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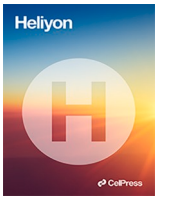

Research article

Refractive and ocular biometric characteristics of non-myopic and pseudomyopic eyes in mild hyperopic Chinese children aged 3–12 years

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ABSTRACT

Purpose: To investigate the refractive and ocular biometric characteristics of children with mild hyperopia and distinguish between non-myopic and pseudomyopic eyes before cycloplegia.
Methods: The eligible children underwent refractive error measurements using a NIDEK autorefractor before and after the administration of 0.5 % tropicamide. Ocular biometric parameters, including axial length (AL), anterior chamber depth (ACD), and lens thickness (LT), were measured using the IOLMaster 700 before cycloplegia. We performed comparative analyses between the non-myopic and pseudomyopic groups, categorized based on whether the spherical equivalent (SE) before cycloplegia exceeded −0.50 diopters (D). Univariable and multivariable regression analyses were performed to control for confounding factors.
Results: The final analysis included 968 eyes. The participants with pseudomyopia were more likely to be boys ($P = 0.029$), younger ($P = 0.004$), less hyperopic ($P < 0.001$) after cycloplegia, and exhibit a higher delta SE ($P < 0.001$) compared to the non-myopic participants. Pseudomyopic eyes were associated with a shallower ACD ($P = 0.004$) and thicker LT ($P < 0.001$) than non-myopic eyes. After adjusting for sex, age, and SE, pseudomyopic eyes showed increased AL ($P = 0.001$) and LT ($P < 0.001$) and decreased ACD ($P = 0.005$) compared with non-myopic eyes before cycloplegia.
Conclusions: Among the children with mild hyperopia, pseudomyopia was more common in younger boys with a lower cycloplegic SE and higher delta SE. A thicker LT, shallower ACD, and increased AL may indicate the presence of pseudomyopia, which may provide insights into the rapid progression of myopia in children with pseudomyopia.

1. Introduction

Refractive errors, including myopia, have emerged as a significant global health concern and a leading cause of visual disability [1, 2]. The COVID-19 pandemic and subsequent lockdowns over the past three years have led to increased screen time, excessive

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near-work, and decreased outdoor activities for children. These factors contribute to the occurrence of near-work-induced transient myopia (NITM) and accelerated myopia progression [3].

Pseudomyopia, a subtype of excessive accommodation, is characterized by a spherical equivalent (SE) of ≤ -0.50 diopters (D) before cycloplegia and > -0.50 D after cycloplegia [4,5]. In children with active accommodative reflexes, non-cycloplegic autorefraction overestimates myopia and underestimates hyperopia compared with the gold standard of cycloplegic refraction [6–8]. Despite the prevalence of pseudomyopia, affecting nearly 24.1 % of Chinese children, clinical research on this condition remains lacking [9].

Pseudomyopia is an independent risk factor for myopia onset; therefore, research on identifying pseudomyopia and exploring its underlying causes is required [10]. However, due to the limitations in measurement techniques, reporting on the distribution of ocular biometric parameters in individuals with pseudomyopia has been relatively limited. This information may provide valuable insights into the pathogenesis of excessive accommodation and early-onset myopia.

This study aimed to investigate the refractive and ocular biometric characteristics of pseudomyopic eyes by comparing them with those of non-myopic eyes in children with mild hyperopia.

2. Materials and methods

2.1. Participants

This observational cross-sectional study included a sample size of 968 patients. The participants were consecutively enrolled from 2021 to 2023 at the Refractive Clinics of the Eye and ENT Hospital of Fudan University, Shanghai, China, a tertiary care medical center with high patient volume. After obtaining medical history and conducting basic ophthalmological evaluations, the eligible children underwent examinations before and after cycloplegia according to the study protocols. Mild hyperopic eyes were defined as those with a cycloplegic SE between +0.50D and +3.00D. Based on non-cycloplegic SE, participants were categorized into the following two independent groups: the Pseudomyopic Group (non-cycloplegic SE ≤ -0.50 D but cycloplegic SE $> +0.50$ D) and the Non-myopic Group (non-cycloplegic and cycloplegic SE $> +0.50$ D).

