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ORIGINAL ARTICLE

Characteristics of refractive development in children aged 4 months to 8 years in urban China: A retrospective screening analysis

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Abstract

Purpose: To conduct a large retrospective study of screening refractive error in young children.

Methods: This retrospective study included children aged from 4 months to 8 years in Daxing District, Beijing, who underwent refractive examinations without cycloplegia. It included a cross-sectional assessment of refractive error screening for all children, and a longitudinal component for a subgroup with data available for two to five visits.

Results: A total of 14,987 children were included in the cross-sectional study. In the group <1 year of age, the percentage of children with a spherical equivalent (SE) >+2.00 D or with cylinder <−1.50 D was 15.25% and 33.24%, respectively. These were significantly higher than for the 1- to 4-year-old group (SE 8.1% higher, cylinder 13.2% higher) ($\chi^2 = 53.57$, $p < 0.001$; $\chi^2 = 790.39$, $p < 0.001$). Furthermore, 34.83% of children in the 0-year-old group had amblyopia risk factors (ARFs). In the 4-year-old group, boys had a significantly longer axial length (AL) than girls (differences in the right and left eyes were 0.53 and 0.56 mm, respectively; $z = 5.48$ $p < 0.001$, $z = 5.80$, $p < 0.001$). AL increased with age, while the AL difference between boys and girls remained stable at 4–8 years of age. The percentage of children aged 5–8 years with myopia in 2020–2021 was significantly higher than that in 2018–2019 ($H = 12.44$, $p = 0.006$). In the longitudinal study of 4406 children (up to 12-month follow-up), annual changes in SE were −0.27, −0.06, 0.19 and 0.13 D between 0 and 3 years, and −0.38, −0.58, −0.70 and −0.75 D between 5 and 8 years.

Conclusions: Children's refractive error varied significantly from ages 4 months to 1 year, with a high proportion having ARFs. Children aged 5–8 years showed a trend towards myopia. The prevalence of myopia in the cross-sectional analysis in 2020–2021 was greater than in 2018–2019. Screening refraction changed minimally over a 12-month period for children aged 1–3 years, but became more myopic for children aged 5–8 years.

KEYWORDS
children, myopia, refraction, retrospective studies, risk factors for amblyopia, significant refractive error

INTRODUCTION

In China, eye care in children has been developing continuously since the 1980s, and children between 0 and 18 years of age receive care. Maternal and child health institutions are the main entities providing eye care and vision examinations aimed at the early detection of common eye diseases and vision problems in children, and when needed,

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timely referral and intervention. Among these tasks, refractive error screening is a primary focus of eye care efforts, with the purpose of preventing myopia and early detection of amblyopia caused by refractive error. Myopia is a common cause of vision reduction. Studies have shown that myopia and high myopia will increase substantially worldwide, affecting 5 billion and 100 million people, respectively, by 2050,[1] especially in Asia,[2] while the myopia rate in China will increase with age.[3] In the field of eye care, particularly in the evaluation of ocular development and refractive error, it is important to assess axial length (AL), particularly in patients with myopia.[4] Furthermore, amblyopia is one of the main causes of visual impairment in children, and early treatment is likely to produce a better treatment outcome.[5] Indeed, significant refractive error is a common cause of amblyopia.[6] Universal screening for refractive error in community-based children in China is usually performed without cycloplegia. The Welch Allyn Spot Vision Screener (hillrom.com) is a device that is often used for screening refractive errors without cycloplegia,[7,8] although it may underestimate spherical hyperopia.[9] Errors in screening refractive errors are larger in children with higher amounts of hyperopia, where differences of up to 4.00 D may be found.[9,10] Therefore, it is particularly important to evaluate the error in data derived from community-based screening without cycloplegia.

In this study, a large sample of children between 4 months and 8 years of age in the Daxing District of Beijing was included. This study focused on screening for refractive errors without cycloplegia. Analysing the results can help understand the characteristics of and trends in ocular development. This analysis provides a crucial foundation for the early detection and timely intervention of abnormal refractive development in children, serving as a significant reference point.[11]

Key points

- In this group of children, refractive error varied significantly during the first 8 years of life, particularly during the first year.
- Children reached emmetropia at 5 years of age, then showed a myopic shift from 5 until 8 years of age.
- Amblyogenic refractive errors were most common in children younger than 1 year of age.
- The changes observed during the COVID-19 pandemic indicate that the environment plays a significant role in refractive error development.

METHODS

Subjects and methods

This was a retrospective study screening for refractive error. The results of infants and children aged from 4 months to 8 years who received eye care and vision examinations in the Department of Ophthalmology of Beijing Daxing Maternal and Child Health Hospital from January 2018 to October 2021 were analysed. Children with ocular conditions (such as congenital glaucoma and congenital cataracts) who had been examined by an ophthalmologist and for whom refractive results were not available were excluded. Participants were grouped according to age when examined as follows: 0-year-old group (<1 year of age), 1-year-old group (between 1 and 2 years of age), 2-year-old group (between 2 and 3 years of age), 3-year-old group (between 3 and 4 years of age), 4-year-old group (between 4 and 5 years of age), 5-year-old group (between 5 and 6 years of age), 6-year-old group (between 6 and 7 years of age), 7-year-old group (between 7 and 8 years of age) and 8-year-old group (between 8 and 9 years of age).

Examination method

Ophthalmic examination of children is conducted mainly to assess refractive conditions without cycloplegia, checking the dioptric sphere (DS) and cylinder (DC) components and calculating the spherical equivalent (SE; $SE = DS + 0.5 \times DC$). Visual acuity was not screened before refraction. Different devices were used to test children 0–4 and 5–8 years of age.

