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RESEARCH

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Relationship between the axial length/corneal radius of curvature ratio and hyperopia reserve in preschool children aged 3 - 6 years

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Abstract

Purpose This study aimed to investigate the association between the axial length (AL) to average corneal curvature (CR) ratio and hyperopia reserve in preschool children.

Methods AL, CR, horizontal and vertical meridians of the corneal radius (CR1, CR2), and 1% atropine cycloplegic refraction were measured in preschool children aged 3 - 6 years. The corneal curvatures were then used to calculate the AL/CR1, AL/CR2, and AL/CR ratios.

Results A total of 338 children were included, comprising 178 boys (52.7%) and 160 girls (47.3%). The mean values for AL, CR, AL/CR1, AL/CR2, AL/CR, and spherical equivalent refractive error (SER) were 22.11 ± 0.88 mm, 7.77 ± 0.26 mm, 2.80 ± 0.09, 2.90 ± 0.09, 2.85 ± 0.09, and + 2.13 ± 1.46 D, respectively. AL, AL/CR1, AL/CR2, and AL/CR increased with age, showing significant differences among age groups ($P < 0.001$). Conversely, SER moved from higher hyperopia toward lesser hyperopia with age, also showing significant differences among age groups ($P < 0.001$). Linear regression equations were established, with Y representing hyperopia reserve and X representing AL/CR: Age 3: Y = 44.67 - 15.02X; Age 4: Y = 33.96 - 11.19X; Age 5: Y = 42.11 - 13.98X; Age 6: Y = 44.94 - 15.00X. These results suggest that the AL/CR ratio could be used to assess hyperopia reserve insufficiency. The optimal cut-off point for the receiver operating characteristic (ROC) curve was ≥ 2.91, with a sensitivity, specificity, and Youden index of 0.84, 0.88, and 0.73, respectively. The critical value of the ROC curve increased with age in children aged 3 - 6 years.

Conclusion This cross-sectional study found that the hyperopia reserve in children of different ages can be estimated using the hyperopia reserve equation. Additionally, the AL/CR ratio can serve as an effective index for detecting hyperopia reserve insufficiency, with an optimal ROC curve cut-off point of ≥ 2.91 in preschool children aged 3 - 6 years, and the critical value increasing with age.

Keywords Hyperopia reserve, Preschool children, Axial length/corneal curvature radius ratio (AL/CR), Refractive error, Myopia

Introduction

The refractive status of newborns varies, with most being hyperopic—a condition physiologically referred to as hyperopia reserve of +2.50~+ 3.00 D [1]. As children and adolescents grow, hyperopia gradually decreases, approaching emmetropia by late adolescence, a process known as emmetropization [2–4]. Wang JJ [5] reported normative values for hyperopia reserve of 2.64 D (range: 2.40 D–2.88 D) at 3 years and 2.08 D (range: 1.72 D–2.45

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D) at 6 years. Generally, refraction shifts towards emmetropia (hyperopia reserve range of − 0.50 to +0.50 D) by the age of 15 [2]. However, due to early educational interventions and insufficient outdoor activities, some children deplete their hyperopia reserves during the preschool years, increasing their risk of developing myopia in primary school and, subsequently, their higher risk of high myopia [6].

According to the refractive development rule mentioned above, we defined preschool children with hyperopia of ≤+ 0.75D after atropine cycloplegic refraction as being in the early stages of myopia, with a high likelihood of progressing to myopia and requiring early intervention [7, 8]. Therefore, decreasing consumption of hyperopia reserve in preschool children is crucial for the prevention and control of myopia. Although,there are several risk factors associated with myopia development such as age, parental myopia, education, urban living environment with reduced outdoor time, etc [9]. The aforementioned risk factors alone are not sufficient to determine the risk of onset and progression accurately.Accurate measurement of hyperopia reserve in preschool children is typically obtained through cycloplegic refraction. Commonly used cycloplegic agents include 1% atropine sulfate ophthalmic gel and 1% cyclopentolate eye drops. However, the use of these agents can cause systemic side effects. For instance, 1% atropine sulfate eye gel can induce symptoms such as skin flushing, dry mouth, fever, nausea, vomiting, photophobia, and dyslexia for up to 21 days after pupil dilation [10, 11]. Similarly, 1% cyclopentolate hydrochloride eye drops may cause adverse reactions such as blushing, dry mouth, drowsiness, and tachycardia. In rare cases, children may experience short-term central nervous system effects, including ataxia, disorientation, dizziness, hallucinations, and incoherent speech [11–15]. These potential side effects often lead to parental concerns regarding cycloplegic refraction in preschool children. Although cycloplegic refraction remains the gold standard for measuring hyperopia reserve, finding a more convenient and feasible index for evaluating hyperopia reserve in the absence of cycloplegic refraction is necessary.In this regard, modern technology for axial length (AL) in combination with other ocular measurements to differentiate normal from excessive ocular growth provides clinicians with a powerful tool to identify at risk children. Additionally, techniques to measure AL and average corneal curvature (CR) are rapid, non-invasive and can be easy for both the practitioner and the young child.

