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Survey of the visual acuity and refractive status of children 4–6 years of age in a district of Nantong, China, from 2021–2023

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Abstract

Objective To understand the visual acuity and refractive development status of kindergarten children in Haimen District of Nantong City, China, and to provide reference for the development of vision protection for preschool children.

Methods All kindergarten children 4–6 years of age were screened for vision and refraction from 2021–2023, and the results were statistically analyzed.

Results A total of 56,755 children (113,510 eyes) were screened. Six-year-old children had significantly better visual acuity than 4- and 5-year-old children. The reduced visual acuity detection rate in girls (7.8%) was significantly higher than boys (7.3%; $\chi^2 = 4.642$; $P = 0.031$). Visual acuity was significantly higher in 6-year-old children than 5-year-old children in the previous year and significantly higher in 5 year olds than in 4 year olds in the previous year ($P < 0.001$). The reduced visual acuity detection rate varied widely according to reference standards but there was consistency in the vision status of children, which showed a better trend year-after-year with an increase in age. The spherical and cylindrical equivalents were nearly the same in all age groups. The screening myopia detection rate in this survey was 0.1%.

Conclusions Attention should focus on the eye care of preschool children to improve visual health of children and adolescents.

Introduction

Myopia among children and adolescents is becoming more severe and at a younger age[1, 2]. Indeed, myopia has become a serious public health problem worldwide [1, 2]. It is predicted that by 2050 nearly 50% of the global population will be affected by myopia with children and adolescents being the most seriously affected [3, 4]. Early detection of reduced visual acuity and abnormal refractive development in children and timely referral for intervention are essential for controlling and reducing the development of poor vision and controllable eye diseases in children and preventing the occurrence of myopia. Assessing the eye health of preschool children serves as a fundamental step in the effort to prevent and control myopia in China [4]. A timely and comprehensive understanding of eye health in preschool children can provide an objective foundation for developing and implementing effective prevention and control measures. Therefore, we conducted a study to examine the visual acuity and refractive status of kindergarten children 4–6 years of age from 2021–2023 in the Haimen District, Nantong City in Jiangsu Province, China.

Study subjects and methods

1.1 Subjects: A total of 56,755 kindergarten children (113,510 eyes) 4–6 years of age in Haimen District, Nantong City underwent visual acuity screening with refraction from 2021–2023. These children comprised 29,178 boys (51.4%) and 27,577 girls (48.6%). The exclusion criteria were as follows: (1)

spherical or cylindrical measurements using a Welch Allyn spot vision screener exceeding − 7.50D to + 7.50D or cases where no measurements could be obtained; and (2) organic eye diseases or strabismus. The data for this study were derived from physical examinations. The legal guardians of the children gave informed consent.

1.2 Screening items and methods: Vision examinations were performed according to the *Specifications for Eye Care and Vision Examination Services for Children Aged 0 ~ 6 Years* (Trial), which was issued by the National Health Commission (hereafter called the *Specifications*)[5]. The examination items included screening eye distance vision using a 5-m standard logarithmic visual acuity chart and refractive examination using a handheld binocular vision screening instrument. The equivalent spherical lens = the spherical lens power + 1/2 cylindrical lens power. Screening myopia refers to the equivalent spherical lens meeting the myopia standard of the instrument and the visual acuity is lower than the average standard of the same age. The myopia standard of the instrument in this study was selected as a spherical equivalent (SE) < -0.75D[6]. All methods were carried out in accordance with relevant guidelines and regulations, and we confirm that all experimental protocols were approved by Medical Ethics Committee of Nanjing Maternal and Child Health Hospital, ethics approval number is Ning Fu Lun Zi (2020) KY-049. The legal guardians of the children gave informed consent.

1.3 Quality control: The examination methods and procedures were strictly in accordance with the *Specifications*. The institutions participating in the physical examination had valid medical institution practice licenses and the personnel were physicians, technicians, or nurses who possessed qualification certificates for ophthalmology-related practice and underwent standardized training.

