Ethnicity-specific prevalence rates of refractive errors vary in Asian children in neighboring Malaysia and Singapore

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Ethnicity-specific prevalences of refractive errors vary in Asian children in neighboring Malaysia and Singapore

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ABSTRACT

Aim: To compare the prevalences of refractive errors in Malay, Chinese, and Indian children in Malaysia and Singapore.

Methods: Children aged 7 to 9 years from 3 schools in the Singapore Cohort study of the Risk factors for Myopia (SCORM) (n=1962) and a random cluster sampling of similarly aged children in the metropolitan Kuala Lumpur area in the Malaysia Refractive Error Study in Children (RESC) (n=1752) were compared. Cycloplegic autorefraction was conducted in both countries.

Results: The prevalence of myopia (spherical equivalent of at least -0.5 Diopters [D] in either eye) was higher in Singapore Malays (22.1%) compared with Malays in Malaysia (9.2%) [95% confidence interval (CI) of difference = 11.2, 14.7; $p< 0.001$]. Similarly, Singapore Chinese (40.1%) had higher prevalences compared with Malaysian Chinese (30.9%) (95% CI of difference = 1.5, 16.9). Singapore Indians had a higher prevalence (34.1%) than Malaysian Indians (12.5%)
(95% CI of difference = 17.4, 25.9). The multivariate odds ratio of astigmatism (cylinder at least 0.75 D in either eye) in Singapore Malays compared with Malaysian Malays is 3.47 (95% CI 2.79, 4.32). Ethnic-specific hyperopia rates did not differ in Singapore and Malaysia.

Conclusion: The ethnicity-specific prevalences of myopia in Singapore Malays, Chinese and Indians are higher than that in Malaysian Malays, Chinese and Indians. Because Malays, Chinese and Indians in Malaysia have similar genetic make-up compared with Malays, Chinese and Indians in Singapore, environmental factors may contribute to the higher myopia rates.

The contributions of genetic and environmental factors towards the perceived "epidemic" of myopia in Asia need further evaluation. [1] Within Asia, the prevalence of myopia is highest in urban Chinese populations such as Hong Kong, Taiwan, Singapore and Southern China, and lowest in non-Chinese rural populations such as Nepal and India. [2] [3] [4] [5] [6] [7] The differences in myopia rates may be attributed to variations in genetic susceptibility or environmental lifestyles in subpopulations. It has been purported that near work activity and a competitive education system may be the primary environmental factors related to myopia; while the genetic susceptibility to myopia may be polygenic in nature. [8] [9]

Multi-ethnic populations allow the evaluation of genetic effects and inter-racial differences in culture and lifestyle. Comparative studies across different populations with similar genetic pools may provide insights to the importance of environmental influences in the development of myopia. Singapore and Malaysia are neighboring countries, separated by a narrow waterway, and are examples of multi-ethnic societies in East Asia. The three major ethnic groups are the same in both countries: Chinese (77% in Singapore and 26% in Malaysia), Malays (14% in Singapore and 65% in Malaysia) and Indians (8% in Singapore and 8% in Malaysia) and other minorities (1% in Singapore and 1% in Malaysia). [10] [11] Chinese in Singapore and Malaysia migrated from the same localities in South China (primarily Fujian and Guangdong Provinces), and Indians in Singapore and Malaysia migrated from the same parts of India, primarily from South India and Sri Lanka. The majority of Chinese and Indian families have lived for decades (primarily second, third or fourth generation) and the Malays are native to Singapore and Malaysia.

We aim to evaluate differences in the prevalences of refractive errors, including myopia, in 7 to 9 year old children of similar ethnicity – Malays, Chinese, and Indians -- from the Refractive Error Study in Children (RESC) and the Singapore Cohort study of the Risk factors for Myopia (SCORM) conducted in two neighboring countries, Malaysia and Singapore. [12] [13] [14] [15] [16]

METHODS

Singapore Population

Children from grades 1 to 3 from the Northern and Western schools and grades 1 and 2 in the Eastern school were invited to participate. Ninety four children with serious medical or ocular disorders were excluded. The participation rate was 71.8% (693/965) in the Northern school, 80.0% (956/1195) in the Western school, and 49.1% (313/638) in the Eastern school. The parents completed a baseline questionnaire and father's and mother's completed educational level were assessed. Written informed consent was obtained from the parents.