For children aged 4 years and younger, the Welch Allyn Spot Vision Screener (v1.1.50) (hillrom.com) was used by an ophthalmologist to screen both eyes for myopia, hyperopia, astigmatism and anisometropia in a dark room, which was convenient and fast, with high cooperation among the children. According to the manufacturer, the operating ranges of the Spot Screener are −7.50 to +7.50 D for the sphere, −3.00 to +3.00 D for the cylinder and 1°–180° for the axis. Values outside this range display 9.99 on the instrument. Amblyopic risk factors (ARFs) were identified based on the prespecified referral criteria of the Spot instrument (Table 1). Previous studies have demonstrated that, in children under 5 years of age, the device's specificity for detecting ARFs is 86.08%, with a sensitivity of 90.15%.[12]

For children 5 years and older, the Topcon KR8900 autorefractor (topconhealthcare.com) was used, with an operating range of −25.50 to +22.00 D for the sphere, −10.00 to +10.00 D for the cylinder and 1°–180° for the axis. Myopia was defined as a SE ≤−0.50 D, emmetropia as −0.50 D < SE < +0.50 D, mild hyperopia as +0.50 D ≤ SE ≤+2.00 D and hyperopia as an SE >+2.00 D. AL was measured using a Haag-Streit Lenstar LS900 (haag-streit.com) in children aged ≥4 years only. The Lenstar LS900 uses optical interferometry to measure the AL. The refraction and AL in both eyes of each child were examined three times and averaged.

The refraction of the right eye and the proportion of refractive errors among children aged 5–8 years were

TABLE 1 Preset referral criteria for the Spot v.1.1.50 instrument.

Age (months)	Anisometropia (D)	Astigmatism (D)	Myopia (D)	Hyperopia (D)
6–12	≥1.50	≥2.25	≤−2.00	≥3.50
12–36	≥1.00	≥2.00	≤−2.00	≥3.00
36–72	≥1.00	≥1.75	≤−1.00	≥2.50
72–240	≥1.00	≥1.50	≤−1.00	≥2.50

analysed. A cross-sectional comparison of refractive status in children from 2018 to 2021 was performed, and the SEs for those 4 years were compared. This study had two components: a cross-sectional assessment of screening refractive error in all of the children included, and a longitudinal component within a subgroup of children ($N = 4406$) for whom there were data available for two to five visits at 3, 6, 9 and 12 months after the initial visit. The measurement values obtained during the initial visit were defined as the baseline. The longitudinal changes in refraction over 1 year were analysed for the right eye only.

Ethics statement

This study was approved by the Ethics Committee of Tianjin Eye Hospital, China. Written informed consent was obtained after providing a detailed explanation of the purpose and procedures to the parents or legal guardians, in accordance with the Declaration of Helsinki. Any questions or concerns were resolved prior to signing the consent form.

Statistical analysis

Statistical analysis was performed using IBM SPSS software (V.20.0; ibm.com). The normality of the data was assessed through the analysis of skewness and kurtosis. Either an absolute skewness value ≤2 or an absolute kurtosis (excess) ≤4 was used as a reference value for determining considerable normality.[13,14] If the data were normally and equally distributed, one-way ANOVA was used for comparison between multiple samples. The results were expressed as the mean ± SD. In instances where the data were not normally and equally distributed, the significance of differences between two groups was evaluated using the Mann–Whitney *U* rank sum test. For multiple comparison analyses, the Kruskal–Wallis rank sum test was applied. The results are expressed as the median (P25, P75). χ^2 tests were used for comparisons of proportions between multiple samples. $p < 0.05$ was considered to indicate statistical significance.

RESULTS

In total, 14,987 children were included in this study, of whom 7923 (52.9%) were boys with a mean age of 3.17 ± 2.35 years and 7064 (47.1%) were girls with a mean age of 3.27 ± 2.37 years. The difference in age was significant ($z = 2.41$, $p = 0.02$). The number of children in the 0-, 1-, 2-, 3-, 4-, 5-, 6-, 7- and 8-year-old groups was 2783, 1748, 1440, 1936, 2491, 1857, 1252, 805 and 675, respectively. The number of children screened in 2018, 2019, 2020 and 2021 was 3547, 4132, 3418 and 3890, respectively. In the longitudinal study, 4406 children were screened twice or more (at 3, 6, 9 and 12 months following the initial visit). Among them, 2338 were boys aged 2.89 ± 2.36 years and 2068 were girls aged 2.78 ± 2.31 years; this age difference was not significant ($z = 1.36$, $p = 0.17$). The number of participants in the longitudinal study is shown in Table 2.

Refraction status and risk factors for amblyopia among children aged 0–4 years

Groups were divided according to age, and the 0-year-old group was further divided into 4-, 5-, 6-, 7-, 8-, 9-, 10- and 11-month (m) groups. The SE and DC of the children in the age groups were compared. The results indicated that the changes in SE and DC were more pronounced in children <1 year of age, whereas SE and DC were more stable in children aged 1–4 years (Figure 1). In the 4-month-old group, the SE was +0.63 D (0.00, 1.72) for boys and +0.19 D (−0.09, 0.97) for girls. The cylinder was −1.50 D (−2.00, −0.81) for boys and −1.25 D (−2.19, −0.75) for girls. In the 1-year-old group, the SE was +0.88 D (0.50, 1.38) for boys and +0.88 D (0.38, 1.38) for girls. The DC was −0.75 D (−1.00, −0.50) for both the boys and the girls (Table 3). In the 0-year group, 15.25% of the SEs were >+2.00 D, while 33.24% of the DCs were −1.50 D; both of these percentages were higher than for the other age groups ($\chi^2 = 53.57$, $p < 0.001$; $\chi^2 = 790.39$, $p < 0.001$; Figure 2).

Using the criteria outlined above, 34.83% of the children in the 0-year-old age group had ARF, the highest proportion among the age groups (Figure 3a). This was followed by 19.80%, 15.80%, 16.93% and 16.09% in the 1-, 2-, 3- and 4-year-old age groups, respectively. As presented in Figure 3b, astigmatism was the most prevalent ARFs in the 0-year-old group at 18.62%. Hyperopia was most prevalent in the 4-year-old group (16.39%), while anisometropia was most prevalent in the 1-year-old group (20.09%). However, the rate of myopia in children under 5 years old was low (0.59%) (Figure 3b).

