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ORIGINAL ARTICLE

Prevalence of astigmatism among 99,515 children in different areas of Xi'an City, China

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Abstract
Purpose: To investigate the prevalence of astigmatism among children in different areas of Xi'an.
Methods: A cross-sectional study was conducted in Xi'an, China, involving children from 139 primary schools, 28 junior high schools, and 10 senior high schools. Data on uncorrected visual acuity (UCVA) and non-cycloplegic spherical equivalent (SE) were collected from March 2023 to June 2023 based on a new screening model by the Department of Ophthalmology of Xi'an Central Hospital. Data from the right eye were included in the statistical analysis. Trend changes in astigmatism prevalence across different areas, educational stages, ages, and genders were analyzed using the X^2 test and trend test.
Results: A total of 99,515 children were included in the analysis. The overall prevalence of astigmatism was 59.3% [95% CI: 59.0% to 59.6%]. The prevalence of astigmatism was higher in urban areas compared to the urban-rural fringe (61.1% [95% CI: 60.6% to 61.6%] vs. 58.3% [95% CI: 57.9% to 58.7%]) (X^2trend = 73.174, $P < 0.05$). Boys had a higher prevalence of astigmatism than girls (59.8% [95% CI: 59.4% to 60.2%] vs. 58.8% [95% CI: 58.6% to 59.0%]) (X^2trend = 11.613, $P < 0.05$). Compared to the primary and senior school, the overall prevalence of astigmatism is most significant during the junior school stage (X^2trend = 1710.133, $P < 0.05$), with rates of 54.6% in primary school, 71.3% in junior high school, and 68.7% in senior high school (X^2trend = 10.694–868.913, $P < 0.05$), among which grade 9 has the highest prevalence (X^2trend = 2766.194, $P < 0.05$). Myopia severity increased with the degree of astigmatism (X^2trend = 2547.677, $P < 0.05$), and boys were more likely to experience worsening myopia with increasing astigmatism compared to girls (X^2trend = 36.878, $P < 0.05$).
Conclusions: Astigmatism was most prevalent among children in Xi'an during junior school, peaking in grade 9. Urban areas showed higher incidence rates than urban-rural ones, and boys had a consistently higher prevalence than girls, with WTR being the most common type.

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Introduction

Astigmatism, a type of refractive error, creates two focal points in the eye, resulting in blurred retinal images and leading to blurred vision. This condition can cause amblyopia during the development of the visual system in children.[1] Studies have even shown that simulated astigmatism can negatively impact children's academic performance.[2] The main symptoms of astigmatism include reduced vision and visual fatigue, with some cases also presenting visual distortion, headaches, and other related issues. The prevalence of astigmatism varies in the literature depending on factors such as region, gender, race, and breastfeeding history.[3] In recent years, the prevalence of astigmatism in children has been increasing, making it a significant clinical and public health concern.

Currently, most large-scale studies on the epidemiology of refractive errors in Chinese children focus on the prevalence of myopia, with less attention given to astigmatism. The literature has shown a significant correlation between astigmatism and the development of myopia.[4–7] Therefore, it is essential to analyze the prevalence of astigmatism across different areas and educational stages in Xi'an, considering related influencing factors and the impact of astigmatism on myopia. This analysis will provide a basis for targeted management of astigmatism and myopia in different regions of Xi'an.

Methods

Study participants

From March 2023 to June 2023, we conducted a cross-sectional study in Xi'an, Shaanxi Province, China, using multistage stratified cluster random sampling. The study targeted three educational stages: primary, junior high, and senior high school. Primary education lasts for six years, junior high for three years, and senior high for three years. We visited all selected schools and invited all students from every grade to participate. A total of 99,808 individuals participated in this screening, among which 29 children were excluded from the study due to missing data, and 264 children were excluded due to wearing orthokeratology lenses. The study ultimately included 99,515 children from 177 schools (139 primary schools, 28 junior high schools, and 10 senior high schools). The screened areas were categorized into urban areas and urban-rural fringe areas. Children with eye conditions such as amblyopia, congenital diseases, systemic diseases, or psychiatric disorders were excluded. The study adhered to the principles of the Declaration of Helsinki and received approval from the Xi'an Central Hospital Medical Ethics Committee (LW-2024–027). Informed consent was obtained from the district, schools, children, and their guardians to ensure smooth study implementation.