Children were examined on the school premises in 1999 in the Northern and Eastern schools and 2001 in the Western school by a team of ophthalmologists and optometrists who were masked to questionnaire data. After measurement of distance logMAR visual acuity measurements, cycloplegia was induced by administering three drops of 1% cyclopentolate solution at 5-minute intervals. At least 30 minutes after the last drop, refraction was obtained with one of two autokeratorefractometers (RK5, Canon, Tochigiken, Japan). A total of 1962 children were refracted: 851 (43.4%) were 7 years of age, 630 (32.1%) were 8 years of age, and 481 (24.5%) were 9 years old. There were 992 (50.6%) males and 970 (49.4%) females. Ethnicity was distributed as follows: In the Northern school, there were 415 (59.9%) Chinese, 227 (32.8%) Malay, 42 (6.1%) Indian, and 9 (1.3%) of Other ethnicity; in the Western school, there were 743 (77.7%) Chinese, 121 (12.7%)

Malay, 83 (8.7%) Indian, and 9 (0.9%) of Other ethnicity, and in the Eastern school, there were 309 (98.7%) Chinese, 1 (0.3%) Indian, and 3 (1.0%) of Other ethnicity. Further details of the SCORM protocol have been described elsewhere along with findings from the baseline examinations. [13] [14] [15] [16]

Malaysia Population

The Malaysian study population was obtained by random cluster sampling of children aged 7 to 15 years in Gombak District in the metropolitan Kuala Lumpur area. Clusters were defined geographically, and using house-to-house visits within randomly selected clusters, eligible children were enumerated by name, gender, and age. All eligible children recruited attended primary school. The ethnicity of the father and years of schooling for each parent were recorded. Years of schooling was grouped as no formal or incomplete primary education (< 6 years of schooling), completed primary education (6 to 9 years of schooling), completed secondary education (10 to 11 years of schooling), or completed tertiary education (12 years or more of schooling). Written consent for each child was obtained from a parent or guardian.

Eye examinations were conducted in 140 schools by two clinical teams, mostly between March and July 2003. After distance logMAR visual acuity measurements, cycloplegia was induced with 2 drops of 1% cyclopentolate administered 5 minutes apart by ophthalmic assistants, with a third drop after 20 minutes, if necessary. Cycloplegia and pupil dilation were evaluated after an additional 15 minutes -- pupillary dilation of 6 mm or more with absence of light reflex was considered complete cycloplegia. Refraction was performed by an optometrist with a handheld autorefractor (Retinomax K-Plus; Nikon, Tokyo, Japan).

Of the 2104 children between the ages of 7 to 9 years, 1781 (84.6%) were examined, and 1752 (83.3%) had autorefraction measurements following successful cycloplegic dilation: 581 (33.2%) were 7 years old, 601 (34.3%) were 8 years old, and 570 (32.5%) were 9 years old. There were 924 (52.7%) males and 828 (47.3%) females. The ethnic composition was: 1245 (71.1%) Malay, 285 (16.3%) Chinese, 152 (8.7%) Indian, and 70 (4.0%) of Other ethnicity.

The complete RESC protocol has been described elsewhere, as have further details regarding the specific sampling and examination methods used in Gombak District. [12] [17] Examination participation rates in both Malaysia and Singapore were reasonably similar across age groups and gender. In Malaysia, the participation rate was highest in the Other ethnicity category (92.1%), followed by Malays (84.1%), Chinese (81.0%), and Indians (77.6%). In Singapore, the participation rate was highest in Indians (82.1%), followed by Malays (78.9%), Others (77.1%), and Chinese (67.4%).

The SCORM study was approved by the Institutional Review Board of the Singapore Eye Research Institute. The RESC study protocol was approved by the World Health Organization Secretariat Committee on Research Involving Human Subjects, and the Ethical Committee of the Standing Committee for Medical Research, Malaysia Ministry of Health.

