Prevalence of uncorrected refractive errors among children aged 3-10 years in western Saudi Arabia

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ABSTRACT

الأهداف: لتقييم مدى انتشار أخطاء الانكسار غير المصححة بين الأطفال الذين تتراوح أعمارهم بين 10–3سنوات في المدينة المنورة بالمملكة العربية السعودية، ولتأكيد ضرورة وجود برنامج فحص مرئي على المستوى الوطني للأطفال في سن المدرسة.

الطريقة: وقد أجريت هذه الدراسة المستعرضة بأثر رجعي في المدينة المنورة خلال عام 2015.وتم اختيار عينة عشوائية متعددة المراحل شملت 2121طفلا 10–3)سنوات (من 8رياض أطفال و 8مدارس ابتدائية .تم فحص العينة التي تم اختيارها لتشخيص الأخطاء الانكسارية غير المصححة باستخدام مخطط حدة البصر ومقياس الانكسار التلقائي وفقا للمبادئ التوجيهية الأمريكية .وقد تم تقدير انتشار الخطأ الانكساري غير المصحح ونوعه، وأجريت الفحوص الإحصائية المناسبة، بما في ذلك دراسات الانحدار اللوجستي.

النتائج: بلغ معدل الاستجابة 89.3في المائة .وفي عام 1893، كان معدل انتشار أخطاء الانكسار غير المصححة 95٪) 34.9٪ فاصل الثقة (37.1٪– 32.8٪ =، مع وجود اختلافات كبيرة في مختلف الفئات العمرية .وكان انتشار الاستجماتيزم (25.3٪)أعلى بالمقارنة مع أنيسومتروبيا (7.4٪)، هايبرميتروبيا (1.5٪)، وقصر النظر .(0.7٪)ارتبطت مخاطر أخطاء الانكسار غير المصححة بين الأطفال المدروسين بشكل إيجابي مع العمر، وقد لوحظ ذلك أيضا في الاستجماتيزم، قصر النظر، وانعدام التوازن .وبالإضافة إلى ذلك، كان خطر مد البصر مرتبطا بالفتيان، في حين أن خطر قصر النظر كان مرتبطا بالفتيات.

الخاتمة: وكان معدل انتشار الأخطاء الانكسارية غير المصححة مرتفعا بين الأطفال الذين تتراوح أعمارهم بين 3و 10سنوات في المدينة المنورة، وخاصة الاستجماتيزم، مع وجود اختلافات كبيرة حسب الفئات العمرية .وتعد برامج الفحص البصري التي تستهدف أطفال رياض الأطفال والمدارس االبتدائية أمراً حاسماً للحد من مخاطر الإعاقة البصرية التي يمكن الوقاية منها.

Objectives: To determine the prevalence of uncorrected refractive errors (URE) among children 3-10 years and to affirm the necessity of a national school-based visual screening program for school-aged children.

Methods: This retrospective cross-sectional study was conducted in Medina, Saudi Arabia in 2015. Children were selected through a multistage stratified random sampling from 8 kindergarten and 8 primary schools. Those included were screened to diagnose UREs using a visual acuity chart and an auto refractometer according to American guidelines. The prevalence and types of UREs were estimated.

Results: Of the 2121 children enumerated, 1893 were examined, yielding a response rate of 89.3%. The prevalence of UREs was 34.9% (95% CI = 32.8%-37.1%), with significant differences in different age groups. The prevalence of astigmatism (25.3%) was higher compared to that of anisometropia (7.4%), hypermetropia (1.5%), and myopia (0.7%). Risk of uncorrected refractive error was positively associated with age, and this was noted in astigmatism, myopia, and anisometropia. In addition, the risk of hypermetropia was associated with boys and that of myopia was associated with girls.

Conclusions: The prevalence of UREs, particularly astigmatism, was high among children aged 3-10 years in Medina, with significant age differences. Vision screening programs targeting kindergarten and primary schoolchildren are crucial to lessen the risk of preventable visual impairment due to UREs.