Study examinations

Parents provided children's personal information, including name, grade, date of birth, gender, and use of orthokeratology, through a QR code generated by the ophthalmic team. Ophthalmologists and optometrists from Xi'an Central Hospital, all with practicing certificates, conducted uncorrected visual acuity (UCVA) and non-cycloplegic SE tests according to China's "Refractive Error Screening Norms for Primary and Junior High School Students." All staff received standardized training to ensure consistent work norms and standards.

In each educational stage, the right eye was examined first, followed by the left, with results recorded accordingly. During the UCVA assessment, mobile devices were used to scan each child's personal QR code, and UCVA was measured at a distance of 5 m, using a logarithmic VA chart with a 5-point scale. The confirmed UCVA data were then uploaded using the 5-point recording method to the backend system.

For the non-cycloplegic spherical equivalent (SE) examination, we scanned the children's QR codes using mobile phones. Reliable SE measurements were obtained three times for each eye using a computerized optometer (TOPCON KP800, Topcon Co., Tokyo, Japan). The average of the three readings from each eye was then recorded and uploaded to the backend via mobile devices. Quality controllers randomly select 5% of the retesting subjects each day to conduct a retest of visual acuity, as well as non-cycloplegic spherical equivalent. An acceptable testing error is defined as a visual acuity error of $\leq\pm 1$ line and an absolute value of non-cycloplegic spherical equivalent (SE) error of ≤ 0.50 D, with the error rate controlled within 5% to ensure that data collection is accurate and reliable. If abnormal data occurs, visual acuity and non-cycloplegic spherical equivalent will be retested under the same environmental conditions to confirm whether the results are consistent. Additionally, the calibration and maintenance status of the computerized refractometer will be checked to ensure that the equipment is functioning correctly and properly maintained, thereby avoiding abnormal results due to equipment malfunction (Fig. 1).

Definition

China's National Health Commission recommends non-cycloplegic vision screening in school,[8] with astigmatism defined as cylinder power (C) ≤ -0.5D in a non-cycloplegic state. Regular astigmatism types are classified as follows[9]: With-the-rule (WTR) astigmatism, where the maximum refractive power is along the main meridian of $180^{\circ}\pm 30^{\circ}$; Against-the-rule (ATR) astigmatism, where the maximum refractive power is along the main meridian of $90^{\circ}\pm 30^{\circ}$; and oblique astigmatism for other orientations. In this study, myopia in a non-cycloplegic state was defined as VA >0.0 Log MAR and SE ≤ -0.50 diopter (D).[10] The SE refractive error was calculated as the sphere plus half the cylinder. According to the International Myopia Institute (IMI), the degree of myopia[11] is classified as low myopia ($-6.00\ D <$ SE ≤ -0.50 D) and high myopia (SE ≤ -6.00 D).

