Vision problems: A review of prevalence studies on refractive errors in school-age children

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Background: Refractive errors are common eye disorders and are leading causes of visual impairment in the general population. Children with uncorrected refractive error may experience reduced visual acuity, transient blurring, headache and persistent ocular discomforts particularly for close work which can impair reading efficiency and school performance.

Aim: This article documents the prevalence of refractive errors in school-age children of different ethnic origins. The goal is to identify possible variation in measuring techniques and diagnostic criteria, as well as limitations of studies, to provide a clear direction for future studies.

Methods: The review was undertaken through a detailed evaluation of peer-reviewed publications of primary research on this topic. The keywords for the search included 'refractive error', 'hyperopia', 'myopia', 'astigmatism' and 'school children'. Only epidemiological studies with participants between 5 and 18 years of age were included.

Results: Although several population and school-based studies have been conducted in various racial groups and populations, their findings were diverse owing to inconsistencies in the methods applied in identifying children in need of refraction, measurement techniques and diagnostic criteria for refractive errors. There are also some limitations associated with the sampling design and characteristics, which may have influenced the outcome measures.

Conclusion: Despite the problems inherent in the studies, the review indicates that refractive error in school-age children is a public health concern in those populations and warrants additional research that will provide reliable data for proper planning of intervention strategies.

Keywords: hyperopia; myopia; astigmatism; school-age children; school performance.

Introduction

Refractive errors (REs) including myopia, hyperopia and astigmatism are common eye disorders and are leading causes of visual impairment and treatable blindness in the general population.[1] Myopia is characterised by axial length elongation and positive image position relative to the retina and is often associated with structural changes of the retina and choroid. Myopia causes a reduction in visual acuity (VA) that cannot be overcome by accommodation.[2,3] In addition, highly myopic eyes, that is, of −6 dioptres (D) or more, may develop sight-threatening complications, leading to visual impairment at a young age.[4] Hyperopia, by contrast, is a condition in which the eye is shorter.[4] Although distance VA may be unaffected, especially in mild hyperopia, it can create visual disturbances which can affect optimum functional performance of school children.[4,5] Hyperopia is also a predisposing factor to convergent strabismus, esophoria, amblyopia and angle closure glaucoma in young children.[6] Astigmatism is a condition that causes a certain degree of blurred vision at all distances including other near vision-related symptoms.[7,8] If uncorrected during early development, astigmatism induces a form of visual deprivation that can result in meridional amblyopia[7,8] and possibly permanent visual impairment.[8]

This article presents a review of the prevalence of REs in school-age children, along with their association with age and gender. A discussion about variation in measuring techniques and diagnostic criteria, as well as limitations of studies, is provided to direct future studies. Considering the implications of uncorrected RE to academic achievement and overall well-being, this review could provide useful information for policymakers and can help in planning, provision and evaluation of child eye health services.

Methods

A literature search was conducted on the online databases of PubMed, Medline, OVID, Google Scholar, ScienceDirect and Embase from November 2016 to November 2017 using the following keywords: refractive error, hyperopia, myopia, astigmatism and school children. The review was restricted to primary research published in English and in peer-reviewed journals. Only epidemiological studies with stated measures of prevalence of corresponding RE among school-age children between 5 and 18 years of age were included.

In this narrative review, findings from studies that met the outlined criteria were reviewed. Variables of interests for review included the following: sample size and sampling method, participant characteristics including gender and age, prevalence rates of corresponding RE, information on diagnostic criteria and measurement techniques. A summary of each study was first presented and evaluated in relation to findings from other studies. Eligible studies on myopia, hyperopia and astigmatism were compared according to geographic regions or ethnicity.[9]

