Changes in Lens Thickness and Power Before and After Myopia Onset

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Purpose. To investigate changes in the crystalline lens before and after the onset of myopia.

Methods. This prospective cohort study was conducted in Guangzhou, Guangdong, China. Participants were initially emmetropic or hyperopic at baseline and were followed for 5 years, during which they were categorized into two groups: those who developed myopia (newly developed myopes [NDM]; $n = 1669$) and those who remained hyperopic or emmetropic (persistent nonmyopes [PNM]; $n = 4259$). Changes in spherical equivalent refraction (SER), axial length, lens thickness, and lens power were analyzed from 5 years before to 4 years after myopia onset. Age-related trends in SER and biometric parameters were compared between the PNM and NDM groups.

Results. The mean age of the included children at baseline was 7.61 ± 2.68 years (range, 3–14 years), with 3272 boys (55.20%). Compared with the PNM group, the NDM group exhibited a faster myopic refraction shift, accelerated axial elongation, and a more rapid reduction in lens thickness and power. Changes in SER and axial length peaked at 1 year before myopia onset ($P < 0.001$), but lens thickness and power remained relatively stable before myopia onset. The rate of change in SER and biometric parameters all slowed after myopia onset. In the PNM group, lens thickness decreased before age 11 and increased thereafter, whereas lens power decreased continuously, with a slower rate of decline after 11 years of age.

Conclusions. SER and axial length demonstrate accelerated changes 1 year before myopia onset, whereas lens thickness and power remain largely stable before and after myopia onset, with changes primarily associated with age.

Keywords: myopia, crystalline lens, onset

Refractive development in children is governed by a delicate interplay among three key ocular components: the cornea, crystalline lens, and axial length.[1] Although the cornea possesses greater refractive power than the crystalline lens, it stabilizes by approximately 2 years of age.[2] In contrast, the crystalline lens undergoes continuous structural and optical changes throughout life.[2–4] Concurrently, axial length increases during the first two decades of life, contributing to myopic shifts in refraction.[5,6] Myopia arises from an imbalance between the rate of axial elongation and the combined optical power of the cornea and crystalline lens. However, the mechanisms underlying this imbalance remain an active area of investigation.[1]

A deeper understanding of biometric changes before and after myopia onset is essential for elucidating the mechanism underlying myopia development. Previous studies have consistently demonstrate accelerated changes in spherical equivalent refraction (SER) and axial length in the year preceding myopia onset.[3,7–9] However, findings regarding crystalline lens changes associated with myopia onset remain inconsistent. Mutti et al. reported that the crystalline lens ceased thinning and losing power within ±1 year of myopia onset in the Collaborative Longitudinal Evaluation of

Ethnicity and Refractive Error Study (CLEERE).[8] In contrast, Rozema et al.[10] observed an increased rate of lens power loss up to 1 year before myopia onset, followed by rapid deceleration, in the Singapore Cohort study of the Risk Factor for Myopia (SCORM). Conversely, Xiang et al.[7] and Xiong et al.[9] found no significant changes in the crystalline lens among Chinese children over follow-up periods of 4 and 2 years, respectively. These discrepancies may stem from variations in ethnicity, participant age, environmental factors, or methodological differences across studies. Consequently, it remains unclear whether the crystalline lens undergoes an acceleration in changes like SER and axial length before myopia onset, and how lens changes interact with age and axial elongation over time.

The aim of this study was to investigate changes in crystalline lens before and after myopia onset in a large cohort of Chinese children over a 5-year follow-up period. Children who were hyperopic or emmetropic at baseline were included. Changes in the refraction and ocular components were compared between children who developed myopia (newly developed myopes [NDM]) and those who remained hyperopic or emmetropic throughout the study period (persistent nonmyopes [PNM]). The NDM group were further stratified by age at myopia onset. Additionally, the interaction between lens parameters and axial elongation was evaluated.

Methods

Study Population

This prospective cohort study was conducted as part of the Zengcheng School Myopia Study.[11–13] Briefly, a total of 7050 children from four grade levels (first year of kindergarten, first and fourth years of primary school, and first year of junior high school) were recruited from the Zengcheng District and Huadu District in Guangzhou, Guangdong, China. Baseline data were collected in 2018, and participants were followed up annually thereafter. The study protocol was approved by the Institutional Review Board of Zhongshan Ophthalmic Center, Guangzhou, China (2018KYPJ079), conducted in accordance with the tenets of the Declaration of Helsinki, and registered on Clinicaltrial.gov (NCT03589937). Written informed consent was obtained from the parents or legal guardians of all participants.

