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Original Article

Prevalence of vision impairment and refractive error in school children in Ba Ria – Vung Tau province, Vietnam

Prakash Paudel PhD,[1] Prasidh Ramson BOptom,[1] Thomas Naduvilath PhD,[1] David Wilson PhD,[1,2] Ha Thanh Phuong MBA,[1] Suit M Ho PhD[1] and Nguyen V Giap, MD[3]

[1]Brien Holden Vision Institute, [2]School of Optometry and Vision Science, University of New South Wales, Sydney, New South Wales, Australia; and [3]Ba Ria – Vung Tau Provincial Eye Center, Ba Ria – Vung Tau, Vietnam

Abstract

Background: To assess the prevalence of vision impairment and refractive error in school children 12–15 years of age in Ba Ria – Vung Tau province, Vietnam.

Design: Prospective, cross-sectional study.

Participants: 2238 secondary school children.

Methods: Subjects were selected based on stratified multistage cluster sampling of 13 secondary schools from urban, rural and semi-urban areas. The examination included visual acuity measurements, ocular motility evaluation, cycloplegic autorefraction, and examination of the external eye, anterior segment, media and fundus.

Main Outcome Measures: Visual acuity and principal cause of vision impairment.

Results: The prevalence of uncorrected and presenting visual acuity ≤6/12 in the better eye were 19.4% (95% confidence interval, 12.5–26.3) and 12.2% (95% confidence interval, 8.8–15.6), respectively. Refractive error was the cause of vision impairment in 92.7%, amblyopia in 2.2%, cataract in 0.7%, retinal disorders in 0.4%, other causes in 1.5% and unexplained causes in the remaining 2.6%. The prevalence of vision impairment due to myopia in either eye (–0.50 diopter or greater) was 20.4% (95% confidence interval, 12.8–28.0), hyperopia (≥2.00 D) was 0.4% (95% confidence interval, 0.0–0.7) and emmetropia with astigmatism (≥0.75 D) was 0.7% (95% confidence interval, 0.2–1.2). Vision impairment due to myopia was associated with higher school grade and increased time spent reading and working on a computer.

Conclusions: Uncorrected refractive error, particularly myopia, among secondary school children in Vietnam is a major public health problem. School-based eye health initiative such as refractive error screening is warranted to reduce vision impairment.

Key words: prevalence, refractive error, school children, vision impairment, Vietnam.

Introduction

Childhood blindness and refractive error (RE) are the major priorities of the global initiative 'Vision

■ **Correspondence:** Dr Prakash Paudel, Brien Holden Vision Institute, Level 4, North Wing, Rupert Myers Building, UNSW, Sydney, NSW 2052, Australia.
Email: p.paudel@brienholdenvision.org

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2020: The Right to Sight'.[1] Uncorrected RE is the leading global cause of vision impairment (VI) and the second most common cause of blindness.[2] A series of Refractive Error Study in Children (RESC) surveys, both population based[3–10] and school based,[11–14] conducted in several countries identified myopia as a major public health problem for different ethnic origins and cultural settings.

Studies have documented a high prevalence of myopia among Asian children, particularly in urban settings,[6,10,14–17] compared with non-Asian populations.[5,7] Studies from Australia have also reported high prevalences of myopia in populations of East Asian and South Asian descent,[18–20] suggesting that race/ethnicity could be a factor. In addition, an association between myopia and its progression with genetic and environmental factors has been established; however, the precise nature of this gene–environment interaction is still unclear.[21] Environmental factors such as prolonged indoor and near activities are known to be associated with myopia,[22–26] and outdoor activities are reported to have a significant protective effect.[27]

Vietnam, with a population of over 85 million (85.8% of whom belong to the Kinh ethnic group), is a developing country located in South-East Asia. In 2010, its Human Development Index ranking was 128 out of 187 countries, with health indicators such as an under-five mortality rate of 23 and an average life expectancy at birth of 75 years.[28] Uncorrected RE (36.4%) is the major cause of childhood blindness in Vietnam.[29] School screening data collated by the Ho Chi Minh eye hospital between 2005 and 2007 showed a high prevalence (39.4%) of RE (both corrected and uncorrected) in primary and secondary school children.[30] According to the Vietnam National Plan for Blindness Prevention and Eye Care, RE is estimated to affect 15–20% Vietnamese children (a majority with uncorrected RE), and thus RE correction is reported as one of the priorities in national plan.[31]