Previous studies on school-age children

Prevalence of hyperopia

African population

Table 1 shows the prevalence of hyperopia from selected countries in various geographic regions. Lower prevalence of hyperopia in African populations was reported by studies that included only significant RE in their prevalence estimation. In Nigeria, Atowa et al.[10] reported 0.9% hyperopia in 1197 school children aged 8–15 years, with only 29.1% of the children with RE wearing spectacles during examination. Hyperopia was defined as a spherical equivalent refraction (SER) of 2 D or more in one or both eyes, if none of the eyes were myopic. All the study participants underwent cycloplegic refraction. Similarly, Mehari and Yimer reported 0.3% hyperopia (SER ≥ 2 D) in 4238 school children between the ages of 7 and 18 years in Ethiopia.[11] Non-cycloplegic retinoscopic refractions were performed on all participants, and VA thresholds of 6/9 or worse in the better eyes were applied to identify those in need of refractive correction. Two studies on African populations included hyperopia of 0.50 D in their prevalence estimation and reported a prevalence of hyperopia of 5.0% in Ghana[12] and South Africa[13] each in high school children. It is important to note that the inclusion of low categories of REs is of clinical significance because such refractive anomalies can possibly impair reading efficiency and school performance.[13]

Asian population

As with studies on African populations, prevalence studies on children from other geographic locations also reported varied results. Although the studies in Asia utilised a logMAR protocol, common definition of SER 2 D or more, large sample sizes, differences in age group of the study participants and study locations (rural or urban) may have influenced the reported prevalence of hyperopia in the various studies reviewed. In rural China,[14] the prevalence was 1.2% in children aged between 13 and 17 years, while in urban China[15] the prevalence was 5.8% in participants between 5 and 15 years. Likewise, in rural India,[16] the prevalence of hyperopia in children aged between 7 and 15 years was 0.4% and in urban India[17] it was 7.7% in children aged 5–15 years. The prevalence of hyperopia in a suburban area of Malaysia[18] was 1.6% in participants aged between 7 and 15 years, whereas in high school children aged between 12 and 15 years in Vietnam,[19] the prevalence was 0.4%. A study in Saudi Arabia[20] reported a prevalence of 0.9% hyperopia in primary school children aged 6–13 years in Al-Qassim region. The authors considered only children with a VA of ≤ 6/12 as needing RE assessment. Norouzirad et al. reported a prevalence of 12.9% in school children between the ages of 6 and 15 years in Iran, with all children refracted irrespective of VA.[21] The evaluation of the refractive status of all children is important because this enables the detection of children with significant hyperopia even when VA is unaffected but the

TABLE 1: Prevalence of hyperopia among school-age children in selected countries from various geographic regions.

Study	Country	Ethnicity	Age (years)	Sample size (*N*)	Definition criteria	Measurement technique	Prevalence (%)
Atowa et al.[10]	Nigeria	African	8–15	1197	SER ≥ 2.00	Cycloplegic autorefraction	0.9
Ovenseri-Ogbomo and Assien[12]	Ghana	African	11–18	595	SPH ≥ 0.75	Non-cycloplegic retinoscopy	5.0
Mehari and Yimer[11]	Ethiopia	African	7–18	4238	SER ≥ 2.00	Non-cycloplegic retinoscopy	0.3
Wajuihian an d Hansraj[13]	South Africa	African	13–18	1586	SER ≥ 0.50	Non-cycloplegic autorefraction/ Subjective refraction	5.0
Aldebasi[20]	Saudi Arabia	Middle East	6–13	5176	SER ≥ 2.00	Cycloplegic autorefraction	0.9
Norouzirad et al.[21]	Iran	Middle East	6–15	1130	SER ≥ 2.00	Non-cycloplegic retinoscopy	12.9
He et al.[14]	Rural China	Asian/East	13–17	2454	SER ≥ 2.00	Cycloplegic autorefraction	1.2
He et al.[15]	Urban China	Asian/East	5–15	4347	SER ≥ 2.00	Cycloplegic autorefraction	-
Paudel et al.[19]	Vietnam	Asian/South East	12–15	2238	SER ≥ 2.00	Cycloplegic autorefraction	0.4
Goh et al.[18]	Malaysia	Asian/South East	7–18	4634	SER ≥ 2.00	Cycloplegic autorefraction	1.6
Dandona et al.[16]	Rural India	Asian/South	7–15	3976	SER ≥ 2.00	Cycloplegic autorefraction	0.4
Murthy et al.[17]	Urban India	Asian/South	5–15	6447	SER ≥ 2.00	Cycloplegic autorefraction	7.7
Zadnik et al.[24]	USA	Caucasian	6–14	2583	SER ≥ 1.25	Cycloplegic autorefraction	8.6
Kleinstein et al.[23]	USA	Caucasian	5–17	2523	SER ≥ 1.25	Cycloplegic autorefraction	12.6
O'Donoghue et al.[25]	United Kingdom	Caucasian	6–7	392	SER ≥ 2.00	Cycloplegic autorefraction	20.6
			12–13	661			14.7
Czepita et al.[26]	Poland	Caucasian	6–18	5724	SER ≥ 2.00	Cycloplegic retinoscopy	4.0
Ip et al.[27]	Australia	Caucasian	11–14	2352	SER ≥ 2.00	Cycloplegic autorefraction	5.0
Fotedar et al.[28]	Australia	Caucasian	12	2233	SER ≥ 2.00	Cycloplegic autorefraction	5.0