Previous studies have shown that an AL/CR exceeding 3 is a high-risk indicator for the transition from emmetropia to myopia [16–18]. Compared to cycloplegic refraction, the AL/CR ratio is easier to measure and less influenced by subjective factors. However, clinical studies have indicated that the AL/CR ratio may not be a reliable predictor for preschool children aged 3–5 years [19]. The refractive parameters of preschool children, such as AL, CR, and hyperopia reserve, vary with age, which may affect research outcomes. Overall, there is a paucity of clinical studies examining the relationship between the AL/CR ratio and hyperopia reserve in preschool children. Therefore, this study aimed to investigate the relationship between the AL/CR ratio and hyperopia reserve in preschool children by analyzing refractive parameters, to guide clinical practice and contribute to the prevention and control of myopia in children and adolescents.

Article types

Original Research articles

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Materials and method

Study design and population

This cross-sectional study was conducted between January 2023 and July 2024, involving a total of 338 preschool children aged 3–6 years who consented to undergo cycloplegic refraction at a hospital in Shanghai. The inclusion criteria included the following: (1) Preschool children aged 3–6 years. (2) Astigmatism< 3.00D after cycloplegic refraction. (3) Absence of diseases related to visual acuity and refractive examinations (such as congenital cataract, ptosis, nystagmus, strabismus, etc. [20]). (4) No history of refractive error correction prior this study examination, and no history of eye surgery or trauma. Detailed information about the examination and important considerations was provided to the guardians of all enrolled children, who signed an informed consent form. On the day of the examination, verbal consent was also obtained from the subjects for reconfirmation. The study protocol was approved by the Ethics Committee of Children's Hospital of Fudan University in Shanghai. All the subjects were treated according to the tenets of the Declaration of Helsinki.

Eye examination

The same equipment was used consistently throughout the study, with daily calibration of all instruments. All subjects underwent cycloplegic refraction using 1% atropine sulfate ophthalmic gel [21, 22]. The gel was applied three times a day for three consecutive days. Pupil diameter and pupillary light reflex were observed, and if the pupil diameter was >6 mm or the pupillary light reflex disappeared, cycloplegic refraction was measured via retinoscopy two times by specialized technicians to ensure exactness. The horizontal and vertical meridian of the corneal radius (CR1, CR2) were measured three times with an autorefractor keratometer (NIDEK, Co; LTD, Japan. Model: ARK- 1) and the CR was calculated. AL was measured three times routinely with an IOL-Master 500 (Carl Zeiss Meditec, Ag. jena, Germany). The examinations were performed by the same specialized technician, and the averages of the two refractive measurements and the three keratometry and AL measurements were used. Spherical equivalent refractive error (SER) was calculated as SER = spherical power + (cylinder power/2). In this study, hyperopia reserve is equal to the SER by 1% atropine sulfate ophthalmic gel cyclo.

Definitions

Based on the SER after cycloplegic refraction, subjects were divided into the following five groups: emmetropia (− 0.50 < SER ≤ + 0.50 D), mild myopia (− 3.00 < SER ≤ − 0.50 D), mild hyperopia (+ 0.50 < SER < + 3.00 D), moderate hyperopia (+ 3.00 ≤ SER < + 5.00 D), and high hyperopia (SER ≥ + 5.00 D). Additionally, subjects were categorized into four groups according to age: ages 3,4,5,6 years.