Till date, no RESC studies have reported the prevalence of RE in school children in Vietnam. The present study was therefore conducted to identify the prevalence of VI from all causes and specifically due to RE. This study is also intended to determine the difference in the prevalence rates between urban and rural locations, as well as association of myopia with environmental factors such as time spent on indoor/outdoor activities.

Methods

Study design

The study was a cross-sectional, school-based survey of VI and RE in children from Ba Ria – Vung Tau (BRVT) province, Vietnam. The study focused on lower secondary school children in the 12–15 years age range, ensuring that the data could be compared with results of school-based RESC studies from other Asian countries. Given that the gross school enrolment rate for lower secondary school (6–9 grades) in Vietnam was 92% in the school year 2007/2008[32] and school attendance rates are generally high in this age range, a sample representative from the school populations of BRVT province was considered an appropriate representation of the specific age range. BRVT is located on the coast of country's southeastern region, approximately 65 km from Ho Chi Minh City. The standard RESC protocol and data collection instruments were used to collect data and necessary information.[33]

Sample selection

The study sample was obtained through stratified multistage cluster sampling. The sample size was estimated for a grade-specific prevalence of RE of 25% with a 20% error bound ($25 \pm 5\%$). Prior studies within the geographical region were taken into consideration to arrive at the anticipated prevalence.[11,12,30] The sample size was adjusted for an anticipated 20% non-response and absenteeism rate and a design effect of 1.5 to arrive at the required minimum sample size of 2200 children, equally distributed between four school grades. The sampling design included stratification at the urban/rural and semi-urban areas. The stratification was proportionate to population size. For the multistage cluster sampling design, the school was the primary sampling unit. A total of 13 schools (17% of all schools) were randomly selected from a sampling frame of the 78 public secondary schools ($n = 59\,212$ children) obtained from the Ministry of Education and Training. There are no private secondary schools in the BRVT province. The study sample consisted of six schools from urban, two from semi-urban and five from rural areas. Within each school, the class was the second stage clustering unit. One to two classes of each grade were randomly selected from each school grade of 6–9, with a minimum cluster size of 40. All students within a class were invited to participate. If the minimum sample of 40 was not achieved from the first class, students from the second selected class were used to attain the required sample size. For this, every second or third student starting from the first child in a class register was included until we reached the desired cluster sample size.

Informed consent and ethics approval

A project ophthalmologist (NVG) contacted the principal of the selected schools by prescheduled

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meeting or phone and received consent prior to commencement of the study. None of the principals of the selected schools refused to participate. An invitation to participate in the study and an informed consent document for parents/guardians was sent home with each child from the enumerated classes of each grade. Children whose parents gave signed consent for an examination under full cycloplegic dilation were included.

Ethics approval was obtained from the Vision Cooperative Research Centre and Institute for Eye Research Human Research Ethics Committee in Australia, and approval was also obtained from the Vietnam Institute of Ophthalmology and BRVT Provincial Eye Center in Vietnam.

Ocular examinations

Examinations were performed by one clinical team comprising two optometrists, two refractionists, two ophthalmic nurses and two ophthalmologists. An additional ophthalmologist participated in quality assurance, and a further two ophthalmic nurses administered the myopia risk factors questionnaire.

The study team underwent training for the RESC study, and a pilot study was arranged in a separate school for familiarization with the study protocol, equipment use, measurement methods, and data collection forms and data entry. Cohen's kappa statistic method was used to find the agreement between the two examiners for each ocular finding, and the agreement was satisfactory (kappa, 0.71–0.82). The examinations took place between November and December 2011 at stations set up in each school. The examination included visual acuity (VA) measurements, ocular motility evaluation, cycloplegic autorefraction, subjective refraction and examination of the external eye, anterior segment, media and fundus.