Refractive status and prevalence of significant refractive error among children 5–8 years of age

As shown in Figure 4a, the median SE in the 5-year group was 0.00 D (−0.50, +0.50). Median SE in the 8-year group was significantly more myopic (−1.00 D, range −2.00 to −0.25 D) (H = 1146.82, p < 0.001). The AL was longer in the 5- to 8-year-olds (Median [P25, P75]: 22.84 [22.21, 23.45] mm) than the 4-year-old group (Median [P25, P75]: 22.13 [21.54, 22.73] mm) (H = 897.24, p < 0.001). In the 4-year-old group, the AL was 22.43 (21.79, 22.89) mm and 21.91 (21.27, 22.50) mm for boys and girls, respectively. In the 5-year-old group, the respective AL values for boys and girls were 22.76 (22.24, 23.20) mm and 22.16 (21.75, 22.61) mm. In the 8-year-old group, the respective AL values were 23.89 (23.34, 24.50) mm and 23.39 (22.81, 23.98) mm (Figure 5a). Similar trends were observed in the left eye (Figure 5b). In the 4-year-old group, boys had significantly longer ALs in their right eyes than girls (z = −5.48, p < 0.001). At 4–8 years of age, this trend was observed in both the right and left eyes. AL increased with age, while the difference in AL between boys and girls remained relatively stable during the 4- to 8-year period (Figure 5). The changes in astigmatism in children aged 5–8 years were less pronounced than those observed in children under 5 years of age (Figure 4b). We observed that the prevalence of clinically significant refractive error in children 5–8 years of age exceeded 50%, with the highest proportion in the 8-year-old group (Figure 6a). As shown in Figure 6b, clinically significant myopia accounted for the highest proportion, followed by astigmatism, mild hyperopia and hyperopia. In particular, the prevalence of myopia in the 7-year-old group increased markedly, with a 19.6% increase compared to the 6-year-old group.

TABLE 2 Number of children who participated in the longitudinal study as per the number of visits.

Number of visits	N
2	3334
3	838
4	194
5	40
Total	4406

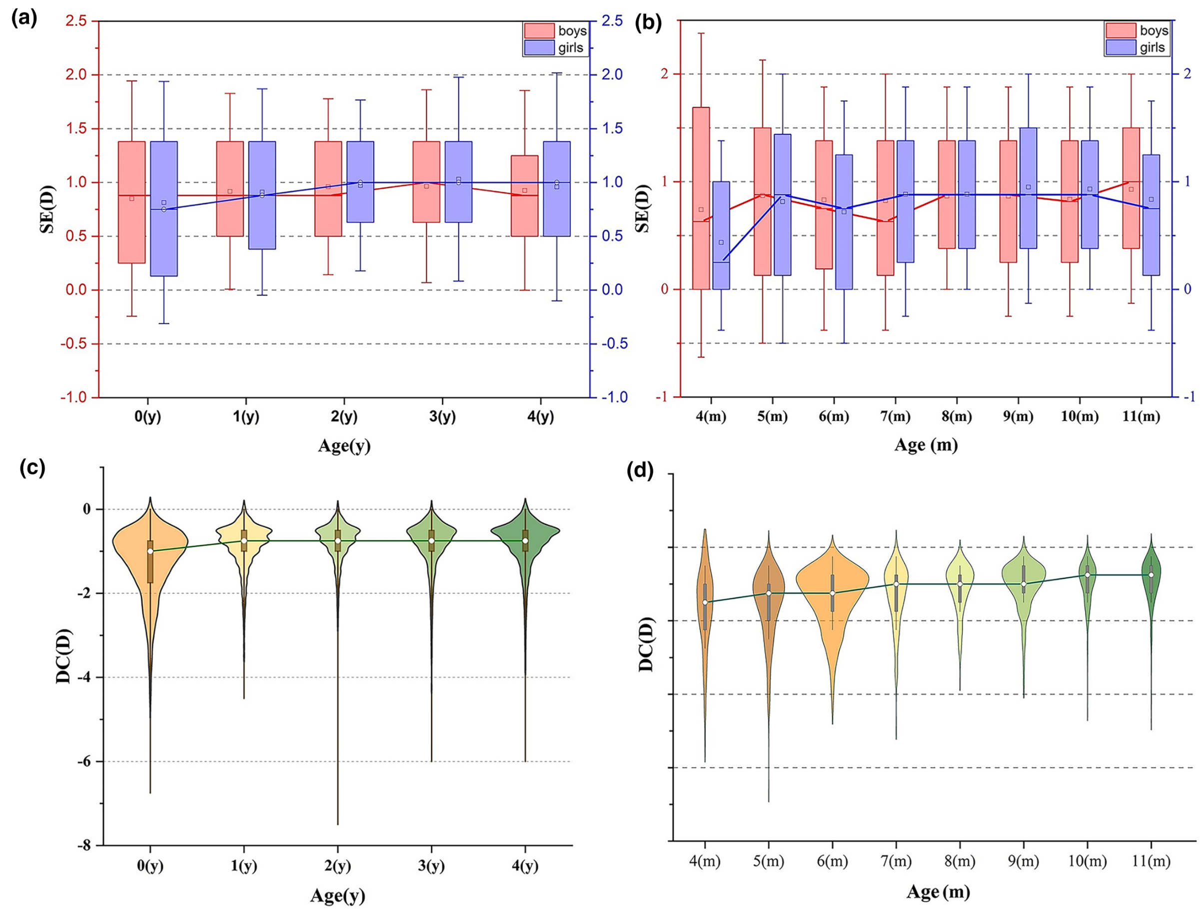

FIGURE 1 Distribution of refractive error in children under 4 years of age who participated in the cross-sectional study. Data are for the right eye only, shown as the median with the 25 and 75 quartiles. (a) Spherical equivalent (SE) for children aged 0–4 years, (b) SE for children aged 4–11 months, (c) Dioptric cylinder (DC) for children aged 0–4 years, (d) DC for children aged 4–11 months.

TABLE 3 Screening refraction results in children from 4 months to 4 years of age.