Statistical analysis

SPSS 26.0 software was used for data analysis. Due to the high correlation between right and left eye refraction, only the results of the right eye were included in the analysis. The Shapiro–Wilk test was used to check the normality. The dates were expressed as mean ± standard deviation (X ± S), while the counted data were expressed as percentages (%). $P< 0.050$ was considered statistically significant. Refractive parameters were compared between sexes using an independent-sample t-test, and one-way analysis of variance (ANOVA) was used to compare refractive parameters among different age groups. Linear regression analysis was performed to evaluate hyperopia reserve across different age groups, and the area under receiver operating characteristic (ROC) curve was used to determine the validity and cut-off values for hyperopia reserve insufficiency. Area under ROC curve (AUC) value of 1.00 is a perfect test, 0.90–0.99 is an excellent test, 0.80–0.89 is a good test, 0.70–0.79 is a fair test, 0.51–0.69 is a poor test, and 0.50 is of no value [23].

Results

Subject characteristics

A total of 338 preschool children participated in the study, comprising 178 boys (52.7%) and 160 girls (47.3%). The average age of the participants was 4.8 years old (58.0 ± 3.0 months). The age distribution was as follows: 95 children (28.1%) were aged 3 years, 101 children (29.9%) were aged 4 years, 95 children (28.1%) were aged 5 years, and 47 children (13.9%) were aged 6 years. The sample size of participants identified as having hyperopia reserve insufficiency was 46 (13.6%). Among the subjects, 16 (4.7%) were classified into the high hyperopia group, 57 (16.9%) into the moderate hyperopia group, 224 (66.3%) into the mild hyperopia group, 28 (8.3%) into the emmetropia group, and 13 (3.8%) into the mild myopia group. The majority of children were hyperopic, with the prevalence decreasing with age, while the incidence of myopia increased with age. Specifically, 92 children (96.8%) aged 3 years, 91 children (90.1%) aged 4 years, 78 children (82.1%) aged 5 years, and 36 children (76.6%) aged 6 years had hyperopia. In total, 297 children (87.9%) exhibited hyperopia. Generally, the refractive status of the children shifted from moderate and high hyperopia to mild hyperopia, eventually progressing to emmetropia and mild myopia. The incidence of emmetropia and mild myopia was higher in boys, while the prevalence of hyperopia was higher in girls (Table 1).

Comparison of refractive parameters among different age and gender groups

The mean values of the measured refractive parameters were as follows: The AL was 22.11 ± 0.88 mm, CR was 7.77 ± 0.26 mm, AL/CR1 ratio was 2.80 ± 0.09,

Table 1 The general refractive status of preschool children of different ages and genders (%)

Variables	Number	Emmetropes	Mild Myopes	Mild Hyperopes	Moderate Hyperopes	High Hyperopes
Total	338	28 (8.3)	13 (3.9)	224 (66.3)	57 (16.9)	16 (4.7)
Age(y)						
3y	95	2 (2.1)	1 (1.1)	54 (56.8)	28 (29.5)	10 (10.5)
4y	101	7 (6.9)	3 (3.0)	72 (71.3)	17 (16.8)	2 (2.0)
5y	95	13 (13.7)	4 (4.2)	65 (68.4)	9 (9.5)	4 (4.2)
6y	47	6 (12.8)	5 (10.6)	33 (70.2)	3 (6.4)	0 (0.0)
SERx						
Male	178	19 (10.7)	8 (4.5)	114 (64.0)	28 (15.7)	9 (5.1)
Female	160	9 (5.6)	5 (3.1)	110 (68.8)	29 (18.1)	7 (4.4)