Ophthalmic nurses measured VA at 4 m using a retroilluminated logarithm of the minimum angle of resolution chart with tumbling-E optotypes (Precision Vision, La Salle, IL, USA). For those presenting with spectacles, VA was measured with their spectacles (presenting VA) and without spectacles (uncorrected VA).

Binocular motor function was assessed by ophthalmologists with a cover test at both 0.5 and 4.0 m. Corneal light reflex was used to estimate the degree of deviation. The anterior segment (eyelid, conjunctiva, cornea, iris and pupil) was examined by the ophthalmologist with a flashlight.

For children with unaided VA 6/12 or worse in either eye, two drops of 1% cyclopentolate were administered 5 min apart to each eye. After an additional 15 min, if a pupillary light reflex was still present when observed with a bright flashlight without magnification, a third drop was administered. Cycloplegia and pupillary dilation were evaluated by an optometrist after an additional 15 min. Pupils were considered fully dilated if 6 mm or greater, and cycloplegia was considered complete if pupillary light reflex was absent. The optometrist performed refraction with a handheld autorefractor (Retinomax K Plus, Righton, Tokyo, Japan) that was calibrated daily. Subjective refraction was performed by refractionists on children with uncorrected VA ≤6/12 in either eye.

Examination of the lens, vitreous and fundus was performed by the ophthalmologist, after cycloplegic dilation, with a direct ophthalmoscope. A principal cause of VI was determined for eyes with uncorrected visual acuity ≤6/12. RE was routinely assigned as the cause for eyes improving to ≥6/9.5 with subjective refractive correction. Amblyopia was considered the cause of impairment in eyes with best-corrected VA ≤6/12 and no apparent organic lesion if one or more of the following criteria were met: (i) esotropia, exotropia or vertical tropia at 4 m fixation or exotropia or vertical tropia at 0.5 m; (ii) anisometropia of 2.00 dioptre (D) or more; and (iii) bilateral ametropia of at least +6.00 D.

Children with vision ≤6/12 in one or both eyes and improving with refractive correction were provided with free spectacles in a second visit to schools. Children requiring further diagnostic tests or medical treatment were referred to nearest eye hospital.

A child RE risk factor questionnaire (supporting information) translated to Vietnamese language was administered to each child participant by two trained ophthalmic nurses. The questions were about how long each child spent during a typical school day and weekend engaged in indoor and outdoor activities. Children provided information about total indoor and outdoor hours they spend, and specific details about time spent on indoor and outdoor activities such as reading, computer, sports and physical exercise during school hours.

Data analysis

Review for accuracy and completeness of data forms was done in the field before computer data entry. Data from the record forms were entered by a data entry operator daily into a Microsoft Excel database (Microsoft Corporation, Redmond, WA, USA). Data entries were later validated by range checks on the variables and outliers rechecked for possible data entry errors.

VA was categorized into normal/near normal (VA ≥6/9.5), low vision (VA ≤6/12 to >6/120) and blind (VA <6/120). The prevalence of VI was calculated based on uncorrected VA and presenting VA of 6/12 or worse in the better eye. The principal cause of VI

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assigned by the ophthalmologists was categorized on World Health Organization's datasheets.

The prevalence of VI due to RE was calculated based on uncorrected VA of 6/12 or worse in one or both eyes. Myopia was defined as the spherical equivalent of at least −0.50 D and hyperopia as +2.00 D or more. Children were considered myopic if one or both eyes were myopic, and hyperopic if one or both eyes were hyperopic, as long as neither eye was myopic. Children who were vision impaired due to astigmatism (–0.75 D or more) but had emmetropia when spherical equivalent conversion was considered were identified as emmetropic with astigmatism. Children with normal/near-normal vision in both eyes were considered emmetropes as the RE data were not collected. The total number of children with myopia, hyperopia and emmetropia with astigmatism in one or both eyes represent the total need for correction.