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Refractive errors (RE) such as myopia, hypermetropia, and astigmatism are very common eye disorders. They are caused by an incongruity between the axial length and the refractive power of the optical elements of the eye.[1] Visual problems due to uncorrected refractive errors (URE) in school-aged children have a profound impact on their educational, social, and general quality of life.[2,3] There are several factors that can influence the lack of correction of RE among children. These factors include unawareness of the problem by the child, the family, the community, or the public health authority; inability to afford refractive services; inadequate provision of affordable corrective lenses; and poor compliance to wearing spectacles.[4] Detecting these errors in any age group older than 10 years might be useless because the patient probably has developed incurable preventable amblyopia that leads to blindness. Although yearly vision screening is an important visual impairment prevention strategy, the school health services in Medina do not provide programs for early visual health care.[5] Therefore, it was necessary to conduct a study identifying the proportion of children aged 3-10 years with URE who may be susceptible to developing permanent preventable complications such as amblyopia and emphasizing the importance of early visual health care during primary school to ensure the safety of children's sight.

The objectives of this study are to determine the prevalence of URE among schoolchildren in Medina, Saudi Arabia and whether or not there is a government-funded service to conduct yearly visual screening for school-aged children.

Methods. Medina has a population of approximately 1.7 million and has a total of 805 primary schools and 172 kindergartens. This cross-sectional retrospective study was performed on kindergarten and elementary schoolchildren in Medina from April to August 2015. A random selection of geographically defined clusters was used to identify a representative sample of children 3 to 10 years of age. Eight kindergartens and 4 primary schools of each gender were chosen to represent these clusters, with an average of 130 children in each, and a total of 2121 children were enumerated. Children whose parents did not consent to have their children examined or those children who were uncooperative during the test were excluded. Also, children who did not understand their role in the screening process or those who were already wearing contact lenses or glasses that compensated for their RE to 6/6 were excluded.

Towards the end of the academic year 2014-2015, the research team arranged visits to the defined schools and kindergartens to examine children aged 3-10 years.

The eye examination consisted of 2 sections. 1) Visual acuities were measured by 2 ophthalmologists using the Snellen tumbling E chart. This chart was placed on a wall 6 meters away from the child being examined. Each eye was measured separately, starting with the child's right eye by covering the left eye; then the same procedure was repeated for the left eye by covering the right. Children being tested were instructed to use either hand (with their fingers extended) to show which direction the "fingers" of the E were pointing: right, left, up, or down. The examiners registered the smallest line which the child correctly read more than half the letters.

The visual acuity test was used only to verify the results of the auto refractometer, and it was excluded from the statistical analysis of the study. The outcomes of the visual acuity test supported the results of the auto refractometer in all examined cases as children with RE were found to have poor visual acuity for their age: (i) Children 3-5 years old who failed to correctly identify the majority of the optotypes on the 20/40 line.[6] (ii) Children 5-10 years old who could not read the majority of the optotypes on the 20/32 line with either eye.[6]

2) Refractive errors were measured with a handheld auto refractometer. This device is a fully automated battery-operated handheld binocular refractometer and vision analyzer that achieves non-cycloplegic auto-refraction and measures the refraction of both eyes at the same time at a stable distance of one meter. It also measures gaze direction, ocular alignment, pupil diameter, pupil distance, and the accommodative balance or imbalance between 2 eyes in an all-in-one process. The measurements were taken in a uniform dimly lit environment as accuracy is affected by external sources of light. The children had to keep their eyes wide open and look toward the center of the camera that was held horizontally by the examiner at the same height of the child's eyes at a distance of one meter. Further, the examiners turned on the vision-fixation targets as these lights attracted the child's attention and ensured they looked at the center of the camera. During the measurement, both eyes had to appear within the alignment window as the line connecting the

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pupils should be horizontal to the viewing window. The examiner then pressed and held the start button to enter the focusing phase and adjusted the distance looking at the corneal reflexes until the image came into focus. If there were squares or purple rings around the pupil, the distance was not right, and the examiner moved slightly closer or farther from the child to find the best focus until 2 green circles appeared around the child's pupil linked by a horizontal line. The examiner then released the start button and the auto refractometer automatically displayed the measurements on the screen within approximately 2 seconds. The top part of the screen showed the sphere, cylinder, and axis of both eyes as well as a reliability index (this should be higher than 5; if it was 5 or less, the examiner repeated the measurement) that indicated the measurement's reliability. It also measured the pupil distance and size and the alignment of the eyes. The results were printed on a portable printer, and the report was saved on the device and uploaded to the examiners' computer.