1.4 Statistical analysis: SPSS 19.0 software was used for data analysis. Measurement data are expressed as $\bar{x} \pm s$. Independent sample t-tests and variance analysis were used for statistical testing. Count data were expressed as the number of cases (%). A χ^2 test was used for statistical testing. Non-normal distribution data are described by the median and percentile. The significance level was set at $\alpha = 0.05$ (two-sided).

Results

2.1 Visual acuity

2.1.1 Visual acuity screening of children in different age groups for three consecutive years

Between 2021 and 2023, the visual acuity of the 5-year-old group was better than the 4-year-old group, and the visual acuity of the 6-year-old group was superior to the 5-year-old group. Variance analysis revealed a statistically significant difference in visual acuity between the different age groups ($P < 0.001$). Overall, the visual acuity of children 4–6 years of age demonstrated a positive developmental trend (Fig. 1).

2.1.2 Comparison of visual acuity and reduced visual acuity detection rates in different groups

2.1.2.1 Comparison of the visual acuity between the left and right eyes: The visual acuity of the left eyes (4.93 ± 0.993) was significantly higher than the right eyes (4.90 ± 0.106; t = 46.118, *P* < 0.001).

2.1.2.2 Detection of reduced visual acuity in different genders: The reduced visual acuity detection rate in girls (7.8%) was higher than boys (7.3%) and the difference was statistically significant (χ2 = 4.642, *P* = 0.031).

2.1.2.3 Changes in visual acuity with age: The children were grouped based on age, as follows: group 1 (children 4 years of age in 2021, 5 years of age in 2022, and 6 years of age in 2023); group 2 (children 5 years of age in 2021 and 6 years of age in 2022); and group 3 (children 4 years of age in 2022 and 5 years of age in 2023). The children in each group had higher visual acuity at 6 years of age than at 5 years of age and at 5 years of age than at 4 years of age (*P* < 0.001). The reduced visual acuity detection rate in the 5-year-old group in 2021 (8.7%) was significantly higher than the 6-year-old group in 2022 (5.9%; χ2 = 69.0, *P* < 0.001). (Table 1)

2.1.3 Reduced visual acuity detection rate under different reference standards

Table 1

Comparison of the increased visual acuity in different groups of children at different ages($\bar{x}\pm s$)

Group	**Number of eyes**	$\bar{x}\pm s$	***F / t***	***P***
Group 1			$4.89*10^3$	<0.001
4 years old in 2021	14116	4.85 ± 0.109		
5 years old in 2022	14256	4.93 ± 0.090		
6 years old in 2023	11534	4.97 ± 0.095		
Group 2			-23.734	<0.001
5 years old in 2021	14246	4.93 ± 0.092		
6 years old in 2022	11072	4.96 ± 0.094		
Group 3			-64.019	<0.001
4 years old in 2022	11648	4.86 ± 0.090		
5 years old in 2023	13302	4.94 ± 0.101		
Note: the data of group 1 was in a accordance with the normal distribution, and the data satisfied homogeneity of variance, so variance analysis were used for statistical; Independent sample t-tests was used to analyze group 1 and group 2.				

Visual acuity screening results were categorized as normal and reduced (abnormal) visual acuity based on different reference standards, which led to significant variations in the reduced visual acuity detection rates. The detection rate under standard 1 was the lowest, slightly higher under standard 2, and significantly higher under standard 3 compared to the other two standards (Fig. 2). The overall reduced visual acuity detection rate showed a yearly decline from 2021–2023 independent of the standard applied, indicating a gradual improvement in the visual acuity of children over time.

2.2 Dynamic refractive status

SE and cylinder values (Sk_{SE} = 0.996, $Sk_{cylindrical\ value}$ = 1.579; Ku_{SE} = 10.87, $Ku_{cylindrical\ value}$ = 10.353) had non-normal distributions, so the median was used for comparative analysis. The median SE values of children 4, 5, and 6 years of age were + 1.25D, + 1.375D, and + 1.375D, respectively. The median cylinder values were all + 1.5D. There was little change in the percentile distribution of SE and cylinder values across the age groups (Table 2).

