Refractive error and amblyopia among primary school children in remote islands of East Coast of Peninsular Malaysia

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ABSTRACT

Introduction: Little is known about the prevalence of refractive errors and amblyopia among school children on the islands of East Coast Malaysia. This study aimed to investigate the prevalence of these conditions and their associated factors in this unique and remote geographical location.

Materials and Methods: This multicentre cross-sectional school-based study included 480 children aged 7 to 12 year from primary schools on the islands of the East Coast of Malaysia. All children underwent visual acuity assessment, orthoptic evaluation, anterior and posterior segment examinations and manifest refraction. Demographic data, history of parental refractive error, parental education level, duration of digital screen time and time spent outdoors were documented in a questionnaire distributed to the parents.

Results: The mean age was 9.53 ± 1.69 years, with an equal distribution of genders. The ethnic composition of the subjects was 99.4% Malay and 0.6% Orang Asli. The overall prevalence of refractive errors was 11.9% (95% CI: 9.1 to 15.1%), with myopia at 7.1% (95% CI: 5.0 to 9.8%), hyperopia at 2.5% (95% CI: 1.3 to 4.3%), astigmatism at 2.3% (95% CI: 1.1 to 4.1%) and amblyopia at 2.5% (95% CI: 1.3 to 4.3%). Older age, an absence of parental history of refractive error and reduced daily outdoor time were significantly associated with refractive errors ($p < 0.05$).

Conclusion: The prevalence of refractive error is 11.9% and amblyopia is 2.5% among primary school children on the islands of the East Coast of Peninsular Malaysia. Older age, an absence of parental history of refractive error and reduced daily outdoor time are associated with refractive error.

KEYWORDS:
Refractive error, amblyopia, primary school children, islands, East Coast Malaysia, associated factors

INTRODUCTION

Given its high prevalence, understanding the epidemiology of refractive error is crucial for developing national health policies. With a global prevalence of 43%, refractive error is a significant public health concern.[1] Uncorrected refractive error in childhood is a major risk factor for amblyopia, leading to impaired visual acuity (VA) and a negative impact on a child's abilities, academic performance and quality of life. The prevalence of amblyopia in children worldwide ranges from 1.44 to 4.3%.[2]

While numerous studies have attempted to ascertain the prevalence of refractive error in Malaysia, the majority have concentrated on the population residing in the mainland regions of East and West Malaysia.[3-11] As a result, the prevalence of refractive error in the island population remains unknown.

The islands of Redang, Perhentian and Tioman are located at a distance range of 19 to 60 km from the mainland, can be accessed in 1 to 2 hours by water transportation and are well equipped with their primary healthcare centres. However, the nearest ophthalmology and optometry facilities are only available on the mainland, which may pose challenges in accessing specialised eye care services for the island-dwelling population. On top of that, there is a lack of dedicated and regular eye-screening programs for children residing in these islands, with most eye-screening being conducted through volunteer initiatives by governmental and non-governmental organisations. Therefore, our study aimed to determine the prevalence of refractive error and amblyopia in children and the associated factors with refractive error in these remote areas.

MATERIALS AND METHODS

This multicentre cross-sectional study was conducted in the islands of the East Coast Malaysia, specifically in the states of Terengganu and Pahang, Malaysia, from December 2022 to

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November 2023, adhering to the principles of the Declaration of Helsinki. The study protocol received approval from the Research and Ethical Committee, School of Medical Sciences, Universiti Sains Malaysia (No. USM/JEPeM/22060444).Written informed consent was obtained from all parents/legal guardians, and verbal assent was obtained from the recruited children.

The inclusion criteria encompassed all primary school children aged 7 to 12 years old residing in the Redang, Perhentian, and Tioman Islands. Exclusion criteria comprised children already under ophthalmology follow-up for known ocular diseases or those absent from school. Participants were categorised into two age groups: 7 to 9 years old and 10 to 12 years old, following the age stratification guidelines of the Malaysian Ministry of Education.