The current analysis included children who were hyperopic or emmetropic at baseline (SER > −0.5 diopters [D]) and either remained hyperopic or emmetropic throughout the follow-up period (referred to as PNM), or developed myopia (referred to as NDM; SER ≤ −0.5 D). The NDM group were further stratified by age at myopia onset (≤8 years, 9–10 years, 11–12 years, and ≥13 years). Participants were excluded from the analysis if they met any of the following criteria: (1) missing SER data; (2) insufficient follow-up data to determine refractive status; (3) a history of ocular disease (including strabismus, retinal disease, etc.) or ocular trauma; (4) a history of myopia treatment; or (5) high hyperopia (SER > +5 D) or astigmatism (cylinder power ≤ −5 D).

Ocular Examinations

Baseline and annual ocular examinations included visual acuity testing, cycloplegic autorefraction, ocular biometry, slit-lamp biomicroscopy, and ophthalmoscopy, all performed using standardized equipment and protocols. Visual acuity was measured at 5 m using the Early Treatment Diabetic Retinopathy Study chart. Ocular biometry was performed before cycloplegia using the IOLMaster 700 (Carl Zeiss Meditec, Jena, Germany), with the average of five measurements recorded if the SD was less than 0.1 mm. Cycloplegia was induced by administering three drops of 1% cyclopentolate hydrochloride (Alcon, Fort Worth, TX, USA) at 0, 5, and 25 minutes. Successful cycloplegia was defined as a pupil diameter of at least 6 mm and the absence of pupillary light reflex. If these criteria were not met, an additional drop of cyclopentolate was administered, and cycloplegia status was reassessed after 20 minutes. Cycloplegic autorefraction was measured using the KR-8800 (Topcon, Japan), with the average of three consecutive readings recorded if the SD was less than 5%.

Statistical Analysis

The current analysis included baseline and 5-year follow-up data (2018–2023). The SER was calculated as the spherical power plus one-half of the cylinder power, and the lens power was calculated using the widely used Bennett's equation.[14] The normality of numerical data was assessed using the Kolmogorov–Smirnov test. The distributions of age, SER, axial length, lens thickness, and lens power are presented as mean ± SD. Gender is presented as frequency percentages. Baseline distribution of numerical variables were compared using ANOVA, and sex differences between NDM with varying ages of onset and PNM were evaluated using the χ^2 test.

A locally weighted scatterplot smoothing plot was generated to show the changes in SER and biometric parameters between refractive groups. The NDM groups were compared with the PNM group using linear regression models with age and sex as covariates. The annual change in SER, axial length, lens thickness, and lens power during the follow-up for each myopia onset group is expressed as mean ± SD. A line graph is used to show the annual change in SER and biometric parameters before and after the onset of myopia. The first year in which children met the criteria for myopia was defined as year 0 (onset year). Year −5, −4, −3, −2, and −1 represent 5, 4, 3, 2, and 1 year before myopia onset, respectively, whereas year 1, 2, 3 and 4 represent 1, 2, 3, 4 years after myopia onset, respectively. Annual changes were derived by subtracting the parameter value of the year from that of the previous year. Comparisons between adjacent time points were conducted using repeated measures ANOVA followed by Bonferroni post hoc tests. The *P* value for trend across groups or time points was determined using a linear regression model. Subgroup analyses were conducted for sex and NDM with the fastest SER change between year −2 and year −1 (defined as the first quartile). Linear regression models were developed to assess the associations between changes in lens thickness or power and changes in axial length before and after myopia onset, with sex and height changes as covariates. All analyses were performed with STATA software (version 17, StataCorp), and a two-tailed *P* value of less than 0.05 was considered statistically significant.

Results

Table 1 shows the baseline characteristics of the study participants. Of the 5928 children enrolled, 4259 were PNM with

Table 1. Baseline Characteristics of the Study Participants

Characteristic	Total	Myopia Onset at ≤8 Years	Myopia Onset at 9–10 Years	Myopia Onset at 11–12 Years	Myopia Onset at ≥13 Years	Persistent Nonmyopia	*P* Value*
N	5928	144	429	718	378	4259	
Age (years)	7.61 ± 2.68 (3 to 14)	5.23 ± 1.22 (3 to 7)	7.24 ± 1.38 (4 to 9)	8.75 ± 1.40 (6 to 11)	10.94 ± 1.47 (9 to 14)	7.24 ± 2.78 (3 to 14)	<0.001
Sex							<0.001
Male	3272 (55.20)	68 (47.22)	193 (44.99)	346 (48.19)	208 (55.03)	2457 (57.69)	
Female	2656 (44.80)	76 (52.78)	236 (55.01)	372 (51.81)	170 (44.97)	1802 (42.31)	
SER (D)	+1.03 ± 0.71 (−0.38 to +5.00)	+0.44 ± 0.54 (−0.38 to +2.38)	+0.56 ± 0.52 (−0.38 to +2.13)	+0.56 ± 0.51 (−0.38 to +2.50)	+0.43 ± 0.53 (−0.38 to +2.50)	+1.23 ± 0.67 (−0.38 to +5.00)	<0.001
AL (mm)	22.77 ± 0.82 (19.44 to 25.87)	22.67 ± 0.72 (21.14 to 24.44)	22.87 ± 0.73 (20.23 to 25.27)	23.09 ± 0.75 (21.05 to 25.62)	23.36 ± 0.75 (21.33 to 25.87)	22.65 ± 0.81 (19.44 to 25.46)	<0.001
LT (mm)	3.39 ± 0.16 (2.80 to 4.10)	3.32 ± 0.15 (2.93 to 3.67)	3.32 ± 0.15 (2.89 to 3.87)	3.34 ± 0.16 (2.88 to 3.85)	3.37 ± 0.15 (2.94 to 3.85)	3.41 ± 0.16 (2.80 to 4.10)	<0.001
LP (D)	24.02 ± 1.94 (16.46 to 31.40)	24.80 ± 1.83 (20.51 to 29.51)	23.79 ± 1.62 (18.96 to 28.72)	23.28 ± 1.56 (17.92 to 29.43)	22.63 ± 1.48 (18.65 to 26.91)	24.26 ± 1.99 (16.46 to 31.40)	<0.001