In this study, the RE cut-off points were defined based on the American guidelines for spectacle-prescribing recommendations of the American Association for Pediatric Ophthalmology and Strabismus (AAPOS) as follows:[7] 1) Hypermetropia was ≥+3 Diopters in children of all ages. 2) Myopia was ≥-3 Diopters in children ages 3-6 years, ≥-1 Diopters in children ages 6 and more years. 3) Astigmatism was >2 Diopters in children ages 3-6 years, and >1 Diopter in children ages 6-10 years. 4) Anisometropia was difference ≥1.00 Diopter. 5) With-the-rule (WTR), against-the-rule (ATR), and oblique types of astigmatism were determined to establish the overall prevalence of astigmatism. Comparing the prevalence of the different variations of astigmatism is not the aim of this study.

The referral criteria included children with URE according to the definitions of the different RE used in this study. The printed reports and a list of children who fit the referral criteria were given to the schools' health guides who were asked to refer them to primary health care units to conduct the proper intervention. Ophthalmoscopy to detect ocular pathology was not performed during the study.

A pilot study involving 20 children who were not included in the primary study was conducted to evaluate the feasibility, time, and logistical operations. Moreover, to prevent inter-observer variation in the assessment, all the examiners used the same visual acuity chart at the same distance and the same handheld auto refractometer and practiced the previous procedures under the supervision of one of the authors who is a qualified ophthalmology consultant. Academic search engines such as PubMed and Google Scholar were used to find and access the scientific literature related to our study.

Statistical analysis. The collected data were entered and analyzed using Statistical Analysis System (SAS 9.1, Cary, North Carolina, USA) software package.[8] The data were tabulated and presented using frequencies and percentages. The presence of URE according to vision screening among the studied children was assessed, analyzed, and compared by the children's age and gender using the chi-squared test. For myopia, we used Fischer's exact test to compare the distribution of this refractive error among the studied children by their age groups (**Table 1**) because the number of children was less than 5 in more than 25% of the table cells. *P*-value ≤0.05 were considered statistically significant. Logistic regression analyses was also used to estimate the risk of diagnosed RE (total and by its types) among the studied children by their age groups and gender.

Ethical consideration. This study adhered to the tenets of the Helsinki Declaration for research involving human subjects. Participation in the study was entirely voluntary. Written consent was obtained from the schools' principals, and verbal consent was obtained from the parents and guardians of the children. Ethical approval to conduct this study was obtained from the ethics committee at College of Medicine, Taibah University, Medina, Saudi Arabia. Confidentiality was maintained throughout the study. Guarantees were provided to the parents that the results would be used only for the research purposes.

Results. The present study screened 2121 children. Of them, 228 (10.7%) were excluded (200 were excluded because their parents did not consent, 25 were already wearing glasses, and 3 were uncooperative during the testing). We screened and analyzed 1893 children from 3-10 years of age to determine the frequency and types of URE among them. The sample included 947 boys (50.3%) and 946 girls (49.7%), and the mean age of the studied children was 6.2 ± 1.9 years.

Table 1 shows the distribution and association of different types of URE by age and gender of the tested children. Hypermetropia was present in 1.5% of the children (29 out of 1893), and astigmatism was present in 25.3% (479 out of 1893), including cases of myopic astigmatism; n = 13 (2.7% of all astigmatism cases). Myopia showed the least prevalence at only 0.7% of the children (13 out of 1893), and 140 had anisometropia (7.4%).

Table 2 shows the distribution of the screened children according to the results of vision screening by their age groups and gender. Among the tested children, those with URE (34.9%; 95% CI = 32.8%-37.1%) were found to have poor visual acuity for their age. In contrast, children with good visual acuity for their age did not show any RE during the examination.

Table 3 shows the association of URE by age and gender distribution of the screened children.

Discussion. The presence of URE among schoolchildren is known to affect scholastic achievement and class performance.[9,10] According to our study, the prevalence of URE among children aged 3-10 years in Medina was 34.9% (95% CI = 32.8%-37.1%). This prevalence was significantly higher among children aged 6 to <8 years (53.5%) and those aged 8-10 years (42.5%). Also, detected URE did not vary by eye, and there was no aphakia in the studied group. These prevalence values appear far higher than the prevalence

Table 1 - Association of different types of uncorrected refractive errors (URE) with age and gender of the studied children.