Questionnaires were distributed to parents to collect demographic data, family history of refractive error, parental education (based on the parent with the highest level of education), digital screen time and time spent outdoors. Visual screening for these children included various assessments such as VA testing using the Snellen chart for distance, cover test, external ocular assessment, ophthalmoscopy and non-cycloplegic refraction. Spectacles were prescribed when indicated, and children diagnosed with ocular anomalies were referred to the nearest ophthalmology service.

Myopia is defined as spherical equivalent (SE) of at least -0.50 D, hyperopia of +0.50 D or more, and astigmatism of 0.50 D or more in either eye. Amblyopia was defined as the best corrected VA worse than or equal to 20/30 using Snellen VA or 0.2 logarithm of the minimum angle of resolution unit in the absence of ocular pathology.

Data were analysed using Statistical Package for Social Sciences (SPSS version 27.0; IBM Corp, Armonk, NY, USA) software. Descriptive statistics were used to analyse demographic data and the prevalence of refractive error, myopia, astigmatism, hyperopia and amblyopia. Data were expressed as mean, standard deviation, median, frequency and percentage. Logistic regression analyses were conducted to identify factors associated with refractive error. All p-values were considered statistically significant when less than 0.05. Pearson's Chi-Square and Fisher's exact test were conducted to investigate the association between variables and amblyopia. All analyses conducted were two-tailed, with an alpha level set at a significance level of 0.05.

RESULTS

A total of 480 children participated in the study, with the majority belonging to the Malay ethnicity (99.4%) and an equal distribution of males and females. Refractive error was identified in 57 children (11.9%) with a 95% confidence interval of 0.091 to 0.151. Other ocular pathologies observed included strabismus (3.3%) and oculodermal melanosis (1.7%).

The average age of children with refractive error was 9.53±1.69 years. Refractive error was most prevalent among older individuals (61.4%), females (56.1%), those without a family history of myopia (77.2%), children who spent less than 2 hours outdoors daily (94.7%) and those with more than 2 hours of daily digital screen time (70.2%). Myopia was the most common type of refractive error, affecting 34 children and accounting for 7.1% of the total refractive errors. Hyperopia was found in 12 (2.5%) children, and astigmatism in 11 children (2.3%). A majority of children with refractive error spent less than 2 hours outdoors (94.7%) and more than 2 hours on electronic devices (70.2%) daily. These are presented in Table I.

Table II shows that unilateral amblyopia was diagnosed in 10 children (83.3%), with refractive amblyopia being the primary cause (83.3%), followed by sensory deprivation amblyopia (16.7%). Amblyopia was identified in 12 children (2.5%), with a mean age of 9.75 ± 2.38 years, predominantly among males (58.3%) from households with a monthly income of RM 1000 or less (33.3%).

Multiple logistic regression analysis revealed that children aged 10 to 12 years old had 2.94 times higher odds of developing refractive error compared to those aged 7 to 9 years old after controlling for outdoor time and digital screen hours (OR: 2.94, 95% CI: 1.02 to 8.48, $p = 0.047$). Furthermore, children with a history of parental refractive error had 52% lower odds of developing refractive error compared to those without after controlling for age and outdoor time (OR: 0.48, 95% CI: 0.23 to 1.00, $p = 0.049$). Children who spent 2 hours or more outdoors had 98% lower odds of refractive error compared to those who spent less than 2 hours outdoors after adjusting for age and digital screen time (OR: 0.02, 95% CI: 0.01 to 0.05, $p < 0.001$) as illustrated by the Table III.

Table IV describes the association of identified variables and amblyopia using Chi-square test in view of small number of children with amblyopia. A higher proportion of the amblyopia group spent less than 2 hours outdoors compared to the non-amblyopia group, 91.7% and 29.5%, respectively ($p < 0.001$). Other factors tested for amblyopia showed no significant association with amblyopia ($p > 0.05$).

