Prevalence of Amblyopia and Strabismus in Young Singaporean Chinese Children

Audrey Chia,[1,2] *Mohamed Dirani,*[3] *Yiong-Huak Chan,*[4] *Gus Gazzard,*[5,6] *Kah-Guan Au Eong,*[7,8,9,10] *Prabakaran Selvaraj,*[4] *Yvonne Ling,*[1,2] *Boon-Long Quah,*[1,2] *Terri L. Young,*[11,12] *Paul Mitchell,*[13] *Rohit Varma,*[14] *Tien-Yin Wong,*[1,2,3,9] *and Seang-Mei Saw*[2,4,11]

Purpose. To determine the prevalence of amblyopia and strabismus in young Singaporean Chinese children.

Methods. Enrolled in the study were 3009 Singaporean children, aged 6 to 72 months. All underwent complete eye examinations and cycloplegic refraction. Visual acuity (VA) was measured with a logMAR chart when possible and the Sheridan-Gardner test when not. Strabismus was defined as any manifest tropia. Unilateral amblyopia was defined as a 2-line difference between eyes with VA < 20/30 in the worse eye and with coexisting anisometropia (≥1.00 D for hyperopia, ≥3.00 D for myopia, and ≥1.50 D for astigmatism), strabismus, or past or present visual axis obstruction. Bilateral amblyopia was defined as VA in both eyes <20/40 (in children 48–72 months) and <20/50 (<48 months), with coexisting hyperopia ≥4.00 D, myopia ≤ −6.00 D, and astigmatism ≥2.50 D, or past or present visual axis obstruction.

Results. The amblyopia prevalence in children aged 30 to 72 months was 1.19% (95% confidence interval [CI], 0.73–1.83) with no age ($P = 0.37$) or sex ($P = 0.22$) differences. Unilateral amblyopia (0.83%) was twice as frequent as bilateral amblyopia (0.36%). The most frequent causes of amblyopia were refractive error (85%) and strabismus (15%); anisometropic astigmatism >1.50 D (42%) and isometropic astigmatism >2.50 D (29%) were frequent refractive errors. The prevalence of strabismus in children aged 6 to 72 months was 0.80% (95% CI, 0.51–1.19), with no sex ($P = 0.52$) or age ($P = 0.08$) effects. The exotropia-esotropia ratio was 7:1, with most exotropia being intermittent (63%). Of children with amblyopia, 15.0% had strabismus, whereas 12.5% of children with strabismus had amblyopia.

Conclusions. The prevalence of amblyopia was similar, whereas the prevalence of strabismus was lower than in other populations. (*Invest Ophthalmol Vis Sci.* 2010;51:3411–3417) DOI:10.1167/iovs.09-4461

Amblyopia and strabismus are two common pediatric eye conditions with functional and cosmetic consequences. Amblyopia is associated with suboptimal vision, despite best spectacle correction in the absence of any other ocular and neural abnormality.[1] Failure to diagnose and manage amblyopia before the age of 8 years can result in life-long visual impairment.[1] Strabismus is the misalignment of the eyes, and if left untreated, may result in loss of binocularity and depth perception.[1]

Overall, global estimates of the prevalence of amblyopia and strabismus in children and teenagers range from 0.20% to 6.2% and 0.13% to 4.7%, respectively.[1–29] However, few studies have been performed on population-based samples, so that variation in study design and disease classification could account for some of the disparity noted, making direct comparison between studies difficult (Table 1).[30,31]

Most past studies of amblyopia and strabismus have involved older school-age children, when therapeutic and preventive strategies are less successful. In a study of 7843 children 7 years of age in the 1991 to 1992 birth cohort in Avon, United Kingdom, a 3.6% prevalence of past or present amblyopia was recorded, with most having had treatment, thus leaving only 0.6% with impaired vision.[28] In this study, a strabismus prevalence of 2.3% was recorded, including 73.4% of cases that were convergent, 21.4% divergent, and 5.2% vertical. In contrast, in an Australian study in which 1736 children aged 6 years were examined, amblyopia was reported in 0.7%, most of which was related to strabismus (37.5%), anisometropia (34.4%), or both (18.8%).[17] Strabismus was present in 2.8% (54% esotropia and 29% exotropia) with even lower rates, particularly of esotropia, noted in the East Asian children included in the study.[16]