Types of URE	Age (years)			Gender	
	3 - <6	6 - <8	8 - 10	Girls	Boys
Hypermetropia (%)					
Yes (n=29)	12 (1.4)	4 (1.0)	13 (2.0)	7 (0.7)	22 (2.3)
No (n=1864)	853 (98.6)	379 (98.9)	632 (98.0)	939 (99.3)	925 (97.7)
OR	1.00	0.75	1.50	1.00	3.20
95% CI	Ref.	0.24-2.35	0.70-3.20	Ref.	1.40-7.50*
P-value		0.42		0.01*	
Astigmatism (%)					
Yes* (n=479)	118 (13.6)	161 (42.0)	200 (31.0)	241 (25.5)	238 (25.1)
No (n=1414)	747 (86.4)	222 (58.0)	445 (69.0)	705 (74.5)	709 (74.9)
OR	1.00	4.60	2.90	1.00	0.98
95% CI	Ref.	3.50-6.10*	2.20-3.70*	Ref.	0.80-1.20
P value		<0.0001‡		0.86	
Myopia (%)					
Yes (n=13)	2 (0.3)	3 (0.7)	8 (1.3)	8 (0.9)	5 (0.5)
No (n=1880)	863 (99.7)	380 (99.3)	637 (98.7)	938 (99.1)	942 (99.5)
OR	1.00	3.40	5.40	1.60	1.00
95% CI	Ref.	0.60.20.5	1.20-25.0*	0.50-4.50	Ref.
P value		0.06		0.40	
Anisometropia *(%)*					
Yes (n=140)	50 (5.7)	37 (9.7)	53 (8.2)	73 (7.7)	67 (7.1)
No (n=1753)	815 (94.3)	346 (90.3)	592 (91.8)	873 (92.3)	880 (92.9)
OR	1.00	1.75	1.50	1.00	1.10
95% CI	Ref.	1.10-2.70*	1.01-2.17*	Ref.	0.78-1.55
P-value		0.03*		0.59	

*Significant, OR - odds ratio, 95%CI - 95% confidence intervals

Table 2 - Distribution of the studied children according to the results of vision screening by their age groups and gender.

Variables	Number screened	Number UREs (%)	*P*-value
Age (years)			
3 - <6	865	182 (21.0)	
6 - <8	383	205 (53.5)	
8 - 10	645	274 (42.5)	<0.0001*
Gender			
Girls	946	329 (34.7)	
Boys	947	332 (35.0)	0.98
Total	**1893**	**661 (34.9)**	

*Significant, URE - uncorrected refractive errors

Table 3 - Association of uncorrected refractive errors (URE) as result of screening with age and gender of the studied children.

Variables	URE		Odds ratio (95% CI)
	Yes (n=661)	No (n=1232)	
Age (years)			
3 - <6	182	683	1.00 (Ref.)
6 - <8	205	178	4.30 (3.10-5.80)*
8 - 10	274	371	2.80 (2.20-3.90)*
P-value		<0.0001*	
Gender			
Girls	329	617	1.00 (Ref.)
Boys	332	615	1.03 (0.82-1.22)
P-value		0.90	

*Significant, 95% CI - 95% confidence intervals

values reported in other similar Saudi studies (**Table 4**). In comparison to other countries, the prevalence of URE in this study was much greater (**Table 5**). This observed variation from results of the previously mentioned studies (even in studies done in the same country) could be attributed to the differences in the operational definition and cut-off points of RE.

Another possible cause of this difference may be related to environmental influences. The better socioeconomic conditions in Saudi Arabia that affect lifestyle such as television viewing, excessive Internet use, and poor lifestyle habits affect low vision in schoolchildren.[11] A Qatari study conducted on children aged 6 to 18 years found that the proportion of children wearing glasses was higher among those using the Internet/television for more than 3 hours a day.[12] In a recent Saudi study, Ghamdi[13] reported a significant difference between students with and without RE concerning daily hours of computer and TV use. Furthermore, the sample in this study was taken from Medina, which represents a well-urbanized community in the western region of Saudi Arabia. The results of previous studies[14,15] reported that the prevalence of RE was higher among urban than among rural children. In this study, we did not only focus on the magnitude of URE by age and gender, but we also focused on the role of these variables as risk factors for different types of RE. The prevalence of hypermetropia was 1.5%, and its distribution did not show significant variation by age groups, although its risk increased 1.5 times among children aged 8-10 years. The prevalence in boys (2.3%) was significantly higher than that in girls (0.7%), with a significantly increased risk among males (OR = 3.20; 95% CI = 1.40-7.50). A study conducted in Riyadh showed that the prevalence of hypermetropia was 2.1% among 1319 children.[16] Similar prevalence figures were also reported in different countries, such as 1.8% in South Africa[17] and 2.1% in Iran.[18] Astigmatism, the predominant form of URE in the current study, was analyzed as with-the-rule (WTR: 90±30°), against-the-rule (ATR: steepest meridian 180 ± 30°), and oblique (OB: 30-60° or 120-150°). Astigmatism showed a total prevalence of 25.3% with a significant variation by age and gender, and its risk significantly increased among older age groups. A study that measured the relationship between age and astigmatism showed that ATR astigmatism was directly proportional to age.[14] The prevalence of astigmatism, however, was similar among boys, with no association found between gender and astigmatism. This observed prevalence was far higher than those studies reported from Saudi[20] and other countries.[17,18,21,22] However, in previous Saudi study,[20] the prevalence and risk of astigmatism were found to increase with increasing age. The prevalence of myopia was 0.7% and it was higher in children aged 8-10 years (1.3%) and in girls (0.9%). The risk of myopia increased by 3.4 and 5.4 in children aged 6 to <8 years and 8-10 years, respectively. A much higher prevalence was reported in a recent Saudi study[20] conducted in the Qassim province, where the prevalence was 5.8%. However, the study

