Refractive error, amblyopia and ocular alignment among schoolchildren in Saudi Arabia

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Abstract

Background: Normal visual development starts early in childhood, and achieving optimal corrected visual acuity, binocular function and ocular alignment is key to healthy visual maturation.

Aim: To assess the prevalence of refractive error, amblyopia and ocular alignment among school children in Qassim Region, Saudi Arabia.

Methods: Using a modified refractive error study in school-aged children protocol, we collected data from 850 children aged 6–17 years from 6 randomly selected schools in Qassim, Saudi Arabia, between March and May 2024. We assessed refractive error with a noncycloplegic autorefractometer, ocular alignment with the alternate cover test and prism bar, and anterior/posterior segments using a slit-lamp and ophthalmoscopy. We analysed the data using SPSS version 25 and further analysed the prevalence of refractive error amblyopia and ocular misalignment using MedCalc for Windows. $P < 0.05$ was regarded as statistical significance.

Results: The overall prevalence of refractive error was 61.1%, including hyperopia (30.5%), myopia (19.3%) and astigmatism (11.3%). Most children (68.0%) had orthophoria at near fixation. Phoria was found in 25.5% of children, predominantly exophoria (19.8%), while strabismus was present in 6.5%, mainly esotropia (4.8%). Ocular alignment status was significantly associated with age and gender ($P < 0.001$). Amblyopia affected 8.4% of the children, with higher prevalence in males ($P = 0.034$) but there was no significant association with age ($P = 0.094$). Children without previous eye examinations were at higher risk for developing amblyopia (odds ratio = 3.58, $P < 0.001$).

Conclusion: The high prevalence of refractive error, amblyopia and strabismus in this study indicates an increased risk of visual disorder among the children. There is therefore a need for routine vision screening and improved access to paediatric eye care.

Keywords: refractive error, visual impairment, amblyopia, myopia, visual acuity, hyperopia, astigmatism, schoolchildren, Saudi Arabia

Citation: Alrasheed SH, Alhoshan SA, Alnasser BN. Refractive error, amblyopia and ocular alignment among schoolchildren in Saudi Arabia. East Mediterr Health J. 2026;32(3):149–155. https://doi.org/10.26719/2026.32.3.149.

Received: 08/09/2025; Accepted: 01/10/2025

Introduction

Vision plays a crucial role in children's overall development. Normal visual development begins early in childhood, and achieving optimal corrected visual acuity, along with proper binocular function and ocular alignment, is essential for healthy visual maturation (*1*,*2*). Any ocular anomalies or visual impairments can disrupt this developmental process, potentially leading to long-term deficits, which can significantly affect quality of life, learning ability, social interaction and overall growth (*3*).

Global estimates indicate that ≈20 million children worldwide, mostly in developing countries, have visual impairments, with 1.4 million being blind and 17.5 million experiencing severe visual impairment (*1*). The Lancet Commission on Global Childhood Eye Health has predicted that childhood blindness will affect > 1.02 million children in the coming years, representing a global prevalence of 4.8 per 10 000 children (*2*). A recent review in the Eastern Mediterranean Region found that prevalence of visual impairment in children was 11.57; mainly due to uncorrected refractive error (51.89%), amblyopia (11.15%) and other causes such as congenital disorders, corneal opacity and cataract (*3*).

Holden et al. projected that by 2050, nearly half the global population of ~4.8 billion people will have myopia (*4*). This imposes a considerable global burden, with a substantial unmet need for visual correction, particularly in low-resource settings (*5*). A recent meta-analysis showed high prevalence of myopia among children in the Eastern Mediterranean Region, especially among older and female children (*6*). A systematic review and meta-analysis reported that the prevalence of hyperopia with cycloplegic refraction was 7.35% among children in the region (*7*). Grosvenor noted that although myopia receives significant attention, hyperopia is often overlooked. He noted few references to hyperopia in major optometry journals, despite its potential to cause serious ocular issues. This under-recognition is partly due to the high accommodative amplitude in children, which makes

hyperopia difficult to detect during standard visual examination (*7*).

Uncorrected refractive errors are a key focus of the global Right to Sight Initiative. The high prevalence of visual impairment often reflects limited access to eye care services in communities (*8,9*). WHO recently launched a new initiative, SPECS 2030, to help nations achieve a 40% increase in the proportion of people with access to appropriate spectacles (*10*). In Saudi Arabia, several studies have reported the prevalence of visual impairment and refractive error. The prevalence of refractive error ranges from 4.5% to 69.7% (*11, 12*), while visual impairment has been reported in up to 27.1% of the population (*10*).