AL, axial length; LP, lens power; LT, lens thickness.
The distribution of age, SER, AL, LT, and LP was presented as mean ± SD (range). Gender was presented as frequency (percentage).
* The *P* values were calculated by the χ^2 test for sex and by ANOVA for all other variables.

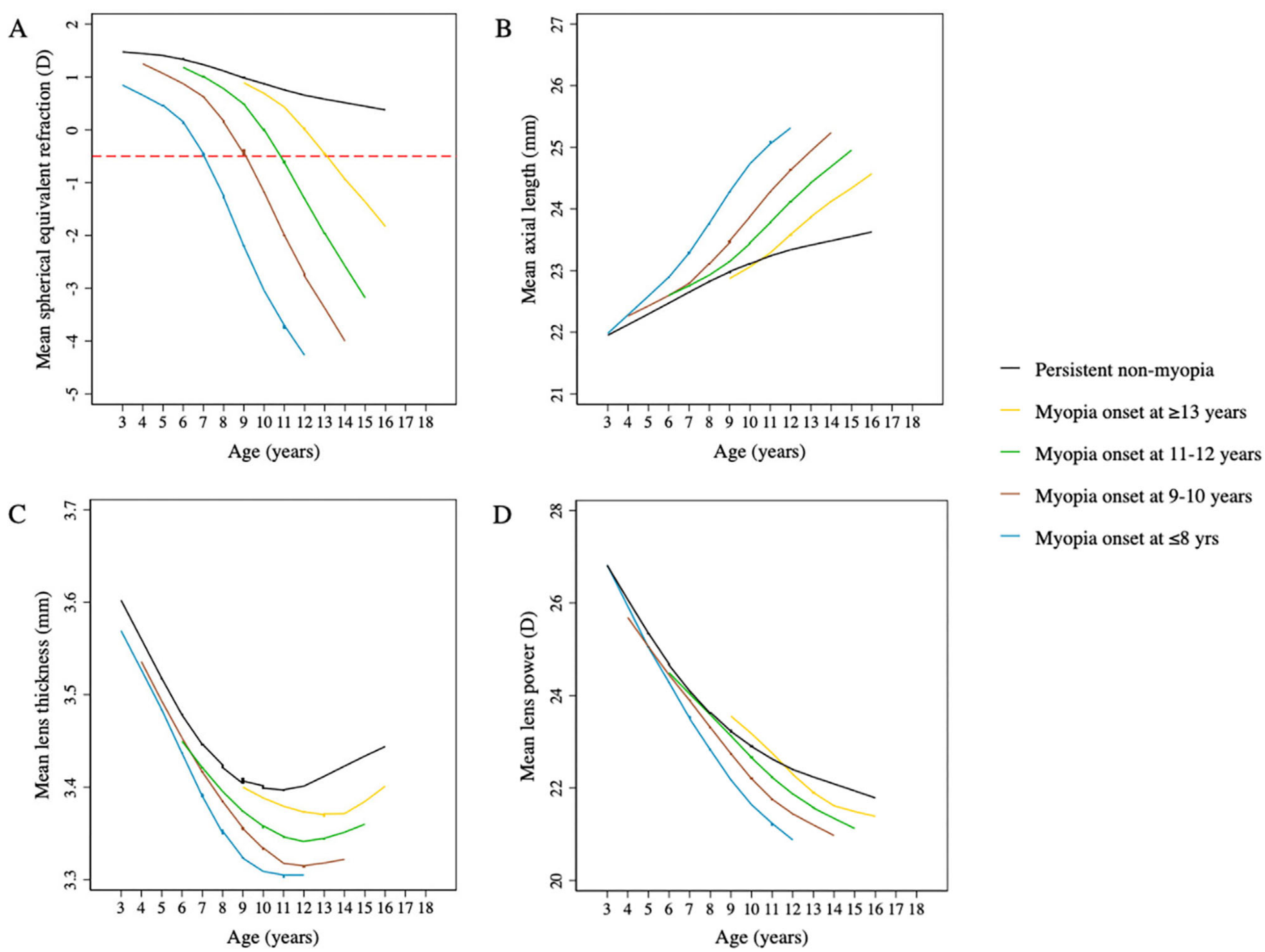

Figure 1. Locally weighted linear regression curves of SER and ocular biometry data in different groups. (**A**) SER, (**B**) axial length, (**C**) lens thickness, and (**D**) lens power.