This study adhered to the principles outlined in the Declaration of Helsinki and was approved by the Ethics Committee of the Eye and ENT Hospital of Fudan University. Informed consent for participation was obtained from the parents or legal guardians of the children.

The inclusion criteria were as follows: 1) age between 3 and 12 years; 2) absence of contraindications for ciliary muscle paralysis; 3) best-corrected visual acuity not <0.5 in logMAR, with proper fixation on the target to ensure that participants can be effectively tested in the study; 4) clear cornea and crystalline lens without visible opacity under slit-lamp examination. The exclusion criteria were as follows: 1) medical history of severe ocular diseases, such as retinopathy of prematurity or abnormal ocular refractive anatomy, such as keratoconus; 2) history of intraocular surgery or eye trauma; 3) systemic diseases that may affect refraction, including endocrine disorders, neurological conditions, and cardiovascular diseases; 4) current or previous use of low-dose atropine, pirenzepine, or any contact lenses aimed at controlling myopia progression.

Demographic data for each eligible participant, including date of birth, age, and sex, were retrieved from the electronic medical records at the outpatient clinic.

2.2. Examinations

Each eligible participant underwent objective refraction measurements three times before the average value was derived. These measurements were conducted by the same eye care professional using a table-mounted NIDEK autorefractor (ARK 510A; NIDEK, Japan).

Biometric measurements were obtained using an IOLMaster 700 (Carl Zeiss, Jena, Germany). Before measurement, the participants were seated with their chins resting on the chinrest and foreheads aligned, with a straight-ahead gaze. All the measurements were automated using an active improved scan display. The valid measurements were indicated by a "green check" status for all the parameters on the interface. Axial length (AL), anterior chamber depth (ACD), lens thickness (LT), and central corneal thickness (CCT) were measured using the swept-source method. The highest corneal radius of curvature (CR1) and least corneal radius of curvature (CR2) in the principal meridians were determined from the reflected light spots on the anterior corneal surface. The mean corneal radius of curvature (CR) was calculated as the average of these values. The axial length-corneal radius (AL/CR) ratio was calculated by dividing AL by CR. White-to-white (WTW) measurements were obtained from scleral and iris photographs.

Following the IOLMaster 700 examination, the participants received cycloplegia using tropicamide 0.5 % (Bausch & Lomb Pharmaceutical Co., Ltd., Shandong, China) administered at 5-min intervals for three doses. An eye care professional assessed accommodation ability through near-vision testing with a close-distance target. An absence of accommodation indicated effective ciliary muscle paralysis. If accommodation was not completely absent, additional drops were administered until complete paralysis was achieved. Subsequently, autorefraction was repeated using the same equipment and by the same professional, 30 min after the final tropicamide administration. The SE for each eye before and after cycloplegia was calculated by adding the sphere to half of the cylinder.

All the participants with cycloplegic SE ranging from +0.50 D to +3.00 D, defined as mild hyperopia, were categorized into the following two groups based on their SE before cycloplegia: 1) Non-myopic Group (non-cycloplegic and cycloplegic SE $> +0.50$ D). 2) Pseudomyopic Group (non-cycloplegic SE ≤ -0.50 D but cycloplegic SE $> +0.50$ D). The delta SE (ΔSE) was computed as the difference between cycloplegic and non-cycloplegic SE.