AL/CR2 ratio was 2.90 ± 0.09, AL/CR ratio was 2.85 ± 0.09, and hyperopia reserve was +2.13 ± 1.46 D. AL increased significantly with age, with a mean annual increase of 0.15–0.64 mm, with significant differences among the age groups (F = 38.4, p < 0.001). Similarly, AL/CR1, AL/CR2, and AL/CR ratios increased with age, with significant differences among the age groups (F = 48.2, F = 25.1, F = 39.9, respectively; all p < 0.001). The annual increments from ages 3–6 were 0.03–0.07, 0.03–0.04, and 0.03–0.06, respectively. Hyperopia reserve decreased significantly with age, with a mean annual decrease of 0.20–0.76 D, and significant differences were found among the age groups (F = 17.7, p < 0.001). CR showed a slow increase with age, there was significant difference among the age groups (F = 3.1, p = 0.026) (Table 2). Boys had significantly longer AL compared to girls (t = 6.19, p < 0.001), and the CR was significantly larger in boys than in girls (t = 6.21, p < 0.001). However, there were no significant differences between boys and girls in the AL/CR1 ratio (t = 1.00, p = 0.32), AL/CR2 ratio (t = 1.38, p = 0.17), AL/CR ratio (t = 1.25, p = 0.21), or hyperopia reserve (t = − 1.13, p = 0.26) (Tables 2, 3). The CR1 and CR2 between sex categories were significantly different (all p < 0.001). A significant difference among age groups was found in CR2 (P= 0.004) and no significant difference was found in CR1 (P= 0.09).

Ocular biometry by different refractive groups

Significant differences in AL were observed among all refractive groups (F = 40.7, p < 0.001), with the order from longest to shortest being mild myopia, emmetropia, mild hyperopia, moderate hyperopia, and high hyperopia. There was no significant difference in CR among the refractive groups (F = 0.4, p = 0.77). However, significant differences were found in the AL/CR1 ratio (F = 94.3, p < 0.001), AL/CR2 ratio (F = 71.2, p < 0.001), and AL/CR ratio (F = 100.6, p < 0.001) among the refractive groups, with the order from highest to lowest being mild myopia, emmetropia, mild hyperopia, moderate hyperopia, and high hyperopia. Additionally, significant differences in hyperopia reserve were observed among the refractive groups (F = 388.6, p < 0.001) (Table 4).

Table 2 Details of study cohort

Variables	AL(mm)	CR(mm)	AL/CR1	AL/CR2	AL/CR	Hyperopia Reserve(D)
Age(year)						
3	21.47 ± 0.78	7.71 ± 0.27	2.72 ± 0.08	2.85 ± 0.09	2.79 ± 0.08	2.84 ± 1.55
4	22.11 ± 0.73	7.77 ± 0.27	2.79 ± 0.08	2.89 ± 0.08	2.85 ± 0.07	2.11 ± 1.19
5	22.50 ± 0.78	7.82 ± 0.25	2.82 ± 0.09	2.93 ± 0.09	2.88 ± 0.09	1.91 ± 1.42
6	22.65 ± 0.74	7.76 ± 0.21	2.88 ± 0.07	2.96 ± 0.06	2.92 ± 0.06	1.15 ± 1.14
F	38.4	3.1	48.2	25.1	39.9	17.7
P	< 0.001	0.03	< 0.001	< 0.001	< 0.001	< 0.001
Sex						
Male	22.38 ± 0.84	7.85 ± 0.26	2.80 ± 0.10	2.91 ± 0.10	2.85 ± 0.10	2.04 ± 1.55
Female	21.82 ± 0.83	7.68 ± 0.23	2.79 ± 0.09	2.89 ± 0.08	2.84 ± 0.08	2.22 ± 1.35
t	6.19	6.21	1.00	1.38	1.25	− 1.13
P	< 0.001	< 0.001	0.32	0.17	0.21	0.26

Table 3 Ocular biometry by gender

Variables	Average	Standard deviation	Average of boys	Standard deviation of boys	Average of girls	Standard deviation of girls	*P* values
Age(month)	57.98	29.87	56.91	12.36	59.17	41.45	0.49
AL (mm)	22.11	0.88	22.38	0.84	21.82	0.83	< 0.001
SER (D)	2.13	1.46	2.04	1.55	2.22	1.35	0.26
CR(mm)	7.77	0.26	7.85	0.26	7.68	0.23	< 0.001
AL/CR1	2.80	0.09	2.80	0.10	2.79	0.09	0.32
AL/CR2	2.90	0.09	2.91	0.10	2.89	0.08	0.17
AL/CR	2.85	0.09	2.85	0.10	2.84	0.08	0.21

Percentile for AL/CR by age and refractive groups

Tables 5 and 6 provide AL/CR age and different refraction 5 th, 10 th, 25 th, 50 th, 75 th, 90 th and 95 th percentiles. Both AL/CR percentiles increased with age and reduction of hyperopia reserve.