SER, spherical equivalent refraction.

development of convergent strabismus and amblyopia because of excessive use of accommodation to maintain normal (6/6) VA may be possible.[22]

Caucasian population

For studies conducted on caucasian populations, diagnostic criteria and age ranges of the study samples affected the reported prevalence of hyperopia (Table 1). Two studies in the United States that adopted a common definition of hyperopia of 1.25 D or more in both meridians reported a prevalence of 12.8%[23] and 8.6%,[24] respectively. Differences between the findings can at least be accounted for by the different age ranges of the study populations. The study by Kleinstein et al.[23] had a larger age range (5–17 years) compared with the study by Zadnik et al.[24] (6–14 years). In Europe, the Northern Ireland Childhood Errors of Refraction study examined 1053 white children (392 aged 6–7 years old and 661 aged 12–13 years old) and reported that the prevalence of hyperopia (SER ≥ 2 D) was 20.6% and 14.7%, respectively.[25] An earlier study in Poland[26] had found a prevalence of hyperopia (SER 1 D) of 38.0% in 5721 school children between the ages of 6 and 18 years. The differences in findings by the studies on the European population may be attributed to the differences in definition criteria for hyperopia, population age group and sample size. Similarly, two studies in Australian children with different age ranges reported different prevalence estimates for hyperopia. The study by Ip et al.[27] conducted with children between the ages of 11 and 14 years reported a prevalence of 5.0%, whereas Fotedar et al.[28] reported a 3.5% prevalence of hyperopia in 12-year-old children.

Prevalence of myopia

African population

Except for two studies in the United States,[23,24] myopia was defined as -0.50 D or worse in all the studies reviewed (Table 2). However, measuring techniques and participants' ages in addition to geographic variations appear to have an influence on the reported prevalence of myopia, with a significantly higher prevalence in Asian children compared with other ethnic backgrounds. For studies on African populations, Mehari and Yimer[11] and Wajuihian and Hansraj[13] included older children and reported a higher prevalence of myopia (6.0% and 7.1%, respectively) compared with the reported 2.7% by Atowa et al.[10] with younger children. Although the prevalence of myopia increases with age because of more involvement and longer duration of near-work activities during high school years,[10,13,19,20] the non-cycloplegic refraction technique applied by the two studies[11,13] tends to overestimate myopia in children.[19] However, Ovenseri-Ogbomo and Assien[12] reported a prevalence of 2.6% in children aged between 11 and 18 years. The low prevalence despite older children and the performance of non-cycloplegic retinoscopic refraction may be related to the use of least myopic corneal meridian in quantifying myopia.

Asian population

Variations in the prevalence of myopia in Asian children have also been widely reported, with considerable differences existing between various countries and study locations. Overall, the studies reviewed showed that myopia is more prevalent in East Asian and South-East Asian countries than in other parts of the world. For instance, studies by He et al. using cycloplegic autorefraction found that 35.1% and 42.4% of school-age children in rural[14] and urban[15] China, respectively, were myopic. These values are higher when compared with the estimates reported for South-East Asian population, such as 20.7% in Malaysia[18] and 20.4% in Vietnam.[19] In contrast, studies on the South Asian population reported a much lower prevalence of myopia than other Asian regions. In rural India,[16] myopia prevalence was 4.1% and in urban India[17] it was 7.4%. Two studies in the Middle East reported a prevalence of 6.5% (Saudi Arabia)[20] and 14.1% (Iran)[21] in children in the age range of 6–15 years.