Few studies have involved East Asian children, in which the prevalence of myopia is highest. Matsuo et al.,[21,22] in a questionnaire-based study of Japanese children aged between 1.5 and 12 years, the reported prevalence rate of amblyopia and strabismus ranging between 0% to 0.2% and 0.01% to 0.99%, respectively. Most such studies, however, were handicapped by their dependence on the return of questionnaires and variability in family or ophthalmologist definitions of amblyopia

From the [1]Singapore National Eye Center and the [2]Singapore Eye Research Institute, Singapore; the [3]Center for Eye Research Australia, Department of Ophthalmology, University of Melbourne, Melbourne, Victoria, Australia; the Departments of [4]Epidemiology and Public Health and [9]Ophthalmology, Yong Loo Lin School of Medicine, National University of Singapore, Singapore; the [5]Institute of Ophthalmology, London, United Kingdom; [6]Moorfields Eye Hospital, London, United Kingdom; the [7]Department of Ophthalmology and Visual Sciences, Alexandra Hospital, Singapore; the [8]Eye Clinic, Jurong Medical Center, Singapore; the [10]Singapore International Eye Cataract Retina Center, Mount Elizabeth Medical Centre, Singapore; [11]Duke-National University of Singapore Graduate Medical School, Singapore; the [12]Department of Ophthalmology, Duke University Medical Center, Durham, North Carolina; the [13]Centre for Vision Research (Westmead Millennium Institute), University of Sydney, Sydney, New South Wales, Australia; and the [14]Doheny Eye Institute, University of Southern California, Los Angeles, California.

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Corresponding author: Audrey Chia, Singapore Eye Center, 11 Third Hospital Road, Singapore 168751; wla_chia@yahoo.com.

Table 1. Table of Strabismus and Amblyopia Prevalence in Children/Teenagers from Selection of Population-Based or Large Cohort Studies, Ranked According to Age of Subjects

Study	Country (y)	Study Population Age (*n*)	Strabismus (%)	XT:ET Ratio*	Definition of Amblyopia Used	Amblyopia (%)
STARS	Singapore	6–72 mo† (3,009)	0.80	7:1	Unilateral: VA <20/30 in the worse eye, 2-line difference and	1.19
MEPED study group[26]	United States (2008)	6–72 mo† (6,014)				
		Hispanic/Latino	2.4	1.2:1	amblyogenic factors.	2.6
		African American	2.5	1.1:1	Bilateral: VA both eyes <20/40	1.5
Friedman et al.[29]	United States (2009)	6–72 mo† (2,546)			(age 48–72 mo) or <20/50 (age	
		White	3.3	1.2:1	<48 mo), and amblyogenic	1.8
		African American	2.1	1:1	factors.	0.8
Matsuo et al.[22]‡	Japan (2007)	1.5 and 3 y† (6,900)	0.01–0.35	2.4:1	As determined by ophthalmologist.	0–0.18
Chang et al.[20]	Taiwan (2007)	3 to 6 y† (5,232)	—	—	VA <20/20 with amblyogenic risk factors.	2.2
Lim et al.[11]	Korea (2004)	3 to 5 y; kindergarten children (36,973)	—	—	VA <20/40 (age, ≤3 y), <20/32 (age, >3 y) or 2-line difference.	0.42
Preslan and Novak[6]	United States (1996)	4 to 7 y; preschool/ school children (680)	3.1	1:9	VA <20/30 with amblyogenic factors.	3.9
Robaei et al.[17,18]	Australia (2006)	6 y; school children (1,739)	2.8	1:1.8	VA <20/40 or 2-line difference.	0.7–1.8
Williams et al.[28]	United Kingdom (2008)	7 y (7,825)†	2.3	1:3.4	VA <20/40, 2-line difference or history.	3.6
He et al.[10]	China (2004)	5–15 y† (4,364)	1.9	4:1	VA ≤20/32 and other factors.	0.87
Matsuo and Matsuo[21]‡	Japan (2007)	6–13 y† (113,763)	0.99–1.28	2.8:1	As determined by ophthalmologist.	0.14–0.20
Goh et al.[14]	Malaysia (2005)	7–15 y† (4,634)	—	—	VA ≤20/32 and other factors.	2.0
Robei et al.[18,27]	Australia (2006, 2008)	12 y; school children (2,353)	2.7	1.3:1	VA <20/40 or 2-line difference.	0.4
Ohlsson et al.[9]	Mexico (2003)	12 to 13 y; school children (1,035)	2.3	1:1.8	VA ≤20/40 or 2-line difference and amblyogenic factors.	2.5
Ohlsson et al.[8]	Sweden (2001)	12 to 13 y; school children (1,046)	2.7	1:2.2	VA ≤20/40, 2-line difference with no organic cause.	1.1
Yassur et al.[2]	Rwanda (1972)	10 to 18 y; school children (1,550)	NA	—	VA ≤20/40.	1.2
Quah et al.[4]	Singapore (1991)	18 y; army recruits (6,556)			VA ≤20/40 with no organic cause.	0.73
Rosman et al.[15]	Singapore (2005)	18 y; army recruits (122,596)	NA	—	VA ≤20/40 with no organic cause.	0.34

