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Original Article

Refractive error among urban preschool children in Xuzhou, China

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Abstract: The prevalence of refractive errors in urban preschool children in Xuzhou, China remains unknown. Children attending twelve randomly selected kindergartens participated in this study. Visual acuity, ocular alignment, cover-uncover test, cycloplegic refraction, slit-lamp and funduscopy were performed under a standardized testing environment. Cycloplegic streak retinoscopy was performed for all subjects. The mean spherical equivalent (SE) refractive error was the main outcome measure. Emmetropia was defined as refractive status between +1.75 diopters (D) and -0.75D. Myopia, hyperopia, astigmatism and anisometropia were defined as SE < -0.50D, SE > +2.0 D, cylindrical error > 1.0 D and SE difference ≥ 1 D between fellow eyes, respectively. Out of 2349 eligible children, 2255 (96%) children completed a refractive examination. Of the 2255 children, the mean SE of right eyes was +1.14 ± 0.95 diopters (D). Mean SE of the right eyes did not decline with age (r = -0.01; P = 0.56). The majority (86.6%) of children were emmetropia. The prevalence of myopia and hyperopia was 0.9% and 14.3%, respectively. The mean astigmatism for the right eyes was 0.87 ± 0.62 D. The prevalence of With-the-rule, against the rule and oblique astigmatism was 93.8%, 4.7% and 1.5%, respectively. The mean anisometropia between two eyes was 0.14 ± 0.38 D. The most common type of refractive error was hyperopia (14.3%), followed by astigmatism (8.8%), anisometropia (3.2%), and myopia (0.9%). The refractive status in this population of urban Xuzhou preschool children was stable and there was no evidence of a myopic refractive shift over this age range in our cross-sectional study.

Keywords: Preschool children, refractive error, China, prevalence, myopia

Introduction

Refractive error is one of the most common causes of visual impairment in East Asia, especially in China. The prevalence of myopia in China is high and still appears to be increasing. Moreover, the onset of myopia apparently occurs at an earlier age in recent years [1]. It has been reported that the prevalence of myopia is more than 70% in young children [2-4]. This trend alone supports the need for vision screening and early detection of amblyopia and strabismus among preschool children. Although many studies have addressed the refractive error of school-aged children [5-10], few population-based studies have been performed focusing on the refractive error among preschool children in world wide [1, 11]. The World Health Organization has recommended vision screening and treatment of vision disorders among preschool children [12]. Recently, the advocation of preschool vision screening programs has been supported by the Xuzhou government. We conducted a population-based cross sectional study of the visual system for urban preschool children aged 24 to 80 months in Xuzhou city. In this study, we demonstrate the distribution of refractive errors and provide insight into the growing public health significance of refractive error among preschool-age children in China.

Methods

This work was approved by the Ethic committee of The Affiliated Eye Hospital of Wenzhou Medical University. Cluster sampling was applied in this study. Twelve kindergartens in Xuzhou were randomly selected in 2011. All children studying in these kindergartens were

Table 1. Demographic characteristics of the participants

Age (months)	*Male (n, %)*	*Female (n, %)*	*Total (n)*
24-36	128 (54.5%)	107 (45.5%)	235
37-48	350 (55.9%)	276 (44.1%)	626
49-60	282 (51.9%)	261 (48.1%)	543
61-72	322 (57.2%)	241 (42.8%)	563
73-80	165 (57.3%)	123 (42.7%)	288
Total	1247 (55.3%)	1008 (44.7%)	2255

Table 2. Summary of visual abnormalities

Visual abnormalities	*Number of children*	*Percentage*
VA ≤ 0.5	109	4.8%
Strabismus	19	0.8%
Nystagmus	1	0.04%
Cataract	1	0.04%
Hyperia ≥ +2.00	294	14.3%
Myopia ≥ -1.00	20	0.9%
Astigmatism ≥ 1.00	199	8.8%
Astigmatism ≥ 3.00	11	0.5%
Anisometropia ≥ 1.00	71	3.2%

invited to participate after obtaining parental written consent. To encourage participation, the investigators arranged a meeting with parents before recruitment to explain the project objectives and procedures and to address the importance of vision screening for children. The study was approved by the ethics committee of Xuzhou Medical College, and the measurements followed the guidelines of the Declaration of Helsinki. Written informed consents were obtained from the parents.