Definitions and Data Analysis

Definitions of refraction employed in the RESC studies were used. Myopia was defined as spherical equivalent (SE) refractive error of at least -0.50 diopter (D), and hyperopia as +2.00 D or more. Astigmatism was defined as cylinder of at least 0.75 D. Clustering effects associated with the cluster sampling design in Malaysia were taken into account in all statistical analyses. Statistical analyses were performed using Stata Statistical Software, Release 8.0 svy commands for analyzing

complex survey design data with clusters as primary sampling units [18]. The primary sampling unit was each geographic cluster in Malaysia and the Singapore data were considered as 1 cluster. Differences in the prevalences of myopia, hyperopia, and astigmatism between Malaysia and Singapore were considered statistically significant, if the 95% confidence intervals of the differences in the prevalences do not cross zero and p values were below 0.05. The data were pooled in order to evaluate the impact of living in Singapore versus Malaysia on myopia, astigmatism and hyperopia within each ethnic group. The age, gender, father's education and/or myopia adjusted ORs were presented. [18]

RESULTS

The Singapore population had a greater proportion of Chinese, 7 year olds and father's with tertiary educational level compared with the Malaysian population (**Table 1**). Similarly, the Singapore site (10.7%) had a greater proportion of mother's with tertiary education compared with the Malaysian site (5.8%) (p<0.001). The mean (standard deviation) of right eye SE refractive error in Malaysian Malay [+0.65D (0.82)], Chinese [-0.14D (1.74)] and Indian children [+0.57D (1.10)] were less myopic, when compared with Singapore Malay [+0.15D (1.42)] (p<0.001), Chinese [-0.52D (1.69)] (p<0.001), and Indian [-0.22D (1.74)] (p<0.001) children (**Figure 1**). Similarly, the mean (standard deviation) refractions of both Malaysian boys and girls were less myopic compared with Singapore boys [+0.50D (1.03)] versus [-0.49D (1.76); p<0.001] and girls [+0.51D (1.17) versus -0.25D (1.56); p<0.001]. Refractive error was less myopic at all ages in Malaysian children compared with Singapore children for 7 year olds [+0.64D (0.92)] versus [-0.03D

Table 1. Characteristics of children in Malaysia and Singapore (n=3714)

	All	**Malaysia (n=1752)**	**Singapore (n=1962)**	**P-value**
	Number (%)	**Number (%)**	**Number (%)**	**(chi-square)**
Ethnicity				
Malay	1593 (42.9)	1245 (71.1)	348 (17.7)	<0.001
Chinese	1752 (47.2)	285 (16.3)	1467 (74.8)	
Indian	278 (7.5)	152 (8.7)	126 (6.4)	
Others	91 (2.5)	70 (4.0)	21 (1.1)	
Age (years)				
7	1432 (38.6)	581 (33.2)	851 (43.4)	<0.001
8	1231 (33.1)	601 (34.3)	630 (32.1)	
9	1051 (28.3)	570 (32.5)	481 (24.5)	
Gender				
Male	1916 (51.6)	924 (52.7)	992 (50.6)	0.19
Female	1798 (48.4)	828 (47.3)	970 (49.4)	
Completed father's education level				
No formal or incomplete education	117 (3.3)	46 (2.9)	71 (3.7)	<0.001
Primary education	857 (24.4)	393 (25.0)	464 (23.8)	
Secondary education	1518 (43.2)	771 (49.1)	747 (38.4)	
Pre-tertiary education	511 (14.5)	202 (12.9)	309 (15.9)	
Tertiary and above	513 (14.6)	158 (10.1)	355 (18.2)	
All	3714 (100)	1962 (100)	1752 (100)	

* There are 16 missing values for father's education for Singapore and 182 for father's education in Malaysia

(1.38); p<0.001], for 8 year olds [+0.51D (0.96) versus -0.29D (1.57); p<0.001], and for 9 year olds [+0.35D (1.35) versus -1.08D (2.01) ; p<0.001].

Overall, the prevalence of myopia was higher in Singapore (36.3%) compared with Malaysia (13.4%) (95% CI of the difference in rates = 20.3, 25.4; p<0.001) (**Table 2**). The prevalence of high myopia (SE in the worse eye of at least -6.0 D) and moderate myopia (SE in the worse eye less than -6.0 D but at least -2.0 D) were 1.4% (95% CI 1.0, 2.1) and 15.0% (95% CI 13.4, 16.6), respectively, in Singapore, versus 0.5% (95% CI 0.1, 0.8) (p=0.004) and 3.0% (95% CI 1.8, 4.3) (p<0.001), respectively, in Malaysia. Myopia prevalences are significantly higher in Singapore compared with Malaysia within specific strata defined by ethnicity alone (Chinese, Malays, Indians), age alone, gender alone, paternal education alone and maternal education alone.