This study assessed the prevalence of refractive error, amblyopia and ocular misalignment among children in the Qassim Region of Saudi Arabia.

Methods

Study design

This cross-sectional, school-based study investigated the prevalence of refractive error, amblyopia and ocular alignment in school children from Qassim Region, Saudi Arabia. Saudi Arabia is divided into 13 regions, each with its own administration, contributing to its geographic, cultural and economic diversity (*13*). The prevalence of refractive error, amblyopia and ocular alignment was assessed using the modified Refractive Error Study in School-aged Children (RESC) protocol. Noncycloplegic refraction was performed to determine refractive error, defined as follows: myopia of at least -0.50 D in 1 or both eyes; hyperopia of at least +1.0 D; and astigmatism of at least -0.75 D (*14*). Unilateral amblyopia was defined as best-corrected VA in the amblyopic eye of 6/12 or worse, with the fellow (sound) eye having a VA of 6/9 or better. Bilateral amblyopia was defined as best-corrected VA of 6/9 or worse in both eyes.

Children aged 6–17 years who attended school on the examination days and whose parents consented to their participation were included in the study. Children who were unable to obtain parental consent or did not agree to participate were excluded.

Study sample

The study sample was chosen using stratified multistage sampling. We assumed a prevalence of refractive error of 18%, based on the estimated prevalence among children in Saudi Arabia (*15*). With a 95% confidence interval (CI) and maximum acceptable random sampling error of 1.5%, the estimated sample size was 542, calculated using the formula below. Considering a design effect of 1.5, the final sample size was adjusted to 813.

$n = (z2\ pq)/d2 = (1.962\times\ 0.18\ \times\ 0.95)/0.0352 = 542 \Rightarrow 542 \times 1.5 = 813$

Considering a nonresponse rate of 10%, the final sample size was 894 children. The study sample was selected from 6 schools (3 for boys and 3 for girls) randomly selected from the Qassim Region. From each grade (*1–6*), one class with at least 24 children was randomly selected.

Stratified multistage sampling ensured balanced representation across gender and grade levels, and a design effect of 1.5 accounted for clustering within schools, thereby improving the accuracy and reliability of prevalence estimates.

Ethics approval

The study was approved by the Qassim University Health Research Ethics Committee (Approval Number: 19-7-06) and complied with the guidelines of the Declaration of Helsinki. Confidentiality of all collected data was strictly maintained, ensuring no personal information was disclosed. All children who underwent eye examinations were included, and each participant and their parents were provided with a written consent form for approval.

Clinical examination

Clinical examination followed the modified RESC protocol. Demographic data were collected, and distance visual acuity was measured using the Snellen tumbling E-chart at 6 m. Objective noncycloplegic and subjective refractions were performed by qualified professionals from Qassim University. Objective measurement of refractive error was obtained using a noncycloplegic autorefractometer (NIDEK autorefractor, model RK-310). The instrument showed high sensitivity and specificity for detecting refractive error in children (*16*). Horizontal ocular alignment was evaluated with the alternate cover test and quantified using a prism bar at a working distance of 33 cm. Ocular motility was assessed in the 9 cardinal positions of gaze to determine extraocular muscle function. Anterior segment examination was performed with slit-lamp biomicroscopy, and posterior segment examination with direct ophthalmoscopy and 90 D fundus biomicroscopy.

Data analysis

The data were entered using Microsoft Excel, cleaned for missing values, and analysed with SPSS version 25 statistical software. Frequencies and percentages were used to describe categorical variables. The presence of refractive error, amblyopia and ocular misalignment was assessed and analysed descriptively using cross-tabulation. The prevalence of refractive error amblyopia and ocular misalignment among children by age groups and gender was further analysed using MedCalc for Windows statistical software. A significance level of $P < 0.05$ was used to determine statistical significance in all analyses.