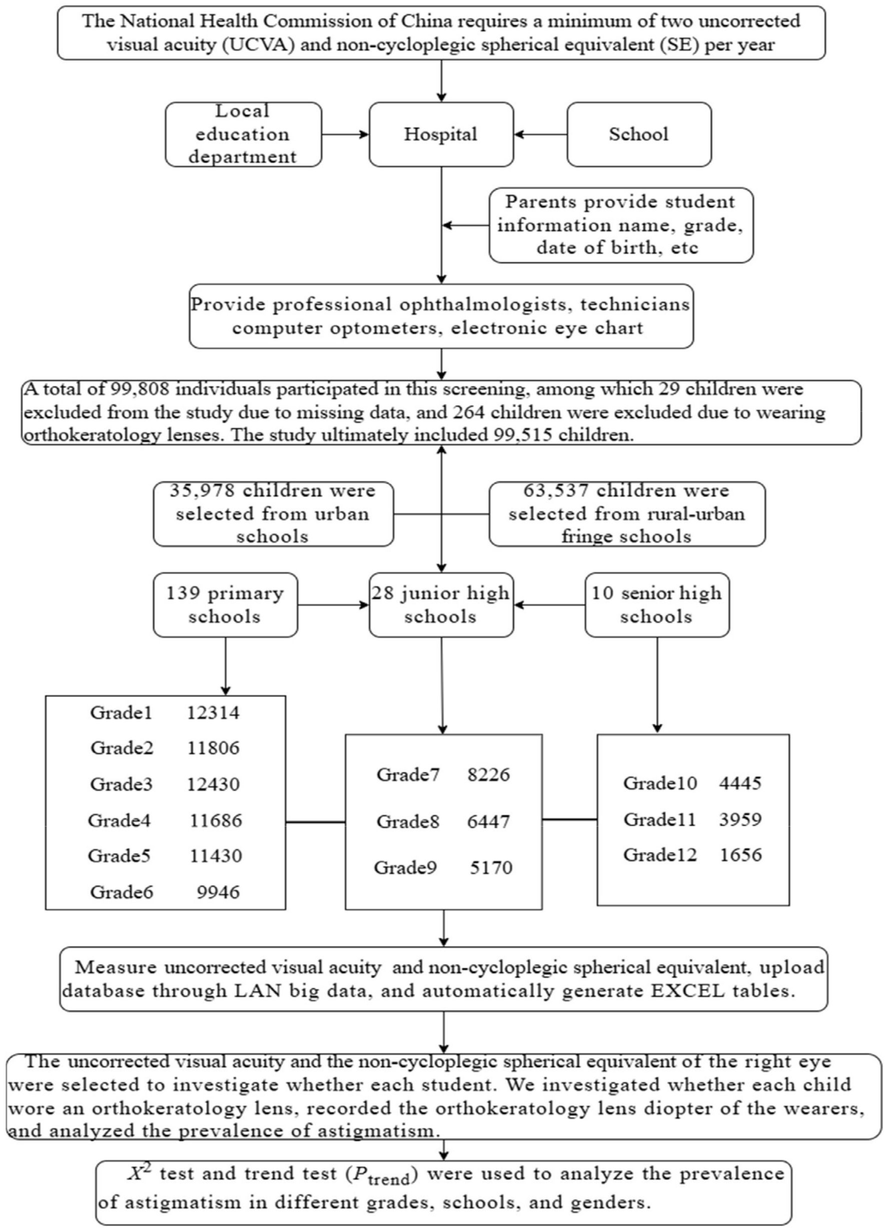

Fig. 1 Data collection and eye examinations.

Statistical analysis

SPSS 18.0 software (Inc., Chicago, IL) was used for statistical data analysis. Categorical data were presented as cases/percentages (%) with 95% confidence intervals (CI), and comparisons between groups were conducted using the X^2 test and trend test (P trend). A *P* value of < 0.05 was considered statistically significant.

Results

Population characteristics

A total of 99,515 children were included in the study, with 35,978 from urban areas and 63,537 from urban-rural fringe areas. The cohort consisted of 48,349 girls and 51,116 boys, distributed across primary (69,612), junior high (19,843), and senior high schools (10,060) (Table 1).

Prevalence of astigmatism in different regions and different education stages

The prevalence of astigmatism was higher in urban areas compared to urban-rural fringes among primary school students (X_{trend}^2 = 305.319, $P < 0.05$). There were no significant differences in astigmatism prevalence between genders in urban areas (X_{trend}^2 = 0.378, P = 0.539), urban-rural fringes (X_{trend}^2 = 0.160, P = 0.689), or overall (X_{trend}^2 = 0.391, P = 0.532). An increasing trend in astigmatism prevalence was observed with advancing grade levels (X_{trend}^2 = 868.913, $P < 0.05$). In primary schools, with-the-rule astigmatism was

Table 1 Characteristics of study participants (*N* = 99,515).