2.3. Statistical analysis

Descriptive statistics are presented based on the normal distribution of data and were assessed using the Shapiro–Wilk test. The characteristics of normally distributed data are expressed as mean (SD), whereas those of non-normally distributed data are presented as median [Interquartile Range (IQR)]. Categorical variables are described using absolute and relative frequencies. To determine the differences between groups, the following statistical tests were employed: independent t-tests for normally distributed continuous variables with equal variance, Welch's *t*-test for normally distributed continuous variables with unequal variance, Wilcoxon Mann–Whitney tests for skewed continuous variables, and McNemar $\chi 2$ tests and Fisher's exact tests for categorical data.

The refractive and ocular biometric parameters selected for the logistic regression analysis were determined based on existing research and their significance in the preceding difference analysis. Variables with $P < 0.250$ were considered suitable for multivariate analyses in the next step [11,12].

Univariate and multivariate analyses were performed to control for confounding factors, such as sex and age, setting sex as a categorical covariate (dummy variable), and yielding unadjusted and adjusted odds ratios (OR), 95 % confidence intervals (CI), and significance levels for each variable using binary logistic analysis.

Box-and-Whisker Plots were used to compare the distributions of multiple groups, visually representing data characteristics, such as distributions, central tendency, spread, and the presence of outliers. The box in the center represents the interquartile range (IQR) covering the middle 50 % of the data. The lower and upper boundaries of the box correspond to the first (Q1) and third quartile (Q3), respectively. The line inside the box represents the median (Q2), indicating the midpoint of the dataset. Whiskers extend from the top to the bottom of the box to display the data range. Data points beyond the whiskers are potential outliers, representing extreme values in the dataset.

Sensitivity analysis was performed to enhance the reliability of the conclusions. This analysis compared the refractive and ocular biometric parameters of non-myopic and pseudomyopic eyes among the participants with cycloplegic SE ranging from +0.50 D to +1.50 D.

Statistical analyses were performed using SPSS V.26.0 and Microsoft Excel 2019, with a two-tailed *P* value < 0.05 considered statistically significant.

3. Results

3.1. Data description

This study included 968 eyes, comprising 834 non-myopic and 134 pseudomyopic eyes. Table 1 presents the characteristics of all participants and their respective groups. Approximately 55.6 % of the participants were female, with a median age of 7 years (IQR = 4 years). Among all participants, the median non-cycloplegic, cycloplegic, and delta SE was +0.50 D (IQR = 1.25 D), +1.50 D (IQR = 1.25 D), and 0.88 D (IQR = 0.88 D), respectively. No significant differences were observed in cylinder diopters ($P = 0.485$) between the two groups. However, individuals with pseudomyopia were younger (6 years vs. 7 years, $P = 0.004$), more myopic before cycloplegia (−1.00 D vs. −0.75 D, $P < 0.001$), less hyperopic after cycloplegia (+1.00 D vs. +1.50 D, $P < 0.001$), and had a higher delta SE (2.13 D vs. 0.75 D, $P < 0.001$) and smaller proportion of girls (45.5 % vs. 54.5 %, $P = 0.029$) compared with those without myopia before cycloplegia.

Table 1
Distribution of demographics and refraction characteristics in the non-myopic group and pseudomyopic group in mild hyperopic eyes.

Characteristics	All	Nonmyopic Group	Pseudomyopic Group	*P*
N (%)	968	834	134	
Sex (N, %)				0.029
Female	525 (54.2 %)	464 (55.6 %)	61 (45.5 %)	
Male	443 (45.8 %)	370 (44.4 %)	73 (54.5 %)	
Age(years)				0.004
Median (IQR)	7 (4)	7 (4)	6 (4)	
Range (Min, Max)	3, 12	3, 12	3, 12	
Non-cycloplegic SE (D)				<0.001
Median (IQR)	0.50 (1.25)	0.75 (1.00)	−1.0 (1.16)	
Range (Min, Max)	−8.38, 9.00	−0.38, 9.00	−8.38, −0.50	
Cycloplegic SE (D)				<0.001
Median (IQR)	1.50 (1.25)	1.50 (1.23)	1.00 (0.75)	
Range (Min, Max)	0.50, 3.00	0.50, 3.00	0.50, 3.00	
Delta SE (D)				<0.001
Median (IQR)	0.88 (0.88)	0.75 (0.88)	2.13 (1.78)	
Range (Min, Max)	−6.00, 9.13	−6.00, 3.00	1.00, 9.13	
Diopter of cylinder (D)				0.485
Median (IQR)	−0.50 (0.75)	−0.75 (0.75)	−0.50 (0.75)	
Range (Min, Max)	−6.00, 0.00	−4.25, 0.00	−6.00, 0.00	

