mm), deeper anterior chambers (3.7 mm vs. 3.6 mm), and steeper corneas (7.7 mm vs. 7.8 mm), compared with nonmyopic children (all $P < 0.001$). The incidence rates of myopia were compared in children with different premyopic ocular biometry characteristics (Table 2). Children with premyopic eyeball axial lengths in the fourth quartile were more prone to development of myopia than children with axial lengths in the first quartile (3-year cumulative rate 58.0% vs. 30.2%). Similarly, the 3-year cumulative incidence rates of myopia were higher in children with vitreous chamber depths in the fourth (56.3%) versus the first (33.3%) quartile. The myopia incidence rates were higher in children with thinner premyopic lenses (first quartile; 50.0%) than in those with thicker lenses (fourth quartile; 40.9%). These relationships between axial length, vitreous chamber depth, lens thickness, and myopia incidence remained significant, even after controlling for age, gender, race, amount of reading, and parental myopia.

The overall mean change in SE per year in the entire population was −0.47 ± 0.37 D (SD). The mean SE at the baseline visit and at visits 1, 2, and 3 are −0.33 D (range, −9.13 to +4.75), −0.92 D (range, −10.15 to +4.88), −1.35 D (range, −10.60 to −4.73), and −1.68 D (range, −10.85 to +4.65), respectively. Table 3 describes the mean and range of SE for non-myopic children, children with low myopia, higher myopia and high myopia at the baseline visit and visits 1, 2 and 3. Figure 2 shows the shifts in refractive error over the 3 years in nonmyopic children and in children with low, higher, and high myopia.

In a multiple linear regression analysis with 3-year cumulative myopia progression rate as the dependent variable and

Table 1. Incidence Rates of Myopia

	Number at Baseline	3-Year Cumulative Incidence Rate of Myopia (%; 95% CI)	Multivariate Odds Ratios of Myopia* (95% CI)
All	569	42.7 (38.6–46.8)	
Age at baseline (y)			
7	310	47.7 (42.2–53.3)	1 (referent)
8	185	38.4 (31.4–45.4)	0.72 (0.49–1.06)
9	74	32.4 (21.8–43.1)	0.66 (0.37–1.15)
P		0.006	0.057
Race			
Chinese	396	49.5 (44.6–54.4)	1 (referent)
Non-Chinese	173	27.2 (20.5–33.8)	0.44 (0.29–0.67)
P		<0.001	<0.001
Gender			
Male	273	39.6 (33.8–45.4)	1 (referent)
Female	296	45.6 (39.9–51.3)	1.34 (0.94–1.90)
P		0.15	0.10

* Adjusted for all other factors in the table, reading in books per week, and parental myopia. *P* from χ^2 tests are used to compare incidence rates while *P* from logistic regression models are used to compare odds ratios.

refractive subgroup as the main covariate, the differences in 3-year cumulative myopia progression rates in children with low myopia compared with children with emmetropia at baseline was −1.09 D (95% CI: −1.24 to −0.94). The 3-year cumulative myopia progression rate differences in children with higher myopia and high myopia at baseline compared with

Table 2. Incidence Rates of Myopia by Biometry Parameters at Baseline

Baseline Biometry	Number at Baseline	3-Year Cumulative Incidence Rate of Myopia (%; 95% CI)	Multivariate Odds Ratios of Myopia* (95% CI)
Axial length (mm)†			
1st quartile (21.12, 22.49)	139	30.2 (22.6–37.9)	1 (referent)
2nd quartile (22.50, 22.96)	145	40.0 (32.0–48.0)	1.61 (0.95–2.73)
3rd quartile (22.98, 23.46)	138	43.5 (35.2–51.8)	2.29 (1.32–3.97)
4th quartile (23.47, 25.21)	135	57.0 (48.7–65.4)	4.34 (2.45–7.68)
P		<0.001	<0.001
Vitreous chamber depth (mm)†			
1st quartile (13.88, 15.41)	138	33.3 (25.5–41.2)	1 (referent)
2nd quartile (15.42, 15.89)	140	36.4 (28.5–44.4)	1.31 (0.77–2.24)
3rd quartile (15.90, 16.36)	142	44.4 (36.2–52.5)	1.81 (1.07–3.09)
4th quartile (16.37, 17.96)	135	56.3 (47.6–64.7)	3.49 (2.00–6.09)
P		<0.001	<0.001
Lens thickness (mm)†			
1st quartile (2.89, 3.34)	132	50.0 (41.5–58.5)	1 (referent)
2nd quartile (3.35, 3.46)	148	42.6 (34.6–50.5)	0.72 (0.44–1.19)
3rd quartile (3.47, 3.58)	126	36.5 (28.1–44.9)	0.55 (0.33–0.93)
4th quartile (3.59, 4.21)	149	40.9 (33.0–48.8)	0.62 (0.37–1.02)
P		0.09	0.037
Anterior chamber depth (mm)†			
1st quartile (2.68, 3.42)	143	35.7 (27.8–43.5)	1 (referent)
2nd quartile (3.43, 3.61)	133	47.4 (38.9–55.9)	1.61 (0.96–2.68)
3rd quartile (3.62, 3.78)	139	39.6 (31.4–47.7)	1.31 (0.79–2.17)
4th quartile (3.79, 4.66)	140	47.9 (39.6–56.1)	1.84 (1.10–3.05)
P		0.12	0.047
Corneal curvature radius (mm)†			
1st quartile (2.89, 3.34)	135	43.0 (34.6–51.3)	1 (referent)
2nd quartile (3.35, 3.46)	148	44.6 (36.6–52.6)	1.10 (0.67–1.80)
3rd quartile (3.47, 3.58)	145	40.7 (32.7–48.7)	0.98 (0.59–1.63)
4th quartile (3.59, 4.21)	140	42.9 (34.7–51.1)	1.05 (0.63–1.76)
P		0.81	0.96