XT, exotropia; ET, esotropia.
* XT:ET ratio calculated from data presented in the papers.
† Population-based studies.
‡ Studies from Matsuo et al.[22] and Matsuo and Matsuo[21] based on questionnaire responses.

and strabismus. Lim et al. used a home screening unit to identify at risk Korean children aged 3 to 5 years. These children were then referred to an ophthalmologist and amblyopia, mostly refractive, was detected in 0.4% of the 43% who responded.[11] In Taiwan, Lai et al.[24] reviewed visual screening records of 625 preschool children and identified amblyopia, using various definitions, in approximately 5% and strabismus in 9.6% of children. He et al.,[10] primarily assessing visual impairment in 4368 children, aged 5 to 15 years, in Guangzhou, China, reported amblyopia in 1.9%, and near and distant tropia in 1.9% and 3% of their subjects, respectively.

Few population-based studies have focused on eye disease in younger children aged <6 years. The Multiethnic Pediatric Eye Disease Study (MEPEDS) and Baltimore Pediatric Eye Disease Study (BPEDS) are two large studies designed to determine the prevalence of decreased visual acuity (VA), strabismus, amblyopia, and refractive errors in children aged 6 to 72 months.[26,29,32] In 2008, the MEPEDS study group reported an amblyopia prevalence of 2.6% and 1.5% and a strabismus prevalence of 2.4% and 2.5% in 3007 Hispanic/Latino and 3007 African-American children, respectively.[26] In 2009, Friedman et al.[29] reported the BEPDS findings on 2546 children, with amblyopia prevalence rates of 1.8% and 0.8%, and strabismus prevalence rates of 3.3% and 2.1% in Caucasian and African-American children, respectively. These data are not generalizable to Asian populations.

The purpose of the Strabismus, Amblyopia, and Refractive Error in Singapore (STARS) study was to determine the prevalence of amblyopia and strabismus in young Chinese preschool children in Singapore. Methods and definitions used in the STARS study are similar to those used in the BPEDS and MEPEDS studies, so that comparisons can readily be made between these studies.[32]

Methods

Sample Population

Chinese children aged 6 to 72 months were recruited from Housing Development Board townships through a door-to-door recruitment exercise. The study area included a large part of the South-Western region of Singapore. The majority of the population (84%) live in such townships, and there are no distinctive demographic differences between this region of Singapore and the rest of the island (Table 2).[33] However, parents of children recruited for this study were generally better educated with higher incomes than other young Singaporean adults aged between the ages of 20 to 40 years, suggesting some underrepresentation of the poorer, less educated, and lower income

TABLE 2. Socioeconomic Differences between Populations within the STARS Recruitment Area and the General Population and between Parents of Children Recruited for the Study and Singaporean Chinese Adults Aged 20–40 y

	Singapore Population (Total %)*	STARS Recruitment Area (%)*	Singaporean Chinese Aged 20–40 y (%)*	STARS Fathers (%)	STARS Mothers (%)
Education					
None	19.5	19.1	5	<1	<1
Primary	12.1	12.9	7	9	6
Secondary	35.5	35.3	34	29	35
Polytechnic	21.1	21.0	33	26	29
University	11.7	11.7	21	32	28
Unknown				3	1
Employment					
Employed	59.4	60.1			
Unemployed	3.8	3.7			
Inactive	36.8	36.2			
Household income				STARS Households	
<S$1000	12.4	10.0	No data available	3	
S$1000–2999	28.0	29.5		21	
S$3000–4999	23.5	25.5		30	
>S$5000	35.6	35.0		44	
Unknown				2	

* Information obtained from Population Census (2000) of persons aged >15 years within different district zones.[33]

groups within the population. Parents were invited to bring their children to one of two visual screening sites. Children of non-Chinese or mixed ethnicity were excluded from the study. Disproportionate stratified sampling by 6-month age groups was performed with an almost equal number of children in each 6-month age group. A total of 4162 Chinese children were eligible to participate in the study, with 3009 examined (response rate 72.3%). There were no significant sex ($P = 0.65$) or age ($P = 0.18$) differences between participants and nonparticipants. Response rates in different age groups were similar and ranged between 71% and 74%. There were, however, significant area differences ($P < 0.001$), with participation rates of districts closer to examination sites being greater than those located farther away.