Values are presented as N (%), mean (SD), or median (IQR) as applicable.
SD, standard deviation; IQR, interquartile range; SE, spherical equivalent; SD, standard deviation.

3.2. Differences in ocular biometry

Table 2 and Fig. 1 illustrate the distribution of ocular biometric parameters in both groups. The pseudomyopic group exhibited significantly shallower ACD (3.38 mm vs. 3.45 mm, $P = 0.004$) and thicker LT (3.65 mm vs. 3.55 mm, $P < 0.001$) than the non-myopic group. Additionally, the pseudomyopic group showed no significant differences in AL (22.80 mm vs. 22.66 mm, $P = 0.087$) and CCT (543.92 mm vs. 548.92 mm, $P = 0.083$), as compared to the non-myopic group.

3.3. Univariate and multivariate logistic regression analysis

Table 3 shows the results of the univariate and multivariate logistic regression analyses comparing ocular biometric differences between the non-myopic and pseudomyopic groups. After adjusting for sex, age, and cycloplegic SE, the pseudomyopic group exhibited increased AL (OR: 1.77, 95 % CI: 1.27–2.48, $P = 0.001$) and LT (OR: 33.06, 95 % CI: 7.78–140.47, $P < 0.001$), and decreased ACD (OR: 0.15, 95 % CI: 0.04–0.56, $P = 0.005$) compared with the non-myopic eyes.

3.4. Sensitivity analysis

Table 4 displays the distributions of demographic and refractive characteristics in the eyes with cycloplegic SE ranging from +0.50 D to +1.50 D, including 425 (80 %) non-myopic and 105 (20 %) pseudomyopic eyes. In this subgroup analysis, pseudomyopic participants were younger (6 years vs. 7 years, $P = 0.003$), less hyperopic after cycloplegia (+0.88 D vs. +1.00 D, $P = 0.003$), and had a significantly higher delta SE (1.88 D vs. 0.63 D, $P < 0.001$) compared with the non-myopic participants. Furthermore, pseudomyopic eyes had a lower AL/CR ratio (2.91 vs. 2.92, $P = 0.009$), shallower ACD (3.39 mm vs. 3.49 mm, $P < 0.001$), and thicker LT (3.63 mm vs. 3.54 mm, $P < 0.001$) than non-myopic eyes. After adjusting for age and cycloplegic SE, pseudomyopic eyes exhibited increased LT (OR: 15.16, 95 % CI: 2.65 to 86.85, $P = 0.002$) compared with non-myopic eyes (See Table 5).

4. Discussion

This study investigated the differences in refractive and ocular biometric parameters between non-myopic and pseudomyopic groups. Our findings regarding the age and refractive characteristics of pseudomyopia align with existing literature. For instance, the Anyang Childhood Eye Study discovered that pseudomyopia is more prevalent among younger, more hyperopic children [9]. Furthermore, a larger difference in refractive error between non-cycloplegic and cycloplegic measurements was associated with a more hyperopic refractive error [13,14]. Additionally, children with myopia tend to accommodate less than those with emmetropia [15,16].

Table 2
Distribution of ocular biometric parameters of nonmyopic group and pseudomyopic group in mild hyperopic eyes.