Results

Demographic characteristics

Of 894 invited children, 850 participated (95.0%) in the study. Ages ranged from 6 to 17 years (mean 9.9 ± 2.7), and 67.2% were male (Table 1). Most children (86.5%) had

Table 1 Demographic characteristics and refractive errors among children in Qassim Region, Saudi Arabia

Demographic characteristics	Refractive error, N (%)	Total, N (%)	P
Age group (years)			
6–10	316 (60.4)	523 (61.5)	
11–17	124 (37.9)	327 (38.5)	0.000
Gender			
Male	337 (59.0)	571 (67.2)	
Female	182 (65.2)	279 (32.8)	0.213
Last examination date			
Never	428 (58.2)	735 (86.5)	
≥1 yr	91 (79.1)	115 (13.5)	0.000
Spectacles			
Yes	62 (93.9)	66 (7.8)	
No	457 (58.3)	784 (92.2)	0.000
Total	**519 (61.1)**	**850 (100)**	

never had an eye examination and 13.5% wore glasses. Refractive error was significantly associated with age ($P < 0.001$) but not gender ($P = 0.213$).

Main ocular complaints

Among the participants, 80.3% attended for a check-up: 10.7% reported blurred vision, 1.8% dry eyes, 2.7% headaches, 1.6% itching, 2.0% redness and 0.9% squinting.

Prevalence of Refractive error

Hyperopia, myopia and astigmatism were found in 30.5%, 19.3% and 11.3% of children, respectively (Table 2). Myopia was more common (27.8%) in older children aged 11–17 years and males (19.6%), while hyperopia was more prevalent (31.0%) in younger children aged 6–10 years and females (33.3%).

Table 3 shows that 68.0% of children had orthophoria at near fixation. Phoria was present in 25.5%, mainly exophoria (19.8%). Strabismus was found in 6.5%, with esotropia being the most common type (4.8%). Ocular alignment was significantly associated with age and gender ($P < 0.001$). Exophoria (20.5%) and esotropia (6.7%) were more common in younger children (6–10 years), while esophoria (7.9%) and esotropia (6.1%) were more frequent in females.

Prevalence of amblyopia among children by age and gender

Amblyopia affected 8.4% of children (95% CI: 6.5–10.3%), with a significant association with gender ($P = 0.034$) but not age ($P = 0.094$) (Table 4). It was more common in males (9.6%) than females (5.7%).

Risk factors for amblyopia

Regression analysis showed that younger children had a higher risk of amblyopia [adjusted odds ratio (OR) = 1.43, $P = 0.149$] (Table 5). Males had lower risk than females (adjusted OR = 0.57, $P < 0.001$). Children without prior eye examination were at greater risk (adjusted OR = 3.58, $P < 0.001$). Amblyopia was less likely in children with hyperopia or myopia than in those with astigmatism ($P < 0.05$).

Discussion

This study assessed refractive errors, amblyopia and ocular alignment among school children in Qassim Region, Saudi Arabia. Uncorrected refractive errors were

Table 2 Prevalence of refractive error by age group and gender among children in Qassim Region, Saudi Arabia

Characteristics	Emmetropia	Hyperopia	Myopia	Astigmatism	Total	P
Age (years)						
6–10	207 (39.6%)	162 (31.0%)	73 (14.0%)	81 (15.5%)	523	0.000
11–17	124 (37.9%)	97 (29.7%)	91 (27.8%)	15 (4.5%)	327	
Gender						
Male	234 (41.0%)	166 (29.1%)	112 (19.6%)	59 (10.3%)	571	0.213
Female	97 (34.8%)	93 (33.3%)	52 (18.6%)	37 (13.3%)	279	
Total	**331 (38.9%)**	**259 (30.5%)**	**164 (19.3%)**	**96 (11.3%)**	**850**	
95% confidence interval	**34.9–43.4**	**26.9–34.4**	**16.5–22.5**	**9.2–13.8**		

P < 0.001

Table 3 **Prevalence of horizontal ocular alignment among children by age group and gender in Qassim Region, Saudi Arabia**

Characteristic	Ocular alignment status					Total	*P*
	Orthophoria *n* = 578	Phoria *n* = 217		Tropia *n* = 55			
		Exophoria	Esophoria	Exotropia	Esotropia		
Age (years)							
6–10	325 (62.1%)	107 (20.5%)	43 (8.2%)	13 (2.5%)	35 (6.7%)		0.000
11–17	253 (77.4%)	61 (18.7%)	6 (1.8%)	1 (0.3%)	6 (1.8%)	327	
Gender							
Male	372 (65.1%)	140 (24.5%)	27 (4.7%)	8 (1.4%)	24 (4.2%)	571	0.000
Female	206 (73.8%)	28 (10.0%)	22 (7.9%)	6 (2.2%)	17 (6.1%)	279	
Total	**578 (68.0%)**	**168 (19.8%)**	**49 (5.7%)**	**14 (1.6%)**	**41 (4.8%)**	**850**	
95% confidence interval	**62.6–73.8**	**16.9–23.0**	**4.3–7.6**	**0.9–2.8**	**3.5–6.5**		