* Adjusted for age, gender, race, reading in books per week, and parental myopia. *P* from χ^2 tests are used to compare incidence rates whereas *P* from logistic regression models are used to compare odds ratios.

† There are 12 children with missing data for axial length; 14 with missing data for vitreous chamber depth, lens thickness, or anterior chamber depth; and 1 with missing data for corneal curvature.

TABLE 3. Spherical Equivalent for Myopic and Nonmyopic Children

	Baseline Visit	Visit 1	Visit 2	Visit 3
No myopia (SE > −0.5 D)	+0.54 (−0.48 to +4.75)	+0.12 (−2.05 to +4.88)	−0.21 (−3.18 to +4.73)	−0.46 (−4.23 to +4.65)
Low myopia (−3 D <SE ≤−0.5 D)	−1.41 (−2.98 to −0.50)	−2.31 (−4.80 to −0.35)	−3.01 (−6.55 to −0.58)	−3.48 (−7.55 to −0.25)
Higher myopia (−6 D < SE ≤−3 D)	−3.98 (−5.70 to −3.03)	−5.08 (−7.68 to −3.53)	−5.82 (−8.10 to −3.93)	−6.31 (−9.15 to −3.85)
High myopia (SE at least −6.0 D)	−7.15 (−9.13 to −6.03)	−7.90 (−10.15 to −6.80)	−8.46 (−10.15 to −7.30)	−8.71 (−10.85 to −7.88)

Data are the mean spherical equivalent (range).

children with emmetropia at baseline were −1.34 D (95% CI: −1.60 to −1.09) and −0.68 (95% CI: −1.29 to −0.07), respectively.

Progression of Myopia

There were 331 myopic children at baseline and 321 children had at least one follow-up visit and 273 children completed 3 years of follow-up. We evaluated the progression of myopia among the 273 myopic children with 3 years of follow-up (Table 4). There were 21 (7.7%) with three visits and 252 (92.3%) with four visits. There were 123 aged 7 years, 95 aged 8 years, and 55 aged 9 years at baseline and 146 (53.5%) were boys. At baseline, the mean SE was −2.13 D (range, −9.13 to −0.50), and there were nine (3.3%) with high myopia (SE at least −6.0 D).

The 3-year cumulative mean myopia progression rate was −2.40 D (95% CI: −2.57 to −2.22) in 7-year-olds, −1.97 D (95% CI: −2.16 to −1.78) in 8-year-olds, and −1.71 D (95% CI: −1.98 to −1.44) in 9-year-olds. The cumulative 3-year myopia progression rate in 7-year-olds was higher (−2.40 D) compared with that in 9-year-olds (−1.71 D; $P < 0.001$). The girls had greater rates of myopia progression (−2.38 D/y) than did the boys (−1.88 D/y; $P < 0.001$), whereas the Chinese children had faster rates of myopia progression (−2.18 D/y) than did the non-Chinese (−1.71 D per year; $P = 0.005$). The associations of age, gender, and race with myopia progression remained positive in a multiple linear regression model with 3-year cumulative myopia progression as the dependent variable and age, gender, race, amount of reading, and parental myopia as covariates. For every yearly increase in baseline age of the child, the 3-year cumulative rate of myopia progression decreased by 0.35 D, after adjustment for gender, race, amount of reading, and parental myopia. The overall yearly rate of change in progression of myopia decreased with time: (−0.95 D, 95% CI: −0.89 to −1.00 in the first year; −0.69 D, 95% CI: −0.64 to −0.74 in the second year; and −0.47 D; 95% CI: −0.42 to −0.51 in the third year; $P < 0.001$).