DISCUSSION

In this study, we examined the prevalence of refractive error, amblyopia and their associated factors on the islands of the East Coast of Peninsular Malaysia. The observed prevalence of refractive error was 11.9%, aligning with findings from similar studies conducted in the United States of America, Indonesia and Saudi Arabia, where rates ranged from 13.1 to 16.8%.[12-14] However, the prevalence of refractive error in our study is notably lower than that reported in New Zealand, Kazakhstan, and China (26.3 59.6%).[15-17] Table V describes refractive error prevalences reported in previous studies conducted in Malaysia, ranging from 70 to 75.6%, including our own study.[7-14]

Several factors contribute to this wide variation in prevalence rates. Notably, individuals of Chinese ethnicity are more

Table I: Sociodemographic characteristics of study subjects (n = 480)

Variables	n (%)	Refractive error, n (%)		Myopia, n (%)		Hyperopia, n (%)		Astigmatism, n (%)	
		Yes (n=57)	No (n=423)	Yes (n=34)	No (n=446)	Yes (n=12)	No (n=468)	Yes (n=11)	No (n=469)
Age group (year)									
7 - 9	228 (47.5)	22 (38.6)	206 (48.7)	11 (32.4)	217 (48.7)	7 (58.3)	221 (47.2)	4 (36.4)	224 (47.8)
10 - 12	252 (52.5)	35 (61.4)	217 (51.3)	23 (67.6)	229 (51.3)	5 (41.7)	247 (52.8)	7 (63.6)	245 (52.2)
Gender									
Female	240 (50)	32 (56.1)	208 (49.2)	18 (52.9)	222 (49.8)	7 (58.3)	233 (49.8)	7 (63.6)	233 (49.7)
Male	240 (50)	25 (43.9)	215 (50.8)	16 (47.1)	224 (50.2)	5 (41.7)	235 (50.2)	4 (36.4)	236 (50.3)
Race									
Malay	477 (99.4)	57 (100)	420 (99.3)	34 (100)	443 (99.3)	12 (100)	465 (99.4)	11 (100)	466 (99.4)
Orang Asli	3 (0.6)	0 (0)	3 (0.7)	0 (0)	3 (0.7)	0 (0)	3 (0.6)	0 (0)	3 (0.6)
Monthly household income (RM)									
RM 1000 and less	137 (28.5)	13 (22.8)	124 (29.3)	6 (17.6)	131 (29.4)	5 (41.7)	132 (28.2)	2 (18.2)	135 (28.8)
RM 1001 - 2999	276 (57.5)	40 (70.2)	236 (55.8)	26 (76.5)	250 (56.1)	7 (58.3)	269 (57.5)	7 (63.6)	269 (57.4)
RM 3000 and more	67 (14)	4 (7)	63 (14.9)	2 (5.9)	65 (14.6)	0 (0)	67 (14.3)	2 (18.2)	65 (13.9)
Parental refractiveerror									
Yes	169 (35.2)	13 (22.8)	156 (36.9)	9 (26.5)	160 (35.9)	2 (16.7)	167 (35.7)	2 (18.2)	167 (35.6)
No	311 (64.8)	44 (77.2)	267 (63.1)	25 (73.5)	286 (64.1)	10 (83.3)	301 (64.3)	9 (81.8)	302 (64.4)
Parental education level									
Primary school	19 (4)	1 (1.8)	18 (4.3)	1 (2.9)	18 (4)	0 (0)	19 (4.1)	0 (0)	19 (4.1)
Secondary school	388 (80.8)	49 (86)	339 (80.1)	29 (85.3)	359 (80.5)	10 (83.3)	378 (80.8)	10 (90.9)	378 (80.6)
University	73 (15.2)	7 (12.3)	66 (15.6)	4 (11.8)	69 (15.5)	2 (16.7)	71 (15.2)	1 (9.1)	72 (15.4)
Daily hours of outdoor activities									
Less than 2 hours	149 (31)	54 (94.7)	95 (22.5)	31 (91.2)	118 (26.5)	12 (100)	137 (29.3)	11 (100)	138 (29.4)
2 hours and more	331 (69)	3 (5.3)	328 (77.5)	3 (8.8)	328 (73.5)	0 (0)	331 (70.7)	0 (0)	331 (70.6)
Daily hours of digital screen time									
Less than 2 hours	110 (22.9)	17 (29.8)	93 (22)	7 (20.6)	103 (23.1)	6 (50)	104 (22.2)	4 (36.4)	106 (22.6)
2 hours and more	370 (77.1)	40 (70.2)	330 (78)	27 (79.4)	343 (76.9)	6 (50)	364 (77.8)	7 (63.6)	363 (77.4)