	N	Boy (N, %)	Girl (N, %)	Year	Cylinder power (D)	SE (D)	UCVA	Type of astigmatism (N, %)			*P*
								WTR	ATR	Oblique	
Grade											< 0.05
Grade 1	12,314	6338 (51.5)	5976 (48.5)	6.74±0.48	−0.48±0.64	−0.38±1.25	4.94±0.16	4654 (79.1)	698 (11.9)	530 (9.0)	
Grade 2	11,806	6142 (52.0)	5664 (48.0)	7.82±0.41	−0.48±0.63	−0.62±1.29	4.91±0.20	4795 (83.6)	503 (8.8)	439 (7.6)	
Grade 3	12,430	6373 (51.3)	6057 (48.7)	8.76±0.45	−0.54±0.65	−1.03±1.42	4.85±0.25	5490 (83.4)	531 (8.0)	565 (8.6)	
Grade 4	11,686	5959 (51.0)	5727 (49.0)	9.78±0.44	−0.58±0.69	−1.38±1.61	4.78±0.29	5523 (84.4)	502 (7.7)	520 (7.9)	
Grade 5	11,430	5834 (51.0)	5596 (49.0)	10.77±0.46	−0.65±0.73	−1.73±1.79	4.74±0.32	5918 (85.0)	548 (7.9)	495 (7.1)	
Grade 6	9946	5235 (52.6)	4724 (47.4)	11.80±0.44	−0.70±0.77	−2.05±1.87	4.67±0.34	5390 (86.0)	451 (7.2)	423 (6.8)	
Grade 7	8226	4275 (52.0)	3951 (48.0)	12.78±0.46	−0.79±0.78	−2.40±2.02	4.63±0.36	5075 (87.5)	342 (5.9)	384 (6.6)	
Grade 8	6447	3347 (51.9)	3100 (48.1)	13.79±0.47	−0.81±0.78	−2.66±2.13	4.58±0.37	3977 (87.6)	274 (6.0)	289 (6.4)	
Grade 9	5170	2649 (51.2)	2521 (48.8)	14.74±0.53	−0.86±0.82	−3.07±2.22	4.54±0.38	3282 (86.1)	284 (7.5)	243 (6.4)	
Grade 10	4445	2220 (49.9)	2225 (50.1)	15.72±0.56	−0.82±0.86	−3.17±2.30	4.48±0.41	2667 (88.8)	172 (5.7)	164 (5.5)	
Grade 11	3959	2008 (50.7)	1951 (49.3)	16.69±0.59	−0.83±0.85	−3.35±2.30	4.48±0.42	2377 (87.7)	164 (6.1)	168 (6.2)	
Grade 12	1656	786 (47.5)	870 (52.5)	17.69±0.65	−0.84±0.78	−3.58±2.39	4.50±0.39	1036 (86.5)	68 (5.7)	94 (7.8)	
Education stage											< 0.05
Primary school[a]	69,612	35,981 (51.6)	33,804 (48.4)	9.18±1.75	−0.57±0.69	−1.17±1.65	4.82±0.28	31,770 (83.7)	3233 (8.5)	2972 (7.8)	
Junior high school[b]	19,843	10,312 (51.8)	9604 (48.2)	13.62±0.93	−0.82±0.79	−2.66±2.13	4.59±0.37	12,334 (87.2)	900 (6.4)	9216 (6.4)	
Senior high school[c]	10,060	5023 (49.8)	5055 (50.2)	16.43±0.93	−0.83±0.84	−3.31±2.32	4.48±0.41	6080 (88.0)	404 (5.8)	426 (6.2)	
Region											< 0.05
Urban	35,978	18,470 (51.3)	17,508 (48.7)	9.87±2.63	−0.69±0.73	−1.51±1.91	4.77±0.31	18,787 (85.5)	1662 (7.5)	1531 (7.0)	
Urban-rural fringe	63,537	32,696 (51.5)	30,841 (48.5)	11.32±3.08	−0.62±0.74	−1.77±2.04	4.72±0.35	31,397 (84.7)	2875 (7.8)	2783 (7.5)	
Total	99,515	51,116 (51.4)	48,349 (48.6)	10.80±3.00	−0.64±0.74	−1.68±2.00	4.74±0.34	50,184 (85.0)	4537 (7.7)	4314 (7.3)	< 0.05

[a] The grade range is grade 1−6.
[b] The grade range is grade 7−9.
[c] The grade range is grade 10−12.

the predominant type in urban areas, urban-rural fringes, and overall (X_{trend}^2 = 327.683, $P < 0.05$).

There was no statistically significant difference in the prevalence of astigmatism between urban and urban-rural fringe areas at the junior high school level (X_{trend}^2 = 0.261, P = 0.609). In urban-rural fringe areas, the prevalence of astigmatism was higher in boys than in girls (X_{trend}^2 = 10.218−11.190, $P < 0.05$), while no significant difference was observed between genders in urban areas (X_{trend}^2 = 0.441, P = 0.506). An increasing trend in astigmatism prevalence was noted with advancing grades in junior high school (X_{trend}^2 = 13.255, $P < 0.05$). There were no statistically significant differences in the type of astigmatism across different grades in urban areas, urban-rural fringes, or overall (X_{trend}^2 = 0.06, P = 0.802).