The proportion of children with high myopia (SE at least −6.0 D) at the final follow-up visit were 17.9% of 7-year-olds, 16.8% of 8-year-olds, and 14.6% of 9-year-olds. The proportion of children who attained a final refraction greater than -6.0 D was highest in those with more severe myopia at baseline ($P <$ 0.001) and who were younger at baseline (0.023), even after controlling for age of onset of myopia, gender, race, amount of reading, and parental myopia.

DISCUSSION

Our findings showed that the incidence rates of myopia (3-year cumulative incidence rates, 42.7%, 38.4%, and 32.4% in 7-, 8-, and 9-year-old children, respectively) were high in Singaporean children. The incidence rates were higher in Chinese and in children with the following premyopic biometry characteristics: longer axial lengths, vitreous chamber depths, and thinner lenses. The 3-year cumulative mean myopia progression rates among 273 myopic children were −2.40 D (95% CI: −2.57 to +2.22) in 7-year-old children, −1.97 (95% CI: −2.16 to −1.78) in 8-year-olds, and −1.71 (95% CI: −1.98 to −1.44) in 9-year-olds. These rates were greater in younger children, girls, and Chinese.

Incidence of Myopia

High cumulative incidence rates of myopia were recorded in our longitudinal study. By comparison, the annualized incidence rates of myopia (SE at least −0.5D) in Shunyi District, China, were 1.6% in 5-year-olds and 10.7% in 12-year-olds.[11] In Hong Kong children, the annualized incidence rates were 13.1% in 7-year-olds, 14.8% in 8-year-olds, and 15.0% in 9-year-olds.[12] Caution should be exercised in the interpretation of this comparison, because the recruitment strategies and ages of the children are not identical. Environmental factors, including a more competitive educational system and increased time spent reading among Singaporean and Hong Kong children, may explain any differences in incidence rates in urban Chinese populations. Previous comparative prevalence surveys include the Singapore-Xiamen study, the prevalence rates of myopia were highest in Singaporean children (12.3%), followed by urban (9.1%) and rural (3.9%) Xiamen children.[18] Whereas prevalence data describe the burden of myopia in society, incidence rates estimate the number of new cases of myopia and the risk of development of myopia in persons who previously were not myopic. The world-wide urban–rural patterns derived from both incidence and prevalence data are consistent with the near work hypothesis that increased reading and computer use may be a risk factor for myopia.[19]

Inter-ethnic comparisons show that the incidence rates of myopia are higher in Chinese than in non-Chinese. Our findings are consistent with prevalence data from prior studies, including the multicenter RESC with the highest rates in Asia found in urban Chinese.[8–10,20–22] Myopia is also very common in East Asian countries, including Taiwan and Hong Kong.[5,12] Chinese may have a hereditary predisposition for myopia or may be more likely to adopt lifestyle behavior associated with myopia. The risks of development of myopia are highest in young children, and the average age of onset of myopia is 8 to 12 years in Asia.[5] In Singaporean children, the incidence rates were even higher in 7-year-old than in 9-year-old children, although this relationship was of borderline significance.

Characteristics of Premyopic Eyes

The incidence rates of myopia are highest in children with greater axial lengths, and vitreous chamber depths, but thinner lenses, in the immediate premyopic stage. In other words, abnormal eye growth occurs in premyopic children. Children with a certain eye size and shape may be destined to develop