Table 2. Prevalences of myopia (SE at least -0.5 D in either eye) in Malaysia and Singapore

	Malaysia (n=1752)				Singapore (n=1962)				Difference (Singapore – Malaysia)		P-value
	Number at risk	Cases	Prevalence (%)	95% confidence interval	Number at risk	Cases	Prevalence (%)	95% confidence interval	(%)	95% confidence interval	
Ethnicity											
Malay	1245	114	9.2	(7.4, 10.9)	348	77	22.1	(17.9, 26.9)	13.0	(11.2, 14.7)	<0.001
Chinese	285	88	30.9	(23.4, 38.3)	1467	588	40.1	(37.6, 42.6)	9.2	(1.5, 16.9)	0.03
Indian	152	19	12.5	(8.3, 16.7)	126	43	34.1	(25.9, 43.1)	21.6	(17.4, 25.9)	<0.001
Others	70	14	20.0	(11.3, 28.7)	21	4	19.0	(5.4, 41.9)	-1.0	(-11.6, 9.7)	0.84
Age (years)											
7	581	58	10.0	(6.8, 13.1)	851	243	28.6	(25.5, 31.7)	18.6	(15.4, 21.7)	<0.001
8	601	84	14.0	(10.3, 17.6)	630	219	34.8	(31.0, 38.6)	20.8	(17.2, 24.4)	<0.001
9	570	93	16.3	(11.7, 20.9)	481	250	52.0	(47.4, 56.5)	35.7	(31.0, 40.3)	<0.001
Gender											
Male	924	126	13.6	(10.2, 17.1)	992	379	38.2	(35.2, 41.3)	24.6	(21.1, 28.0)	<0.001
Female	828	109	13.2	(10.2, 16.1)	970	333	34.3	(31.3, 37.4)	21.2	(18.2, 24.1)	<0.001
Completed father's education level											
No formal or incomplete education	46	4	8.7	(1.5, 15.9)	71	18	25.4	(15.8, 37.1)	16.7	(9.2, 24.1)	0.008
Primary education	393	63	16.0	(11.5, 20.6)	464	149	32.1	(27.9, 36.6)	16.1	(11.5, 20.7)	<0.001
Secondary education	771	91	11.8	(8.8, 14.8)	747	268	35.9	(32.4, 39.4)	24.1	(21.0, 27.1)	<0.001
Pre-tertiary education	202	20	9.9	(4.2, 15.6)	309	117	37.9	(32.4, 43.5)	28.0	(22.2, 33.7)	<0.001
Tertiary and above	158	30	19.0	(13.4, 24.6)	355	153	43.1	(37.9, 48.4)	24.1	(18.3, 29.9)	<0.001
All	1752	235	13.4	(10.8, 16.0)	1962	712	36.3	(34.2, 38.5)	22.9	(20.3, 25.4)	<0.001

The mean (standard deviation) of astigmatic cylinder in the right eyes for Malays in Malaysia and Malays in Singapore was [-0.34D (0.56)] versus [-0.83D (0.88); p<0.001]; [-0.51D (0.68) versus -0.71D (0.67); p<0.001] for Chinese, and [-0.46D (0.72) versus -0.94D (1.03); p<0.001] for Indians.

Overall, the prevalence of astigmatism was higher in Singapore (42.6%) compared with Malaysia (22.2%) (95% CI of the difference in rates = 17.3, 23.5; p<0.001) (**Table 3**). The rates of astigmatism were higher in Singapore compared with Malaysia within each ethnic, age, gender, father's educational and mother's educational strata.