Table 2
Distribution of spherical equivalent and cylinder values in each age group

Age (Years old)		Number of eyes	Spherical equivalent (D)			Cylinder values(D)		
			P_{25}	Median	P_{75}	P_{25}	Median	P_{75}
4	37344	+ 1.00	+ 1.25	+ 1.625	+ 1.25	+ 1.5	+ 2.0	
5	41804	+ 1.00	+ 1.375	+ 1.75	+ 1.25	+ 1.5	+ 2.0	
6	34362	+ 1.00	+ 1.375	+ 1.875	+ 1.25	+ 1.5	+ 2.0	
Note: the median SE values of children 4, 5, and 6 years of age were + 1.25D, + 1.375D, and + 1.375D, respectively. The median cylinder values were all + 1.5D. There was little change in the percentile distribution of SE and cylinder values across the age groups.								

2.3. Screening myopia: Of 113,510 eyes, 160 met the criteria for screening myopia, representing a 0.1% screening myopia rate. The number of myopia screenings in the 4-, 5-, and 6-year-old groups was 97, 42, and 21, respectively. The screening myopia detection rates in all age groups decreased year-after-year with age (Fig. 3).

Discussion

3.1 Visual acuity

3.1.1 The results of this study showed that for three consecutive years the visual acuity of kindergarten children 4–6 years of age in Haimen District gradually increased with age, which was consistent with the study conducted by Wang et al.[7]. First, 0–6 years of age is the critical period for the development of eye structure and visual function. Newborns only have light perception at birth and visual acuity gradually develops after birth. The visual acuity of 4-year-old children is > 0.6 and the visual acuity of 5-year-old

children can exceed 0.8. From the standpoint of the natural progression of vision development in young children, visual acuity gradually improves with age and tends to approach emmetropia, which is aligned with the typical course of visual development[8]. Second, in the context of a society-wide focus on eye health[9], enhancing lighting conditions, reducing the duration of near-vision tasks, increasing outdoor activities[10], and ensuring proper nutrition[11], regular sleep, and adequate rest can significantly improve vision in children when combined with early detection, diagnosis, and treatment.

3.1.2 The visual acuity of the left eyes of children 4–6 years of age was better than the right eyes and the difference was statistically significant. However, the visual acuity values (left 4.93, right 4.90) were clinically negligible. There was a difference in the reduced visual acuity detection rate between genders. The reduced visual acuity detection rate was higher in girls than in boys. This finding differed from some studies[12, 13]. This difference may be attributed to the age composition and geographic region of the samples in various studies. Boys tend to be more active and spend more time outdoors than girls. Ultraviolet rays can inhibit the elongation of the eye axis, increase the release of retinal dopamine, and reduce the axial elongation of the eyes. Long-term outdoor activities can improve dynamic vision, increase naked eye distance vision, and slow the rate of myopia occurrence[14–15]. Girls have more static activity and sedentary behavior than boys, and more after-school homework time[16–17] is likely to cause poor visual acuity. The conclusion that girls have a higher reduced visual acuity detection rate than boys requires further support from studies examining the impact of outdoor activities and activity duration on vision across different genders.

3.2 Dynamic refractive status

3.2.1 The results of dynamic refractive status in the current study showed that the cylinder value of children 4–6 years of age remained unchanged and the SE had a nominal change. This result is essentially the same as the conclusion reached by Xie et al.[18] and Gui et al.[19]. The refractive status in the current study was determined using non-mydriatic optometry. The SE value did not represent the hyperopic reserve and therefore it did not align with the static refractive development pattern in children in whom the hyperopic reserve gradually decreases.