		Boys		Girls		Boys		Girls	
Age	***N***	**SE (M)**	**(P25, P75)**	**SE (M)**	**(P25, P75)**	**DC (M)**	**(P25, P75)**	**DC (M)**	**(P25, P75)**
4 (m)	150	0.63	(0.00, 1.72)	0.19	(−0.09, 0.97)	−1.50	(−2.00, −0.81)	−1.25	(−2.19, −0.75)
5 (m)	430	0.86	(0.13, 1.50)	0.88	(0.13, 1.47)	−1.25	(−2.00, −0.75)	−1.50	(−2.00, −0.75)
6 (m)	981	0.75	(0.16, 1.38)	0.75	(0.00, 1.25)	−1.25	(−1.75, −0.75)	−1.25	(−1.75, −0.75)
7 (m)	294	0.63	(0.13, 0.63)	0.88	(0.25, 1.38)	−1.25	(−1.75, −0.75)	−1.00	(−1.50, −0.75)
8 (m)	288	0.88	(0.38, 1.38)	0.88	(0.38, 1.38)	−1.00	(−1.25, −0.50)	−1.00	(−1.25, −0.75)
9 (m)	332	0.88	(0.25, 1.38)	0.88	(0.38, 1.50)	−1.00	(−1.25, −0.50)	−0.75	(−1.25, −0.50)
10 (m)	147	0.81	(0.25, 1.38	0.88	(0.38, 1.38)	−0.75	(−1.06, −0.50)	−0.75	(−1.25, −0.50)
11 (m)	161	1.00	(0.38, 1.50)	0.75	(0.13, 1.31)	−0.75	(−1.25, −0.50)	−0.75	(−1.00, −0.50)
1 (y)	1748	0.88	(0.50, 1.38)	0.88	(0.38, 1.38)	−0.75	(−1.00, −0.50)	−0.75	(−1.00, −0.50)
2 (y)	1440	0.88	(0.50, 1.38)	1.00	(0.63, 1.38)	−0.75	(−1.00, −0.50)	−0.75	(−1.00, −0.50)
3 (y)	1936	1.00	(0.63, 1.38)	1.00	(0.63, 1.38)	−0.75	(−1.00, −0.50)	−0.75	(−1.00, −0.50)
4 (y)	2491	0.88	(0.50, 1.25)	1.00	(0.50, 1.38)	−0.75	(−1.00, −0.50)	−0.75	(−1.00, −0.50)
Total	10,398	0.88	(0.50, 1.38)	0.88	(0.50, 1.38)	−0.75	(−1.00, −0.50)	−0.75	(−1.25, −0.50)
	H	34.74		69.52		501.26		538.66	
	p-value*	<0.001		<0.001		<0.001		<0.001	

Note: The data did not conform to a normal distribution and were represented as median (P25, P75). *p*-values were reported for repeated measures Kruskal–Wallis test across various age groups.

Abbreviations: DC, cylinder dioptres; M, median; m, months; *N*, number of records; SE, spherical equivalent in dioptres; y, years.

*Across different age groups, $p < 0.05$ was considered to indicate statistical significance.

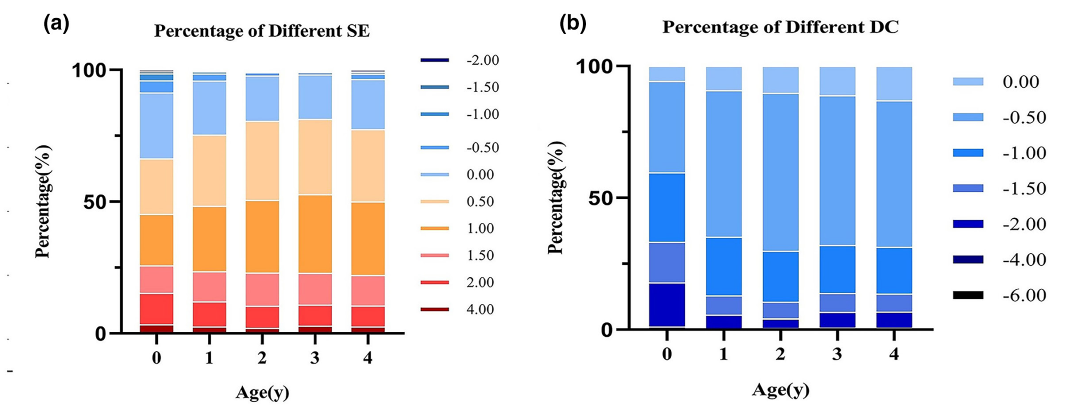

FIGURE 2 Proportion of refractive errors for each age cluster. The groups indicate the proportion of children having at least that level of refractive error. For example, −2.00 includes children who had at least 2.00 D of myopia, −1.50 includes children who had at least 1.50 D of myopia but less than 2.00 D, 4.00 indicates children that had at least 4.00 D of hyperopia. (a) Proportion of spherical equivalent (SE). (b) Proportion of astigmatism (DC).

Cross-sectional values of refractive error in children 0–8 years of age, measured in the years 2018–2021

In this cross-sectional study, we compared the changes in SE among children aged 0–8 years in 2018, 2019, 2020 and 2021. The results showed that the median SE in children aged 4 years in 2021 was significantly more myopic than that found for children of the same age in 2020 ($H = 8.29$, $p = 0.04$). This trend was also observed for children aged 0–4 years (Figure 7). The median SE of children aged 5–8 years was significantly more myopic in 2020 and 2021 than the corresponding values for 2019 and 2020 (Figure 8a–d). In particular, the SE was significantly more myopic for children 8 years of age in 2021 than those of the same age in 2020 ($H = 12.44$, $p = 0.006$). From 2018 to 2021, the prevalence of myopia among children 5–8 years of age showed a yearly upward trend, from 17.17% to 46.10%, 37.63% to 53.13%, 65.75% to 69.98% and 70.10% to 79.70% for children aged 5, 6, 7 and 8 years of age, respectively (Figure 8e).

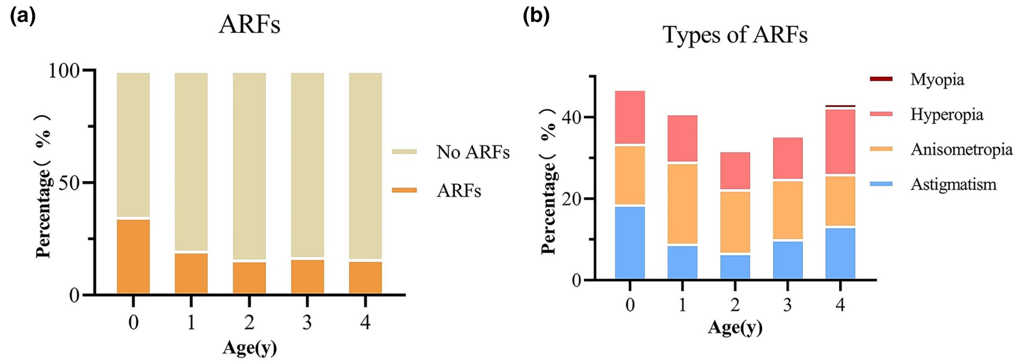

FIGURE 3 Amblyopia risk factors (ARFs) in children of different ages: (a) percentage of children with ARFs, (b) types and percentages of ARFs.