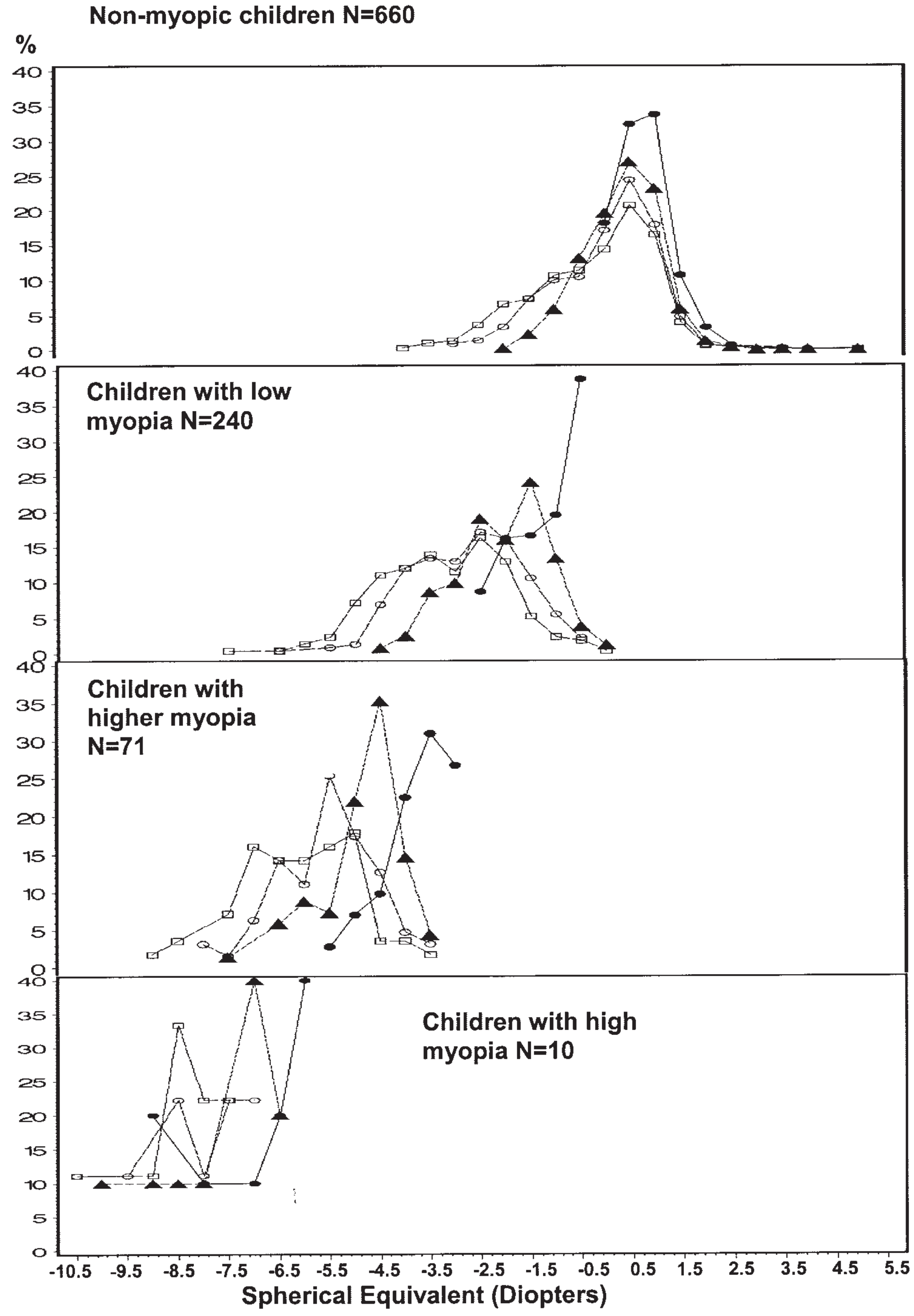

FIGURE 2. The distribution of SE in children with no myopia (SE > −0.5 D), low myopia (−3 D < SE ≤ −0.5 D), higher myopia (−6 D < SE ≤ −3 D), and high myopia (SE at least −6.0 D) at baseline. Nonmyopic children, $n = 660$. (●) Baseline visit; (▲) visit 1; (○) visit 2; and (□) visit 3.

myopia. During the time a child enters school, the premyopic eye is already excessively long. However, premyopic biometry may be a surrogate for socioeconomic status: children with greater axial lengths may be taller and perhaps from families with higher socioeconomic status.[17] The characteristics of at-risk premyopic children needs further definition, and comparisons of eye growth during the premyopic, myopia-onset, and postmyopic phases should be made in future studies. In the Orinda Longitudinal Study, premyopic children with greater axial lengths were more likely to have parents who were myopic.[23] Because the eye destined to become myopic is longer in axial length, these data may help in the prediction of myopia onset and the identification of high-risk children who may benefit from lifestyle modification measures.

Progression among Myopic Children

The 3-year cumulative mean rates of progression of myopia in our school-based study are high. We report rates of −2.40 D in 7-year-olds, −1.97 D in 8-year-olds, and −1.71 D in 9-year-olds. In the Hong Kong myopia study of school children aged 5 to 16 years, the myopia progression rate was −0.63 D per year.[12] The Houston Myopia Control Study (1981–1982) of bifocals reported rates of annual myopia progression of −0.34 D per year in children aged 6 to 15 years in the control arm.[14] Interstudy comparisons are limited by differences in the nature of recruitment strategies, ethnic composition, and ages of the children. It appears that the rates of myopia progression in the United States are half those in children in Asian countries.