At the senior high school level, the prevalence of astigmatism was higher in urban areas compared to urban-rural fringes (X_{trend}^2 = 40.896, $P < 0.05$). In urban-rural fringes and overall areas, boys had a higher prevalence of astigmatism than girls (X_{trend}^2 = 27.555−40.896, $P < 0.05$). However, there was no statistically significant difference in astigmatism prevalence between genders in urban areas (X_{trend}^2 = 3.751, P = 0.053). The type of astigmatism was predominantly with-the-rule in senior high schools across urban, urban-rural fringe, and overall areas (X_{trend}^2 = 37.122, $P < 0.05$).

Astigmatism status of children in different grades in different regions

In urban areas, the prevalence of astigmatism increased with both the school year (X_{trend}^2 = 435.075, $P < 0.05$) and grade level (X_{trend}^2 = 878.852, $P < 0.05$). The dominant type of astigmatism was with-the-rule across all educational stages in urban areas (X_{trend}^2 = 461.953, $P < 0.05$), with no significant difference in prevalence between genders (X_{trend}^2 = 1.423, P = 0.233).

The prevalence of astigmatism was higher in junior high schools compared to senior high and primary schools in the urban-rural fringe (X_{trend}^2 = 1474.107, $P < 0.05$). The highest prevalence occurred in grade 9 (X_{trend}^2 = 2262.853, $P < 0.05$). In all urban-rural fringe educational stages, with-the-rule astigmatism was the predominant type (X_{trend}^2 = 1578.805, $P < 0.05$), and the prevalence was higher in boys than in girls (X_{trend}^2 = 11.385, $P < 0.05$).

The overall prevalence of astigmatism was greater in urban areas than in urban-rural fringes (X_{trend}^2 = 73.174, $P < 0.05$). Among different educational stages, junior high school had the highest prevalence, surpassing that of primary and senior high schools (X_{trend}^2 = 1710.133, $P < 0.05$), with the peak prevalence occurring in grade 9 (X_{trend}^2 = 2766.194, $P < 0.05$). Across all educational stages, with-the-rule astigmatism was the predominant type (X_{trend}^2 = 90,317.242, $P < 0.05$) (Fig. 2). Boys had a higher prevalence of astigmatism than girls in all areas (X_{trend}^2 = 11.613, $P < 0.05$) (Table 2).

Degree of myopia condition

Low myopia was the dominant type from grade 1 in primary school to grade 12 in senior high school across urban, urban-rural fringe, and overall areas. Myopia severity progressively increased with grade level (X_{trend}^2 = 15.385−207.484, All $P < 0.05$) (Fig. 3), with no significant difference between genders in myopia severity (X_{trend}^2 = 0.097−1.171, All $P > 0.05$).

The effect of astigmatism on myopia

Myopia worsened with increasing astigmatism (X_{trend}^2 = 2603.927, $P < 0.05$), and boys were more likely to experience a greater increase in myopia with worsening astigmatism compared to girls (X_{trend}^2 = 36.878, $P < 0.05$). With-the-rule astigmatism was predominant in both low and high myopia cases (X_{trend}^2 = 343.002, $P < 0.05$) (Table 3). Despite the increase in grade level, with-the-rule remains predominant (X_{trend}^2 = 170.673, $P < 0.05$) (Fig. 4).

Discussion

This study, conducted in collaboration with the Xi'an Education Bureau, aimed to assess the prevalence of astigmatism across different educational stages and regions. The

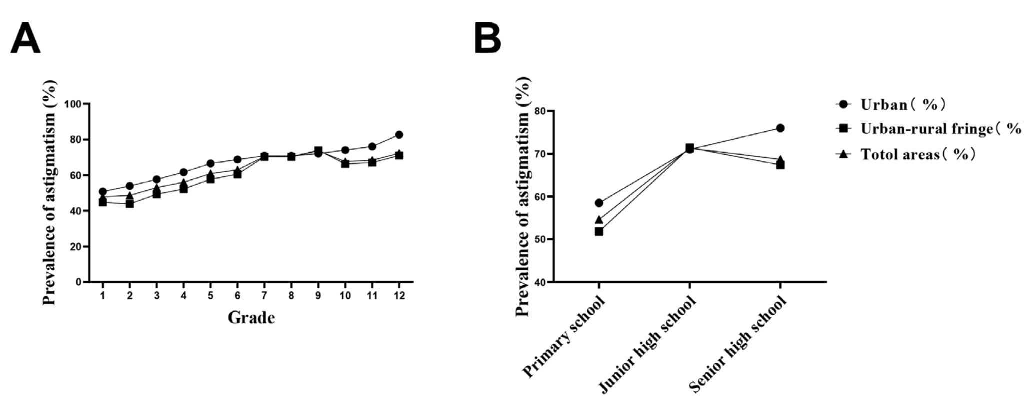

Fig. 2 (A) The prevalence(%) of astigmatism of grades 1−12 in different areas. (B)The prevalence(%) of astigmatism of different education stages in different areas.