Statistical analyses were performed using SPSS version 19.0 (SPSS Inc., Chicago, IL, USA) and Stata version 10 (StataCorp, College Station, TX, USA). Frequency distributions and point prevalence estimates of the visual outcomes for the overall sample and various demographic categories are reported. The variance and the associated 95% confidence interval (CI) were estimated based on a multistage cluster design sample, with the individual schools defined as the primary sampling unit. Taylor linearization was used for variance estimation.[34] The association of demographic factors such as age, gender, grade level and locality (urban/semi-urban/rural) with myopic VI compared with emmetropes was explored with logistic regression with robust standard error. Similarly, questionnaire-based data on time spent on indoor and outdoor activities was compared between myopes and emmetropes using logistic regression analysis. For this analysis, activity time was coded as number of hours per week, where hours less than 1 was coded as 0.5 and 'not at all' as 0. The total hours spent per week for each activity was calculated as the summation of weekday hours multiplied by 5 and weekend hours multiplied by 2.

Results

A total of 2238 children were examined from 13 secondary schools in the BRVT province between November and December 2011. Distribution of age, gender, grade and locality of the examined children are shown in Table 1. Grade-specific information about children in the selected 13 schools and the study sample is presented in Table 2.

VA

VA findings are presented in Table 3. A total of 1965 children (87.8%) presented with normal or near-normal vision (≥6/9.5) in the better eye. Of these, 161 (8.2%) were wearing spectacles. A total of 434 (19.4%) children had uncorrected VA of ≤6/12 in both eyes, with 71 (3.2% of the total) blind. The prevalence of VI (presenting vision ≤6/12 in the better eye) was 12.2 % (95% CI, 8.8–15.6; 271 children), including six blind children. None of them were attending special schools. We found that with best-corrected VA, no one had blindness.

Table 1. Demographic characteristics of lower secondary school children

	Examined children, *n* (%)	Total children in BRVT, *n* (%)
Age (in years) (mean 13.1 ± 1.0)		
12	835 (37.3)	NA
13	611 (27.3)	NA
14	539 (24.1)	NA
15	253 (11.3)	NA
Gender		
Male	1032 (46.1)	30,347 (50.6%)
Female	1206 (53.9)	29,577 (49.4%)
Grade		
6th	556 (24.8)	15,946 (26.6%)
7th	554 (24.8)	14,228 (23.7%)
8th	560 (25.0)	15,164 (25.3%)
9th	568 (25.4)	14,586 (24.3%)
Locality		
Urban	1040 (46.5)	27,965 (46.7%)
Semi-urban	335 (15.0)	9,037 (15.1%)
Rural	863 (38.6)	22,922 (38.2%)
Total	2238 (100%)	59,924 (100%)

BVRT, Ba Ria – Vung Tau; NA, not available.

Binocular motor function

Tropia was observed in three (0.1%) children: one had esotropia, 15–30 degrees, at both near and distance fixation. The second had esotropia, <15 degrees at both near and distance fixation, and the third child had esotropia, 15–30 degrees at near and <15 degrees at distance fixation.

Causes of VI

The causes of presenting and uncorrected VA of 6/12 or worse in the better eye are presented in Table 4. RE was the main cause of VI, with 92.7% (253/273) of the vision-impaired children. Amblyopia was the cause of VI in 2.2%. Other causes of VI were less common in this population.

RE

Prevalence of VI due to RE in one or both eyes was evaluated based on cycloplegic autorefraction

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Table 2. Grade-specific information about school children and the study sample

School grades	Total children in 13 schools, *n*	Size of selected classes,† 1st class + 2nd class = total	Examined children, *n*	Consent rate in 1st class (%)
6th	3831	484 + 475 = 959	556	360/484 (74.3)
7th	3323	438 + 446 = 884	554	323/438 (73.7)
8th	2769	419 + 408 = 827	560	324/419 (77.3)
9th	2964	384 + 358 = 742	568	321/384 (83.5)
Total	12,887	1,725 + 1,687 = 3,412	2,238	1328/1725 (77.0)

†Attendance rate was above 95% in each school.