Table 4. Three-year Cumulative Myopia Progression Rates among Myopic Children

	Number at Baseline	3-Year Cumulative Myopia Progression Rate (D)* Mean (95% CI)	Multivariable Adjusted Beta Coefficient† (95% CI)	% with Change > −2.0 D	% with Myopia > −6.0 D at the Final Follow-up Visit
All	273	−2.11 (−2.23 to −1.99)	-	20.2	16.9
Age at baseline (y)					
7	123	−2.40 (−2.57 to −2.22)		65.9	17.9
8	95	−1.97 (−2.16 to −1.78)		51.6	16.8
9	55	−1.71 (−1.98 to −1.44)	0.35 (0.19 to 0.50)	32.7	14.6
P		<0.001	<0.001	<0.001	0.86
Gender					
Male	146	−1.88 (−2.03 to −1.72)		47.3	18.5
Female	127	−2.38 (−2.55 to −2.20)	−0.51 (−0.74 to −0.29)	62.2	15.0
P		<0.001	<0.001	0.013	0.44
Race					
Chinese	231	−2.18 (−2.31 to −2.06)		57.1	18.2
Non-Chinese	42	−1.71 (−2.05 to −1.38)	0.38 (0.05 to 0.70)	38.1	9.5
P		0.005	0.025	0.023	0.17

* *P* from *t*-tests or ANOVA were used to compare the 3-year cumulative myopia progression rates, whereas *P* from χ^2 tests were used to compare proportion with 3-year myopia progression > and ≤ −2.0 D and proportion with and without myopia more than −6.0 D at final follow-up visit.

† Adjusted for all other factors in the table, reading in books per week, and parental myopia in a multiple linear regression model with 3-year cumulative myopia progression as the dependent variable.

In multivariate analysis, the rate of myopia progression in Singaporean school children is highest in younger children, Chinese children, and girls. In 142 Hong Kong Chinese children aged 6 to 17 years, the myopia progression rates were greatest in younger children, but there were no gender differences.[24] The data from the Hong Kong study are not directly comparable, because adolescent children were included. A greater change toward myopia in younger than in older children was found in Finnish children aged 7 to 15 years.[25]

In our study, the proportion of myopic children with high myopia (SE at least −6.0 D) at the end of the 3- year follow-up (children aged 9–11 years) was 16.8%. Myopia continues to progress into the early 20s and thus, with earlier ages of onset, as seen in our cohort, a longer period of progression may mean more highly myopic children in the future. The risks of development of high myopia (SE at least −6.0 D) and associated complications such as retinal tears or myopic macular degeneration in adulthood will be considerably higher in this young cohort.

There are tremendous public health implications in the observed trend of development of early myopia during the preschool or early elementary years. Large-scale visual acuity screening programs may be launched to detect low vision due to undercorrected myopia early and to update current spectacle prescriptions. Public and school-based health education programs may also be targeted at the very young. Myopia prevention strategies may include reassessments of current educational systems in urban East Asian communities. The overemphasis on academic performance and paucity of structured outdoor activity in Asian schools may be a leading factor contributing to the high myopia incidence rates in the very young. For children with high myopia, referrals to ophthalmologists or optometrists to screen for potentially blinding conditions are recommended.

The strengths of our study are the availability of 3-year longitudinal cycloplegic refraction and biometry data of 1019 young children in an area where myopia is apparently endemic. The limitations of the present study must be acknowledged. There is a possibility that the data are not entirely generalizable to all children in Singapore, as the schools were not selected at random. The children (38%) who did not agree to participate may have had a different (either higher or lower) incidence rate of myopia, and thus the overall incidence rates in the study population may be biased. However, comparisons of demographic factors within the cohort should hold. As with all cohort incidence studies, some children may not remain throughout the entire duration of the study and may be lost to follow-up. The 3-year loss to follow-up rate was low (119/688; 17.3%) and children who were lost to follow-up were more likely to be non-Chinese and therefore may have lower incidence rates than did children not lost to follow-up. The distribution of baseline refractive errors for children who remained in the study and those lost to follow-up was similar.

In conclusion, the 3-year cumulative incidence rates of myopia are 47.7% in 7-year-old children, 38.4% in 8-year-old children, and 32.4% in 9-year-old children. Premyopic children with greater axial lengths, vitreous chamber depths, and thinner lenses are more prone to the development of myopia. The 3-year cumulative mean myopia progression rate is −2.40 D in 7-year-olds, −1.97 D in 8-year-olds, and −1.71 D in 9-year-olds. These data are important to ophthalmologists and health administrators for health care evaluation and planning.

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