Table 2 The prevalence(%) of astigmatism in different regions with different genders.

Gender	Primary school		Junior high school		Senior high school		Total	X_{trend}^2	p
	Urban %(95% CI)	Urban-rural fringe%(95% CI)	Urban %(95%CI)	Urban-rural fringe%(95% CI)	Urban %(95% CI)	Urban-rural fringe%(95% CI)	% (95% CI)		
Girl	58.30(57.5−59.1)	51.70(51.0−52.4)	70.60(58.9−72.3)	70.10(69.0−71.2)	73.70(70.5−76.9)	64.80(63.4−66.2)	58.80(58.4−59.2)	11.61	< 0.05
Boy	58.60(58.2−59.0)	51.90(51.2−52.6)	71.40(69.7−73.1)	72.60(71.6−73.6)	78.10(75.2−81.0)	70.10(68.7−71.5)	59.80(59.4−60.2)		

prevalence of astigmatism in primary schools was 58.4% in urban areas and 51.8% in urban-rural fringes. In junior high schools, the prevalence was 71.0% in urban areas and 71.4% in urban-rural fringes. In senior high schools, the prevalence was 75.6% in urban areas and 67.4% in urban-rural fringes. Overall, the prevalence of astigmatism was 61.1% in urban areas, 58.3% in urban-rural fringes, and 59.321% across all areas.

In this study, the prevalence of astigmatism in Xi'an was higher than reported in similar studies from other regions in China and abroad, such as Guangzhou (33.6%),[12] Xinjiang (36.1%),[9] Hainan (31.9%),[13] Iran (45.3%),[14] China (16.5%).[15] The high prevalence in Xi'an may be influenced by factors such as age, definition of astigmatism, regional differences,[16] genetics,[17] ethnicity,[18] body weight,[19] and other factors. Additionally, the prevalence of astigmatism was higher in urban areas than in urban-rural fringes, consistent with previous studies.[15] This difference may be related to the duration of electronic screen use,[20] eye habits,[7] and exposure to sunlight. Urban children, who are exposed to screens earlier and for longer periods,[21] experience prolonged eye strain,[22] increased eye rubbing,[23] and squinting, leading to a higher risk of myopia and astigmatism. In contrast, children in urban-rural fringes have more opportunities for outdoor activities, which helps prevent the development of astigmatism.[21] Therefore, it is crucial to manage children's screen time, encourage outdoor and long-distance viewing, and reduce academic pressure, especially in urban educational settings.

Among different educational stages, the overall prevalence of astigmatism is highest among junior high school children, followed by senior high school children, while primary school children have the lowest prevalence. The most significant prevalence was observed in grade 9. This trend may be influenced by factors such as the large number of boarding students and left-behind children in the urban-rural fringe of Xi'an, where eye care habits are poorly regulated and medical resources are limited. A study[24] indicated a bias in the accuracy of optometry in urban-rural fringe areas of western China, suggesting that inadequate medical care may lead to delayed correction of astigmatism. Uncorrected astigmatism significantly impairs visual function,[25] adversely affects visual development, and can result in amblyopia.[26] The highest prevalence of astigmatism was found in grade 9 students from urban-rural fringes and overall junior high schools in Xi'an. A study on risk factors for astigmatism in children and adolescents aged 7 to 19 years,[9] found that 15-year-olds had a higher risk of developing astigmatism compared to 7-year-olds. Therefore, it is essential to focus on refractive errors in junior high school students, particularly those in urban-rural fringes. There is a need to actively promote the establishment of vision monitoring records for children and to strengthen astigmatism management. Early warning, detection, and diagnosis are crucial to prevent uncorrected astigmatism from leading to further vision loss.