Table 3. Prevalence rates of astigmatism (cylinder ≥ 0.75 D in either eye) in Malaysia and Singapore

	Malaysia (n=1752)				Singapore (n=1962)				Difference (Singapore – Malaysia)		P-value
	Number at risk	Cases	Prevalence (%)	95% confidence interval	Number at risk	Cases	Prevalence (%)	95% confidence interval	(%)	95% confidence interval	
Ethnicity											
Malay	1245	233	18.7	(16.4, 21.1)	348	154	44.3	(39.0, 49.6)	25.5	(23.2, 27.9)	<0.001
Chinese	285	97	34.0	(29.2, 38.9)	1467	623	42.5	(39.9, 45.0)	8.4	(3.4, 13.4)	0.003
Indian	152	34	22.4	(15.1, 29.6)	126	52	41.3	(32.6, 50.4)	18.9	(11.5, 26.3)	<0.001
Others	70	25	35.7	(20.7, 50.7)	21	7	33.3	(14.6, 57.0)	-2.4	(-20.8, 16.0)	0.76
Age (years)											
7	581	135	23.2	(18.3, 28.2)	851	376	44.2	(40.8, 47.6)	20.9	(16.0, 25.9)	<0.001
8	601	144	24.0	(20.4, 27.5)	630	267	42.4	(38.5, 46.3)	18.4	(14.9, 21.9)	<0.001
9	570	110	19.3	(15.1, 23.5)	481	193	40.1	(35.7, 44.7)	20.8	(16.6, 25.0)	<0.001
Gender											
Male	924	206	22.3	(19.1, 25.5)	992	441	44.5	(41.3, 47.6)	22.2	(18.9, 25.4)	<0.001
Female	828	183	22.1	(17.7, 26.5)	970	395	40.7	(37.6, 43.9)	18.6	(14.2, 23.0)	<0.001
Completed father's education level											
No formal or incomplete education	46	8	17.4	(4.6, 30.2)	71	39	54.9	(42.7, 66.8)	37.5	(24.3, 50.8)	<0.001
Primary education	393	107	27.2	(23.0, 31.5)	464	191	41.2	(36.6, 45.8)	13.9	(9.7, 18.2)	<0.001
Secondary education	771	136	17.6	(14.7, 20.6)	747	303	40.6	(37.0, 44.2)	22.9	(20.0, 25.9)	<0.001
Pre-tertiary education	202	44	21.8	(16.3, 27.3)	309	137	44.3	(38.7, 50.1)	22.6	(17.0, 28.1)	<0.001
Tertiary and above	158	47	29.7	(21.1, 38.4)	355	158	44.5	(39.3, 49.8)	14.8	(5.8, 23.8)	0.005
Myopia											
No	1517	262	17.3	(14.6, 20.0)	1250	454	36.3	(33.6, 39.1)	19.0	(16.4, 21.7)	<0.001
Yes	235	127	54.0	(47.3, 60.8)	712	382	53.7	(49.9, 57.4)	-0.4	(-7.1, 6.3)	0.91
All	1752	389	22.2	(19.1, 25.3)	1962	836	42.6	(40.4, 44.8)	20.4	(17.3, 23.5)	<0.001

The overall prevalence of hyperopia was lower in Singapore children (1.7%) compared with Malaysian children (2.9%) (95% CI of the difference in rates = -2.1, -0.2; p=0.005) (**Table 4**). The hyperopia rates were lower in Singapore compared with Malaysia within the strata for 7 year old children only (p<0.001) and the strata of males only (p<0.001), but similar within other strata of ethnicity, age, gender, paternal and maternal education levels.

Table 4. Prevalences of hyperopia (SE ≥ +2.00 D in either eye) in Malaysia and Singapore children.