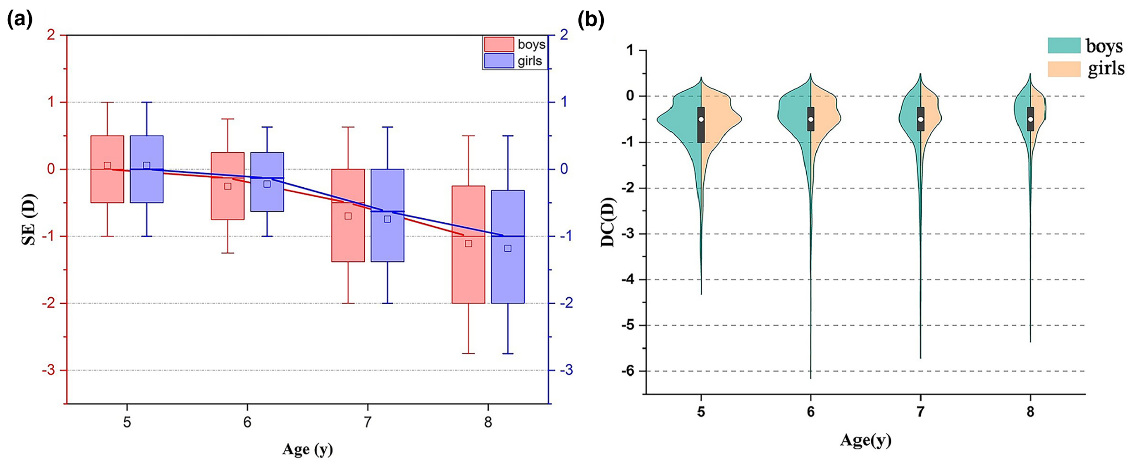

FIGURE 4 Distribution of refractive error in children 5–8 years of age who participated in the cross-sectional study. Data are presented for the right eye only; shown are the medians with 25 and 75 quartiles. (a) Spherical equivalent (SE), (b) astigmatism (DC).

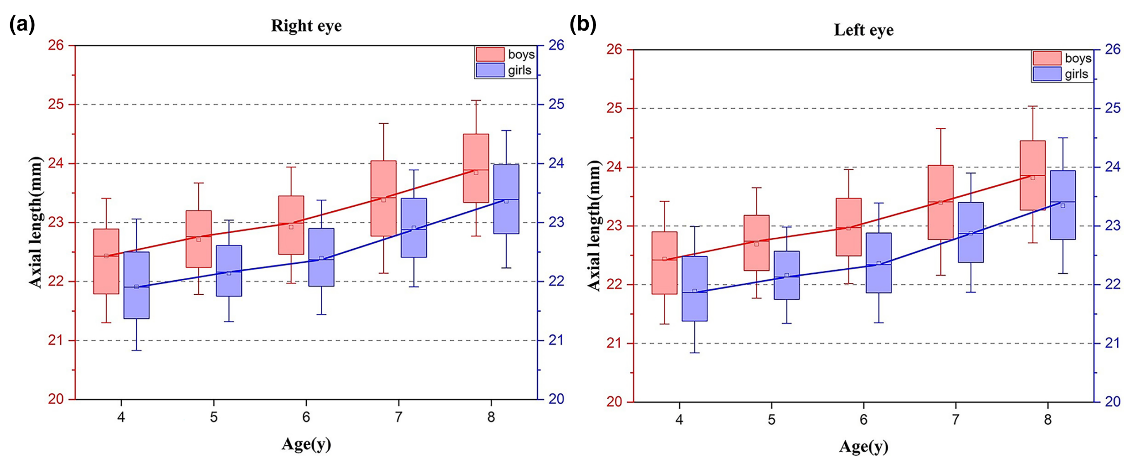

FIGURE 5 Axial length in children 4–8 years of age. (a) Right eye. (b) Left eye. Data are presented as the median (P25, P75). The solid lines indicate the median values.

Longitudinal data for 4406 children

In total, 4406 children aged 0–8 years underwent at least two examinations between 2018 and 2021. SE data were collected from these children at 3-, 6-, 9- and 12-month follow-up time points and the change in SE was analysed as $\Delta SE = SE_{\text{follow-up time}} - SE_{\text{baseline}}$. At the 12-month follow-up, the ΔSE for children under 1 year of age was −0.27 D, while

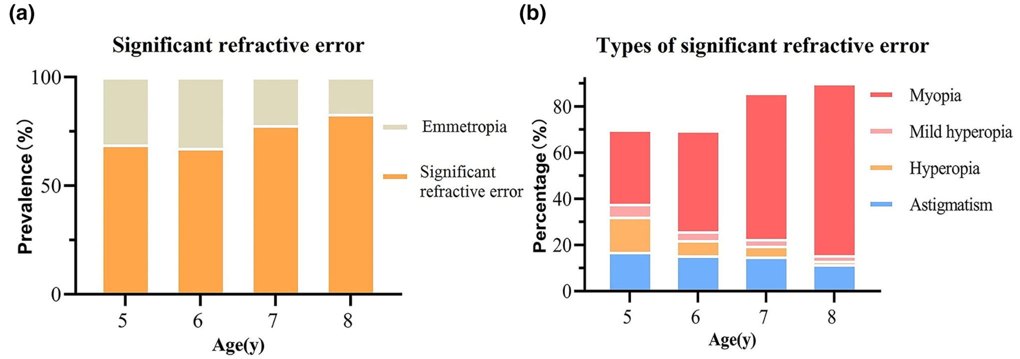

FIGURE 6 The prevalence of significant refractive error in children aged 5–8 years. (a) Prevalence of children with significant refractive error. (b) Types of significant refractive error.