TABLE 2: Prevalence of myopia among school-age children in selected countries from various geographic regions.

Study	Country	Ethnicity	Age (years)	Sample size (*N*)	Definition criteria	Measurement technique	Prevalence (%)
Atowa et al.[10]	Nigeria	African	8–15	1197	SER ≤ -0.50	Cycloplegic autorefraction	2.7
Ovenseri-Ogbomo and Assien[12]	Ghana	African	11–18	595	SPH ≤ -0.50	Non-cycloplegic retinoscopy	2.6
Mehari and Yimer[11]	Ethiopia	African	7–18	4238	SER ≤ -0.50	Non-cycloplegic retinoscopy	6.0
Wajuihian and Hansraj[13]	South Africa	African	13–18	1586	SER ≤ -0.50	Non-cycloplegic autorefraction	7.1
Aldebasi[20]	Saudi Arabia	Middle East	6–13	5176	SER ≤ -0.50	Cycloplegic autorefraction	6.5
Norouzirad et al.[21]	Iran	Middle East	6–15	1130	SER ≤ -0.50	Non-cycloplegic retinoscopy	14.9
He et al.[14]	Rural China	Asian/East	13–17	2454	SER ≤ -0.50	Cycloplegic autorefraction	42.4
He et al.[15]	Urban China	Asian/East	5–15	4347	SER ≤ -0.50	Cycloplegic autorefraction	35.1
Paudel et al.[19]	Vietnam	Asian/South East	12–15	2238	SER ≤ -0.50	Cycloplegic autorefraction	20.4
Goh et al.[18]	Malaysia	Asian/South East	7–18	4634	SER ≤ -0.50	Cycloplegic autorefraction	20.7
Dandona et al.[16]	Rural India	Asian/South	7–15	3976	SER ≤ -0.50	Cycloplegic autorefraction	4.1
Murthy et al.[17]	Urban India	Asian/South	5–15	6447	SER ≤ -0.50	Cycloplegic autorefraction	7.4
Zadnik et al.[24]	USA	Caucasian	6–14	2583	SER ≤ -0.75	Cycloplegic autorefraction	10.1
Kleinstein et al.[23]	USA	Caucasian	5–17	2523	SER ≤ -0.75	Cycloplegic autorefraction	9.2
O'Donoghue et al.[25]	United Kingdom	Caucasian	6–7	392	SER ≤ -0.50	Cycloplegic autorefraction	2.3
			12–13	661			17.1
Czepita et al.[26]	Poland	Caucasian	6–18	5724	SER ≤ -0.50	Cycloplegic retinoscopy	13.1
Fotedar et al.[28]	Australia	Caucasian	12	2233	SER ≤ -0.50	Cycloplegic autorefraction	9.8

SER, spherical equivalent refraction.

Caucasian population

As with studies on African and Asian populations, the prevalence of myopia in Caucasian children was also influenced by the definition criteria and participants' ages (Table 3). A comparatively similar finding was reported by two studies[18,24] in the United States that defined myopia as -0.75 D or worse in participants of similar age group. However, studies in Europe, which defined myopia as SER ≤ -0.50 D, reported varied results, possibly because of dissimilar age ranges of the study participants. O'Donoghue et al.[25] found that 2.3% of children who are between 6 and 7 years old are myopic compared with 17.7% of 12 to 13-year-olds. Czepita et al.[26] reported a myopia prevalence of 13.0% in children between 6 and 18 years in Poland, which was 1.9% in 6-year-olds and 31.9% in 18-year-olds. In Australia, Fotedar et al.[28] found a myopia prevalence of 9.8% in 12-year-old students.

Prevalence of astigmatism

African population

Previous studies exploring the prevalence of astigmatism in school-age children have also shown marked variations in prevalence levels (Table 3). Although most of the studies[10,11,12,13] on African children defined astigmatism as cylindrical error of at least -0.75 D, different measuring techniques (retinoscopy or autorefraction) were applied in the detection of astigmatism. For studies that performed autorefraction technique, Atowa et al.[10] who applied cycloplegia reported a higher estimate compared with Wajuihian and Hansraj[13] who utilised non-cycloplegic refraction method, which was followed by subjective refraction. Similarly, two studies that utilised non-cycloplegic retinoscopic technique reported varied results. Ovenseri-Ogbomo and Assien[12] with a smaller sample size and older children reported a higher prevalence value compared with Mehari and Yimer[11] with a larger sample size and younger children.