3.2.2 Hyperopia can be classified into three types based on the varying effects of accommodation on hyperopia: manifest hyperopia, which is detectable during optometry without ciliary muscle paralysis and equivalent to the maximum orthokeratology correction that achieves emmetropia; latent hyperopia, which cannot be detected during optometry without ciliary muscle paralysis and is typically caused by physiologic tension in the ciliary muscle; total hyperopia, which is the sum of manifest and latent hyperopia, representing the maximum orthokeratology correction achievable under ciliary muscle paralysis; absolute hyperopia (hyperopia that cannot be compensated by accommodation, i.e., hyperopia that exceeds the range of accommodation and can only be corrected by positive lenses); and facultative hyperopia (hyperopia that is concealed by self-accommodation but can be found during optometry without ciliary muscle paralysis, i.e., the difference between manifest and absolute hyperopia)[20]. The SE obtained from refractive screening is equivalent to absolute hyperopia, which is affected by total

hyperopia and accommodation ability (facultative hyperopia + latent hyperopia). From the perspective of human eye visual function, objects are seen clearly only when the overall dynamic refraction is 0 or close to 0. Therefore, in the absence of ciliary muscle paralysis, the dynamic refraction of a normal human eye should be 0 and is not influenced by age.

3.3 Screening myopia: The current study showed that the screening myopia detection rate in children 4–6 years of age showed a decreasing trend with age. Visual acuity in children within this age group should improve each year based on the process of visual development. It is possible that some children with delayed visual development experience catch-up growth with the visual acuity gradually normalizing with age, leading to a reduction in the screening myopia rate. This is merely a hypothesis because the current screening myopia standards are primarily designed for children > 6 years of age[21] and do not address the screening criteria for children 4–6 years of age. Therefore, the validity of this conclusion warrants further research to explore and establish a more precise cut-off point or reference range for determining screening myopia in this age group.

The limitations of our study included the following: (1) the data collection involved a refractive examination without ciliary muscle paralysis that was intended solely for screening purposes, which led to some deviation from the diagnostic results; and (2) this study did not longitudinally track the development of dynamic visual changes in each child, resulting in a weak correlation of the data.

The visual development of preschool children progresses from hyperopia to emmetropia. During this period, visual function in children is highly adaptable. Early detection and treatment can minimize the impact on visual development and help prevent lifelong visual impairment[22]. Myopia can be prevented, controlled, and corrected but myopia cannot be cured[9]. Prevention of myopia is essential. Therefore, the age of myopia prevention should be moved forward and preschool children should be an important monitoring population of eye health. This strategy will help promote the establishment of a system of early detection, early diagnosis, and early intervention for myopia among children and adolescents in China, and improve the visual health of children and adolescents.

Declarations

No funding.

Statement：The datasets generated and analysed during the current study are not publicly available due to the data from this study is a small part of the national physical examination program,but are available from the corresponding author on reasonable request. All methods were carried out in accordance with relevant guidelines and regulations. Figure A does not appear in the article.

Authors' contributions

Conception, ZHANG Yu; design of the work, ZHANG Yu and SUN Yanli; Vision screening and data collation , CHEN Xinwei, JIANG Jun, HUANG Saihua, and LU Jiajun;SB; interpretation of data, SUN Yanli ,

WU Guangqiang and WEI Ning; drafted the work or substantively revised it, SUN Yanli, WU Guangqiang , WEI Ning, and ZHANG Yu. All authors read and approved the final manuscript.

Corresponding Author: ZHANG Yu, master, chief physician.

Competing interests

The authors declare that they have no competing interests.

Ethical Approval. The data for this study were derived from physical examinations witch was regular project. This article does not contain any new studies with human participants or animals performed by any of the authors.

Data availability. The datasets generated and analysed during the current study are not publicly available due to the data from this study is a small part of the national physical examination program,but are available from the corresponding author on reasonable request.