The study was conducted from April to December in 2011. The children underwent ocular examinations in their respective kindergartens. Ocular alignment, visual acuity (VA), cover and uncover test, cycloplegic refraction, slit-lamp and fundi examinations were performed using a standardized testing environment. Cycloplegic streak retinoscopy was performed on the subjects. Cover and uncover testing was conducted to determine strabismus at a 33-cm distance before cyclopedia. VA was tested with an E chart and best-corrected visual acuity (BCVA) would be measured if the VA was less than 0.5. The participants were administered topical tropicamide phenylephrine (Santen Pharmaceutical Co., Ltd) eye drops 3 times, with 10 min between each dose. Cycloplegic refraction was determined by streak retinoscopy 30 min after the last drop to ensure maximal cycloplegic effect.

Definition of refractive error

The refractive error was taken as the spherical equivalent (SE) in diopters (D) and calculated as the power of the sphere plus half the cylindrical power. Eyes with a SE from -0.75 to +1.75 D were classified as emmetropic. Myopia was defined as SE refractive error of at least -0.75 D and hyperopia as +1.75 D or more. Astigmatism was defined as the cylinder power of 1.00 D or more and was classified into three categories: with-the-rule (WTR) astigmatism (cylinder axes between 1° and 15° or 165° and 180°), against-the-rule (ATR) astigmatism (cylinder axes between 75° and 105°), and oblique astigmatism (cylinder axes between 16° and 74° or 106° and 164°). Anisometropia was defined as an interocular difference of 1.00 D or more in SE. Significant visual abnormalities included: visual acuity of < 0.5, manifested strabismus, myopia (SE ≤ -1.00 D), hyperopia (SE ≥ +2.00 D), astigmatism (cylinder ≥ 1.00 D), anisometropia (SE difference between the right and left eye ≥ 1.00 D), nystagmus, and cataract.

Statistical analysis and data management

Age and 95% confidence intervals were estimated using the Poisson distribution. All data were analyzed using the Statistical Package for Social Sciences (SPSS) computer program for Windows version 11.0 (SPSS Inc; Chicago, IL, USA). A *P*-value of < 0.05 was considered statistically significant. Spearman's correlation test was used to analyze the cycloplegic spherical equivalent (SE) in the right eyes and age.

Results

There were 2349 children in Xuzhou from twelve kindergartens that participated in this study, and 2255 children (participation rate of 96%) successfully completing their cycloplegic refractive error examination. Ninety-four children were excluded from these analyses because they did not complete their vision assessment. The demographic characteristics of the subjects are shown in **Table 1**. The mean age of the children was 54.4 ± 13.9 months, with a range from 24 to 80 months. We found

Table 3. Spherical equivalent (SE) by age

Age (months)	Right eye			Left eye		
	Mean	SD	95% CI	Mean	SD	95% CI
24-36	1.11	1.12	0.96-1.26	1.15	1.16	0.10-1.30
37-48	1.19	0.85	1.13-1.26	1.18	0.83	1.11-1.24
49-60	1.09	0.84	1.02-1.16	1.06	0.80	0.10-1.13
61-72	1.14	1.10	1.11-1.24	1.12	1.06	1.04-1.21
73-80	1.12	0.84	1.02-1.22	1.09	0.77	1.01-1.18
Total	1.14	0.95	1.10-1.18	1.12	0.92	1.09-1.16

Table 4. Distribution of myopia in different age

Months	Number of left eyes	Number of right eyes	Total number
24-36	2	3	3
37-48	3	2	3
49-60	2	4	4
61-72	4	5	5
73-80	3	4	5
Total	14	18	20

that 495 (22.0%) of the children had a VA of ≥ 1.0, and 725 (32.2%) children were identified in having visual abnormalities including a VA of < 0.5, strabismus, significant refractive error, nystagmus and cataract (**Table 2**).