This study was approved by the National Medical Research Council (NMRC) in Singapore, and all procedures adhered to the Declaration of Helsinki. Written informed consent was obtained from parents or legal guardians before any tests were conducted.

Examination of Alignment and VA

Ocular Motility. Ocular alignment was assessed by using the Hirschberg light reflex, cover test, and prism cover–uncover tests. Cover tests were performed by using fixation targets at both distance (6 m) and near (30 cm). The presence of strabismus, its characteristics (constant or intermittent), type (exotropia, esotropia, hyper/hypotropia or dissociated vertical deviation), and size (prism diopters) were also recorded.

Visual Acuity. VA was measured in children aged 30 to 72 months with a logarithm of the minimum angle of resolution (logMAR) distance vision chart. If this was not possible, single-letter Sheridan-Gardner tests were used. When initial VA was < 20/30 (logMAR 0.18) in either eye, it was retested. If the results were still poor, or if the children were unable to co-operate with the VA testing, they were given Sheridan-Gardner single letters to learn, and a retest date was scheduled.

Pupil Dilation. Cycloplegic refraction was performed 30 minutes after the use of 3 drops of cyclopentolate 1% (Cyclogyl; Alcon-Couvreur, Purrs, Belgium) administered at 5-minute intervals, with 0.5% cyclopentolate used for children aged <12 months. Refraction was measured with a table-mounted autorefractor (model RKF-1; Canon, Ltd., Tochigiken, Japan) or a handheld autorefractor (Retinomax; Nikon Corp., Tokyo, Japan) whenever possible, or streak retinoscopy when not possible. Five consecutive autorefractor readings were obtained from each subject, all of which had to be within 0.25 D of each other. Spherical equivalent (SE) was calculated as the sum of the spherical plus half the cylindrical error.

Ocular Examination. The children underwent a full ocular examination, and any pathology involving the anterior and posterior ocular segments was documented.

Interview

Parents were asked a series of questions about their children, including questions on the past or present history of amblyopia and strabismus, the type and duration of any treatment provided for amblyopia or strabismus, and the presence of any other past or present ocular problems.

Definitions

Children were classified as having strabismus if any tropia was present at distance or near, with or without spectacles.

Anisometropia, the presence of significant refractive error differences between eyes, was defined as spherical when there was a difference in spherical equivalent, or astigmatic when there were differences in cylinder power. Isometropia occurred when less-significant refractive differences were present between the eyes. Levels of amblyogenic anisometropia and isometropia varied for both ametropia (myopia or hyperopia) and astigmatism, depending on whether the children had unilateral or bilateral amblyopia.

Unilateral amblyopia was defined, as in the MEPEDS, as a ≥2-line difference in best VA, when <20/30 (logMAR 0.18) in the worse eye, and with amblyogenic factors such as past or present strabismus, anisometropia (≥1.00 D difference in hyperopia, ≥3.00 D difference in myopia, or ≥1.50 D difference in astigmatism), and past or present obstruction of the visual axis.[26,32]

Bilateral amblyopia was defined as best VA in both eyes <20/40 (logMAR 0.3) in children aged 48 to 72 months or <20/50 (logMAR 0.4) in children aged <48 months, in the presence of amblyogenic factors such as hyperopia ≥4 D, myopia ≤ −6.00 D, or astigmatism ≥2.50 D, or past or present obstruction of the visual axis.[26,32]

Statistical Analyses

Age and sex-specific prevalence rates for strabismus and amblyopia were calculated. Poisson distribution was used to construct 95% CIs for all prevalence estimates. Data were weighted to the Singapore Popu-

