Longitudinal Changes in Axial Length and Spherical Equivalent in Children and Adolescents With High Myopia

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Purpose. To investigate longitudinal changes in axial length (AL) and spherical equivalent (SE) in children and adolescents with high myopia and to explore associated risk factors.

Methods. This was a longitudinal, observational cohort study of highly myopic participants (aged 7–17 years) to evaluate the mean rates of change in AL and SE. Mixed effects regression models were used to explore the risk factors.

Results. The sample consisted of 293 participants (mean age at the baseline, 13.63 ± 2.66 years; mean AL, 27.03 ± 1.30 mm diopters; mean SE, −8.99 ± 2.30 diopters) who were followed for 7.09 ± 1.64 years. Pathological myopia (PM) was present in 11.95% of the participants at the baseline. Over the follow-up period, the mean AL and SE progression rates were 0.13 mm/y (95% CI, 0.12–0.14) and −0.36 diopters/y (95% CI, −0.39 to −0.34). The multivariate analysis showed that the AL elongation and myopic SE progression decreased significantly after age 11 ($\beta = -0.080$, $P < 0.001$; $\beta = 0.146$, $P < 0.001$), increased with a greater baseline SE ($\beta = -0.006$, $P = 0.014$; $\beta = 0.017$, $P = 0.005$), and accelerated in children and adolescents who had PM at the baseline ($\beta = 0.043$, $P = 0.011$; $\beta = -0.097$, $P = 0.025$).

Conclusions. A significant association was found between acceleration of AL elongation and myopic SE progression among the children and adolescents with age, especially those younger than 11 years, and the presence of PM.

Keywords: high myopia, adolescents, axial length, spherical equivalent, longitudinal changes

In recent decades, myopia has emerged as a clinical and global public health problem owing to the substantial increases in the number of individuals affected by it.[1,2] It has been predicted that the prevalence of myopia and high myopia will continue to increase dramatically in the coming decades and will affect 49.8% and 9.8% of the global population by 2050, respectively.[3] Notably, the prevalence of high myopia among children and adolescents in East Asia, including China, Japan, and Korea, is escalating at a higher rate than in other regions worldwide; approximately 80% to 90% of high school graduates in these regions are affected by myopia, of whom 10% to 20% are suffering from high myopia.[1,4–6] High myopia is characterized by excessive axial elongation and is associated with risks of various serious ophthalmic complications, such as glaucoma, cataracts, retinal detachment, and myopia macular degeneration, which can ultimately lead to loss of vision.[7–9] The visual impairment caused by high myopia in young individuals can impose a significant socioeconomic burden.[10]

Many studies have investigated the natural processes and risk factors affecting axial length (AL) and spherical equivalent (SE), mainly among children and adolescents with mild to moderate myopia, as well as among adults with high myopia. However, there are few longitudinal studies specifically on high myopia in children and adolescents.[11–14] Chen et al.[14] demonstrated a significant deceleration of changes in AL and SE after the age of 10 to 12 years in children with emmetropia and myopia. Additionally, Lee et al.[12] observed a continued increase in AL of 0.05 mm/y over 4 years in 60 highly myopic adults without myopic degeneration. They further found that individuals with a longer AL at the baseline exhibited a faster rate of AL elongation. The progression of AL and SE in children and adolescents with high myopia is unusual in that physiological growth occurs parallel to myopic growth. Thus, studying AL and SE development in

this population can enhance the management of their clinical eye health.

Therefore, this study aimed to evaluate long-term longitudinal changes in AL and SE among children and adolescents with high myopia and to explore the associated risk factors.

Methods

Population

Participants with a binocular spherical refractive error of −6 diopter (D) or greater were recruited from the Zhongshan Ophthalmic Center. There were 426 subjects aged 7 to 17 years at baseline, of whom 293 completed at least two follow-up visits. The exclusion criteria included a history of myopia treatment without spectacles, such as contact lenses, pharmaceutical interventions, ocular surgeries including implantable collamer lens implantation, or other ocular conditions that affect AL and SE measurements. Additionally, subjects with serious systemic diseases during the follow-up period were excluded.

This study strictly adhered to the Declaration of Helsinki and was conducted with the approval of the Institutional Review Board of Zhongshan Ophthalmic Center. The written informed consent of all the participants was secured.