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Figures

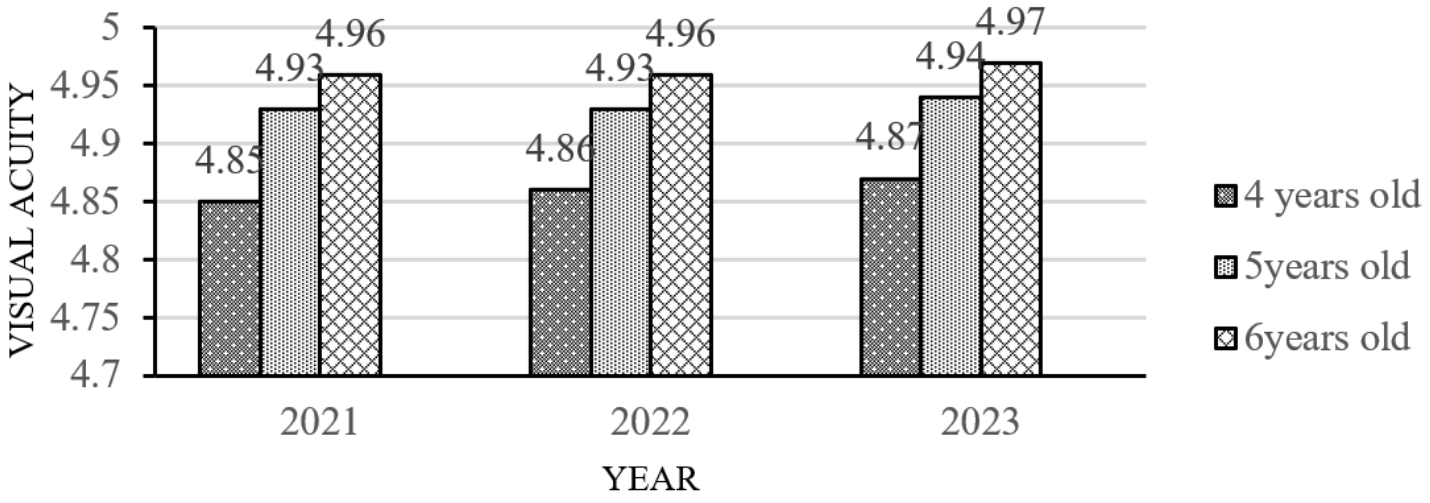

Figure 1

Mean values of visual acuity for different age groups from 2021 to 2023

Note: between 2021 and 2023, the visual acuity of the 5-year-old group was better than the 4-year-old group, and the visual acuity of the 6-year-old group was superior to the 5-year-old group. Variance analysis revealed a statistically significant difference in visual acuity between the different age groups ($P < 0.001$).