Table 3. Prevalence of Strabismus in Children Aged 6 to 72 Months

	n	Any Strabismus* *n* (%, 95% CI)	Exotropia *n* (%, 95% CI)	Esotropia *n* (%, 95% CI)
All children				
Crude rate	3009	24 (0.80, 0.51–1.19)	20 (0.67, 0.41–1.03)	3 (0.10, 0.02–0.29)
Adjusted rate†		(0.84, 0.80–0.88)	(0.70, 0.66–0.74)	(0.10, 0.086–0.12)
6–11 mo	189	0 (0, 0.0–1.9)	0 (0, 0.0–1.6)	0 (0, 0.0–1.6)
12–23 mo	537	2 (0.37, 0.04–1.32)	2 (0.37, 0.04–1.32)	0 (0, 0.0–0.55)
24–35 mo	514	5 (0.97, 0.31–2.23)	3 (0.58, 0.12–1.68)	2 (0.39, 0.005–1.07)
36–47 mo	574	4 (0.69, 0.11–1.50)	3 (0.52, 0.11–1.50)	1 (0, 0.0–0.51)
48–59 mo	602	7 (1.16, 0.46–2.35)	7 (1.16, 0.46–2.35)	0 (0, 0.0–0.49)
60–72 mo	576	6 (1.04, 0.38–2.23)	5 (0.86, 0.28–1.99)	0 (0, 0.0–0.95)
P (trend)		0.08	0.07	0.57
Boys (all)	1561	14 (0.89, 0.44–1.41)	12 (0.77, 0.39–1.33)	1 (0.064, 0.002–0.36)
6–11 mo	88	0 (0, 0.0–3.27)	0 (0, 0.0–3.27)	0 (0, 0.0–3.27)
12–23 mo	308	1 (0.32, 0.008–1.79)	1 (0.33, 0.008–1.79)	0 (0, 0.0–0.96)
24–35 mo	262	1 (0.38, 0.01–2.10)	1 (0.38, 0.01–2.10)	0 (0, 0.0–1.13)
36–47 mo	291	4 (1.36, 0.21–2.94)	3 (1.02, 0.21–2.94)	1 (0.34, 0.01–1.89)
48–59 mo	321	4 (1.24, 0.33–3.11)	4 (1.23, 0.33–3.11)	0 (0, 0.0–0.91)
60–72 mo	291	4 (1.37, 0.37–3.45)	3 (1.03, 0.21–2.96)	0 (0, 0.0–1.02)
P (trend)		0.06	0.10	0.92
Girls (all)	1431	10 (0.69, 0.33–1.27)	8 (0.56, 0.24–1.09)	2 (0.14, 0.02–0.50)
6–11 mo	101	0 (0, 0.0–2.92)	0 (0, 0.0–2.92)	0 (0, 0.0–2.92)
12–23 mo	229	1 (0.44, 0.01–2.37)	1 (0.44, 0.01–2.37)	0 (0, 0.0–1.28)
24–35 mo	252	4 (1.58, 0.43–3.95)	2 (0.79, 0.09–2.79)	2 (0.80, 0.01–2.16)
36–47 mo	283	0 (0, 0.0–1.04)	0 (0, 0.0–1.04)	0 (0, 0.0–1.04)
48–59 mo	281	3 (1.06, 0.22–3.08)	3 (1.06, 0.22–3.08)	0 (0, 0.0–1.06)
60–72 mo	285	2 (0.69, 0.08–2.48)	2 (0.70, 0.08–2.48)	0 (0, 0.0–1.91)
P (trend)		0.67	0.38	0.43

95% CI, binomial distribution.

* Includes 1 child, a 71-month-old boy, who had DVD alone.

† Weighted to Census of Population 2000 (taking into account Location sampling and familial clustering).[33]

lation Census 2000, taking into account disproportionate age sampling and familial clustering[33] (Stata 10; StataCorp, College Station, TX).

Results

Prevalence of Strabismus

A total of 3009 children aged 6 to 72 months were recruited, of which 17 (0.5%) were excluded because of an inability to perform motility assessments. These included one child (0.5%) aged 6 to 11 months, three children (0.5%) aged 12 to 23 months, two (0.4%) aged 24 to 35 months, five (0.8%) aged 36 to 47 months, three (0.5%) aged 48 to 59 months, and three (0.5%) aged 60 to 72 months.

The overall prevalence of strabismus in children aged 6 to 72 months was 0.80%, with exotropia exceeding esotropia by a ratio of 7:1 (Table 3). There was no significant difference in strabismus prevalence between the boys and the girls ($P = 0.52$), and there were no age trends ($P = 0.08$).

The most frequent strabismus type was intermittent exotropia (58%), followed by constant exotropia (25%) and constant esotropia (12%). One subject, a 71-month-old boy, had an isolated dissociated vertical deviation (DVD; Table 4). Three children (12%) with strabismus also had amblyopia.

Prevalence of Amblyopia

Of the 2015 children aged 30 to 72 months, 333 (16.5%) were excluded because of an inability to complete VA testing. Excluded were 169 (67%) children aged 30 to 35 months, 133 (23%) aged 36 to 47 months, 24 (4%) aged 48 to 59 months, and 7 (1%) aged 60 to 72 months.