Examination

The subjects underwent a comprehensive eye examination at the baseline and during all the follow-up visits. AL was measured using a Lenstar LS-900 optical biometer (Haag-Streit AG, Gartenstadtstrasse, Koeniz, Switzerland) before cycloplegia. If AL exceeded 32 mm (the valid Lenstar range of measurement), an IOLMaster biometer (Carl Zeiss Meditec, Oberkochen, Germany) was used instead. The AL measurements were performed under low ambient illumination. Measurements of refraction were taken with a Topcon KR-8800 autorefractor (Topcon, Tokyo, Japan) by a professional optometrist following cycloplegia. Five measurements were recorded at deviations of less than 0.50 D for the sphere and the cylinder and less than 5° for the axis. The fundus of each eye was photographed in color with a Canon CX-1 camera (Canon, Tokyo, Japan) after the pupils were fully dilated. These photographs were subsequently graded by professional ophthalmologists (ZXL, RL, OX, and XXG) in accordance with the classification system established by the Meta-Analysis for Pathologic Myopia (META-PM) Study Group.[15] This classification system consisted of five categories: no myopic lesions (0), tessellated fundus (1), diffuse atrophy (2), patchy atrophy (3), and macular atrophy (4). Three "plus" lesions—lacquer cracks, choroidal neovascularization, and Fuch's spots—were also considered. An eye was classified as pathologically myopic when the myopic maculopathy was equal to or more severe than diffuse atrophy (category 2).

Statistical Analyses

The right eyes were selected for analysis. SE was calculated as the sum of the spherical power + 1/2 cylindrical power. The mean change rate of AL and SE was defined as the differential value between the final and baseline AL and SE divided by the number of follow-up years. To investigate the progression of AL and SE with different baseline characteristics, age was categorized into 7 to 11 years and 12 to 17 years; baseline SE, into −6 to −8 D, −8 to −10 D, and ≤−10 D; and baseline AL, into <26 mm, 26 to 28 mm, and ≥28 mm. The descriptive statistics were reported as the mean and SD or 95% CI, depending on the situation. The χ^2 test was used for categorical variables, and two-sample *t*-tests and one-way ANOVA, for continuous variables. Locally weighted scatterplot smoothing (LOWESS) plots with 95% CIs were generated to visualize the trends of Al and SE. AL and SE were fitted with linear mixed effects models, with age, gender, baseline AL, baseline SE, and baseline pathological myopia (PM) as the fixed effects. A random intercept was included at the subject level, and the follow-up time since the baseline visit was used as the time variable in the model. Univariate and multivariate linear mixed-effects models were used to identify the factors associated with the rates of change in AL and SE. Factors with *P* values of less than 0.10 in the univariate models were entered into the multivariate models, and a *P* value of less than 0.05 was considered statistically significant. All the statistical analyses were performed using STATA version 17.0 (Stata Corporation, College Station, TX, USA) or R (available at https://www.r-project.org/).

Results

A total of 293 individuals were included in the analysis, and their baseline characteristics are presented in Table 1. The mean age of the subjects at the baseline was 13.63 ± 2.66 years, with no significant differences ($P > 0.05$) observed between girls (51.54%) and boys (48.46%). The mean follow-up time for the subjects was 7.09 ± 1.64 years. AL and SE at the baseline were 27.03 ± 1.30 mm and –8.99 ± 2.30 D, respectively. PM was present in 11.95% of the population at the baseline visit, characterized only by diffuse atrophy.

Figure 1 shows a LOWESS plot of the changes in AL and SE according to age at the baseline visit. A turning point was observed at approximately 11 years of age, after which the change gradually decelerated. Based on this observation, the sample was divided into two groups at 11 years of age. Table 2 shows the mean AL and SE change rates based on the different baseline characteristics. The mean AL change rate was 0.13 mm/y (95% CI, 0.12–0.14 mm/y), and the mean SE change rate was −0.36 D/y (95% CI, −0.39 to −0.34 D/y). Notably, the rates of change in AL significantly decreased from 0.21 mm/y (95% CI, 0.18–0.24 mm/y) to 0.12 mm/y (95% CI, 0.10–0.13 mm/y) before and after 11 years of age, respectively. The myopic SE progression had a similar trend, decelerating from −0.47 D/y (95% CI, −0.55 to −0.40 D/y) before 11 years of age to −0.34 D/y (95% CI, −0.37 to −0.31 D/y) after 11 years. Moreover, for the individuals with PM and AL of 28 mm or greater or an SE of −10 D or greater, the AL elongation and myopic SE progression accelerated significantly, with no significant difference between boys and girls.