a mean baseline age of 7.24 ± 2.78 years (57.69% boys and 42.31% girls) and 1669 were NDM. The NDM group comprised 144 children with an age at myopia onset at 8 years of age or younger (baseline age of 5.23 ± 1.22 years; 47.22% boys and 52.78% girls), 429 children with myopia onset at 9 to 10 years of age (baseline age of 7.24 ± 1.38

years; 44.99% boys and 55.01% girls), 718 children with myopia onset at 11 to 12 years of age (baseline age of 8.75 ± 1.40 years; 48.19% boys and 51.81% girls), and 378 children with an age at myopia onset of 13 years or older (baseline age of 10.94 ± 1.47 years; 55.03% boys and 44.97% girls). The distributions of SER, axial length, lens thickness, and lens power showed significant differences at baseline among the PNM and NDM groups with different ages of onset.

Figure 1 shows the changes in SER, axial length, lens thickness, and lens power with age in the PNM and NDM groups. For children with PNM, the SER gradually shifted toward myopia with inflection points at 6 and 12 years of age; axial length exhibited rapid growth initially, which slowed after 11 years; lens thickness decreased rapidly before 7 years, continued to decline at a reduced rate from 7 to 11 years, and increased thereafter; the lens power decreased rapidly and then slowed after 11 years. Compared with the PNM group, NDM demonstrated a faster decrease in SER (coefficients, −2.20 to −0.55; all $P < 0.001$) and greater axial elongation (coefficients, 0.20 to 0.90; all $P < 0.001$). The earlier the myopia onset, the more pronounced the decrease in SER and the increase in axial length (*P* for trend across groups < 0.001). The lens thickness of NDM followed a similar three-stage pattern, but the lens thinning started earlier and was more pronounced in those with myopia onset before the age of 13 (coefficients: −0.065 to −0.049, all $P < 0.001$). These children also showed a faster decline in lens power compared with the PNM group (coefficients, −0.80 to −0.43; all $P < 0.001$). No significant difference in lens thinning or lens power loss was observed between the PNM group and NDM with myopia onset at 13 years of age or older.

The mean annual changes in SER, axial length, lens thickness, and lens power for each myopia onset group from year −5 to year +4 are presented in Table 2 and Figure 2. Compared with changes at adjacent time points, the annual changes in SER and axial length were significantly greater from year −1 to the onset year (SER, −0.98 D/year; axial length, 0.47 mm/year; both $P < 0.001$). Children with earlier myopia onset showed faster changes in SER and axial length at 1 year before myopia onset (both *P* for trend across NDM groups < 0.001). Overall, lens thinning decelerated before myopia onset (*P* for trend across time points before myopia onset < 0.001) and transitioned to thickening after 2 years of myopia onset (*P* for trend across time points after myopia onset < 0.001). The annual changes in lens thickness from year 0 to year 2 were significantly different from those at adjacent time points (both $P < 0.001$). The rate of lens power loss remained stable before myopia onset (−0.56 to −0.45 D/year; *P* for trend across time points before myopia onset, 0.56), but decreased after year 1 (−0.35 to −0.18 D/year; *P* for trend across time points after myopia onset < 0.001). A similar trend in SER and biometric parameter changes was observed across most myopia onset groups, as well as between sexes (Supplementary Fig. S1) and in the subgroup of NDM with the fastest SER changes between year −2 and year −1 (Supplementary Fig. S2).

The interaction between changes in lens thickness or power and changes in axial length is shown in Supplementary Table S1. A significant association was observed between changes in lens parameters and changes in axial length (all $P < 0.001$), but the association was significantly weaker after myopia onset than before myopia onset (β difference, lens thickness and axial length, 0.029 [95% confidence interval, 0.017–0.040]; lens power and axial length, 0.37 [95% confidence interval, 0.20–0.54]; both $P < 0.001$).

Discussion

In this prospective cohort study, we observed that children with earlier myopia onset showed greater and more rapid changes in SER, axial length, lens thickness, and power compared with those with a later onset. Changes in SER and axial length peaked at 1 year before myopia onset, but no significant acceleration in lens thickness or lens power changes were observed before myopia onset. After myopia onset, the rates of change in SER and these biometric parameters all decelerated gradually.