Ocular biometry correlation coefficients and regression equation of hyperopia reserve in different age groups

Regression equations were developed for hyperopic reserve across different age groups, with hyperopia reserve as the dependent variable and the AL/CR ratio as the independent variable. Y denotes the hyperopia reserve, and X denotes the AL/CR ratio. The equations for each age group are as follows (Table 7):

Age 3: Y = 44.67 - 15.02X

Age 4: Y = 33.96 - 11.19X

Age 5: Y = 42.11 - 13.98X

Age 6: Y = 44.94 - 15.00X

ROC curve of AL/CR in judging hyperopia reserve insufficiency

The ROC curves for AL/CR1, AL/CR2, and AL/CR in detecting hyperopia reserve insufficiency yielded the following AUC values:

AL/CR1: 0.906 (95% CI: 0.866–0.946)

AL/CR2: 0.924 (95% CI: 0.883–0.965)

AL/CR: 0.935 (95% CI: 0.903–0.968)

The respective cut-off values were 2.85, 2.95, and 2.91 (Figure 1). These results suggest that the AL/CR ratio is a reliable metric for assessing hyperopia reserve insufficiency, with the optimal cut-off point being ≥ 2.91. This threshold was associated with a sensitivity of 0.84, specificity of 0.88, and a Youden index of 0.73. Additionally, no significant differences were observed in the ROC curves or AL/CR ratios between boys and girls aged 3 to 6 years ($P = 0.95$). Notably, the diagnostic threshold for hyperopia reserve insufficiency increased with age, ranging from > 2.91 at age 3 to > 2.97 at age 6.

Table 4 Comparison of refractive parameters among different refractive groups X ± S

Group	AL (mm)	CR (mm)	AL/CR1	AL/CR2	AL/CR	Hyperopia Reserve(D)
High hyperopia	20.83 ± 0.83	7.77 ± 0.40	2.63 ± 0.08	2.73 ± 0.10	2.68 ± 0.07	5.84 ± 0.91
Moderate hyperopia	21.61 ± 0.71	7.80 ± 0.29	2.72 ± 0.06	2.83 ± 0.05	2.77 ± 0.05	3.60 ± 0.53
Mild hyperopia	22.15 ± 0.73	7.76 ± 0.25	2.80 ± 0.06	2.91 ± 0.07	2.86 ± 0.06	1.91 ± 0.64
Emmetropia	23.00 ± 0.69	7.76 ± 0.22	2.92 ± 0.06	3.00 ± 0.05	2.96 ± 0.05	0.16 ± 0.30
Mild myopia	23.44 ± 0.52	7.82 ± 0.26	2.96 ± 0.08	3.04 ± 0.07	3.00 ± 0.07	– 0.99± 0.67
F	40.7	0.4	94.3	71.2	100.6	388.6
P **value**	< 0.001	0.77	< 0.001	< 0.001	< 0.001	< 0.001

Table 5 AL/CR percentiles for age groups

Age	AL/CR percentiles						
	5	**10**	**25**	**50**	**75**	**90**	**95**
3	2.66	2.68	2.74	2.79	2.83	2.87	2.91
4	2.71	2.77	2.80	2.85	2.89	2.94	2.95
5	2.71	2.77	2.83	2.88	2.91	2.99	3.01
6	2.80	2.85	2.88	2.92	2.97	3.00	3.01

Table 6 AL/CR percentiles for refractive groups

Group	AL/CR percentiles						
	5	**10**	**25**	**50**	**75**	**90**	**95**
High hyperopia	2.52	2.59	2.65	2.68	2.71	2.79	/
Moderate hyperopia	2.68	2.70	2.74	2.78	2.81	2.83	2.86
Mild hyperopia	2.75	2.78	2.82	2.86	2.90	2.93	2.96
Emmetropia	2.87	2.89	2.92	2.97	2.99	3.03	3.06
Mild myopia	2.85	2.86	2.98	3.00	3.05	3.10	/