Spherical equivalent refractive error

The refractive error was determined by cycloplegic streak retinoscopy in 2255 subjects for both eyes. The range for SE was -9.50 to +10.00 D and majority of children (86.6%) were emmetropia (between -0.75 D and +1.75 D). The mean SE refractive error for the right and left eyes by age is shown in **Table 3**, and the distribution of myopia for different ages is shown in **Table 4**. There was a slight difference in statistics between two eyes (t = 2.23; P = 0.03). Mean SE refractive error for girls was 1.19 D (95% CI, 1.13-1.25) for right eyes and 1.17 D (95% CI, 1.11-1.23) for left eyes. The mean SE error for boys was 1.10 D (95% CI, 1.05-1.15) for right eyes and 1.08D (95% CI, 1.03-1.13) for left eyes. SE analyses showed a slight difference by gender (F = 4.60; P = 0.03). The distribution of the SE for the right eye by age is shown in **Figure 1**. The SE refractive error did not significantly decline with age (r = -0.01; P = 0.56). Large clinical SE refractive errors were uncommon.

Astigmatic refractive error

The range for astigmatism was from -0.50 to -6.00 D. Mean astigmatism was +0.88 ± 0.63 D for right eyes and +0.87 ± 0.62 D for left eyes. Among the 543 children with astigmatisms, 179 (33%) had astigmatisms of 1.00 D or more. There was a low prevalence of astigmatism of 3.00 D or more (0.3%), ATR in 3.9% and oblique in 1.8% (**Table 5**). The mean astigmatic error remained stable across the age ranges studied from 24 to 80 months (P = 0.25). Astigmatic refractive error analyses showed no significant difference by gender (F = 1.12; P = 0.35).

Anisometropia

The mean anisometropia for urban children was 0.14 D (95% CI, 0.12-0.16). Clinical anisometropia was uncommon. The prevalence of anisometropia of 1.00 D or more was present in 71 (3.2%) of children and anisometropia of 3.00 D or more was 9 (0.4%).

Discussion

We conducted a population-based cross-sectional study of ocular disease among children between 24 and 80 months living in the urban city of Xuzhou. Over 96% of children were included in these enrolled kindergartens and we believe that this was representative of the Xuzhou community as a whole. Our study indicated that there was a significant number of preschool children in Xuzhou had visual abnormalities including a visual acuity of < 0.5, refractive error, nystagmus, strabismus, and cataract, and among them, refractive error was the leading problem.

In comparison of prevalence rates among different stuies, we should note the differences in definition of refractive error, age compositions of the study population, and refractive error measurement techniques. In our study, we examined preschool children using cycloplegic streak retinoscopy, which can be easily influenced by subject factors because it is possible to ignore a 0.25D difference in refractive error. We defined myopia as -1.00 D or less, similar to previous studies in Hong Kong and Singapore. Despite differences between these studies,