Table 3. Distribution of uncorrected and presenting visual acuity

Category	Uncorrected VA *n* (%, 95% CI)	Presenting VA *n* (%, 95% CI)
Normal (≥6/9.5 both eyes)	1804 (80.6; 73.7–87.5)	1965 (87.8; 84.4–91.2)
Low vision (≤6/12 to >6/120 better eye)	363 (16.2; 10.5–22.0)	267 (11.9; 8.6–15.3)
Blind (≤6/120 better eye)	71 (3.2; 1.7–4.6)	6 (0.3; 0.1–0.5)
Total vision impairment (low vision + blind)	434 (19.4; 12.5–26.3)	273 (12.2; 8.8–15.6)

CI, confidence interval; VA, visual acuity.

Table 4. Causes of vision impairment (≤6/12 in better eye)

Causes	Presenting VA *n* (%)	Uncorrected VA *n* (%)
Refractive error†	253 (92.7)	414 (95.4)
Amblyopia‡	6 (2.2)	6 (1.4)
Cataract	2 (0.7)	2 (0.5)
Retinal disorder	1 (0.4)	1 (0.2)
Other causes	4 (1.5)	4 (0.9)
Unexplained cause	7 (2.6)	7 (1.6)
Any cause	273 (100.0)	434 (100.0)

†Assigned as the cause of reduced vision for all eyes correcting to better than 6/12 with subjective refraction, even if other contributing pathology was present. ‡Amblyopia was cause of reduced vision because of anisometropia and bilateral ametropia. No child had strabismic amblyopia. VA, visual acuity.

readings (Table 5). Prevalence of VI due to myopia, hyperopia and emmetropia with astigmatism was 20.4% (95% CI, 12.8–28.0; 456 children), 0.4% (95% CI, 0.0–0.7; 8 children) and 0.7% (95% CI, 0.2–1.2; 16 children), respectively. The prevalence of VI due to myopia showed an increasing trend from 19.2% in 12 years aged children to 22.8% in 14 years and 20.9% in children aged 15 years. Because of the grade-based sampling method, proportions of children skewed towards the younger age groups. However, the gender balance was not affected in either group. For instance, the proportions of males ranged from 46.0% in 12 years to 47.8% in 15 years age group. Myopia rate was higher among females, and hyperopia was higher among males. Similarly, myopia was higher in urban schools (26.6%) compared with semi-urban (11.3%) and rural schools (16.3%). Prevalence of emmetropia with astigmatism was 0.7%, and the prevalence of VI due to hyperopia was 0.4%.

Of 480 children who needed RE correction in one or both eyes, 161 (33.5%) presented with their spectacles. Need of spectacles was higher among females and children in higher grades. A higher proportion of vision-impaired children in urban locality (18.0%) had no refractive correction compared with those in rural (13.9%) and semi-urban (9.3%) areas.

The multivariate logistic regression analysis showed that the prevalence of VI due to myopia compared with emmetropes was significantly associated with increasing grade and urban locality (Table 6). Females were at a higher risk of myopia (22.4% *vs.* 18.0%); however, gender did not reach statistical significance in the multivariate model, which accounted for the multistage cluster sampling design. Grade showed a significant association with myopic VI, in particular with 8th (odds ratio [OR] 1.3, $P = 0.04$) and 9th school grades (OR 1.6, $P \leq 0.001$) compared with 6th grade. The likelihood of VI due to myopia decreased by half or more in children enrolled in rural (OR 0.5) and semi-urban schools (OR 0.4) compared with those in urban schools. When rural and semi-urban were combined, the risk of myopia was twice in the urban areas compared with non-urban areas (OR 2.1, 95% CI: 1.0–4.4, $P = 0.054$).