Table 1. Baseline Characteristics of Participants

Characteristics	Participants ($N = 293$)
Follow-up time (years)	7.09 ± 1.64
Age (years)	13.63 ± 2.66
Girls (%)	51.54
AL (mm)	27.03 ± 1.30
SE (D)	−8.99 ± 2.30
Baseline PM (%)	11.95

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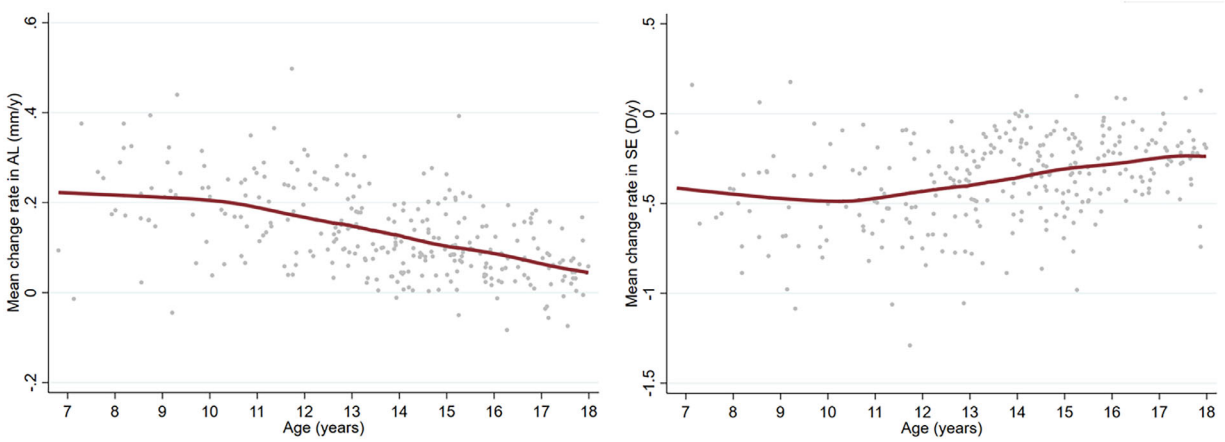

Figure 1. Mean change rates in AL and SE with increasing age at the baseline. The curves were estimated with LOWESS plots with a smoothing value of 0.80.

Table 2. Annual Rates of Change for SE Refraction and AL as a Function of Baseline Characteristics

Characteristics	No.	Mean Rates of Change: SE (D/y) Mean (95% CI)	Mean Rates of Change: AL (mm/y) Mean (95% CI)
Total	293	−0.36 (−0.39 to −0.34)	0.13 (0.12–0.14)
Age (years)			
≥7 and <11	52	−0.47 (−0.55 to −0.40)	0.21 (0.18–0.24)
≥11 and <18	241	−0.34 (−0.37 to −0.31)	0.12 (0.10–0.13)
P value*		<0.01	<0.01
Gender			
Boys	142	−0.37 (−0.41 to −0.32)	0.14 (0.13–0.15)
Girls	151	−0.35 (−0.39 to −0.32)	0.13 (0.12–0.14)
P value‡		0.47	0.65
Baseline SE (D)			
>−8 and ≤−6	116	−0.34 (−0.38 to −0.30)	0.13 (0.11–0.14)
>−10 and ≤−8	103	−0.34 (−0.38 to −0.29)	0.12 (0.10–0.14)
≤−10	74	−0.44 (−0.50 to −0.37)	0.16 (0.13–0.18)
P value†		0.01	0.02
Baseline AL (mm)			
<26	58	−0.36 (−0.43 to −0.29)	0.13 (0.11–0.16)
≥26 and <28	179	−0.34 (−0.37 to −0.31)	0.12 (0.11–0.14)
≥28	56	−0.44 (−0.52 to −0.36)	0.16 (0.13–0.19)
P value†		0.02	0.05
Baseline PM			
0	258	−0.34 (−0.37 to −0.32)	0.12 (0.11–0.13)
1	35	−0.51 (−0.61 to −0.40)	0.19 (0.15–0.23)
P value‡		<0.01	<0.01

Values are presented as means (95% CIs) unless otherwise indicated.
* Comparison by the two-sample *t*-test.
† Comparison by the one-way ANOVA.
‡ Comparison by the Pearson χ^2 test.

To investigate the risk factors associated with AL and SE change rates, mixed effects univariate and multivariate models were developed, and showed in Table 3 and Table 4. The results of the univariate analysis revealed that AL elongation was correlated with age ($\beta = -0.093$; $P < 0.001$), baseline SE ($\beta = -0.009$; $P < 0.001$), baseline AL ($\beta = 0.008$; $P = 0.045$), and baseline PM ($\beta = 0.086$; $P < 0.001$). Similar patterns were observed for myopic SE progression (age, $\beta = 0.180$ [$P < 0.001$]; baseline SE, $\beta = 0.025$ [$P < 0.001$]; baseline PM, $\beta = -0.189$ [$P < 0.001$]). The multivariate analysis revealed that AL elongation were negatively correlated with age ($\beta = -0.080$; $P < 0.001$) and baseline SE ($\beta = -0.006$; $P = 0.014$), and significantly increased in the presence of baseline PM ($\beta = 0.043$; $P = 0.011$), similar to myopic SE progression (age, $\beta = 0.146$ [$P < 0.001$]; baseline SE, $\beta = 0.017$ [$P = 0.005$]; baseline PM, $\beta = -0.097$ [$P = 0.025$]). Among these factors, age and baseline PM had the greatest effects on rates of change, while baseline SE had a smaller effect. The turning point at age 11 was particularly significant.