Characteristics	All	Nonmyopic Group	Pseudomyopic Group	*P*
Axial length(mm)				0.087
Mean (SD)	22.68 (0.84)	22.66 (0.83)	22.80 (0.88)	
Range (Min, Max)	20.09, 26.12	20.09, 25.27	20.87, 26.12	
Mean corneal radius of curvature (mm)				0.364
Mean (SD)	7.86 (0.27)	7.86 (0.28)	7.88 (0.27)	
Range (Min, Max)	7.11, 8.92	7.11, 8.92	7.29, 8.60	
AL/CR ratio				0.246
Mean (SD)	2.89 (0.08)	2.89 (0.08)	2.89 (0.09)	
Range (Min, Max)	2.61, 3.31	2.61, 3.19	2.72, 3.31	
Greatest corneal radius of curvature (mm)				0.299
Mean (SD)	7.99 (0.28)	7.98 (0.28)	8.01 (0.26)	
Range (Min, Max)	6.90, 9.09	6.90, 9.09	7.35, 8.70	
Least corneal radius of curvature (mm)				0.388
Mean (SD)	7.73 (0.29)	7.72 (0.29)	7.75 (0.30)	
Range (Min, Max)	6.97, 8.85	6.97, 8.85	7.11, 8.49	
Anterior chamber depth (mm)				0.004
Mean (SD)	3.44 (0.24)	3.45 (0.24)	3.38 (0.24)	
Range (Min, Max)	2.74, 4.30	2.74, 4.30	2.77, 4.14	
Lens thickness (mm)				<0.001
Mean (SD)	3.56 (0.20)	3.55 (0.20)	3.65 (0.21)	
Range (Min, Max)	2.88, 4.18	2.88, 4.13	3.19, 4.18	
Central corneal thickness (μm)				0.083
Mean (SD)	548.23 (31.02)	548.92 (31.45)	543.92 (27.89)	
Range (Min, Max)	442.00, 669.00	442.00, 669.00	487.00, 612.00	
White-to-white (mm)				0.623
Mean (SD)	12.16 (0.42)	12.16 (0.43)	12.18 (0.33)	
Range (Min, Max)	10.10, 13.50	10.10, 13.50	11.30, 13.20	

Values are presented as N (%), mean (SD), or median (IQR) as applicable.
SD, standard deviation; IQR, interquartile range; SE, spherical equivalent; SD, standard deviation.