The activity questionnaire administered to children provided a weekly estimate of hours spent on various indoor and outdoor activities. Table 7 shows the summary of hours spent per week by myopes and emmetropes. The data suggest that on average,

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Table 5. Prevalence of vision impairment due to refractive error (one or both eyes) by age, gender, grade and locality

Category	Total No screened	Myopia *n* (%)	Hyperopia *n* (%)	Emmetropia with astigmatism† *n* (%)	Total need for correction *n* (%)
Age (years)					
12	835	160 (19.2)	3 (0.4)	5 (0.6)	168 (20.1)
13	611	120 (19.6)	3 (0.5)	1 (0.2)	124 (20.3)
14	539	123 (22.8)	2 (0.4)	7 (1.3)	132 (24.5)
15	253	53 (20.9)	0	3 (1.2)	56 (22.1)
Gender					
Male	1032	186 (18.0)	6 (0.6)	5 (0.5)	197 (19.1)
Female	1206	270 (22.4)	2 (0.2)	11 (0.9)	283 (23.5)
Grade					
6th	556	93 (16.7)	3 (0.5)	2 (0.4)	98 (17.6)
7th	554	106 (19.1)	2 (0.4)	5 (0.9)	113 (20.4)
8th	560	116 (20.7)	2 (0.4)	4 (0.7)	122 (21.8)
9th	568	141 (24.8)	1 (0.2)	5 (0.9)	147 (25.9)
Locality					
Urban	1040	277 (26.6)	3 (0.3)	6 (0.6)	286 (27.5)
Semi-urban	335	38 (11.3)	1 (0.3)	1 (0.3)	40 (11.9)
Rural	863	141 (16.3)	4 (0.5)	9 (1.0)	154 (17.8)
Total	2238	456 (20.4) (95% CI, 12.8 to 28.0)	8 (0.4) (95% CI, 0.0 to 0.7)	16 (0.7) (95% CI, 0.2–1.2)	480 (21.4) (95% CI, 13.5–29.4)

†Children who were vision impaired because of astigmatism (–0.75 D or more) but had emmetropia when spherical equivalent conversion used. CI, confidence interval.

Table 6. Multivariate logistic regression for myopic vision impairment (one or both eyes) with grade, gender and locality

Category	Odds ratio, 95% CI (adjusted)	*P*-value
Grade		
6th	Reference	
7th	1.2; 0.8–1.7	0.362
8th	1.3; 1.0–1.7	***0.036***
9th	1.6; 1.3–2.1	***<0.001***
Gender		
Male	Reference	
Female	1.3; 0.9–1.8	0.142
Locality		
Urban	Reference	
Semi-urban	0.4; 0.2–0.6	***0.001***
Rural	0.5; 0.2–1.2	0.133

Bold italic values refer to statistical significance. CI, confidence interval.

myopes spent more hours on indoor activities (4.2 h more per school week, $P < 0.001$) and less time on outdoor activities (1.9 h less per school week, $P < 0.001$) compared with emmetropes. This was subject to multivariate analysis, which showed that myopia was significantly associated with hours spent on indoor activities (Table 8). Analysis of the activity times showed that increased reading hours and computer hours were associated with myopia, and increased outdoor hours had a protective effect for myopia.

Discussion

This study aimed to assess the prevalence of VI and RE in school children aged between 12 and 15 in the BRVT province, Vietnam. The RESC findings, which are reported for the first time in this region, showed that VI is a common school health problem in the BRVT province. The prevalence of presenting VI (12.2%) is higher than that of any other RESC studies, except studies from rural southern China.[12,35] Similar to the findings of most RESC studies, uncorrected RE accounted the major cause of VI (92.7%) in the present study. The high burden of VI due to uncorrected RE among secondary school children in BRVT province suggests that RE screening should be an immediate intervention in schools.

The prevalence of uncorrected VI due to RE in one or both eyes was 21.4% (480/2238) in the present study. This is higher than that reported by other school-based studies conducted in similar age group such as Cambodia,[11] Fiji,[13] Australia,[18] Nepal,[14] Iran,[36,37] Tanzania,[38] Ethiopia[39] and Ireland.[40] Two studies from southern China reported exceptionally high prevalence of VI with RE.[10,12] This can partly be attributed to the larger age range, with myopia increasing with age, and secondly to the study design where all children were refracted. In contrast to the high prevalence of VI due to RE in the present study, an RESC survey from Cambodia reported a very low prevalence of 3.3% in a similar age range. Geographically, the location of this study is in close

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Table 7. Summary of hours spent per week by myopes and emmetropes

