Myopia, Lifestyle, and Schooling in Students of Chinese Ethnicity in Singapore and Sydney

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Objective: To compare the prevalence and risk factors for myopia in 6- and 7-year-old children of Chinese ethnicity in Sydney and Singapore.

Methods: Two cross-sectional samples of age- and ethnicity-matched primary school children participated: 124 from the Sydney Myopia Study and 628 from the Singapore Cohort Study on the Risk Factors for Myopia. Cycloplegic autorefraction was used to determine myopia prevalence (spherical equivalent ≤ -0.5 diopter). Lifestyle activities were ascertained by questionnaire.

Results: The prevalence of myopia in 6- and 7-year-old children of Chinese ethnicity was significantly lower in Sydney (3.3%) than in Singapore (29.1%) ($P < .001$). The prevalence of myopia in 1 or more parents was 68% in Sydney and 71% in Singapore. Children in Sydney read more books per week ($P < .001$) and did more total near-work activity ($P = .002$). Children in Sydney spent more time on outdoor activities (13.75 vs 3.05 hours per week; $P < .001$), which was the most significant factor associated with the differences in the prevalence of myopia between the 2 sites.

Conclusions: The lower prevalence of myopia in Sydney was associated with increased hours of outdoor activities. We hypothesize that another factor contributing to the differences in the prevalence of myopia may be the early educational pressures found in Singapore but not in Sydney.

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MYOPIA IS A COMMON REfractive error associated with excessive axial elongation of the eye. In East Asian cities, the onset of myopia is now early, with a prevalence of more than 20% in the early primary school years,[1-3] resulting in a prevalence of myopia in young adults of more than 80%[1,3,4] and an increasing proportion (approximately 20%) of young adults with high myopia.[3]

There has been considerable debate about the factors that contribute to the present epidemic of myopia in urban East Asia.[5-7] In this article, we document marked differences in the prevalence of myopia in age-matched students of Chinese origin in 2 distinct physical, social, and educational environments, Singapore and Sydney, and analyze the risk factor exposures that could contribute to these differences.

METHODS

STUDY POPULATION

Children of Chinese ethnicity living in Sydney (n = 124) were drawn from a survey of 1742 year 1 students selected using a stratified random cluster design.[8] The child's ethnicity was defined as Chinese only if both parents self-identified this ethnic origin. Data were also obtained for 628 children of Chinese ethnicity from 631 grade 1 students examined in 3 schools in Singapore.[2] In this study, ethnicity was determined using the father's reported ethnicity, as defined by the Singapore Population Census 2000 (http://www.singstat.gov.sg). Interethnic marriage at the time of parental marriages was less than 10%; thus, the differences in definition of ethnicity are not significant.

PROCEDURES

Refraction was measured using table-mounted autokeratorefractors (model RK-F1 in Sydney and model RK-F5 in Singapore; Canon, Tokyo, Japan) after cycloplegia, induced after instillation of local anesthetic using cyclopentolate, 1% (3 drops in Singapore and 2 drops in Sydney with additional tropicamide, 1%[9]). In Sydney, cycloplegia was assessed by pupil dilation greater than 6 mm and the absence of pupil miosis in response to light or an accommodative target. In Singapore, cycloplegia was not formally assessed. Corneal radius of curvature, anterior chamber depth, and axial length were measured using an optical biometer (IOLMaster; Carl Zeiss Meditec Inc, Jena, Germany) in Sydney. Autokeratorefraction was used to measure corneal radius of curvature in Singapore, whereas anterior chamber depth and axial length were mea-

Table 1. Distribution of Refractive Error and Ocular Biometry Values in the Right Eyes of Children of Chinese Origin Living in Singapore and Sydney

	Sydney		Singapore		
	Children, No. (n=124)	Mean (SD)[a]	Children, No. (n=628)	Mean (SD)[a]	*P* Value
Female sex, %		53.2		50.3	.60
Myopia (spherical equivalent of ≤–0.5 D), %		3.3		29.1	<.001
Age, y	124	6.41 (0.35)	628	7.16 (0.39)	<.001
Spherical equivalent refraction, D	124	0.86 (0.78)	628	–0.16 (1.43)	<.001
Axial length, mm	123	22.60 (0.67)	613	23.13 (0.90)	<.001
Anterior chamber depth, mm	124	3.27 (0.22)	613	3.58 (0.27)	<.001
Corneal radius of curvature, mm	124	7.87 (0.25)	626	7.73 (0.25)	<.001
Axial length to corneal radius ratio	123	2.87 (0.07)	611	2.99 (0.10)	<.001