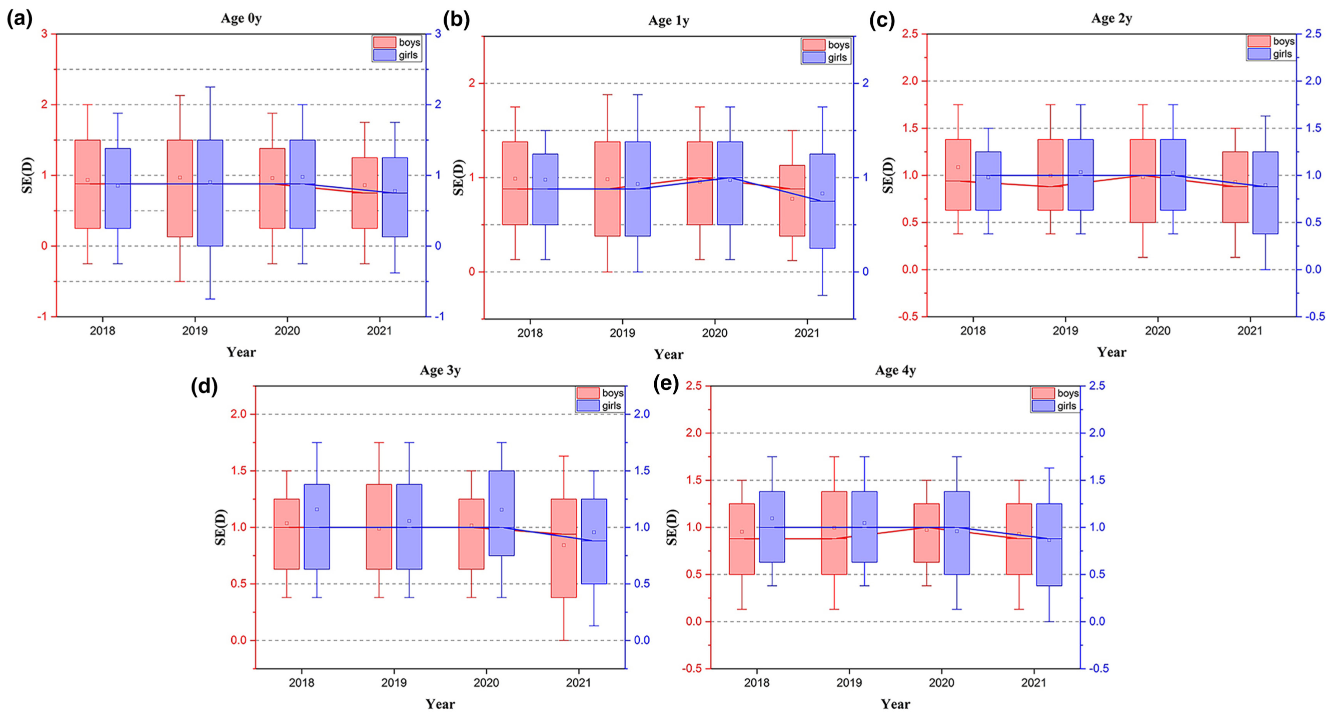

FIGURE 7 Differences in the spherical equivalent of children aged 0–4 years in 2018, 2019, 2020 and 2021. (a) Age 0 year, (b) Age 1 year, (c) Age 2 years, (d) Age 3 years, (e) Age 4 years. Data are presented for the right eye only; shown are the median with the 25 and 75 quartiles. The solid lines indicate the medians.

the ΔSE for children aged 1, 2 and 3 years was closer to 0 D, being −0.06, 0.19 and 0.13 D, respectively. The absolute value of the ΔSE for children aged 5–8 years was higher than that of children under 5 years old (ΔSE = −0.38, −0.58, −0.70 and −0.75 D for ages 5, 6, 7 and 8 years, respectively; Figure 9a). At the 3-month follow-up, the ΔSE of children between 0 and 4 years tended to be around 0 D (ΔSE = 0.19, 0.03, −0.06, 0.03 and −0.10 D, respectively; Figure 9b). The absolute value of ΔSE in 5- to 8-year-old children was higher than for 0- to 4-year-olds at the 3-month follow-up (ΔSE = −0.15, −0.24, −0.24 and −0.16 D, respectively) (Figure 9c).

DISCUSSION

In this study, refractive screening data without cycloplegia were analysed in children aged 0–8 years. These findings can aid in understanding the trends and characteristics of refractive development, providing a foundation for preventing and treating refractive errors in children and improving eye care. The Spot Vision Screener was used for children aged 0–4 years in this study, serving as a handheld, portable screening tool designed to detect vision issues including amblyopia quickly and easily. However, numerous studies[9,10] have