Activities	Emmetropes Mean (SD) h/week	Myopes Mean (SD) h/week	*P*-value
Indoor hours	49.0 (16.3)	53.2 (15.0)	***0.000***
Indoor reading hours	15.4 (8.0)	18.2 (8.3)	***0.000***
Indoor computer hours	4.3 (6.4)	4.9 (6.5)	0.077
Indoor TV/movie hours	12.5 (7.1)	11.9 (6.6)	0.129
Indoor sports hours	0.7 (2.1)	0.8 (2.2)	0.526
Outdoor hours	15.1 (7.1)	13.2 (6.4)	***0.000***
Outdoor sports hours	4.5 (5.0)	4.0 (4.4)	***0.036***

Bold italic values refer to statistical significance. SD, standard deviation.

Table 8. Multivariate logistic regression for factors associated with myopic vision impairment (one or both eyes)

Activities (h/week)	Odds ratio, 95% CI (adjusted)	*P*-value
Outdoor hours	0.96; 0.94–0.98	***0.000***
Indoor reading hours	1.05; 1.03–1.06	***0.000***
Indoor computer hours	1.02; 1.00–1.04	***0.022***

Bold italic values refer to statistical significance. CI, confidence interval.

proximity to Cambodia. The reasons for the significant differences in prevalence remain speculative. Some of the reasons for the observed differences may be attributed to the amount of near work exposed to the children in the two countries. The lower secondary curriculum and textbooks in Vietnam focuses more on forming the skills of individual learning, researching issues and problem solving, which possibly engage children in high levels near-work activities. In contrast, basic education with a breadth of knowledge and skills are taught in Cambodia to enable them to pursue higher or vocational studies and participate in social life.[32] Another speculative reason may be attributed to the genetic influences from varying ethnicities. The Vietnamese population comprises 85% Kinh ethnic group, which has been postulated to have a close genetic relationship with the Chinese and oriental populations.[41] In contrast, Cambodian population comprises 92% Khmer ethnic group. It is commonly thought that Khmer people originated from people that migrated from Southern India in the first century AD.[42] Difference in ethnicities has also been attributed to an exceptionally low prevalence of RE in younger Lao population.[43]

Similar to the findings of the RESC surveys, myopia is the main cause of VI in school children in Vietnam. However, VI due to hyperopia was very rare (0.4%) in this sample population. The low prevalence of hyperopia could be attributed to the consequence of mild hyperopia and emmetropia present in their primary school age, which proportionately shift to emmetropia and myopia respectively in secondary school age.[44] It could also be supported with the fact from previous RESC studies that early significant hyperopia rapidly decreases to insignificant levels by the age of 15, with a predominant myopic shift taking place around the age of 12.[10,12]

Age was not a significant risk factor for myopia, and school grade was a contributing factor. Similar to the findings of school-based RESC studies,[12,14] the present study showed that children in higher grades were more likely to develop VI due to myopia. Age and school grades being highly correlated, only one of these remains in the multivariate model. The association of higher school grades with myopia could be attributed to children's involvement in more schooling hours and near/indoor activities as they progress to higher grades.

The prevalence of myopia was slightly higher in females compared with males (22.4% *vs.* 18.0%, $P = 0.012$); however, its significance was lost ($P = 0.142$) in the multivariate analysis when multistage cluster sampling design was accounted for. Previous RESC studies have shown a higher prevalence of myopia in females.[4,9–12] Our data show that females spent more time on activities associated with increased risk of developing myopia such as indoor reading (4 h more per school week, $P < 0.001$) and less time outdoors (3 h less per week, $P < 0.001$) than boys.