The overall prevalence of astigmatism was higher in boys than in girls. This finding aligns with previous studies,[9,27] although some research has reported a higher prevalence of astigmatism in girls or found no statistically significant difference between genders.[12,28] Meanwhile, the results of this study suggest that boys with high astigmatism are more

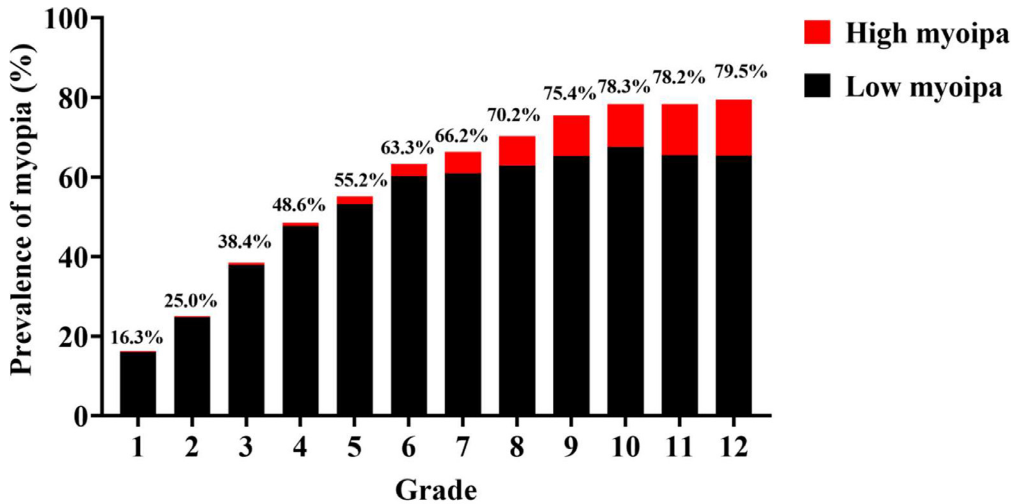

Fig. 3 The prevalence(%) of myopia in grades 1−12.

likely to develop myopia than girls. This conclusion is similar to findings from a study conducted in China,[29] which indicates a significant correlation between male gender and the incidence and severity of myopia or hyperopia with astigmatism. However, whether different genders with varying cylinder power contribute to a faster progression of myopia remains inconclusive, necessitating further research to clarify this relationship.

Additionally, this study observed that myopia worsened as astigmatism increased in children. This conclusion is consistent with relevant research findings. Increased astigmatism in children is associated with the onset and progression of myopia.[30] Furthermore, myopic elongation is more significant when astigmatism > 1.0 D.[7] This may be due to the regulation of ocular development during childhood by visual environmental stimuli and genetic factors,[32] which tends towards emmetropia. The presence of astigmatism causes blurred signals and accommodative lag, leading to decreased accommodative function,[31] potentially resulting in inaccurate axial elongation and the development of myopia.[32] With-the-rule astigmatism is a common type of astigmatism, and the results of this study indicate that it is prevalent across different regions, ages, educational stages, and grades, consistent with earlier studies.[7,12,33] This type of astigmatism may be related to the tighter eyelid structure in Asian populations, which exerts pressure on the cornea.[34] Early intervention for children with astigmatism that contributes to increased myopia is crucial,[35] as managing astigmatism is one of the most important strategies for preventing and controlling myopia.

We analyzed the current prevalence of astigmatism across different regional schools in Xi'an, China. A key strength of this study is the large sample size, which allowed for a rapid collection of UCVA and non-cycloplegic SE data across various educational stages in both urban areas and urban-rural fringes. This provides a representative snapshot

Table 3 The prevalence(%) of astigmatism on the degree of myopia.

Feature	Non-myopia% (95% CI)	Degree of myopia: Low myopia% (95% CI)	Degree of myopia: High myopia% (95% CI)	N	X_{trend}^2	*P*
Degree of astigmatism						
<−1.00D	48.1(47.6−48.6)	49.9 (49.4−50.4)	2.0(1.9−2.2)	35,350	2603.927	< 0.05
<−2.00D	35.1(34.4−35.8)	58.0(57.3−58.7)	6.9(6.6−7.3)	18,279		
<−3.00D	27.2(25.7−28.7)	54.2(52.6−55.8)	18.6(17.3−19.9)	3606		
<−4.00D	25.3(22.8−27.8)	51.5(48.6−54.4)	23.2(20.7−25.7)	1125		
<−5.00D	23.3(19.2−27.4)	54.8(49.9−59.7)	21.8(17.8−25.8)	403		
≥−5.00D	32.4(26.8−38.0)	36.8(31.1−42.5)	30.9(25.4−36.4)	272		
Type of astigmatism						
WTR	40.4(40.0−40.8)	53.9(53.5−54.3)	5.7(5.5−5.9)	50,184	343.002	< 0.05
ATR	53.0(51.5−54.5)	44.9(43.5−46.3)	2.1(1.8−2.6)	4537		
Oblique	49.9(48.4−51.4)	46.9(45.4−48.4)	3.2(2.7−3.7)	4314		
Total	42.1(41.7−42.5)	52.7(52.3−53.1)	5.2(5.1−5.4)	59,035		

WTR: with-the-rule; ATR: against-the-rule;.