Cycloplegic refraction was available in 1796 (89.1%) of the 2015 children aged 30 to 72 months and in 1521 (90.5%) of the 1682 children in whom VA could be tested. Noncycloplegic autorefraction and manifest refraction were available for the remaining children. The mean SE in those who were able and unable to complete the VA test was 0.69 ± 1.12 and 0.41 ± 1.24 D respectively ($P < 0.0001$). However, there was no significant difference between children who were or were not able to complete the VA testing, in terms of the proportion with hyperopia ≥3.00 D (1.6% vs. 1.2%, $P = 0.58$), myopia ≤−6.00 D (0.3% vs. 0.4%, $P = 0.76$), or astigmatism ≥2.50 D (3.6% vs. 4.5%, $P = 0.57$). Overall, significant bilateral amblyo-

Table 4. Strabismus Subtypes and Characteristics*

	n
Strabismus type at distance	
Intermittent exotropia	12
Constant exotropia	7
Intermittent esotropia	0
Constant esotropia	3
Strabismus identified only at near	1
Strabismus type at near	
Intermittent exotropia	12
Constant exotropia	6
Intermittent esotropia	0
Constant esotropia	3
Strabismus identified only at distance	2
Strabismus magnitude at distance	
1–9 PD	0
10–30 PD	5
>30 PD	6
Unable to measure	12
Strabismus magnitude at near	
1–9 PD	0
10–30 PD	6
>30 PD	5
Unable to measure	12

* Data from one child with DVD are not included.

TABLE 5. Prevalence of Amblyopia by Sex and Age

	n	Any Amblyopia *n* (%, 95% CI)
All children		
Crude rate	1682	20 (1.19, 0.73–1.83)
Adjusted rate*		(1.15, 1.12–1.25)
30–35 mo	83	1 (1.21, 0.03–6.53)
36–47 mo	446	6 (1.35, 0.50–2.91)
48–55 mo	581	9 (1.55, 0.71–2.92)
56–72 mo	572	4 (0.70, 0.19–1.78)
P (trend)		0.37
Boys (all)	850	12 (1.41, 0.73–2.45)
30–47 mo	253	2 (0.79, 0.10–2.83)
48–72 mo	597	10 (1.68, 0.81–3.06)
P (trend)		0.31
Girls (All)	832	8 (0.96, 0.42–1.89)
30–47 mo	276	5 (1.81, 0.59–4.180)
48–72 mo	556	3 (0.54, 0.11–1.57)
P (trend)		0.07

95% CI, binomial distribution.

* Weighted to Census of Population 2000 (taking into account location sampling and familial clustering).[33]

genic refractive risk factors were identified in 19 (5.7%) of the 333 children unable to complete the VA screening testing, and in 100 (5.9%) in whom VA could be assessed ($P = 0.86$).

Of the 1682 children in whom VA assessment was possible, 48 (2.8%) met the VA criteria for amblyopia, but of these, 28 (58%) were not considered amblyopic because insufficient amblyogenic risk factors were identified. In these 28 subjects, 19 (67%) had minimal refractive error, with no past or present strabismus or visual obstruction. Nine children, however, missed refractive cutoff levels by smaller margins; four children with potential unilateral amblyopia had astigmatism between 1.50 and 4.00 D, but with anisometropic astigmatism <1.50 D; and five children with potential bilateral amblyopia had astigmatism between 1.45 and 2.50 D.

Twenty children satisfied all amblyopic requirements, so that the overall amblyopia prevalence in this study among children aged 30 to 72 months was 1.19% (Table 5). There was no significant difference in amblyopia prevalence between boys and girls ($P = 0.22$), and no age trend was evident ($P = 0.37$).

Amblyopia was attributed to refractive error in 17 children (85%) and to strabismus in 3 (15%; Table 6). Among children with unilateral amblyopia, refractive error was most frequently associated with anisometropic astigmatism ≥1.50 D ($n = 7$), followed by anisometropic myopia ≥3.00 D ($n = 2$) and anisometropic hyperopia ≥1.00 D ($n = 2$). In the bilateral amblyopia group, refractive errors recorded included astigmatism ≥2.50 D ($n = 2$), combined astigmatism and myopia ≤ −6.00 D ($n = 2$), combined astigmatism and hyperopia ≥4.00 D ($n = 1$) and myopia ≤ −6.00 D ($n = 1$). Of the three children in whom amblyopia was attributed to strabismus, two had intermittent exotropia and one had a constant esotropia.