RM = Ringgit Malaysia

Table II: Distribution of amblyopia according to laterality and aetiology (n = 12)

Amblyopia	n (%)
Laterality	
Right	6 (50)
Left	4 (33.3)
Bilateral	2 (16.7)
Aetiology	
Refractive	
Myopia	4 (33.3)
Hyperopia	2 (16.7)
Anisometropia	4 (33.3)
Sensory deprivation	2 (16.7)

Table III: Association of refractive error and sociodemographic factors

Variables	Simple logistic regression		Multiple logistic regression	
	Crude OR (95%CI)	p-value	Adjusted OR (95%CI)	p-value
Age (years)				
7 - 9	1		1	
10 - 12				
Gender	1.51 (0.86, 2.66)	0.154	2.94 (1.02, 8.48)	0.047*
Female	1			
Male	0.76 (0.43, 1.32)	0.324		
Monthly household income				
RM 1000 and less	1			
RM 1001 - 2999	1.65 (0.52, 5.27)	0.397		
RM 3000 and more	2.67 (0.92, 7.74)	0.071		
Parental refractive error				
No	1		1	
Yes	0.51 (0.26, 0.97)	0.040*	0.48 (0.23, 1.00)	0.049*
Parental education level				
Primary School	1.00			
Secondary School	0.52 (0.06, 4.54)	0.557		
University	1.36 (0.59, 3.14)	0.467		
Daily hours of outdoor activities				
Less than 2 hours	1		1	
2 hours and more	0.16 (0.05, 0.53)	0.000*	0.02 (0.01, 0.05)	0.000*
Daily hours of digital screen time				
Less than 2 hours	1		1	
2 hours and more	0.66 (0.36, 1.22)	0.189	0.23 (0.08, 0.65)	0.085

OR = odds ratio
CI = confidence interval
p < 0.05 is significant for simple logistic regression
* Statistically significant value
No multicollinearity and no interaction.
Hosmer Lemeshow test, p-value = 0.578

Table IV: Association of amblyopia and sociodemographic factors

Variable	Amblyopia, n (%)		c^2 (df)	p-value
	Yes (n = 12)	No (n = 468)		
Age (years)				
7 - 9	6 (50)	222 (47.4)		
10 - 12				
Gender	6 (50)	246 (52.6)	0.031 (1)	>0.950[a]
Female	5 (41.7)	235 (50.2)		
Male	7 (58.3)	233 (49.8)	0.342 (1)	0.772[a]
Monthly household income				
RM 1000 and less	6 (50)	131 (28)		
RM 1001 - 2999	4 (33.3)	272 (58.1)		
RM 3000 and more	2 (16.7)	65 (13.9)		0.157[b]
Parental refractive error				
No	6 (50)	305 (65.2)		
Yes	6 (50)	163 (34.8)		0.359[b]
Parental education level				
Primary School	0 (0)	19 (4.1)		
Secondary School	11 (91.7)	377 (80.6)		
University	1 (8.3)	72 (15.4)		0.817[b]
Daily hours of outdoor activities				
Less than 2 hours	11 (91.7)	138 (29.5)		
2 hours and more	1 (8.3)	330 (70.5)		0.000*[b]
Daily hours of digital screen time				
Less than 2 hours	3 (25)	107 (97.3)		
2 hours and more	9 (75)	361 (77.1)		0.742[b]

[a]Pearson's chi-square
[b]Fischer's-exact test
*p-value < 0.05.