In previous studies, children with early-onset myopia showed a higher probability of ending up with high myopia.[15,16] As expected, the earlier the onset of myopia, the faster the acceleration in SER and the more rapid the changes in biometric parameters. In the present study, the SER showed a remarkable parallel acceleration among different onset groups, accompanied by faster axial elongation in children with earlier myopia onset. Children with earlier myopia onset also showed an earlier and more pronounced decrease in lens thickness and power. The inflection points at which the lens thickness started to increase and the lens power reduction slowed were observed later in children with myopia onset at an older age. The CLEERE study[8] also found that children with myopia onset older than 12 years of age showed a later inflection point of the increase in lens thickness compared with emmetropes. However, the SCORM study[10] showed a similar pattern of lens thickness and power changes with age in PNM and NDM with different ages of myopia onset, which may be limited by the narrow age range of participants in the study (7–13 years of age). These findings suggest that the crystalline lens plays a role in counteracting the development of myopia. In children who experience myopia onset at an older age, the lens may begin to counteract at a later stage, resulting in a delayed decrease of the lens power and subsequently leading to a later inflection point.

Studies on the role of crystalline lens before and after the myopia onset have yielded conflicting results. In this study, we observed no acceleration in the changes of lens thickness and lens power during the year before myopia onset. All NDM groups showed a deceleration in the rate of reduction in lens thickness and lens power at approximately 11 years of age, a pattern similar to that observed in PNM. Xiong et al.[9] examined 131 NDM, 1231 PNM, and 103 persistent myopes aged 6 to 8 years from Chinese populations. They reported no significant differences in lens power loss (calculated by Bennett formula) between those who remained emmetropic and those who developed myopia over a 2-year follow-up period, which aligns with our findings in children with myopia onset at less than 13 years of age. The CLEERE study[8] found that the lens stopped compensatory thinning within ± 1 year of onset in California children, with a majority (510/732 [69.67%]) older than 10 years of age, similar to our observations in children with myopia onset after 11 years of age. As mentioned elsewhere in this article, the slower lens thinning observed at approximately 11 years of age is more likely attributable to a physiological inflection point occurring around this age. Xiang et al.[7] included 175 Chinese NDM aged 7 to 15 years with a 4-year follow-up and found that the annual change in lens power did not change significantly before and after the onset of

Table 2. Mean Annual Changes in SER, Axial Length, Lens Thickness, and Lens Power for Each Myopia Onset Group