	Malaysia (n=1752)				Singapore (n=1962)				Difference (Singapore – Malaysia)		P-value
	Number at risk	Cases	Prevalence (%)	95% confidence interval	Number at risk	Cases	Prevalence (%)	95% confidence interval	(%)	95% confidence interval	
Ethnicity											
Malay	1245	36	2.9	(1.9, 3.8)	348	12	3.4	(1.8, 5.9)	0.6	(-0.4, 1.5)	0.29
Chinese	285	5	1.8	(0.4, 3.1)	1467	18	1.2	(0.7, 1.9)	-0.5	(-2.0, 0.9)	0.37
Indian	152	6	3.9	(0.4, 7.5)	126	3	2.4	(0.5, 6.8)	-1.6	(-5.2, 2.1)	0.27
Others	70	3	4.3	(2.0, 6.6)	21	1	4.8	(0.1, 23.8)	0.5	(-2.3, 3.3)	0.71
Age (years)											
7	581	29	5.0	(3.0, 7.0)	851	18	2.1	(1.3, 3.3)	-2.9	(-4.8, -0.9)	<0.001
8	601	12	2.0	(0.7, 3.3)	630	12	1.9	(1.0, 3.3)	-0.1	(-1.4, 1.2)	0.88
9	570	9	1.6	(0.4, 2.8)	481	4	0.8	(0.2, 2.1)	-0.7	(-1.9, 0.5)	0.09
Gender											
Male	924	30	3.2	(1.9, 4.6)	992	13	1.3	(0.7, 2.2)	-1.9	(-3.3, -0.6)	<0.001
Female	828	20	2.4	(1.2, 3.6)	970	21	2.2	(1.3, 3.3)	-0.3	(-1.5, 1.0)	0.66
Completed father's education level											
No formal or incomplete education	46	2	4.3	(0.5, 14.8)	71	1	1.4	(0.0, 7.6)	-2.9	(-9.1, 3.3)	0.10
Primary education	393	13	3.3	(1.4, 5.2)	464	11	2.4	(1.2, 4.2)	-0.9	(-2.8, 1.0)	0.25
Secondary education	771	20	2.6	(1.4, 3.8)	747	11	1.5	(0.7, 2.6)	-1.1	(-2.3, 0.1)	0.02
Pre-tertiary education	202	3	1.5	(0.3, 4.3)	309	5	1.6	(0.5, 3.7)	0.1	(-1.6, 1.9)	0.88
Tertiary and above	158	5	3.2	(0.4, 5.9)	355	6	1.7	(0.6, 3.6)	-1.5	(-4.3, 1.4)	0.16
All	1752	50	2.9	(1.9, 3.8)	1962	34	1.7	(1.2, 2.4)	-1.1	(-2.1, -0.2)	0.005

The multivariate analyses show that the rates of myopia are higher in Singapore compared with Malaysia for Malays only, Chinese only and Indians only (**Table 5**). Singapore Malays and Indians had significantly different astigmatism rates compared with Malaysian Malays and Indians, after adjusting for other factors including myopia. After adjusting for mother's education instead of father's education, the multivariate odds ratios for myopia in Singapore versus Malaysia for Malays only, Chinese only or Indians only were 3.57, 1.58, and 3.82, respectively. The multivariate odds ratios for astigmatism after controlling for mother's education instead of father's education for Malays only, Chinese only or Indians only were 3.30, 1.33, and 1.82, respectively.

Table 5. Odds ratio of myopia, astigmatism and hyperopia in Singapore and Malaysia, by ethnic group

	Crude OR (95% confidence interval)	P-value	Age-gender adjusted OR (95% confidence interval)	P-value	Multivariate OR (95% confidence interval)	P-value
Myopia						
Malay						
Site (Singapore versus Malaysia)	2.82 (2.29, 3.48)	<0.001	2.94 (2.33, 3.69)	<0.001	3.32 (2.64, 4.17)	<0.001
Chinese						
Site (Singapore versus Malaysia)	1.50 (1.04, 2.15)	0.03	1.73 (1.17, 2.58)	0.009	1.70 (1.13, 2.56)	0.013
Indian						
Site (Singapore versus Malaysia)	3.63 (2.46, 5.35)	<0.001	3.89 (2.52, 6.01)	<0.001	5.12 (2.68, 9.81)	<0.001
Astigmatism						
Malay						
Site (Singapore versus Malaysia)	3.45 (2.95, 4.03)	<0.001	3.45 (2.91, 4.09)	<0.001	3.47 (2.79, 4.32)	<0.001
Chinese						
Site (Singapore versus Malaysia)	1.43 (1.15, 1.79)	0.003	1.42 (1.13, 1.77)	0.004	1.26 (0.95, 1.66)	0.10
Indian						
Site (Singapore versus Malaysia)	2.44 (1.60, 3.73)	<0.001	2.41 (1.55, 3.75)	<0.001	1.90 (1.18, 3.08)	0.011
Hyperopia						
Malay						
Site (Singapore versus Malaysia)	1.20 (0.85, 1.69)	0.29	1.12 (0.79, 1.58)	0.51	1.13 (0.76, 1.69)	0.54
Chinese						
Site (Singapore versus Malaysia)	0.70 (0.30, 1.60)	0.37	0.60 (0.26, 1.41)	0.23	0.52 (0.23, 1.16)	0.11
Indian						
Site (Singapore versus Malaysia)	0.59 (0.23, 1.55)	0.27	0.53 (0.19, 1.50)	0.22	0.73 (0.12, 4.33)	0.71