Similar to the previous studies finding,[6,10,14–17] urban schooling was significantly associated with myopia in the present study. The high prevalence of VI due to myopia among children in urban schools may be attributed to the increased time spent on indoor activities compared with the activities of children in rural and semi-urban areas. In addition, this variation in prevalence rates could be due to educational pressures, lifestyle changes and nutritional status, which tend to be different in rural and urban environments.[45,46]

The study findings showed that prolonged indoor activities such as reading and computer usage are associated with myopia, and outdoor activities are

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protective against myopia. The findings are similar to those reported in other RE studies.[21–27,47,48] For instance, children with low outdoor and high near-work activity in Australia had twofold to threefold higher chance for myopia than children with high levels of outdoor activity and low levels of near work.[47] A similar finding was reported from a study of Singapore school children, where more time spent on outdoor activities was protective against myopia development; however, they also reported that this was independent of time spent reading.[48] The 5% increased risk of myopia associated with increased reading hours in present study is the risk associated with an increase of 1 h per week. This implies that if a myope reads 5 h more than an emmetrope, then the risk is increased by 25%. The data showed that 40% of myopes recorded 20 h and more of indoor reading as compared with only 26% of emmetropes. Our data also suggested that older children spent more hours on indoor activities compared with younger children. For instance, 15 years old children on average spent 16.7 h on indoor reading compared with 15.3 h by 12 years old. The present study findings suggest the need for school eye health awareness programmes in Vietnam that emphasize the importance of outdoor leisure activities. Further study is needed to determine myopia progression rate and its association with increased indoor time when children progress in higher grades.

The study revealed that two thirds of vision-impaired children had never received refractive correction or did not wear spectacles. A similarly high unmet need for refractive correction has been documented in other studies.[3–12,14] Interestingly, despite the presence of high RE prevalence and better access to eye units and optical shops in urban areas, a higher proportion of urban school children did not receive RE correction compared with those from rural areas. Health education regarding spectacle wear is therefore important along with vision screening and affordable optical dispensing.

The major limitation of the present study is a school-based sampling method that may have resulted in prevalence estimates not fully representative of the province population. A grade-stratified cluster sampling and subdividing classes increased the sampling efficiency. However, the results suggest that prevalence of RE was not uniform across grades, indicating the need to have used grade-specific sample sizes. Future RESC studies need to consider the use of sample sizes specific to each age or school grade in relation to age-specific prevalence of RE. Unequal sample in the age groups possibly occurred because of higher repetition rates in lower grades resulting in older children in lower grades (e.g. 2.2% repeated in grade 6 in 2005/2006).[32]

Every cluster-based sampling design involves the use of design effect to account for the increased variance due to the use of clusters. While the design effect was set based on prior studies at the sampling stage, the actual design effect for each analysed variable was estimated, and the 95% CIs were adjusted accordingly. As a result, there were CIs that were wider than expected; however, the ability to test for differences between strata levels was not unduly affected (Table 6).

Similarly, non-response rate (23%) from the first enumerated class adds an element of bias to the prevalence estimates. It was observed that the failure to sign the informed consent was due to the fear of cycloplegic refraction. Parental permission issues in RE screening among children resulted in low response rates (40 to 80%) in similar studies.[5,18,36,40,49] If the prevalence of VI was higher among the 23% non-responders, the prevalence rates in this study is likely to be underestimated to a level not more than 5% of the current estimates because of the unequal sample weights of the responder and non-responder samples. Given the increasing rate of non-response due to cycloplegic refraction, presenting vision should be enumerated for such non-responders in future school-based screening studies. The presenting vision will provide an indication of the randomness of the non-responders in relation to the entire study sample.

Another important limitation is that the present study did not attempt cycloplegic autorefraction on children with normal/subnormal vision (≥6/9.5), which restricted from presenting the prevalence estimates of RE. However, high prevalence of VI due to myopia suggests that the prevalence figure of myopia could be exceptionally high when every child is examined under cycloplegia.

In conclusion, uncorrected RE (myopia in particular) is the most common cause of VI in secondary school children in Vietnam. Most vision-impaired children did not have spectacles, indicating that the need for RE services is significant. Further, with rapid economic growth and urbanization in Vietnam, the incidence of myopia might be expected to increase significantly in coming years. Effective vision screening programmes, appropriate referral with the provision of affordable spectacles, and health education on outdoor activities and spectacle compliance are therefore required for eliminating VI caused by RE.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Child Refractive Error Risk Factor Questionnaire

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