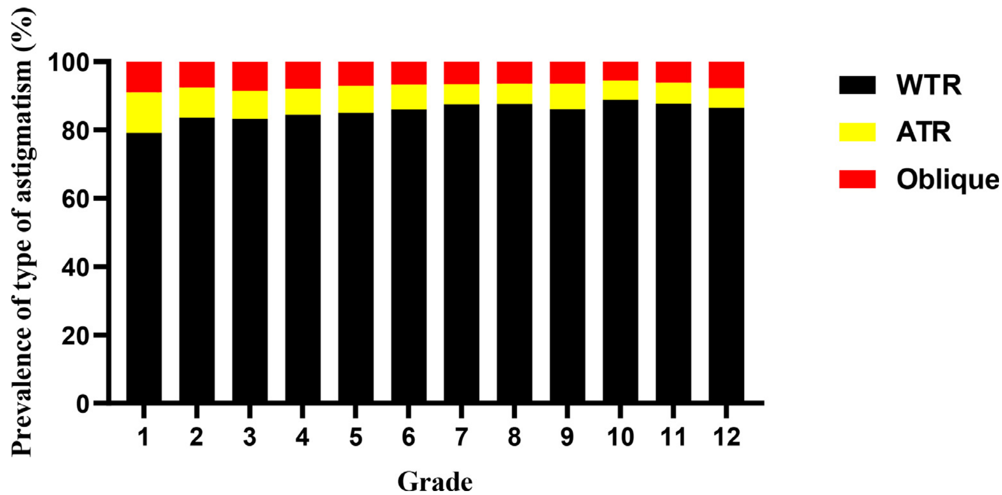

Fig. 4 Different astigmatism types in grades 1–12.

of the prevalence of astigmatism in the region and its relationship with factors such as location, gender, grade, educational stage, and degree of myopia. However, this study has some limitations. First, being cross-sectional, it only provides data from a single point in time, which does not allow for continuous dynamic observation, potentially introducing bias. Second, the use of non-cycloplegic screening may have led to an overestimation of myopia prevalence. Third, according to the national conditions of China, the Chinese government implemented nine years of compulsory education for primary and junior high school stages and required that school-aged children and adolescents enroll for free. As a result, the overall number of students in primary and junior high education stages was relatively large. This study focuses on Xi'an, one of China's key educational metropolises. In urban areas, educational resources are generally more abundant, and students face significant pressure to advance in their studies. Therefore, it is common to see a smaller sample size in urban areas while having a larger sample size in primary and junior high education stages. Therefore, although there are significant differences in the number of individuals across different educational levels, the included population and regions are representative. Additionally, the methodology adopted in this study allows for the rapid acquisition of large sample data, making it more suitable for school screening than cycloplegic optometry.

In conclusion, the overall prevalence of astigmatism was higher in urban areas compared to urban-rural fringes. In the same educational stage, the overall prevalence of astigmatism increases with the advancement of grades, while across different educational stages, the overall prevalence of astigmatism peaks in grade 9 of junior high school. At the same time, the prevalence of astigmatism among boys is consistently higher than that among girls at different educational stages. As astigmatism severity increased, the degree of myopia also worsened. With-the-rule astigmatism was predominantly conformal across axial types.

Astigmatism, one of the most common global vision problems,[25] requires focused regional management[36] across different educational stages in Xi'an. Attention should be given to gender differences in children with astigmatism. To control the occurrence and progression of astigmatism, healthcare providers[39] must implement effective measures, including comprehensive systematic screening and referrals, educators[37,38] advocating for increased outdoor activity time, reducing close-range learning, parents[39] ensuring a healthy diet and sleep for children, and managing screen time to reducing its incidence and impact.

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Declaration of competing interest

State that this study is free from any conflict of interest.

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