	Total		Myopia Onset at ≤8 Years		Myopia Onset at 9–10 Years		Myopia Onset at 11–12 Years		Myopia Onset at ≥13 Years		*P* Value for Trend Among Groups*
	No.	Mean ± SD	No.	Mean ± SD	No.	Mean ± SD	No.	Mean ± SD	No.	Mean ± SD	
SER (D)											
Year −5 to year −4	216	−0.23 ± 0.30	–	–	–	–	137	−0.23 ± 0.30	65	−0.25 ± 0.33	0.14
Year −4 to year −3	400	−0.17 ± 0.30	30	−0.23 ± 0.54	65	−0.18 ± 0.35	175	−0.12 ± 0.24	130	−0.21 ± 0.27	0.86
Year −3 to year −2	724	−0.31 ± 0.32†	42	−0.18 ± 0.33	218	−0.24 ± 0.28	273	−0.41 ± 0.35	191	−0.27 ± 0.29	0.02
Year −2 to year −1	1110	−0.39 ± 0.34†	92	−0.31 ± 0.43	254	−0.39 ± 0.37†	518	−0.40 ± 0.34	246	−0.37 ± 0.28†	0.32
Year −1 to year 0	1571	−0.98 ± 0.49†	138	−1.07 ± 0.59	412	−1.16 ± 0.51†	659	−0.97 ± 0.43†	362	−0.77 ± 0.43†	<0.001
Year 0 to year 1	1037	−0.72 ± 0.54	93	−1.03 ± 0.76	362	−0.70 ± 0.50†	375	−0.77 ± 0.55†	207	−0.51 ± 0.37	<0.001
Year 1 to year 2	615	−0.70 ± 0.52	59	−0.84 ± 0.50	227	−0.89 ± 0.58†	274	−0.55 ± 0.42	55	−0.55 ± 0.37	<0.001
Year 2 to year 3	293	−0.58 ± 0.42	51	−0.75 ± 0.48	69	−0.52 ± 0.40	171	−0.56 ± 0.40	–	–	0.034
Year 3 to year 4	93	−0.55 ± 0.42	22	−0.53 ± 0.47	45	−0.51 ± 0.40	26	−0.63 ± 0.39	–	–	0.38
P for trend before onset*		<0.001		<0.001		<0.001		<0.001		<0.001	
P for trend after onset*		<0.001		<0.001		0.058		<0.001		0.33	
AL (mm)											
Year −5 to year −4	216	0.18 ± 0.07	–	–	–	–	137	0.17 ± 0.06	65	0.19 ± 0.09	0.50
Year −4 to year −3	398	0.17 ± 0.10	29	0.22 ± 0.06	65	0.18 ± 0.08	175	0.18 ± 0.11	129	0.15 ± 0.08	<0.001
Year −3 to year −2	714	0.25 ± 0.13	40	0.25 ± 0.13	218	0.21 ± 0.09	267	0.30 ± 0.16	189	0.22 ± 0.12†	0.39
Year −2 to year −1	1087	0.27 ± 0.19	89	0.26 ± 0.18	251	0.30 ± 0.15†	504	0.27 ± 0.22	243	0.25 ± 0.15†	0.03
Year −1 to year 0	1529	0.47 ± 0.25†	135	0.52 ± 0.25†	399	0.57 ± 0.26†	640	0.47 ± 0.24†	355	0.34 ± 0.19†	<0.001
Year 0 to year 1	995	0.39 ± 0.26†	90	0.61 ± 0.26†	339	0.39 ± 0.23†	363	0.42 ± 0.29†	203	0.25 ± 0.13	<0.001
Year 1 to year 2	595	0.34 ± 0.20†	56	0.44 ± 0.22	219	0.45 ± 0.19†	265	0.25 ± 0.16	55	0.27 ± 0.11	<0.001
Year 2 to year 3	284	0.26 ± 0.15	48	0.38 ± 0.20	67	0.25 ± 0.14	167	0.23 ± 0.11	–	–	<0.001
Year 3 to year 4	91	0.28 ± 0.13	22	0.36 ± 0.17	44	0.25 ± 0.12	25	0.26 ± 0.10	–	–	0.01
P for trend before onset*		<0.001		<0.001		<0.001		<0.001		<0.001	
P for trend after onset*		<0.001		<0.001		<0.001		<0.001		0.54	
LT (mm)											
Year −5 to year −4	215	−0.036 ± 0.029	–	–	–	–	137	−0.038 ± 0.030	64	−0.026 ± 0.025	<0.001
Year −4 to year −3	395	−0.022 ± 0.035	29	−0.046 ± 0.034	64	−0.041 ± 0.034	175	−0.023 ± 0.032	127	−0.005 ± 0.033	<0.001
Year −3 to year −2	710	−0.024 ± 0.039	39	−0.028 ± 0.064	217	−0.039 ± 0.032	268	−0.029 ± 0.032	186	−0.0015 ± 0.036	<0.001
Year −2 to year −1	1082	−0.022 ± 0.037	87	−0.050 ± 0.051	252	−0.030 ± 0.028	503	−0.021 ± 0.037†	240	−0.0034 ± 0.029	<0.001
Year −1 to year 0	1521	−0.019 ± 0.040	133	−0.050 ± 0.037	398	−0.036 ± 0.038	636	−0.011 ± 0.039	354	−0.0024 ± 0.028	<0.001
Year 0 to year 1	993	−0.010 ± 0.033†	91	−0.042 ± 0.029	338	−0.013 ± 0.033	362	−0.0062 ± 0.033	202	0.0014 ± 0.025	<0.001
Year 1 to year 2	587	−0.0021 ± 0.027†	55	−0.015 ± 0.025	213	−0.0063 ± 0.031	264	0.0013 ± 0.022	55	0.011 ± 0.021	<0.001
Year 2 to year 3	283	0.0074 ± 0.022	48	−0.0035 ± 0.024	67	−0.00066 ± 0.020	166	0.014 ± 0.021	–	–	<0.001
Year 3 to year 4	89	0.012 ± 0.023	20	0.00081 ± 0.025	44	0.014 ± 0.021	25	0.018 ± 0.022	–	–	0.016
P for trend before onset*		<0.001		0.21		0.12		<0.001		0.001	
P for trend after onset*		<0.001		<0.001		<0.001		<0.001		0.008	