Based on questionnaire information, 15 children, aged 30 to 72 months, had previously had a diagnosis and treatment of amblyopia. One child was unable to co-operate with the VA testing and two were found to be still amblyopic at our examination. The remaining 12 children (with presumably successfully treated amblyopia) were aged 63.5 ± 9.7 months (range, 53.2–72.0 months): six had high astigmatism ≥1.50 D, two had anisometropia ≥1.00 D, one had strabismus, and three had no identifiable cause.

DISCUSSION

In this study of young Singaporean Chinese children, we report an 0.80% prevalence of strabismus in children aged 6 to 72 months and a 1.19% prevalence of amblyopia in children aged 30 to 72 months. The overall exotropia and esotropia prevalence rates were 0.70% and 0.10%, respectively. Unilateral amblyopia was twice as frequent as bilateral amblyopia, whereas amblyopia was associated with a refractive error in >90% of the children, with astigmatism the most frequent amblyogenic risk factor.

Our prevalence estimate (0.80%; 95% CI, 0.51–1.19) for strabismus in young Chinese children was much lower than in Hispanic/Latino (2.4%; 95% CI, 1.9–3.0) and African-American (2.5%, 95% CI, 2.0–3.1) children who participated in the MEPEDS and also compared with Caucasian (3.3%, 95% CI, 2.3–4.6) and African-American (2.1%, 95% CI, 1.3–3.0) children in the BPEDS (Fig. 1).[26,29] It was also lower than in children aged between 4 and 7 years in the United States, United Kingdom, and Australia where the reported prevalence has ranged from 2.3% to 3.4% (Table 1).[7,17,18] Similar lower strabismus prevalence rates have been reported in other East Asian communities, such as those in Australia, Japan, and China.[10,16,21,22]

In regard to strabismus type, the prevalence of esotropia in young Singaporean Chinese children was much lower, whereas the prevalence of exotropia was only half that reported in Hispanic/Latino, African-American, and white American children in the MEPEDS and BPEDS (Fig. 1). The cause of this difference is uncertain, and although lower hyperopia rates in East Asian populations may be partly responsible, genetic and ethnic differences may also exist. Indeed, studies suggest that the strabismus risk is greater in those with a positive family history, and twin studies indicate that genetic liabilities exceed environmental ones.[34,35] The resultant high exotropia-esotropia ratio is typical of East Asian populations where it is often greater than 2:1.[10,21,22,36–39] In contrast, the ratio in many Caucasian studies is frequently reversed (Table 1).[8,16,17,18,28] More recently, Yu et al.[36] and Matsuo et al.[37] reported that the exotropia-esotropia ratio appears to be increasing in Hong Kong and Japan presumably as their populations become less hyperopic. A similar shift may also be occurring in the West as the exotropia-esotropia ratio in white children in the BPEDS study and 12-year-old children in Australia were recently reported to be 1.2:1 and 1.3:1, respectively.[18,29]

The prevalence of amblyopia in our Singaporean preschool sample was 1.19% (95% CI, 0.73–1.83). Compared with children in the MEPEDS and BPEDS, this prevalence was less than for Hispanic/Latino (2.6%, 95% CI, 1.8–3.4) and more similar to that found in white (1.8%, 95% CI, 0.9–3.1) and African-American (0.8%, 95% CI, 0.3–1.6, in the MEPEDS, and 1.5%, 95% CI, 0.9–2.1, in the BPEDS) children (Fig. 1).[26,29] Unfortunately, differences in study design and the lack of a consistent definition of amblyopia makes comparison with other studies difficult (Table 1).[40] Some of these studies have used definitions

TABLE 6. Type of Amblyopia

	n	Prevalence (%) (95% CI)
Unilateral	14	0.83 (0.46–1.39)
Anisometropic	11	0.65 (0.33–1.17)
Strabismic	3	0.18 (0.04–0.52)
Combined refractive/strabismus	0	0.0 (0.0–0.18)
Deprivational	0	0.0 (0.0–0.18)
Bilateral ametropic	6	0.36 (0.13–0.77)
Total	20	1.19 (0.73–1.83)