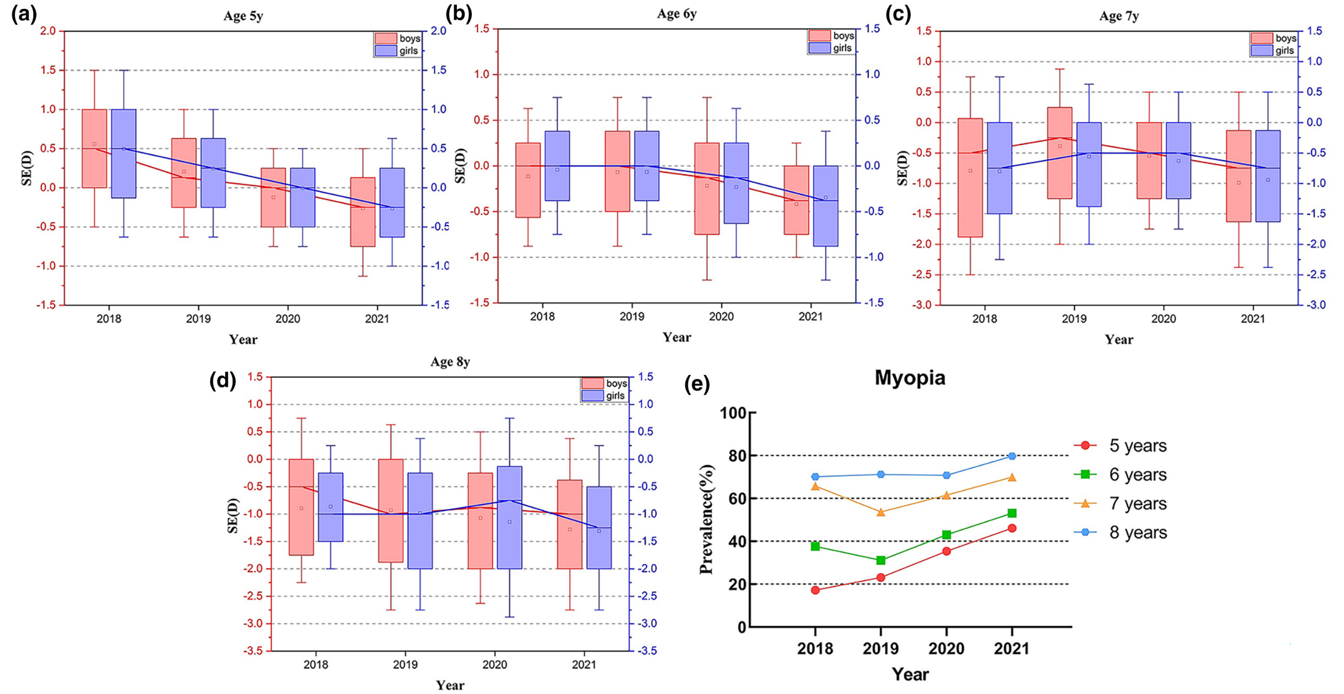

FIGURE 8 Differences in the spherical equivalent (SE) refractive error of children aged 5–8 years in the years 2018, 2019, 2020 and 2021. (a) Age 5 years, (b) age 6 years, (c) age 7 years, (d) age 8 years. (e) Changes in the prevalence of myopia among children aged 5–8 years from 2018 to 2021. Data are presented for the right eye only; shown are the median with the 25 and 75 quartiles. The solid lines indicate the medians.

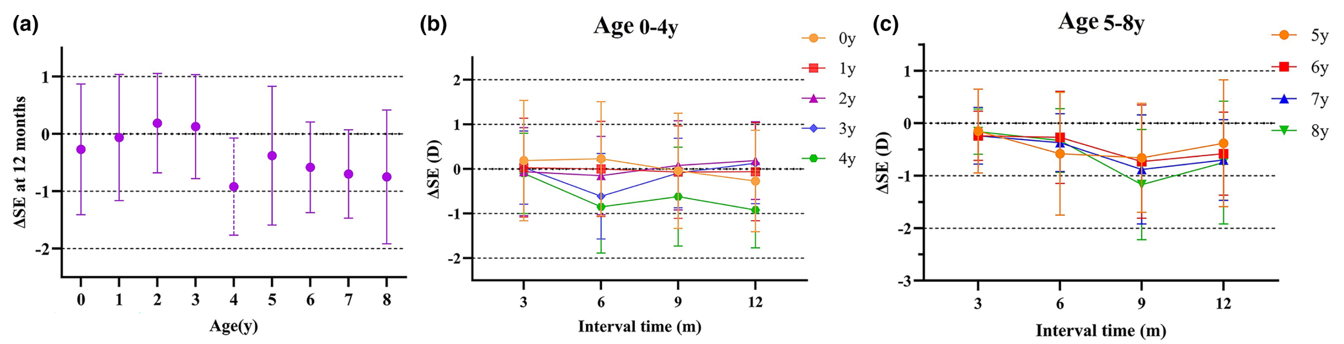

FIGURE 9 Changes in the spherical equivalent (SE) in children aged 0–8 years at the follow-up visits. (a) Changes in SE at 12 months, (b) age 0–4 years, (c) age 5–8 years. The data are presented as the means ± SDs. The solid lines indicate the means.

demonstrated that the Spot Vision Screener tends to yield higher myopia and lower hyperopia compared with standard refraction under cycloplegia. This discrepancy is particularly concerning in those with high hyperopia, with differences of 2–4 D, as these children are at the highest risk for amblyopia and are the ones most in need of identification. According to Peterseim et al.[15] the 2021 American Association for Pediatric Ophthalmology and Strabismus (AAPOS) guidelines for ARFs recommend increasing the instrument referral standard for treating astigmatism from 1.5 D (the Spot Screener's pre-set standard) to 2 D in children over 4 years of age. They also suggested that lowering the refractive parameter threshold from 1 to 0.75 D could increase sensitivity from 0.59 to 0.8.[16] Importantly, the current investigation adhered to the preset criteria of the instrument at the time of referral, even though this screening specifically focused on ARFs in children aged 0–4 years, utilising data from 2018 to 2021. Here, children under 5 years of age were screened with a Spot Vision Screener, whereas children over 5 years of age were screened with an autorefractor.

It has previously been shown that neonates often exhibit high hyperopia after birth,[17–19] while older children show less hyperopia.[20] However, using retinoscopy, Chen et al.[11] found that the mean cycloplegia SE was highly hyperopic (+3.55 ± 2.39 D), compared with the mean non-cycloplegia SE of +0.58 ± 2.32 D. Previous studies have shown that the use of the Spot Vision Screener results in an increase in the degree of myopia and a decrease in hyperopia compared to refraction with cycloplegia.[12,15] This error is particularly significant in hyperopia >2–4 D. In the present study, the SE at 4 months of age was +0.63 D (0.00, 1.72) for boys and +0.19 D (−0.09, 0.97) for girls. It is likely that the Spot Vision Screener without cycloplegia underestimated the spherical value of their hyperopia. Astigmatism in children under 1 year of age significantly improved with development.[21] Lu et al. reported that the prevalence of astigmatism in infants aged 1–18 months was 49.9%. It was highest at 3 months of age and decreased with age.[20] Similar to previous studies, we observed that the incidence of astigmatism was higher for children under 1 year of age, with significant variability and individual differences, and the proportion of children having astigmatism exceeding 1.50 D was also higher than for children over 1 year of age.