Asian and Caucasian populations

The studies on Asian populations were consistent in the definition of astigmatism and the use of cycloplegic objective measurement methods. In most of the studies, both objective (retinoscopy and autorefraction) methods were applied and the results showed that autorefraction technique yielded higher values compared with the retinoscopic technique (Table 3). In using cycloplegic retinoscopic technique, the prevalence of astigmatism ranged between 3.8% and 33.6%, while with cycloplegic autorefraction technique the estimates ranged between 9.7% and 42.7%. Overall, a higher prevalence of astigmatism was reported for East Asian children compared with other regions of Asia as well as other continents (Table 3).

For studies on Caucasian children, the prevalence of astigmatism was also influenced by the definition criteria and measurement methods (Table 3). Two studies[23,29] that applied cycloplegic autorefraction method and defined astigmatism as cylindrical error of at least -1.00 D reported comparatively similar findings, whereas a study in Poland[26] which defined astigmatism error of at least -0.50 D determined by cycloplegic refraction reported a prevalence of 4.0% in children aged between 6 and 18 years.

Age and refractive errors

Most of the studies showed that the prevalence of hyperopia decreases significantly with age.[14,15,18,20,21,24,25,26] In using the same RE definition and logMAR protocol to assess children aged 5–15 years, Murthy et al.[17] and He et al.[15] revealed that early significant hyperopia decreases rapidly from age 5 years to an insignificant level by the age of 15 years, with a noticeable myopic shift taking place around age 12. This agrees with the views of Saunders et al.[30] and Borish[31] that infants are usually born with some amount of hyperopia which tends towards emmetropia and possibly myopia as they grow older.

Regarding myopia, several studies reviewed were consistent in reporting a significant age increase in the prevalence of myopia.[15,16,17,18,19,20,21,24,25,26] Atowa et al.[10] reported that 12 to 15-year-old children had a 1.2 times higher risk of developing

TABLE 3: Prevalence of astigmatism among school-age children in selected countries from various geographic regions.

Study	Country	Ethnicity	Age (years)	Sample size (*N*)	Definition criteria	Measurement technique	Prevalence (%)
Atowa et al.[10]	Nigeria	African	8–15	1197	≤ -0.75	Cycloplegic autorefraction	4.4
Ovenseri-Ogbomo and Assien[12]	Ghana	African	11–18	595	≤ -0.75	Non-cycloplegic retinoscopy	6.5
Mehari and Yimer[11]	Ethiopia	African	7–18	4238	≤ -0.75	Non-cycloplegic retinoscopy	2.0
Wajuihian and Hansraj[13]	South Africa	African	1318	1586	≤ -0.75	Non-cycloplegic autorefraction	3.0
Aldebasi[20]	Saudi Arabia	Middle East	6–13	5176	≤ -0.75	Cycloplegic autorefraction	11.2
He et al.[14]	Rural China	Asian/East	13–17	2454	≤ -0.75	Cycloplegic autorefraction	25.3
He et al.[15]	Urban China	Asian/East	5–15	4347	≤ -0.75	Cycloplegic retinoscopy	33.6
						Cycloplegic autorefraction	42.7
Paudel et al.[19]	Vietnam	Asian/South East	12–15	2238	≤ -0.75	Cycloplegic autorefraction	20.4
Goh et al.[18]	Malaysia	Asian/South East	7–18	4634	≤ -0.75	Cycloplegic retinoscopy	15.7
						Cycloplegic autorefraction	21.3
Dandona et al.[16]	Rural India	Asian/South	7–15	3976	≤ -0.75	Cycloplegic retinoscopy	3.8
						Cycloplegic autorefraction	9.7
Murthy et al.[17]	Urban India	Asian/South	5–15	6447	≤ -0.75	Cycloplegic retinoscopy	7.0
						Cycloplegic autorefraction	14.6
Kleinstein et al.[23]	USA	Caucasian	5–17	2523	≤ -1.00	Cycloplegic autorefraction	28.4
Czepita et al.[26]	Poland	Caucasian	6–18	5724	≤ -0.50	Cycloplegic retinoscopy	4.0
Robaei et al.[29]	Australia	Caucasian	12	2353	≤ -1.00	Cycloplegic autorefraction	21.8