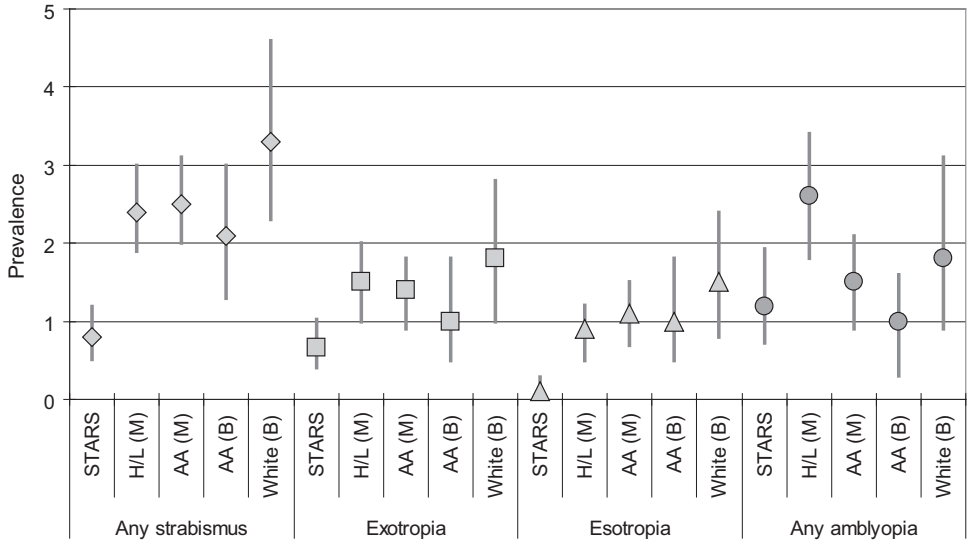

FIGURE 1. Comparison of strabismus and amblyopia prevalence in Singaporean Chinese children in the STARS study with Hispanic/Latino and African-American children from MEPEDS (M) and African-American and white children from BPEDS (B) studies.[26,29] H/L (M) denotes Hispanic/Latino and AA (M) denotes African-American children in the MEPEDS, and AA (B) denotes African-American and White (B) denotes white children in the BPEDS. *Central symbol*: prevalence; *vertical lines*: 95% CI.

similar to those of the American Association of Pediatric Ophthalmology and Strabismus (AAPOS), which classify suspected amblyopia as VA <20/40 in at least one eye in children aged 30 to 59 months and <20/30 in children aged over 60 months; a 2-line difference between eyes, even if vision is within the passing range; and the presence of amblyogenic risk factors including anisometropia >1.5 D, hyperopia >3.50 D, myopia < −3.00 D, astigmatism >1.50 D at the 90° or 180° meridian or >1.00 D in the oblique meridian, any manifest strabismus, media opacity >1 mm, and ptosis with a pupillary margin reflex ≤1 mm.[41,42] If we had used these more liberal criteria in our study, the amblyopia prevalence would increase 2.7-fold to 3.27%, with rates of 2.41%, 4.26%, 2.75%, and 3.15% in the 30- to 35-month, 36- to 47-month, 48- to 59-month, and 60- to 72-month age groups, respectively.

In terms of amblyopia type, Singapore preschool children were more likely to have refractive rather than strabismic amblyopia. Lower levels of strabismic amblyopia have also been noted in preschool children in other East Asian countries such as Korea (12.8%) and Taiwan (2.6%).[11,20] Hispanic/Latino and African-American children in the MEPEDS study were also more likely to have refractive amblyopic (80%) compared with strabismic amblyopia.[26] In contrast, amblyopia in Caucasian children in the United States, United Kingdom, and Australia was more likely to be associated with strabismus alone (26%–44%) or combined strabismus and refractive error (20%), rather than refractive error alone (40%–50%).[6,7,17,27–29]

There are several limitations to this study. It is possible that children already receiving ophthalmic care did not attend, resulting in an underestimation of prevalence. Conversely, families in whom parents suspected disease, or in whom there was a strong family history of eye disorders may have been more motivated to participate. There was also difficulty in determining whether a child was truly amblyopic. Half of the children aged 30 to 48 months were unable to co-operate with the optotype identification tests used, making any estimation of amblyopia prevalence in this group unreliable.[20,26] Children who were unable to perform the VA test were excluded from the study, but it is uncertain how many failed to co-operate because they were amblyopic. Children who cooperated but failed the VA test were also required to have certain levels of amblyogenic risk factors to be considered amblyopic; some of these children may have had past amblyogenic factors that lessened over time or milder levels or combinations of amblyogenic influences that were sufficiently amblyogenic in their case.[26]

CONCLUSIONS

In summary, the prevalence of amblyopia in Singaporean Chinese preschool children appears to be similar and that of strabismus much lower than that in Hispanic/Latino, white, and African-American children in the MEPEDS and BPEDS cohorts.

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