Younger children show a better response to amblyopia treatment,[10] and the detection of ARFs in young children plays a crucial role in the timely treatment of the condition.[22,23] It has previously been shown that the prevalence of ARFs worldwide is 10–20%,[24] with hyperopia and astigmatism being the main ARFs among children in different ethnic regions.[12,25] Other studies have found that the degree of anisometropia is more closely related to amblyopia in children under 3 years of age.[26] The results of the present study showed that astigmatism was more common in infants, and there were more cases of astigmatism and anisometropia among infants less than 1 year of age. In other studies,[12,26] the proportion of ARFs varied, which may be related to differences in ethnicity, location and the use of different screening instruments. Saunders et al.[21] demonstrated that newborns commonly had high hyperopia and astigmatism when tested without cycloplegia, which decreased rapidly in the first year of life. If astigmatism persists after 1 year of age, this may indicate failure of the emmetropisation process, and timely intervention is required to prevent amblyopia and reduce the risk of strabismus. Early screening can substantially improve the therapeutic effect on amblyopia.[27] Therefore, regular examinations should be carried out at the early stages of the child's development. Screening younger children for ARFs remains the focus of primary eye care institutions.

In a study of Chinese children aged 4–18 years, He et al.[28] reported that the ALs were 22.50, 22.77, 22.95, 23.22 and 23.43 mm for boys aged 4 to 8 years, respectively, and 21.88, 22.19, 22.36, 22.66 and 22.93 mm for girls within the same age range in 2019–2020. In the present study, ALs of the right eye in boys aged 4 to 8 years were 22.43, 22.76, 22.99, 23.43 and 23.89 mm, respectively, and 21.91, 22.16, 22.37, 22.88 and 23.39 mm for girls, respectively. The present results are similar to previous studies, and older children had longer ALs. While the boys had longer ALs than the girls, there was no significant difference in SE with gender, which may be due to the smaller corneal curvature in girls.[28] In the current study, we found that for children 5–8 years of age, refractive status was biased towards myopia, and the prevalence of myopia was high, similar to the findings of Guo et al.[29] There was a prominent increase in the prevalence of myopia at 7 years of age, which may be related to the fact that children 6 years of age are in primary school in China and are beginning to feel school-related pressure.

In 2020, Wang et al.[30] showed that 6- to 8-year-old children experienced a significant myopic shift (approximately −0.30 D), which was not observed before 2020 and may be related to home isolation. During the COVID-19 pandemic, the time spent by children in outdoor activities decreased considerably, while the time spent using electronic screens increased in both 2020 and 2021.[31] Furthermore, there was a significant association between changes in these environmental factors and an increased incidence of myopia.[32–35] At 3 years of age, the more time spent outdoors, the lower the risk of myopia.[32] Myopic plasticity is higher in children aged 6–8 years and this can be controlled by changing environmental factors.[36] In the present study, no significant myopic shift was observed in children 0–4 years of age from 2018 to 2020, while a significant myopic shift occurred in 2021. Five-year-old children experienced a significant myopic shift lasting 4 years, and 6- to 8-year-old children experienced a significant increase in myopia in 2020 and 2021. Home quarantine due to the pandemic may have caused a change towards myopia, and the present results indicated that it had a greater effect on 5- to 8-year-old children in the short term and may affect children younger than 5 years in the long term. Therefore, during epidemic prevention and control, parents should try to control children's screen time, increase the time spent engaging in outdoor activities, pay attention to their children's eyes and increase the frequency of eye examinations.

Previous studies have demonstrated that refractive error changes with age throughout childhood, whereas emmetropisation occurs early in infancy.[19] After 12 months of follow-up, the largest change in SE (−0.27 D) occurred in the 0-year group among children 0–3 years of age. In a longitudinal investigation of refractive changes in children, You et al.[37] reported that the SE of children 1–6 years of age changed during a 1- to 2-year follow-up period, with the most overt change being observed in the 3-year-old group. Similar to the findings of a previous study, the current results indicated that the SE in 3-year-old children fluctuated during the 12-month follow-up period, possibly due to their transition into kindergarten. In the longitudinal study, SE changes in children aged 4 years were obtained from two types of devices due to children over 5 years of age being screened using autorefractometers. This is a significant factor that should not be overlooked when considering the observed changes in 4-year-old children. For 5- to 8-year-olds, the change towards myopia was higher in the 8-year-old children at the 12-month follow-up. Moreover, in children aged 5–8 years, there was a significant change in refraction at the 3-month follow-up visit, compared with children aged 0–4 years. Hence, preventive myopia measures should be implemented in children aged 5 years and older.

The main limitation of this study is that the refractive measurements were obtained without cycloplegia; the study presents only screening results. Another limitation is the use of two different screening techniques for children 4 years of age and younger (Spot Vision Screener) versus those 5 years of age and older (Topcon autorefractor). Additionally, the use of refractive vectors would have been preferred over SE and cylinder power; however, the absence of axis findings in one-third of our data set prevented us from employing this approach.

CONCLUSION

Ocular development in children varies greatly within the first year of life, and the proportion of ARFs was high in this age group. Development gradually stabilises by 1–4 years of age and shows a significant trend towards myopia at 5–8 years. In recent times, likely due to home confinement during the COVID-19 pandemic, children's refractive errors have shown a significant myopic shift, and the prevalence of myopia among 5- to 8-year-old children has increased. Consequently, we recommend initiating eye care examinations for infants at 4–6 months of age, with at least one follow-up visit annually. The development of the eye is susceptible to environmental changes, and under occasions such as the recent pandemic, the frequency of examination may need to be increased.

AUTHOR CONTRIBUTIONS

Yarong Yan: Conceptualization (equal); data curation (lead); formal analysis (lead); investigation (lead); project administration (equal); supervision (equal); validation (supporting); visualization (equal); writing – original draft (lead); writing – review and editing (lead). **Xuewen Xia:** Conceptualization (supporting); data curation (lead); formal analysis (supporting); investigation (lead); project administration (equal); supervision (equal); validation (lead); visualization (supporting). **Qinghui Zhang:** Data curation (lead); formal analysis (supporting); investigation (lead); project administration (equal); supervision (supporting); validation (lead); visualization (equal). **Xuan Li:** Conceptualization (lead); formal analysis (lead); funding acquisition (lead); project administration (lead); resources (lead); supervision (lead); visualization (lead); writing – review and editing (lead).

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CONFLICT OF INTEREST STATEMENT

No conflict of interest is declared.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

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