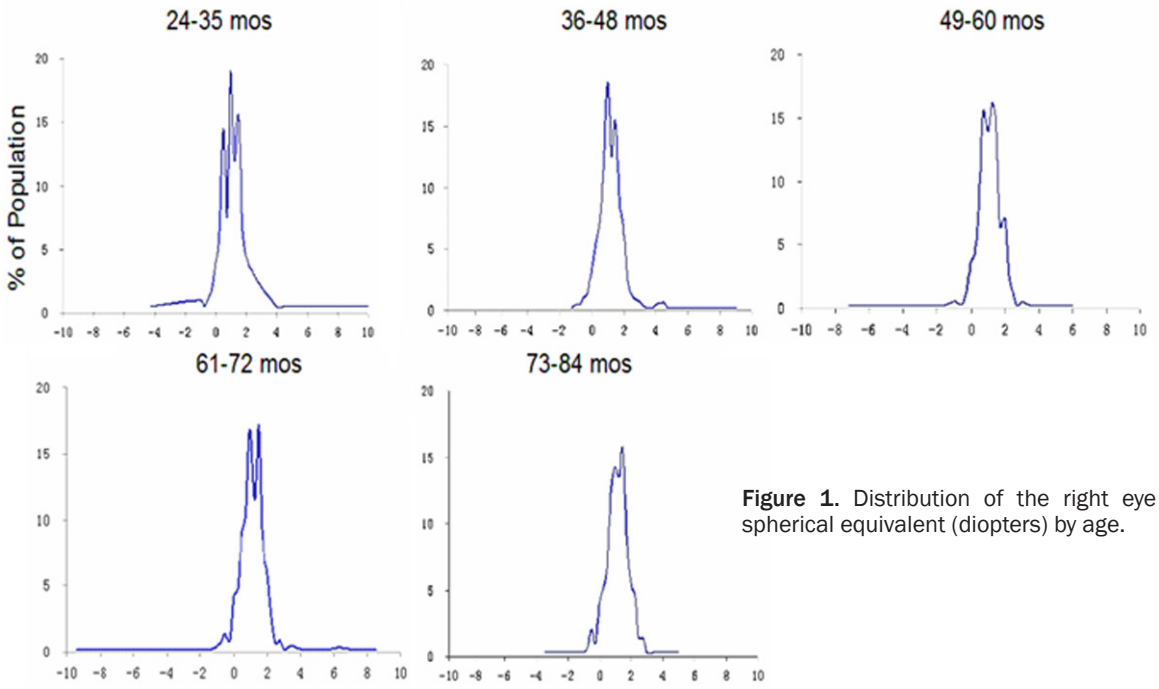

Figure 1. Distribution of the right eye spherical equivalent (diopters) by age.

Table 5. Right eye astigmatism by age

Months	Mean ± SD	WTR n (%)	ATR n (%)	Oblique n (%)
24-36	-0.99 ± 0.94	49 (90.7)	2 (3.7)	3 (5.6)
37-48	-0.84 ± 0.52	145 (96.0)	4 (2.6)	2 (1.3)
49-60	-0.85 ± 0.53	115 (98.3)	2 (1.7)	0 (0)
61-72	-0.94 ± 0.68	135 (90.6)	9 (6.0)	5 (3.4)
73-80	-0.83 ± 0.58	67 (94.4)	4 (5.6)	0 (0)
Total	-0.88 ± 0.63	511 (94.3)	21 (3.9)	10 (1.8)

were 0.1%, 14.3%, 8.8%, and 3.2%, respectively. The most common type of refractive error was hyperopia, followed by astigmatism, anisometropia and myopia. The results of similar screenings in other districts of China and other countries are summarized in **Table 6** [1, 9, 11, 13, 14]. Although these studies differed in terms of age and protocols used, similarities were evident.

there was a relatively higher prevalence of myopia in Chinese children. Moreover, the prevalence of myopia among all Chinese children varied from districts and states. These differences were related to the environment including amount of near vision work, education, economic status, and outdoor activity level. It is suggested that children in developed regions tend to be myopic. Xuzhou is a developing city on the central of China, and to our knowledge, this study was the first to report on the refractive error of preschool children in this area.

This population-based survey of Xuzhou preschool children aged 24 to 80 months reported the prevalence of refractive error, including myopia, hyperopia, astigmatism, and anisometropia. We found that large SE refractive error was uncommon among preschool children. The rate of myopia (-6.00 D or less), hyperopia (+2.00 D or greater), astigmatism (1.00 D or greater), and anisometropia (1.00 D or more)

The mean SE was 1.14 ± 0.95 D in Xuzhou preschool children, who were more hyperopic than Hong Kong and Singaporean Chinese children, but similar to the population of 5-year-old children in Guangdong. While comparing with children in Western countries, Chinese children were less hyperopic. However, in the current study we found a relatively high prevalence of hyperopia (14.3%), which was consistent with the results of a 2004 study by He et al. [9]. In addition, our data identified that children in Xuzhou did not have a higher percentage of myopia (0.9%) than children in the United States and Sweden [14]. As far as astigmatism was concerned, previous studies demonstrated differences in the prevalence of astigmatism, and some reported that the most common type of astigmatism was WTR [15, 16], while others reported ATR [17, 18]. In our study, the mean astigmatism for the right eyes was -0.88 ± 0.63 D. 179 (3.2%) children had astig-