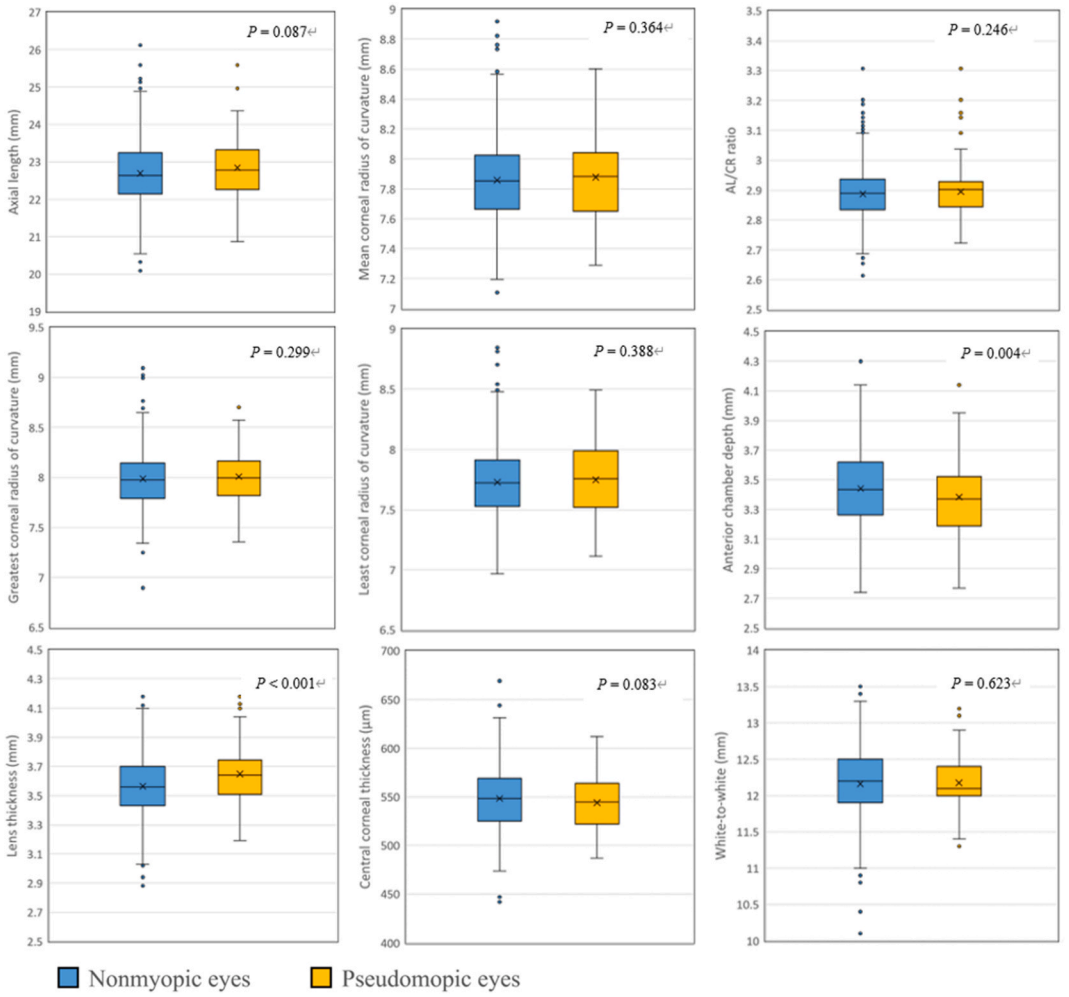

Fig. 1. Distribution of ocular biometric parameters of non-myopic and pseudomyopic groups in mild hyperopic eyes. Box-and-Whisker Plots were used to compare the distributions of multiple groups, visually representing data characteristics, such as distributions, central tendency, spread, and the presence of outliers. The box in the center represents the interquartile range (IQR), covering the middle 50 % of the data. The lower and upper boundaries of the box correspond to the first (Q1) and third (Q3) quartile, respectively. The line inside the box represents the median (Q2), indicating the dataset's midpoint. The whiskers extend from the top and bottom of the box to display the data range. Data points beyond the whiskers are potential outliers, representing extreme values in the dataset.

Table 3
Univariable and multivariable regression analysis of refractive and ocular biometric differences between nonmyopic group and pseudomyopic group in mild hyperopic eyes.

Variables	Non-adjusted		Adjusted[a]	
	OR (95%CI)	*P*	OR (95%CI)	*P*
AL (mm)	1.21 (0.97, 1.49)	0.087	1.77 (1.27, 2.48)	0.001
ACD (mm)	0.32 (0.15, 0.70)	0.004	0.15 (0.04, 0.56)	0.005
LT (mm)	12.47 (4.83, 32.21)	<0.001	33.06 (7.78, 140.47)	<0.001
CCT (mm)	1.00[b]	0.084	0.99 (0.99, 1.00)	0.093

D, diopters; AL, axial length; ACD, anterior chamber depth; LT, lens thickness; OR, odds ratio; CI, confidence interval.
[a] Adjust for: sex; age; cycloplegic SE.
[b] The 95%CI for OR of the variable spans 1.00.

However, research on the astigmatism features of pseudomyopia remains lacking.

Pseudomyopia is caused by a persistent yet temporary ciliary spasm or excessive accommodation [5]. Accommodation refers to the ability of the eyes to adjust their focal point to achieve a clear image on the retina [17]. While the exact mechanisms are not fully

Table 4
Distribution of demographics and refraction characteristics of nonmyopic group and pseudomyopic group in eyes with cycloplegic SE from +0.50D to +1.50D.