Table 2. Continued

	Total		Myopia Onset at ≤8 Years		Myopia Onset at 9–10 Years		Myopia Onset at 11–12 Years		Myopia Onset at ≥13 Years		*P* Value for Trend Among Groups*
	No.	Mean ± SD	No.	Mean ± SD	No.	Mean ± SD	No.	Mean ± SD	No.	Mean ± SD	
LP (D)											
Year −5 to year −4	203	−0.48 ± 0.46	–	–	–	–	126	−0.43 ± 0.43	63	−0.43 ± 0.42	<0.001
Year −4 to year −3	377	−0.45 ± 0.47	28	−0.65 ± 0.92	62	−0.53 ± 0.52	161	−0.52 ± 0.38	126	−0.27 ± 0.35	<0.001
Year −3 to year −2	686	−0.51 ± 0.49	39	−0.66 ± 0.76	207	−0.53 ± 0.43	261	−0.55 ± 0.51	179	−0.40 ± 0.44	0.003
Year −2 to year −1	1048	−0.56 ± 0.59	86	−0.78 ± 0.87	244	−0.64 ± 0.39	494	−0.53 ± 0.66	224	−0.45 ± 0.45	<0.001
Year −1 to year 0	1466	−0.45 ± 0.72	130	−0.63 ± 0.91	386	−0.62 ± 0.63	620	−0.43 ± 0.74	330	−0.24 ± 0.63	<0.001
Year 0 to year 1	928	−0.48 ± 0.57	87	−0.86 ± 0.59	317	−0.52 ± 0.67	343	−0.47 ± 0.47	181	−0.26 ± 0.39	<0.001
Year 1 to year 2	550	−0.35 ± 0.45†	54	−0.57 ± 0.40	198	−0.40 ± 0.52	248	−0.29 ± 0.38†	50	−0.22 ± 0.40	<0.001
Year 2 to year 3	266	−0.18 ± 0.42	46	−0.35 ± 0.39	63	−0.30 ± 0.39	155	−0.09 ± 0.41	–	–	<0.001
Year 3 to year 4	83	−0.19 ± 0.42	17	−0.55 ± 0.34	42	−0.14 ± 0.38	24	−0.02 ± 0.40	–	–	<0.001
P for trend before onset*		0.56		0.33		0.11		0.16		0.026	
P for trend after onset*		<0.001		<0.001		<0.001		<0.001		0.17	

AL, axial length; LP, lens power; LT, lens thickness.

The first year in which children met the criteria for myopia was defined as year 0 (the onset year). Years before myopia onset were represented as year −5, −4, −3, −2, and −1, indicating 5, 4, 3, 2, and 1 year(s) before onset, respectively, whereas years after onset were represented as year 1, 2, 3, and 4, indicating 1, 2, 3, and 4 years after onset, respectively. Annual changes were calculated by subtracting parameter of the year from that of the former year, and some subgroups were not reported due to small sample sizes (<10).

* *P* for trend was calculated by linear regression model.

† Comparisons between adjacent time points were performed using repeated measures ANOVA followed by Bonferroni post hoc tests. The annual change in the year was significantly different from those of the previous and subsequent years.