Table 6. Results of vision screening in children in different studies

Place of study	Guangdong [9]	Hong Kong [1]	Germany [13]	Sweden [14]	American [11]		Our study
					African American	White	
Age of children	5-15 y	2-6 y	2-6 y	4-10 y	6-71 m	6-71 m	24-80 m
Total number	4364	823	8	90	1268	1030	2255
spherical equivalent	+1.25 D in 5 y	0.67 ± 1.14 D	2.81 ± 2.49 D	NA	0.69 ± 1.15	1.49 ± 1.23 D	+1.14 ± 0.95
Refractive error							
Hyperopia	≥ +2.00 D (16.7%)	≥ +2.50 D (5.1%)	≥ +0.50 D (9.8%)	≥ +2.00 D (10%)	≥ +2.00 D (7.8%)	≥ +3.00 D (8.9%)	≥ +2.00 D (14.3%)
Myopia	≤ -0.5 D 3.3%	≤ -1.00 (6.3%)	≤ -0.5 D (0%)	≤ -0.5 D (1%)	≤ -1.00 D (5.3%)	≤ -1.0 D (0.7%)	≤ -1.00 D (0.9%)
Astigmatism	> 0.75 D (33.6%)	≥ 2.00 D (5.7%)	NA (37.5%)	≥ 0.75 D (23%)	≥ 1.50 D (13.1%)	≥ 1.50 D (11.4%)	≥ 1.00 D (7.9%)
Anisometropia	≥ 2.00 D (3.7%)	≥ 1.00 D (1.6%)	NA	≥ 1.00 D (1%)	≥ +2.00 D (1.0%)	≥ +2.00D (1.5%)	≥ 1.000D (3.2%)

NA, not available.

matisms (1.00 D or more) and the most common type of astigmatism was WTR.

In the current study, we did not find a myopic shift in preschool children. Two years ago, we also found that there was no significant difference among different age groups in 1698 preschoolers in Xuzhou [19]. One study by Giordano et al. [11] of preschool children aged 6 through 71 months showed a similar result to our observation. Many studies have reported that the process of emmetropization occurs largely by the age of 2 years [20, 21] and that the refractive error is hyperopic in infants and shifts towards emmetropia during the first few years of life [22, 23]. In one study, the SE of 298 infants between 3 and 36 months of age residing in Contra Costa, California was found to decrease significantly between 3 and 9 months of age, and no significant change was observed after 9 months of age [24]. Moreover, previously studies mentioned that the refractive status showed a dramatic myopic shift when children entered school [25-27]. Myopic progression was highly related to the amount of intense near work and intense schoolwork that has been widely inferred from cross-sectional studies [9]. Fan et al. [29] reported myopic progression among Hong Kong Chinese school children and showed that the annual progression rate for myopic children was -0.46 D, while the rate of myopic progression was greatest between ages 6 and 10 years. In 2005, a Malaysian cohort identified that the prevalence of myopia was 9.8% for 7-year-olds, increasing to 34.4% for 15-year-olds [28]. Furthermore, He et al. [9] showed that the prevalence of myopia was 3.3% for 5-year-old preschool children, increasing dramatically to 73.1% for 15-year-olds. A myopic shift occurred at ages 7-8 and 11-12 years old. In our study, we had an adjacent refractive error in the overlapping part for 5-year-old children. This period was ahead of the myopic shift peak.

In conclusion, this population-based study of urban Xuzhou children aged 24 through 80 months of age demonstrated low rates of clinically significant SE refractive error anisometropia and astigmatism. Moreover, the refractive status of this population of urban preschool children in Xuzhou was stable. Although the mean SE of children in this cross-sectional study was less hyperopic than children in Western countries, no evidence existed to support a myopic shift. Further study is necessary to address this interesting area.

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Disclosure of conflict of interest

None.

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