myopia than those aged 8–11 years. Near-work activities, such as reading, writing, computer use and playing video games, have been indicated in the significant increase in the prevalence of myopia as well as increased risk for developing myopia.[32] The prevalence of astigmatism has been found to vary with age. Some studies[28,33] associated astigmatism with older age children, while others[14,15,18,26] associated astigmatism with younger age children.

Gender and refractive errors

It has been suggested that, on average, women have shorter axial length when compared with men.[27,34,35] As such, women are more likely to be hyperopic when compared with men. These findings are consistent with the observations of studies in China,[14,15] India[17] and Malaysia[18] that found more hyperopia in women than in men. In Australia,[27] the significant increase in hyperopia prevalence with women compared with men were only found in younger children (6 years old) and not in older children (12 years old). In contrast, a study in Saudi Arabia[20] found that the prevalence of hyperopia was higher in boys than in girls. For the study participants, physiological maturation occurred faster in girls than in boys.[20] Several studies[10,11,13] on African children found no difference between gender and myopia risk, whereas studies in Asia[14,15,17,18,20] revealed that the prevalence of myopia was significantly higher in female subjects than in male subjects. Some studies have also found astigmatism to be significantly higher in boys than in girls.[20,21] He et al.[15] and Dandona et al.[16] reported contrary results.

Limitations of previous studies

There are some limitations associated with the studies reviewed, which may have influenced the interpretation of their findings and conclusions. All studies except Atowa et al.[10] and Wajuihian and Hansraj[13] failed to indicate how sample sizes were derived. The use of small sample sizes,[21,24] limited age range of participants[25,28,29] and non-use of cycloplegia or the plus lens test to screen for latent hyperopia[11] may have affected the results of some studies. Although the study by Ovenseri-Ogbomo and Assien[12] applied a random sampling approach at classroom level, the use of convenience sampling technique in selecting the participating schools may limit the generalisation of findings of the study.

Discussion

This literature review has highlighted the prevalence of RE in school-age children in various countries. However, inconsistent methods were applied across studies in identifying children in need of refraction. Although a VA threshold of 6/9 or less can reliably detect myopia in school-age children, there is no reliable VA threshold for clinically significant hyperopia and astigmatism. High amounts of hyperopia (> 5 D) and astigmatism (> 1.5 D) have been reported in children who were able to read 6/6 (20/20) on the VA chart.[20,21] Reports indicate that uncorrected hyperopia, which is less likely to cause a reduction in VA, is a risk factor for strabismus, amblyopia and angle closure glaucoma.[4,5,22] Therefore, to determine the actual prevalence of RE in a study sample, refraction should be performed on all children irrespective of VA.

There is no consensus on the most appropriate method for the measurement of RE. Some studies reported myopia and hyperopia in terms of the spherical component, while others reported them based on the SER (sphere + ½ cylindrical components). Although an objective method (retinoscopy or autorefraction) was the preferred measuring technique, the use of cycloplegia was not a constant factor. Instead some studies utilised the plus lens test to screen for latent hyperopia because cycloplegia was contraindicated as accommodative tests were also included in their evaluations or for concerns of ethical issues.[11,12,13] For the studies that adopted the plus lens technique, analysis was based on the subjective findings, while that of the cycloplegic refraction technique was based on cycloplegic findings. In addition, most studies identified an individual as having RE after binocular examination, but others use the eyes separately as unit samples or examine only one of the eyes (usually the right eye) relying on evidence of good correlation between ametropia in both eyes. To facilitate comparison of findings among studies, a better approach will be to develop a standardised method of measuring RE in children.