* For models with myopia and hyperopia as the dependent variable, adjusted for gender, age, and father's completed education level
** For models with astigmatism as the dependent variable, adjusted for gender, age, father's completed education level and myopia

DISCUSSION

The ethnic-specific myopia prevalences of myopia are higher in Singapore compared with Malaysia. Malays are native to both Malaysia and Singapore, the Chinese in both countries migrated from the same parts of Southern China, and the Indians in both countries migrated from similar localities in India (Southern India) and Sri Lanka several decades ago. Thus, the inter-country ethnic-specific differences in myopia prevalences are unlikely to be due to genetic dissimilarities and may be primarily environmental in nature. For example, the majority of children in Singapore attend pre-school (kindergarten or a child-care centre) and the syllabus may more structured and vigorous with a greater use of information technology, compared with the Malaysian pre-school system, although the evidence is scarse and primarily anecdotal. [19] Differences in urban population density may also be relevant. Singapore is a small, urban city-centre (population density of 6,026 per square kilometer), compared with the Gombak District population with a population density of 851 per square kilometer, based on the 2000 Census.[11] In Singapore, 82% live in Housing Development Board apartments, whereas the majority of Malaysians reside in private houses. [10] The per capita Gross Domestic Product of Singapore is $24,040 compared to $9,120 in Malaysia, perhaps individuals with certain characteristics may tend to migrate to a relatively more prosperous Singapore.

The environmental hypothesis is also supported by comparisons of myopia prevalences among 7 to 9 year old Chinese in the two mainland China RESC studies: 18.4% in urban Guangzhou in Southern China, and 8.7% in semi-rural Shunyi District in Northern China. [5] [20] Prevalences of myopia in the RESC studies of 7 to 9 year old Indian children in both urban and rural Indian were relatively low: 4.6% and 3.9%, respectively. [7] [21]

Astigmatism is more common in Singapore Malays compared with Malaysian Malays, even after adjusting for age, gender, father's completed education level and myopia status. Evidence gathered from the RESC studies suggest that country-specific differences in astigmatism are not accounted for solely by differences in the prevalence of myopia. Other factors must come into play -- although little is known about specific environmental risk factors for astigmatism. The prevalence of astigmatism in 7 to 9 year old children in the RESC studies is as follows: Guangzhou, China (41.6%), Shunyi District, China (13.9%), urban India (14.6%), and rural India (8.4%). [5] [7] [20] [21]

The prevalences of hyperopia are low in both Malaysia (2.9%) and in Singapore (1.7%). Comparatively, the prevalence of hyperopia in 7 to 9 year olds is higher in Guangzhou, China (5.1%), Shunyi District, China (4.2%), and urban India (8.0%). [5] [20] [21] The prevalence of hyperopia is lowest in rural India (0.3%). [7]

Two features were particularly advantageous in this direct comparative evaluation of refractive errors from two separate studies in Malaysia and Singapore: similar school-going populations and essentially identical measurement methods. First, the multi-ethnic similarity between neighboring Malaysia and Singapore (Malays, Chinese and Indians), each with a common genetic origin, allowed us to better understand the relative influences of genes and environment. Second, the use of autorefraction for measurement of refractive error under cycloplegia induced with 1% cyclopentolate in both studies reduced the possibility of differences introduced by systematic measurement bias. Although, a handheld autorefractor was used in Malaysia and a table-mounted autorefractor in Singapore, the SE readings in

children from the handheld autorefractor were more minus compared with the table-mounted autorefractor. [22,23] In our study, because the handheld autorefractor readings in Malaysia may tend to deviate towards more minus readings, measurement biases may contribute to smaller perceived differences in the prevalences of myopia across countries.