Abbreviation: D, diopter.
[a]Except where noted otherwise.

sured using A-scan ultrasonography. Axial length and anterior chamber depth dimensions are slightly greater when measured using the IOLMaster compared with ultrasonography.[9]

In both studies, parents completed questionnaires on their child's near-, middle-, and distance-vision activities. The Singapore questionnaire has been validated using 24-hour near-work diaries,[10] and the Sydney data were similarly validated against a 24-hour clock for weekdays and weekends. Parents reported ethnicity by self-identification and refractive status via questions on the use of glasses for distance vision.

These studies were approved by the University of Sydney human ethics committee, the New South Wales Department of Education and Training, the Catholic Education Office of the Archdiocese of Sydney, and the ethics committee of the Singapore Eye Research Institute and adhered to the tenets of the Declaration of Helsinki.

STATISTICAL ANALYSES

Analyses were conducted on the right eye only because refractive error was highly correlated between eyes in the Sydney (r=0.95) and Singapore (r=0.92) samples. The data were entered into a database program (Microsoft Access; Microsoft Corp, Redmond, Washington). All statistical analyses were performed using a software program (SAS V9.1; SAS Institute Inc, Cary, North Carolina). The χ^2 test was used to compare proportions (prevalence) between the 2 cities. A t test was used to assess the significance of the differences between the mean values of the selected characteristics at the 2 sites. Stepwise multiple linear regression was used to examine the relationship between refraction and baseline characteristics.

RESULTS

The prevalence of myopia (defined as a right eye spherical equivalent of at least –0.5 diopter [D]) was much higher in children of Chinese ethnicity in Singapore (29.1%) than in similarly aged children in Sydney (3.3%) ($P<.001$). The mean spherical equivalent refraction was considerably more myopic in Singapore than in Sydney (–0.16 vs +0.86 D; $P<.001$), which is reflected in the range of spherical equivalents (–6.70 to +4.85 D vs –2.88 to +3.50 D). Consistent with these differences in refraction, axial lengths and anterior chamber depths were significantly greater in Singapore than in Sydney (**Table 1**).

One factor that could contribute to these large differences is parental myopia, which has been associated with a greater likelihood of myopia in children,[11] although whether this represents the effect of shared genes or shared environments is not clear. However, there was no difference in the proportion of children with 0, 1, or 2 myopic parents in the 2 cities (P=.84). In the Sydney sample, 32% of children had no parents with myopia, 43% had 1 myopic parent, and 25% had 2 myopic parents compared with 29%, 43%, and 28%, respectively, in Singapore. To the extent that parental myopia is a surrogate measure of genetic differences, this suggests that genetic differences related to myopia in the 2 populations are not significant.

Possible lifestyle factors that contribute to the differences are outlined in **Table 2**. The children of Chinese origin living in Sydney read slightly more books; spent more time reading, writing, or using computers outside of school; and watched slightly less television than did the Chinese children living in Singapore. They also had fewer hours per week of coaching (additional lessons outside school hours) than did the children from Singapore. All these differences were statistically significant but were small in magnitude. However, a cumulative measure of near-work activity was significantly different between the 2 cities, with more total near-work activity being performed by the children in Sydney. The largest difference observed was that children of Chinese ethnicity spent nearly 14 hours per week in outdoor activities in Sydney compared with just more than 3 hours per week in Singapore ($P<.001$). In Sydney, near-work activity was highly correlated with outdoor activity (r=0.55); however, in Singapore it was not (r=0.08).

Linear regression of the pooled data, with spherical equivalent refraction as the dependent variable, identified 4 significant independent variables: location, outdoor activities, parental myopia, and number of books read. A model using location alone gave an R^2 of 0.146, and the sequential addition of the other identified factors increased the R^2 only marginally to 0.148. Outdoor activities on their own gave an R^2 of 0.080, suggesting that all the individual factors were subsumed within location and that the differences in outdoor activity ac-

Table 2. Myopia Risk Factors in Children of Chinese Origin Living in Singapore and Sydney

Activity Outside School	Sydney Children, No. (n=124)	Sydney Mean (SD)	Singapore Children, No. (n=628)	Singapore Mean (SD)	*P* Value
Books read, No./wk	119	4.44 (2.46)	628	2.39 (2.27)	<.001
Reading and writing, h/wk	109	20.81 (13.88)	611	17.76 (8.78)	.03
Computer use, including computer games, h/wk	108	4.65 (6.62)	625	3.55 (4.48)	.10
Total near-work activity, h/wk[a]	106	29.93 (20.09)	608	23.54 (11.84)	.002
Coaching classes, h/wk	118	1.21 (1.75)	622	1.74 (2.02)	.007
Television viewing, h/wk	113	11.32 (6.47)	627	12.65 (7.37)	.07
Outdoor activities and sports, h/wk	102	13.75 (1.02)	586	3.05 (0.12)	<.001

[a] Includes reading, writing, computer use, crafts, and playing musical instruments.

counted for a significant part, but not all, of the location effect.