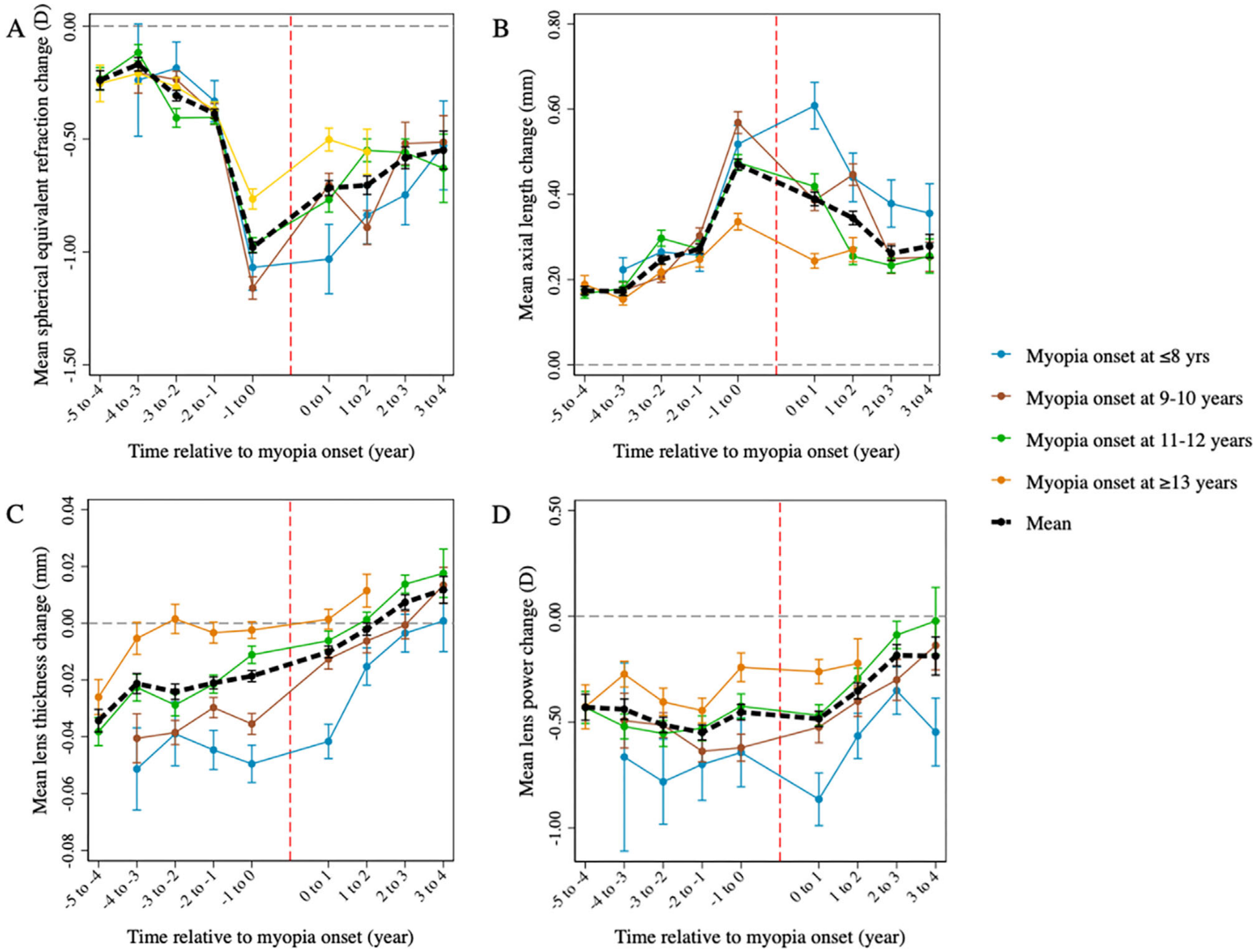

Figure 2. Mean changes in (**A**) SER, (**B**) axial length, (**C**) lens thickness, and (**D**) lens power with respect to the year of myopia onset. *Colored lines* correspond with the different onset ages; the *black line* represents the mean of all new myopes. Error bars are 95% confidence interval of the mean. The first year in which children met the criteria for myopia was defined as year 0 (the onset year, *red dashed line*). Years before myopia onset are represented as year −5, −4, −3, −2, and −1, indicating 5, 4, 3, 2, and 1 year(s) before onset, respectively, whereas years after onset were represented as year 1, 2, 3, and 4, indicating 1, 2, 3, and 4years after onset, respectively. Annual changes were calculated by subtracting parameter of the year from that of the previous year, and some subgroups were not reported due to small sample sizes (<10). For example, annual changes in year −3 were calculated by subtracting the parameters in year −3 from those in year −2.

myopia. Although this finding is consistent with our overall results, their study did not analyze further the changing patterns in NDM with different ages of onset. Moreover, lens power was calculated using the Bennett and Rabbetts formula (which does not incorporate lens parameters in its calculation), potentially confounding the results. However, the SCORM study[10] reported a higher lens power loss (−0.71 D/year, calculated with Bennett formula) up to 1 year before myopia onset in Singaporean children aged 6 to 9 years ($n = 303$).[10] No statistical differences were detected in our study, which may be attributed to limitations in sample size and relatively higher heterogeneity within this age group. An alternative explanation is that the counteracting effect of the lens may have occurred earlier (e.g., year −2) or at a younger age. To sum up, our study and most of the previous literature suggest no significant changes in lens thickness and lens power before and after myopia onset, a conclusion further supported by our sensitivity analysis in NDM showing the fastest SER acceleration. However, for children with myopia onset at a younger age (e.g., <8 years), it remains inconclusive whether lens thickness and lens power changes peak before myopia onset, warranting further investigation with a larger sample size.

In agreement with previous studies,[3,7–9] we observed that SER and axial length changed more rapidly in the year before the first detection of myopia, and there was a stronger interaction between changes in crystalline lens and changes in axial length before myopia onset than after myopia onset. A higher rate of annual change in SER and axial length in the year before first detection of myopia was consistent with the hypothesis that critical events leading to myopia onset occur well before the SER reaches −0.5 D. Therefore, myopia prevention strategies should be implemented during the pre-myopia phase or even earlier.[17] After myopia onset, the rate of change in SER, axial length, lens thickness, and lens power all slowed, and the interaction between axial length and crystalline lens also weakened, suggesting that different physiological mechanisms may operate before and after myopia onset. Exposure to myopic defocus and an age-related slowing in axial elongation have been proposed as explanations for the reduced rate of myopic progression and axial elongation after myopia onset.[7,10] Regarding the different trend of lens changes before and after myopia onset, there could be two reasons. One is that the counteraction response of the lens is interrupted at myopia onset, and the other is that the changes are simply attributable to increasing age. Our results in children with myopia onset after 11 years of age suggest that the counteraction effect of lens becomes minimal, and age might play a major role in the changing trends of lens thickness and lens power after myopia onset.

The strengths of the current study include a large sample size, long follow-up duration, wide age range, and a consistent study methodology. Several limitations should be noted. First, this study exclusively included Chinese children and further investigation into ethnic differences in lens changes before and after myopia onset is warranted. Second, the sample size of NDM with myopia onset before 8 years of age or after 13 years of age was relatively small. Third, lens power cannot be measured directly in vivo currently. Although we used the widely used and validated Bennett's formula to calculate lens power, there may have been a possible error in approximately 5% of cases.[18] However, because the same formula was applied consistently across all visits, the potential error would have minimal impact on the annual changes in lens power.

In conclusion, our study revealed that the axial length and SER changes peaked during the year before the onset of myopia, whereas the lens thickness and lens power remain relatively stable before and after myopia onset, with changes primarily associated with age.

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