Characteristics	All	Nonmyopic Group	Pseudomyopic Group	*P*
N (%)	530	425 (80 %)	105 (20 %)	
Sex (N, %)				0.143
Female	256 (48.3 %)	212 (49.9 %)	44 (41.9 %)	
Male	274 (51.7 %)	213 (50.1 %)	61 (58.1 %)	
Age(years)				0.003
Median (IQR)	7 (4)	7 (4)	6 (4)	
Range (Min, Max)	3, 12	3, 12	3, 12	
Non-cycloplegic SE (D)				<0.001
Median (IQR)	0.25 (0.75)	0.25 (0.63)	−0.88 (1.00)	
Range (Min, Max)	−8.38, 1.63	−0.38, 1.63	−8.38, −0.50	
Cycloplegic SE (D)				0.003
Median (IQR)	1.00 (0.50)	1.00 (0.50)	0.88 (0.50)	
Range (Min, Max)	0.50, 1.50	0.50, 1.50	0.50, 1.50	
Delta SE (D)				<0.001
Median (IQR)	0.75 (0.88)	0.63 (0.75)	1.88 (1.19)	
Range (Min, Max)	−0.13, 8.88	−0.12, 1.88	1.00, 8.88	
Diopter of cylinder (D)				0.570
Median (IQR)	−0.50 (0.75)	−0.50 (0.75)	−0.50 (0.75)	
Range (Min, Max)	−6.00, 1.50	−3.50, 1.50	−6.00, 0.00	

Values are presented as N (%), mean (SD), or median (IQR) as applicable.
SD, standard deviation; IQR, interquartile range; SE, spherical equivalent; SD, standard deviation.

Table 5
Difference analysis and multivariable regression analysis of ocular biometric parameters between nonmyopic group and pseudomyopic group in eyes with cycloplegic SE from +0.50D to +1.50D.

Variables	Non-adjusted			Adjusted[a]	
	Median (IQR)		*P*	OR (95%CI)	*P*
	Nonmyopic Group	Pseudomyopic Group			
AL/CR	2.92 (0.08)	2.91 (0.08)	0.009	21.436[b]	0.203
ACD (mm)	3.49 (0.34)	3.39 (0.32)	<0.001	0.303 (0.076, 1.209)	0.091
LT (mm)	3.54 (0.26)	3.63 (0.21)	<0.001	15.162 (2.647, 86.849)	0.002

AL, axial length; CR, Mean corneal radius of curvature; ACD, anterior chamber depth; LT, lens thickness; SE, spherical equivalent; IQR, interquartile range; OR, odds ratio; CI, confidence interval.
[a] Adjust for: age; cycloplegic SE.
[b] The 95 % CI for OR of the variable spans 1.00.

agreed upon, the Helmholtzian accommodation model is widely accepted [18]. In this model, the ciliary muscle contracts as the eye focuses on a close object, resulting in a forward and centripetal shift in its mass. This relieves tension on the zonules, reduces anterior chamber depth, and increases the overall length of the anterior segment (from the cornea to the posterior surface of the lens) [19,20]. The tonus of the ciliary muscles may also influence choroidal tension, leading to AL change. Alternatively, thicker ciliary muscles may inhibit equatorial stretching, a process linked to myopia development [21].

Despite its status as an independent risk factor for myopia onset, ocular biometry in pseudomyopia has not been extensively explored [10]. In this present study, pseudomyopic eyes exhibited increased ALs compared with non-myopic eyes after adjusting for sex, age, and cycloplegic spherical equivalent. Saw et al. [22] reported that premyopic children with greater axial lengths, vitreous chamber depths, and thinner lenses were more prone to developing myopia. Interestingly, our findings contrast with those of a previous cross-sectional study that indicated a reduction in the overestimation of refractive errors by non-cycloplegic measurements with increasing axial length [13]. This discrepancy may stem from variations in the study populations, as the previous study included participants aged 5–18 years, whereas our study focused on those aged 3–12 years.