Table V: Summary of refractive error and amblyopia prevalence in children in Malaysia.

Variables	Saw et al., 2006 [9]	Goh et al., 2005 [3]	Hashim et al., 2008 [6]	Jayaraman et al., 2016 [10]	Min et al., 2017 [7]	Omar et al. 2019 [4]	Ismail et al., 2022 [11]	Omar et al., 2022 [5]	Current study 2024
Place, Country	Singapore and Gombak, Malaysia	Gombak, Selangor, Malaysia	Kota Bahru, Kelantan, Malaysia	Urban Malaysia	Segamat, Johor, Malaysia	Negeri Sembilan, Malaysia	Wang Maju, Kuala Lumpur, Malaysia	Bentong, Pahang, Malaysia	East Coast Islands, Malaysia
Locality	Urban	Urban	Rural	Urban	Rural	Rural	Urban	Rural	Island
Sample size	3714	5528	840	168	1287	110	245	82	480
Age (years)	7 - 9	7 - 15	6 - 13	10 -12	4 - 6	7 - 12	8 - 12	7 - 12	7 - 12
Prevalence (%)									
Refractive error	-	17.1	7.0	66.7	12.5	38	47.8	75.6	11.9
Myopia	9.2 – 40.9	9.8 - 34.3	5.4	58.4	9	5.5	30.2	64.6	7.1
Hyperopia	1.2 – 3.9	1 – 3.8	1.0	0	6.9	28.2	1.2	15.9	2.5
Astigmatism	18.7 – 44.3	15.7	0.6	8.3	84	NA	16.3	NA	2.3
Amblyopia	-	2.9	-	-	7.53	2.7	-	NA	2.5
Criteria	M≤ -0.50D H≥ +2.0D A≥ 0.75D	M≤ -0.50D H≥ +2.0D A≥ 0.75D	M≤ -0.50D H≥ +2.0D A≥ 0.75D	-	M≤ -0.50D H≥ +2.0D A≥ 0.75D	M≤ -0.50D H≥ +1.50D A≥ 0.75D	M≤ -0.50D H≥ +2.0D A≥ 0.75D	M≤ -0.25D H≥ +0.25D	M≤ -0.50D H≥ +0.50D A≥ 0.50D
Method of assessment	CAR, CRS	CAR, CRS	NCAR, NCRS	Not stated	CRS, NCRS	CRS	NCAR, CRS	CRS	NCRS

NCRS: Non-cycloplegic retinoscopy; CRS: Cycloplegic retinoscopy; NCAR: Non-cycloplegic autorefraction; CAR: Cycloplegic autorefraction; M: Myopia; H: Hyperopia; A: Astigmatism, D: Dioptre

susceptible to refractive errors, particularly myopia,[3,5,9,10,18,19] whereas most of our study participants were Malay. Moreover, our study was conducted in rural Malaysia, likely contributing to the lower prevalence of refractive errors. This is supported by various refractive error prevalence studies done in Malaysia, Indonesia, China, India, Bhutan and Iran.[3,4,6,8,18,20-24] The high prevalence of refractive error in urban areas was thought to be related to factors like increased near work, academic pressures, and reduced outdoor time.[17,23,24]

In our study, refractive error was associated with older age, no parental history of refractive error and reduced daily outdoor time. The prevalence of refractive error increases with age aligns with findings from other studies.[3,5,6,9,10,25,26] During pre-pubertal childhood, rapid growth can cause myopia to escalate due to changes in the refractive power, corneal curvature and axial length.[27,28]

Our data revealed a significant association between a positive history of parental refractive error and a reduced refractive error rate. This contradicts data reported by studies done in Malaysia, China and Sweden in which a positive history of parental refractive error is associated with development of refractive error.[6,10,11,22,29,30] This difference could be attributed to heightened awareness among myopic parents regarding refractive error prevention, including the adoption of healthy visual habits and early identification of refractive issues at home.