Table 7 Regression equation of hyperopia reserve in different age groups

Group	R square	Regression equation analysis of variance		Regression coefficient t test			
		F	P	t	P	B	AL/CR
Age(year)							
3	0.548	112.6	< 0.001	11.33	< 0.001	44.67	− 15.02
4	0.474	89.4	< 0.001	10.08	< 0.001	33.96	− 11.19
5	0.718	236.3	< 0.001	16.10	< 0.001	42.11	− 13.98
6	0.614	71.5	< 0.001	8.67	< 0.001	44.94	− 15.00

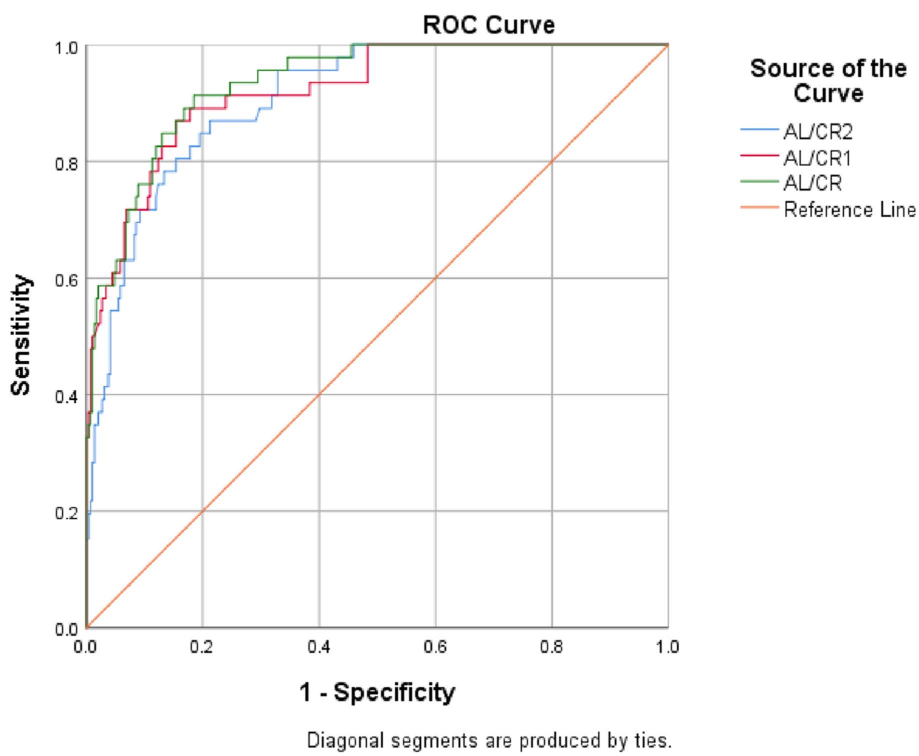

Fig. 1 AL/CR'S ROC curve

Discussion

By 2050, the global incidence of myopia is projected to rise to 49.8% of the world's population, with high myopia expected to affect 9.8% [24]. High myopia often leads to vision-threatening complications, such as retinal detachment, myopic macular degeneration, glaucoma, and cataracts, among others [25–27]. According to the latest data released in 2020, the overall myopia rate among children and adolescents in China was 52.7% [24, 28]. In recent years, the prevalence of myopia has been increasing year by year, posing a significant challenge to children's vision health.

This study demonstrates that for preschool children (aged 3–6 years), AL, CR, AL/CR1, AL/CR2 and AL/CR all increase with age, while hyperopia reserve decreases as children get older. These findings are consistent with previous Wang J and He X et al's research conclusions. [17, 29]. AL and CR were significantly higher in boys than in girls; however, there were no statistically significant differences in AL/CR1, AL/CR2, AL/CR, or hyperopia reserve between genders. In this study, the myopia group had the longest AL, whereas the high hyperopia group had the shortest,among the different refractive groups. There was no significant difference in CR among the different refractive groups. AL/CR1, AL/CR2, and AL/CR ratios progressively increased from high hyperopia, moderate hyperopia, and mild hyperopia to emmetropia and mild myopia. These results align with prior clinical findings. [17, 29–32] Previous studies have demonstrated that the growth of the AL was related to the thickness of the choroid which leads to eye dilation at growth phase [33]. However, the emmetropization is the dynamic matching result between the AL and other parameters such as corneal and crystalline refractive power, in addition to thickness of the choroid at growth phase. Therefore, it is necessary to analyze the refractive status of children of different ages. Secondly, we choose AL/CR to reflect children's hyperopia reserve which has a higher net benefit as the biometric technique is rapid, accurate, objective and less resource intensive.