Our findings reveal that pseudomyopic eyes had significantly thicker lenses than non-myopic eyes after adjusting for sex, age, and cycloplegic spherical equivalent, which, to the best of the authors' knowledge, is a novel discovery. Typically, lenses tend to thin out as a compensatory mechanism for lengthening of the axial dimension during normal eye growth, which may play a pivotal role in the onset of myopia. The Collaborative Longitudinal Evaluation of Ethnicity and Refractive Error (CLEERE) study observed disruptions in these compensatory changes in lens thickness at the onset of myopia, where the lens no longer undergoes thinning and flattening, resulting in no reduction in refractive power [23]. Zadnik et al. [24] observed a decrease in lens thickness by about 0.2 mm with increasing age from 6 to 10 years, while Li et al. [25] found that younger children had significantly greater lens thickness than older children. Hyperopic children exhibited more substantial changes in LT before and after cycloplegia than myopic individuals, potentially explaining the significant difference in LT between the non-myopic and pseudomyopic groups after adjustment [26].

The association between prolonged near-work, which demands high levels of ocular accommodation, and refractive error

advancement has been extensively studied [22,27]. Lin et al. [28] discovered that hyperopic children with more pronounced NITM experience greater relative myopic refractive progression. The authors postulated that this phenomenon could be attributed to mild ciliary spasm and increased variability in the decay response of NITM. Consequently, hyperopic children with heightened NITM may exhibit inaccuracies in their accommodative function [28]. Notably, our study was conducted during the COVID-19 outbreak and subsequent lockdowns, which led to inevitable increases in near-work.

This study had some limitations. First, the study population comprised children attending clinics who might have had visual symptoms or parental myopia, potentially introducing selection bias compared with the populations in school-based studies. Second, measurement errors could have occurred, potentially impacting the results [29]. Finally, while cyclopentolate is widely considered the gold standard for achieving cycloplegia, it is unavailable in most Chinese hospitals. Tropicamide is a reasonable alternative due to its lower toxicity and reduced side effects in children [30]. Although the cycloplegic effectiveness of 0.5 % tropicamide is comparable to that of 1 % cyclopentolate in myopic eyes, the cycloplegic effectiveness of tropicamide is weaker than that of cyclopentolate in hyperopic eyes [31]. Consequently, a possibility that our study may underestimate the cycloplegic effect on the refractive error of children exists.

Nevertheless, this study had several strengths, including a large sample size, wide age range (3–12 years), comprehensive ocular biometric measurements, and high-quality assessments of non-cycloplegic and cycloplegic refractive errors following a standardized study protocol. Future research should focus on elucidating the mechanisms underlying the pathogenesis of pseudomyopia and the transitional processes from pseudomyopia to myopia.

5. Conclusions

This study observed that among children with mild hyperopia, pseudomyopia was more common in younger boys, with lesser cycloplegic SE and a higher delta SE. A thicker LT, shallower ACD, and longer AL may indicate the presence of pseudomyopia. These findings could provide insight into the rapid progression of myopia in children with pseudomyopia.

Declarations

Ethical statement

Ethical approval statement

Institutional review board statement. This study was approved by the Ethics Committee of the Eye and ENT Hospital of Fudan University in January 2022 and was conducted in accordance with the tenets of the Declaration of Helsinki. The approval number is 2018008-1.

Informed consent statement. Informed consent was obtained from all the participants (parents) involved in the study.

Data availability statement

Data associated with our study have not been deposited into a publicly available repository. The data presented in this study are available upon request from the corresponding author.

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CRediT authorship contribution statement

Yujia Liu: Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Jianmin Shang:** Resources, Project administration, Methodology. **Yuliang Wang:** Project administration. **Xingxue Zhu:** Project administration. **Chaoying Ye:** Project administration. **Xiaomei Qu:** Writing – review & editing, Supervision, Resources, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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