highly prevalent. Most children had orthophoria at near fixation, while ≈25% showed phoria (mainly exophoria). Strabismus was found in 6.5%, mostly esotropia (4.8%), with ocular alignment significantly linked to age and gender. Amblyopia affected 8.4% of children and was more common in males, suggesting a gender-related disparity. Although gender differences in refractive errors and amblyopia were significant, children without previous eye examination had a higher risk of amblyopia, highlighting the need for early screening. However, this association may partly reflect detection bias, as unscreened children are more likely to have undiagnosed amblyopia.

The high prevalence of amblyopia and refractive error highlights the importance of early screening and intervention at the school or community level to prevent long-term visual defects. Aldebasi (*17*) reported a high prevalence of amblyopia in Qassim, mainly due to anisometropic refractive error, and recommended early screening. Similarly, Aljohani et al. identified strabismus and anisometropia as leading causes of amblyopia and noted the importance of timely diagnosis and treatment to reduce the impact on quality of life (*18*).

The prevalence of hyperopia (30.5%), myopia (19.3%) and astigmatism (11.3%) in this study aligns with findings in other countries. A study conducted in São Paulo, Brazil, described comparable patterns of refractive errors among children (*19*). A systematic review and meta-analysis of children in the Eastern Mediterranean Region reported a high prevalence of myopia and recommended early interventions to slow its progression and reduce visual impairment (*6*). Another regional study reported a high prevalence of hyperopia and emphasized early detection and management to prevent amblyopia and strabismus (*7*). Aldebasi reported a high number of children in the Qassim Region with uncorrected refractive errors. He noted that many children were noncompliant with refractive correction because of various addressable factors (*20*). The high prevalence of hyperopia observed in this study may be partly attributed to the benchmark for defining hyperopia as having at least +1.0 D in 1 or both eyes. The predominance of children aged 6–10 years in the sample likely contributed, because some degree of hyperopia at this age is considered physiological and is often compensated by accommodation amplitude without affecting vision. Future studies should consider adopting a higher threshold of +2.0 D and using cycloplegic refraction to improve diagnostic accuracy.

The elevated prevalence of myopia may reflect environmental factors, such as reduced outdoor activity and increased time spent on near tasks. Genetic predisposition may also play a role, given the high rates of consanguineous marriage in the Saudi community. Holden et al. predicted that by 2050 the number of

Table 4 **Prevalence of amblyopia among children by age group and gender in Qassim Region, Saudi Arabia**

Characteristics	Amblyopia	Total	*P*
Age (years)			
6–10	38 (7.3%) 5.1–9.9	523	0.094
11–17	33 (10.1%) 6.9–14.2	327	
Gender			
Male	55 (9.6%) 7.3–12.5	571	0.034
Female	16 (5.7%) 3.3–9.3	279	
Total	**71 (8.4%) 6.5–10.3**	**850**	

Results presented as n (%), 95% confidence interval

Table 5 Impact of demographic characteristics on amblyopia among children (multinomial logistic regression analysis) in Qassim Region, Saudi Arabia

Characteristics	Adjusted OR (95% CI)	*P*
Age group (years)		
11–17	Reference	
6–10	1.43 (0.88–2.34)	0.149
Gender		
Female	Reference	
Male	0.57 (0.32–1.0)	<0.001
Date of last examination		
≥1 yr	Reference	
Never	3.58 (2.10–6.16)	<0.001
Refractive error		
Astigmtism	Reference	
Hyperopia	0.19 (0.10–0.62)	<0.001
Myopia	0.21 (0.10–0.72)	0.001

myopic individuals will reach 4.8 billion, nearly half of the world's population (*4*).

Strabismus has a significant impact on children's quality of life. It disrupts binocular vision development and overall visual function, and it can also negatively affect self-esteem and psychosocial well-being (*21,22*). In this study, the overall prevalence of strabismus was 6.5%, with esotropia accounting for 4.8%. Age-specific analysis showed that esotropia was present in 6.7% of children aged 6–10 years and 1.8% of those aged 11–17 years. This rate is higher than those in previous studies, which have reported prevalence ranging from 1.5% to 2.48% (*23*). Early detection of strabismus, ideally before school age, is crucial to prevent its adverse effects on visual development, learning and quality of life. This study highlights the need for preschool visual screening programmes. Despite the high prevalence of refractive errors, visual impairment and strabismus, comprehensive eye examination in young children is underused. Enhancing early screening could greatly improve visual and developmental outcomes.