A wide variety of criteria were applied in the diagnosis of individuals with different types of RE, with many studies focusing mainly on RE that significantly affects VA (Tables 1–3).[10,11,12,13,14,15,16,17,19,20,21,23,24,25,26,27,28,29] Overall, myopia was defined as -0.50 D or -0.75 D or more; hyperopia definition ranged between 0.50 D and 2 D and astigmatism varying from -0.50 D to -1 D. Given the progressive nature of myopia during the teenage years,[10] all myopic eyes are at risk for complications.[4] Likewise, visual discomfort is more common in children with low degrees of hyperopia and astigmatism because of excessive use of accommodation to maintain normal vision.[5,6] For high school children who are engaged in intensive reading and longer duration of near-work activities, it will be difficult to comfortably sustain normal vision for long periods of time, especially at close distances where reading takes place. As a result, the child may lose interest in reading and other near-vision-related academic tasks which may affect his or her school performance. It is, therefore, important to include low categories of RE in prevalence estimations as this will provide comprehensive data for proper planning and implementation of intervention strategies.

The studies[14,15,18,20,21,24,25,26] consistently reported a significant age-related decrease in hyperopia prevalence and a significant age-related increase in prevalence of myopia. Hyperopia in infants usually decreases to emmetropia as they grow, with myopia starting to develop around age 6 years when school begins.[29,31] However, myopia becomes significant during high school and teenage years when there is rapid growth and heavier load of near work.[10,19,20] Regarding gender and different types of REs, variations in trends were observed for men and women by some studies, which may be partly related to gender representativeness in these studies. Differences in growth spurts and maturation rate between genders may also explain the gender differences in the prevalence of REs. Peak height velocity is associated with earlier axial length peak and spherical equivalent velocity[20,36] and some studies noted that peak height velocity was commonly earlier in women.[14,15,17,20] In these studies, physiological maturation occurred faster in female participants than in male participants; therefore, a higher prevalence of myopia was found in women and a higher prevalence of hyperopia was found in men as women would have already undergone emmetropisation with men lagging slightly behind. Cultural distinctiveness and lifestyle characteristics, such as number of hours spent on near work and outdoor activities, between men and women have also been shown to affect gender pathogenesis of RE in each geographic area.[10,20] It has been suggested that hyperopic SER is more common in children who dedicated less time to near activities and more time to outdoor activities.[37]

The disparity in the RE prevalence by regions and study locations can be explained by ethnicity and geographical factors. Hyperopia prevalence was low in African and East Asian populations compared with Caucasians. Similarly, myopia and astigmatism were higher in East and South-East Asian populations compared with other regions. Reports indicate that South-East Asian children are genetically predisposed to having myopia because of the influence of ethnicity, family history of myopia and schooling system.[10,19,38] About ocular components, axial length in both African and Asian children is longer than in Caucasian children.[38] In addition, reports show that populations with high myopia prevalence rates, like in China, generally have a low hyperopia prevalence.[13,14,15,31] The higher prevalence of hyperopia and low prevalence of myopia in rural populations may be because of their involvement in more outdoor activities. Competitive education may also be a contributory factor to the higher prevalence of myopia reported for East Asian and South-East Asian children. The implications are that, even within the same country, RE estimates in one population cannot necessarily be extrapolated to another population.

Conclusion

This article indicates that the prevalence of RE in school-age children is a public health concern in the various study locations. The methodological differences, such as inappropriate study designs, variations in defining and quantifying the RE and improper measuring techniques, complicate the comparison of the corresponding findings. The article highlights the gaps in knowledge in this area of study, including the non-inclusion of low categories of RE, non-inclusion of all children for refraction within some studies, non-application of cycloplegia or the plus lens test, limited age range, small sample size and inappropriate sampling methods. The review of the literature also reveals regional variations in the prevalence of RE, which may be related to differences in socio-economic development, race, cultural factors as well as availability of interventions. Considering the implication of visual anomalies for academic achievement, as well as overall well-being, this review could provide useful information for policymakers and can help in planning, provision and evaluation of child health services. Future research should include near vision anomalies which are capable of affecting school performance even when VA is not affected. This would assist in developing broad interventions and management strategies targeting these conditions in school-age populations.

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Competing interests

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Authors' contributions

U.C.A. wrote the article. R.H. and S.O.W. provided feedback on the structure and content of the manuscript.

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