COMMENT

These data demonstrate major differences in the prevalence of myopia in children of Chinese origin aged 6 and 7 years growing up in Sydney and Singapore, with major associations with location-specific engagement in outdoor activities. The ocular biometry profile in Singapore (longer axial length, greater depth of the anterior chamber, and a higher axial length to corneal radius ratio) is consistent with the higher prevalence of myopia.

The strong association between increased time spent outdoors and decreased myopia is consistent with other studies[11,12] of such associations with sports and outdoor activities. Data from the Sydney Myopia Study[13] suggest that the critical factor is time spent outdoors rather than engagement in sports because indoor sporting activity has no effect, whereas outdoor sports and outdoor leisure activities show the association. It is not clear whether the effect of time spent outdoors is a result of the greater viewing distances or the brighter light typical of outdoor daylight hours. Brighter light could reduce the development of myopia through pupil constriction, resulting in less visual blur, or through stimulation of the release of dopamine from the retina, which is known to act as an eye growth inhibitor.[14] However, the differences in time spent outdoors do not explain all the between-site differences.

The Singaporean children are a mean of 10 months older than the children in Sydney. However, this age difference cannot account for the higher prevalence of myopia in Singapore, even given the high incidence rates in Singapore.[15] The greater number of books read in Sydney was surprising given the reported association between more books read per week and higher myopia in Singapore in 6- and 7-year-olds,[16] but subsequent studies in Singapore suggest that this measure is not associated with later incident myopia.[15]

The 2 locations have a variety of intrinsic differences. For any difference to provide an explanation for the rapid increase in the prevalence of myopia in Singapore during the past few decades,[4,17-19] it would have had to emerge at an appropriate time and at a relatively rapid rate. It would need to have a plausible biological mechanism for affecting the development of myopia. These criteria rule out some obvious differences, such as those in climate.

The standard of living has changed during the past decades in both locations, but more rapidly in Singapore. The reported current difference in gross domestic product per capita between Sydney and Singapore (2005 data: Australia, US $31 900; and Singapore, US $28 100) is small,[20] and higher incomes are associated with less myopia, whereas the reported relationship is normally the reverse.[21] Population density is higher in Singapore,[20] with patterns of housing that have changed rapidly. People in Sydney predominantly live in single houses, whereas Singaporeans predominantly live in high-rise housing complexes. However, myopia in Singapore is associated with more spacious living conditions,[21] possibly because of independent associations of socioeconomic status with housing and education. A role for diet in the etiology of myopia has also been proposed.[22] Diet was not measured in the Sydney sample, but migrant Chinese parents in Sydney retain a large component of the traditional Chinese diet in their Western environment, whereas in Singapore, traditional diets are also retained but with an increasing popularity of components of Western diets, suggesting that their diets may not be markedly different.

One factor that is different and has changed rapidly is education.[23,24] In Singapore, most students are enrolled in a structured 3-year preschool program with the aim of ensuring that children are reading when they start school. In Sydney, most children have at least 1 year of part-time preschool, which is largely concerned with social development. This is followed by enrollment in a full-time kindergarten year before year 1. Differences in educational intensity at this early stage may have a considerable impact given the very early appearance of myopia in Singapore.[2]

A link to education is plausible. Adult myopia is strongly associated with years of schooling,[17] and myopia during the school years is associated with higher school performance.[25,26] We, therefore, suggest that another major factor that contributes to the high levels of myopia in Singapore may be Singapore's competitive, academically oriented schooling and, in particular, the emphasis on very early educational achievements. Associated increases in academic activity, combined with deficits in outdoor activity, may start children in Singapore on a trajectory toward myopia from a very early age. Overall, these comparative results suggest that promotion of outdoor activities may help reduce the epidemic of myopia in Singapore and that reform of school structures also has the potential to contribute to this goal.

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