In this study the prevalence of amblyopia was higher among males (9.6%) than females (5.7%), and the adjusted odds ratio indicated lower risk in males after controlling for other variables. This suggests the presence of confounding factors such as age, RE type or access to eye care. To effectively address the high rates of refractive errors and amblyopia and binocular vision anomalies among children in the Qassim Region, it is essential to improve access to eye care services. Timely detection and treatment can be facilitated through mobile eye clinics, community outreach programmes and school-based screening programmes. Public health campaigns should emphasize the impact of uncorrected refractive errors, amblyopia and binocular vision disorders on academic performance and overall well-being.

Policy-makers should support subsidized eye care and foster public–private partnerships to improve access and affordability. Further research is needed to explore service barriers and the genetic and environmental causes of refractive errors, amblyopia and binocular disorders. We recommend collaboration with local healthcare providers and nongovernmental organizations in Saudi Arabia to enhance paediatric eye care and implement sustainable solutions. This study highlights high prevalence of uncorrected refractive errors, amblyopia and strabismus among children in the Qassim Region, which underlines the need for timely and routine visual screening at school. We recommend implementing school-based eye health programmes, increasing access to paediatric eye care, raising parental awareness, training teachers to identify eye disorders, and integrating ocular health into school policies. These measures aim to ensure early detection and intervention, reduce the risk of long-term visual impairment, and support healthy visual development in children. Longitudinal studies should be conducted to assess the long-term effects of uncorrected refractive errors and amblyopia on quality of life. Evaluating the effectiveness and cost-efficiency of interventions such as mobile clinics and health education programmes will help guide resource allocation and policy development. These measures will support the development of targeted strategies to reduce the burden of uncorrected refractive errors and improve eye health outcomes among children.

This study had some limitations. First, although cycloplegic refraction is considered the gold standard for assessing refractive errors in children, this study used noncycloplegic methods. This approach may have led to less accurate detection of some refractive errors, particularly latent hyperopia. Nevertheless, noncycloplegic refraction can serve as a practical alternative in screening settings where cycloplegia is challenging to implement. Furthermore, noncycloplegic refraction in children is limited by the active accommodation of the eyes, often leading to overestimation of myopia and underestimation of hyperopia. This reduces diagnostic accuracy, especially in younger children, and may result in misclassification

of refractive errors. Although noncycloplegic refraction is more practical in large-scale screening, it lacks the precision of cycloplegic methods and should be interpreted with caution. Second, the high prevalence of hyperopia observed may be partly attributable to defining hyperopia as +1.0 D or greater in 1 or both eyes. The sample predominantly included children aged 6–10 years; an age group in which mild hyperopia is frequently considered physiological and often compensated by accommodation. This age distribution may have influenced the results. This study did not assess vergence and accommodation functions. Future studies should consider including a broader age range and using cycloplegic refraction to enhance the accuracy of hyperopia detection, while also incorporating detailed amblyopia classification and comprehensive assessments of binocular vision, such as accommodation and vergence. Despite these limitations, this study provides key insights into the prevalence and risk factors of refractive errors, binocular vision disorders and amblyopia in Qassim Region. Its strengths include a large, representative sample, use of the standardized RESC protocol, and comprehensive eye assessments. By assessing refractive errors, amblyopia and strabismus, the study offers a comprehensive view of paediatric visual development. Moreover, the analysis of demographic and clinical associations adds depth to the findings and supports targeted public health interventions.

Conclusion

This study provides valuable insights into the prevalence of refractive errors, amblyopia and ocular alignment among school children in the Qassim Region of Saudi Arabia. The findings indicate a notably high prevalence of hyperopia, myopia and astigmatism, along with significant rates of amblyopia and strabismus, particularly esotropia. These results suggest a potentially considerable future burden of visual disorders in this population if not addressed promptly. The high rates observed indicate the urgent need for early detection and timely intervention to prevent long-term visual impairment and its adverse effects on children's academic achievement, psychosocial development and overall quality of life. To address the high rates of childhood visual disorders, practical steps could include routine school-based visual screening, increased access to paediatric eye care, and greater awareness among parents and educators. These actions support early detection and timely treatment of eye disorders, leading to improved visual outcomes and healthier overall development in children.

Funding: None.

Conflicts of interests: None declared.

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