In this study, 13(3.85%) of the 338 preschool children were found to have developed myopia, with the incidence increasing gradually with age, which is consistent with findings from previous studies [34, 35]. If preschool children deplete their hyperopia reserve excessively, they are at a higher risk of developing myopia during primary school years. Therefore, myopia prevention and control strategies should be initiated during the preschool years, with an emphasis on early detection and intervention [36, 37]. Previous studies have demonstrated that the AL/CR ratio has higher accuracy in predicting myopia compared to AL alone, highlighting the importance of focusing on the AL/CR ratio in clinical practice [19].Therefore we recommend using the average AL/CR ratio to assess hyperopia reserve insufficiency. Based on the regression equations from this study, it is possible to estimate the hyperopia reserve in preschool children with an optimal cutoff value of 2.91. Foo VHX [38] reported that the AL/CR ratio in a group of 3-year-old myopic children was 2.91 ± 0.06, which is consistent with our findings, although his study only included 3-year-old children. Similarly, Tong Li et al. [32] reported that the average AL/CR value in children aged 3 to 6 years was 2.90 ± 0.09, which is also in line with our results. Therefore, using AL/CR ratio ≥ 3 to evaluate the degree of hyperopia reserve in preschool children is inappropriate in clinical, as their eyes are still developing between the ages of 3 to 6 years. When preschool children's AL/CR ratio exceeds 2.91, it is recommended to closely monitor the development of their refractive state and the potential onset of myopia, with cycloplegic refraction performed if necessary.Further myopia prevention and control interventions are needed when necessary.

Conclusion

Though this was a cross-sectional study, our study data suggests that the hyperopia linear regression equation might be able to help detect hyperopia reserve which has important clinical significance. In addition, the AL/CR can be used as an ideal index to detect hyperopia reserve insufficiency in preschool children aged 3–6 years old, and the recommended detection threshold is 2.91, which increases with age.

This study has some limitations: (1) The sample size and study duration were limited. A larger sample size and more objective detection methods are still needed for further observation and research. (2) We used the same cut-off value to define hyperopia reserve insufficiency for all ages from 3 to 6 in this study. However, physiological hyperopia reserve varies among different ages. So a larger sample size will be needed for different age groups research in the future. (3) The regression equations developed have not been validated on an independent sample. Prediction equations have value for estimating populations, but they don't always work for the individual patient. The formulas may therefore be more suitable for screening purposes to identify those at highest risk. Those individuals who are deemed at high risk based on the predictive equation may then need to be tested more precisely with cycloplegic refraction. (4) In addition, this study cannot exclude influencing factors such as parental myopia, education, urban living environment with reduced time outdoors, etc, which are difficult to avoid completely in retrospective studies. (5) The effect of atropine thickening the choroid as a limitation of our research.

Abbreviations

AL	Axial length
SER	Spherical equivalent refractive
CR	Average corneal radius
CR1	Horizontal meridians of the corneal radius
CR2	Vertical meridians of the corneal radius
ROC	Receiver operating characteristic
AUC	Area under ROC curve

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Associated data

This section collects any data citations, data availability statements, or supplementary materials included in this article.

Authors' contributions

Conceptualization and manuscript revision (JW & JZ); Manuscript drafting ((JW); Literature screening (JZ); Literature search (JZ); Manuscript revision (JW & JZ); Supervision and manuscript revision (JW & JZ); Critical revision and final approval of article (all authors).

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Data availability

This section collects any data citations, data availability statements, or supplementary materials included in this article. The data used to support the findings of this study are available from the corresponding authors upon request.

Declarations

Ethics approval and consent to participate
This study was approved by the Ethics Committee of Children's Hospital of Fudan University. Informed written consent was obtained from all patients. For the patients under 18 years old, informed consents were signed with their parents before the study. We confirm that all methods were performed in accordance with the relevant guidelines and regulations.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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