Our study also reported that increased outdoor time is significantly associated with a reduced rate of refractive error. This aligns with findings from other studies conducted in Malaysia, Kazakhstan, China and New Zealand.[4,6,7,10,11,15-17] Recent evidence supports the notion that spending more time outdoors in natural light offers protection against myopia by producing higher levels of retinal dopamine, which can delay the onset and progression of myopia.[25,27,31-33] While reducing screen time may help prevent refractive error, our study did not find a statistically significant association between digital screen time and refractive error, contrary to the findings of a meta-analysis by Foreman et al.[34]

In our study, the prevalence of myopia is 7.1%, making it the most common type of refractive error, consistent with the findings of numerous previous studies.[2–7,9–11,21,35] The global prevalence of myopia ranges from 4.4 to 55%.[5,6,9,18,20,22,23,36,37] This variability may stem from differences in study design and methodology. Myopia is closely linked to emmetropisation, particularly its feedback theory. This theory suggests that several factors, such as increased near work, atropine, lenses, defocus and reduced outdoor time may contribute to myopia development. Near vision is optically similar to using a minus lens, a known myopigenic factor. Therefore, spending more time outdoors may decrease myopia development.[38] Additionally, increased exposure to bright light outdoors may slow ocular axial length growth, further supporting this theory. Our study reveals a statistically significant association, indicating that increased outdoor time is linked to a 65% lower odd of developing myopia ($p < 0.001$).

The prevalence of hyperopia in our study was 2.3%. Previous studies in Malaysia have shown hyperopia prevalence rates varying from 1 to 28.2%.[3–11] The global pooled prevalence of hyperopia is 4.6%.22 A meta-analysis conducted by Mavi and colleagues indicates that uncorrected hyperopia has been associated with lower academic achievement and literacy abilities in children.[39] Left undetected, this condition could significantly impact one's economic and academic prospects throughout life.

The prevalence of astigmatism in our study population is 2.3%, which is significantly lower than the astigmatism prevalence reported in China (41.6%) and Norway (8.4 to 57%).[18,40] Tang et al. postulated that ethnicity significantly influenced astigmatism development due to anatomical differences in Asian eyes, such as narrow palpebral apertures and tight eyelids.[18] However, Hashemi et al. discovered that astigmatism prevalence among Caucasians, ranging from 22 to 45.6%, mirrors the high rates among Asians, challenging the theory of anatomical variation as the sole influence.[22] Further research is needed to uncover additional factors contributing to astigmatism.

In our study, the prevalence of amblyopia was 2.5%, a figure similar to that reported by Goh et al. (2.9%) and Omar et al. (2.7%).[3,4] A larger proportion of the amblyopia group spent less than 2 hours outdoors compared to the non-amblyopic group, 91.7% vs 29.5% respectively ($p < 0.001$). This finding supports the theory that children who spend less time outdoors are more prone to amblyopia. Early diagnosis and treatment before the age of 10 can fully resolve amblyopia. However, if not properly diagnosed and treated, the condition can result in lifelong visual impairment. Studies on amblyopia indicate that refractive errors pose a prevalent risk across all age demographics.[21]

An inherent limitation of our study was the reliance on recall-based estimations to assess outdoor and digital screen time, lacking the precision of objective measures. To mitigate this limitation, future research endeavours should incorporate more robust methodologies, such as objective monitoring devices or electronic tracking systems, to provide accurate and real-time data on these variables.

CONCLUSION

The present study reported a low prevalence of refractive error and amblyopia among school children in the East Coast Islands of Peninsular Malaysia. Reduced time spent outdoors was consistently linked to refractive error and amblyopia. Early detection and treatment of refractive error are crucial in preventing amblyopia.

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CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

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