It is recognized, however, that our comparisons may not necessarily apply to all Singapore or Malaysia children. The three schools in Singapore may not be entirely representative of Singapore school children, nor is there evidence that children in Gombak District are representative of Malaysian children at large. Selection bias may occur because the response rate in the Eastern school (amongst the top 20 schools) in Singapore was only 49.1%: the overall rates of myopia in the Singapore sample could be underestimated. Perhaps parents of myopic children in Singapore may perceive that their child will not benefit from the study and not enroll their children. The multivariate regression models reveal that the differences in myopia rates in Malaysia and Singapore cannot be completely explained by differences in parental educational level, and other environmental factors may contribute to the observed differences. The lack of near work activity, preschool activity, height or parental myopia from both countries may preclude definitive conclusions about the nature of country-specific differences. Future studies could investigate specific risk factors for differences in myopia rates across countries.

Nonetheless, we conclude that the prevalences of myopia, in 7 to 9 year old children are higher in Singapore Chinese compared with Malaysian Chinese, higher in Singapore Indians compared with Malaysian Indians, and higher in Singapore Malays compared with Malaysian Malays.

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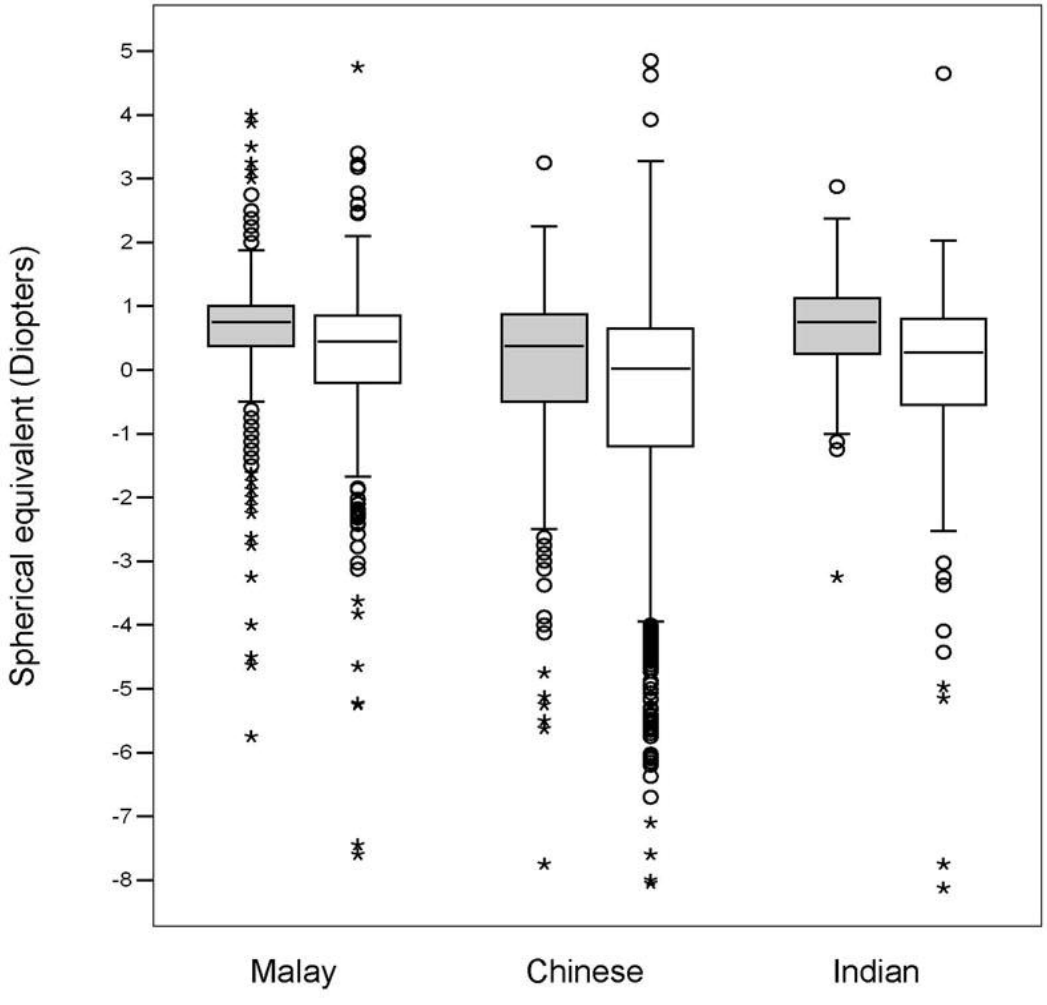
Spherical equivalent (Diopters)
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
Malay
Chinese
Indian