Table 4 - The reported prevalence of uncorrected refractive errors (URE) in other similar Saudi studies with the number and age of the studied children.

Country	Sample size	Studied age group (years)	Prevalence of refractive errors (%)
Saudi Arabia (Abha)[25]	975 children (boys only)	6 - 12	23.0
Saudi Arabia (Jeddah)[26]	102 children of both genders	Kindergartens	10.7
Saudi Arabia (Al-Hasa region)[27]	2246 children of both genders	6 - 14	13.7
Saudi Arabia (Riyadh)[28]	1319 children of both genders	4 - 8	4.5

Table 5 - The reported prevalence of uncorrected refractive errors (URE) in other similar foreign studies with the number and age of the examined children.

Country	Sample size (children of both genders)	Studied age group (years)	Prevalence of refractive errors (%)
Egypt[29]	1292	7-15	17.5
Qatar[30]	670	Primary schoolchildren (grades 1 to 6)	15.2
Malaysia[31]	4634	7 -15	17.1
Chile[32]	6998	5 -15	15.8
India[33]	18500	5 -15	13.1

reported similar results to our study as the prevalence of myopia was significantly higher in girls compared to boys and the risk was increased by 1.52 among the studied girls. According to an article published by the American Academy of Ophthalmology, myopia shows a greater prevalence in girls around the age of 9 years and continues into adolescence. This pattern of gender difference is highly suggestive of a hormonal role in myopia development.[23] The observation of a high prevalence of anisometropia in our study corroborates various studies on anisometropia. The prevalence of this refractive error showed statistically significant differences in the studied age groups, with the highest prevalence was among children aged 6 to <8 years (9.7%), with the risk increasing in this group by 1.75. Although the prevalence of anisometropia was higher in girls, the difference was not statistically significant. This finding is in agreement with a Taiwan study that found the prevalence of anisometropia was 6% in 1995 and 7% in 2000.[24]

The present study appeared to have many strengths, including being a school-based study with a relatively large sample size and a high response rate (89.3%), which consolidates the research findings. This study might be the first to examine the magnitude of URE in very young children (3-10 years) in Medina. Finally, the association of RE with age groups and gender was examined for different types of RE.

Study limitations. This study was carried out towards the end of the academic year, which is a very limited period to conduct such an important study with a large sample, in addition to the high number of student absences and gender issues. Children with autism, attention deficit hyperactivity disorder (ADHD), or other disorders that might affect their cooperation and understanding of the performed tests were excluded. Schools in more rural areas were also excluded due to transportation difficulties.

The main purpose of this study was to estimate the prevalence of RE and to compare the results of this study with similar studies in Saudi Arabia and other countries to raise the need for implementing a school-based child eye care system in Saudi Arabia. However, this research calls for more similar studies that also focus on the causes, risk factors, and the association between different RE as these factors will help to explain the results, reason them, and contribute to formulating the required prevention procedures that will add more weight to future research.

In conclusion, the prevalence of URE among children 3-10 years old in Medina, Saudi Arabia, is very high, particularly astigmatism, with significant variations by age groups. These findings reflect the need to design an appropriate and adequate vision screening program for kindergarten and primary schoolchildren in Medina for an efficient and sustainable early detection of children with URE. This suggested program may be integrated into school health programs, for instance.

The current school healthcare program in Saudi Arabia lacks any system of child eye care. Therefore, the screening of children for refractive error and visual impairment should be conducted periodically (from kindergarten to grade 6 at a large-scale community level and should be integrated with regular school screening programs and in preschool health screening.

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