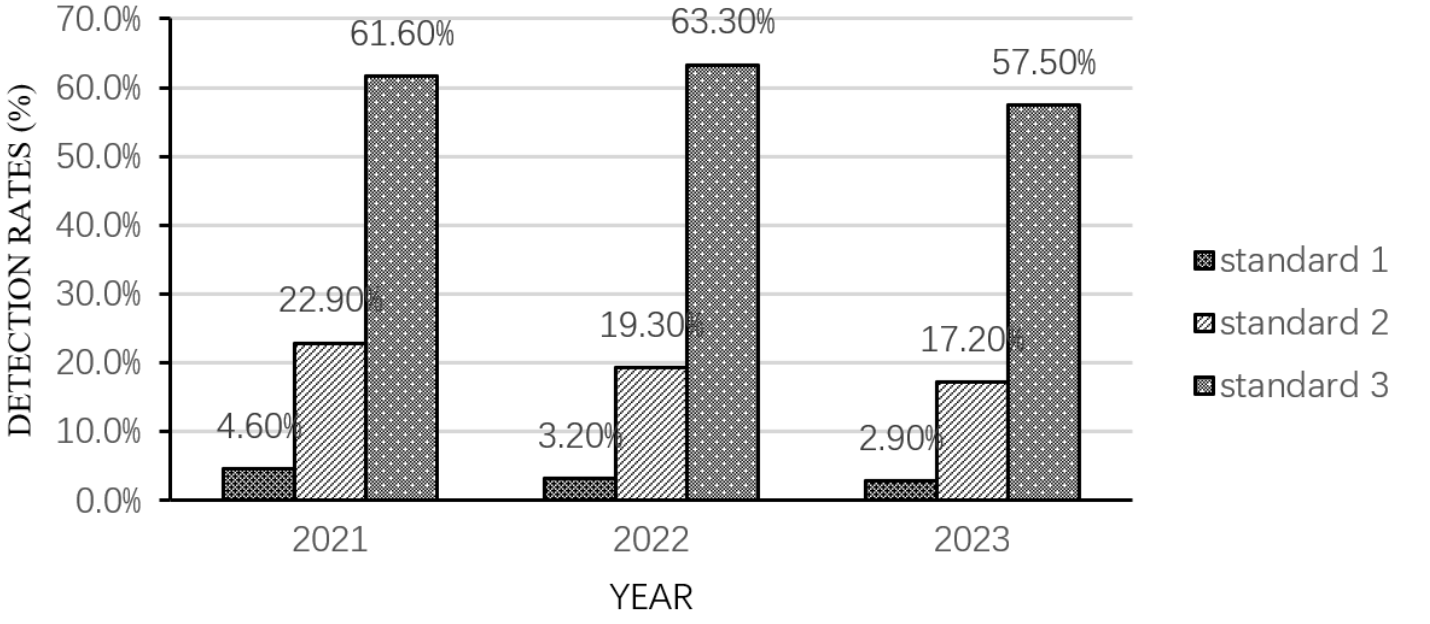

Figure 2

Detection rates of abnormal visual acuity under different reference standards

Note: regarding reduced visual acuity, **standard 1**follows the *Guidelines for the Diagnosis and Treatment of Amblyopia (2018 edition)*, defining reduced visual acuity as < 4.7 for children 4–5 years of age and <

4.8 for children 6 years of age. Standard 2 refers to the *Standards for Eye Care and Vision Examination Services for Children Aged 0–6 (Trial),* in which reduced visual acuity is defined as< 4.8 for children 4 years of age and < 4.9 for children 5–6 years of age. Standard 3 refers to the *Guidelines for Appropriate Technologies for the Prevention and Control of Myopia in Children and Adolescents (updated edition),* in which reduced visual acuity is defined as ≤ 4.8 for 4-year-old children and ≤ 4.9 for children 5–6 years of age.

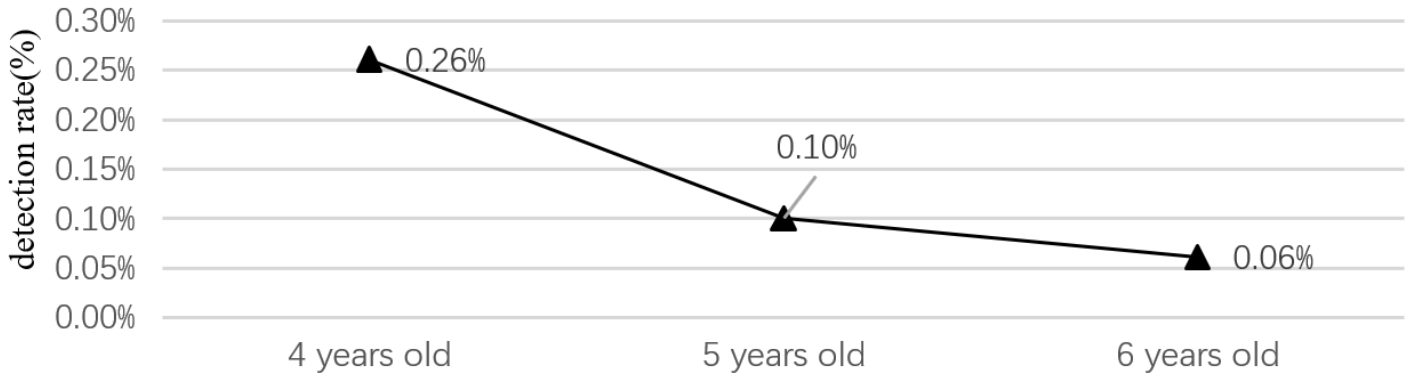

Figure 3

Screening myopia detection rate in each age group

Note: the number of myopia screenings in the 4-, 5-, and 6-year-old groups was 97, 42, and 21, respectively. Screening myopia: Of 113,510 eyes, 160 met the criteria for screening myopia, representing a 0.1% screening myopia rate. The screening myopia detection rates in all age groups decreased year-after-year with age.