Figure 2 illustrates the trends of AL and SE for all the subjects. It shows that the individual AL and SE values

Table 3. Linear Mixed-Effects Models for Baseline Characteristics Associated With the Rate of Change Rate in AL

	Univariate		Multivariate (Model 1)†		Multivariate (Model 2)‡	
Characteristics	**β (95% CI)**	***P* Value***	**β (95% CI)**	***P* Value***	**β (95% CI)**	***P* Value***
Rate of change in AL						
Age (years)						
≥7 and <11						Reference
≥11 and <18	−0.093 (−0.118 to −0.068)	<0.001	−0.082 (−0.109 to −0.056)	<0.001	−0.080 (−0.106 to −0.055)	<0.001
Gender						
Boys						Reference
Girls	−0.009 (−0.030 to 0.013)	0.420				
Baseline SE (D)	−0.009 (−0.013 to −0.005)	<0.001	—	—	−0.006 (−0.010 to −0.001)	0.014
Baseline AL (mm)	0.008 (0.000 to 0.016)	0.045	0.005 (−0.003 to 0.013)	0.246	–	–
Baseline PM						
0						Reference
1	0.086 (0.054 to 0.117)	<0.001	0.055 (0.021 to 0.088)	0.001	0.043 (0.010 to 0.076)	0.011

* *P* was calculated using a linear mixed-effects regression model.
† Multivariate Model 1: The covariates were age, gender, baseline AL, and baseline PM.
‡ Multivariate Model 2: The covariates were age, gender, baseline SE, and baseline PM.

Table 4. Linear Mixed-Effects Models for Baseline Characteristics Associated With the Rates of Change in SE

	Univariate		Multivariate	
Characteristics	**β (95% CI)**	***P* Value***	**β (95% CI)**	***P* Value***
Rate of change in SE				
Age (years)				
≥7 and <11				Reference
≥11 and <18	0.180 (0.114 to 0.246)	<0.001	0.146 (0.081 to 0.021)	<0.001
Gender				
Boys				Reference
Girls	0.020 (−0.033 to 0.074)	0.460	—	—
Baseline SE (D)	0.025 (0.014 to 0.036)	<0.001	0.017 (0.005 to 0.028)	0.005
Baseline AL (mm)	−0.009 (−0.029 to 0.012)	0.415	—	—
Baseline PM				
0				Reference
1	−0.189 (−0.267 to −0.111)	<0.001	−0.097 (−0.181 to −0.012)	0.025

* *P* was calculated using a linear mixed-effects regression model.

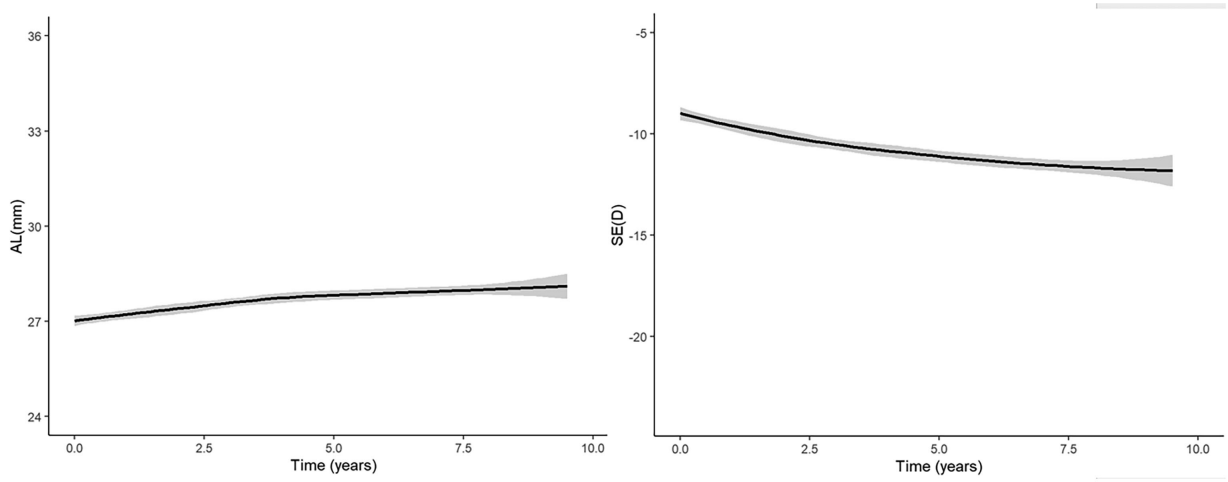

Figure 2. Estimated growth curves of AL and SE using LOWESS plots with 95% CIs.

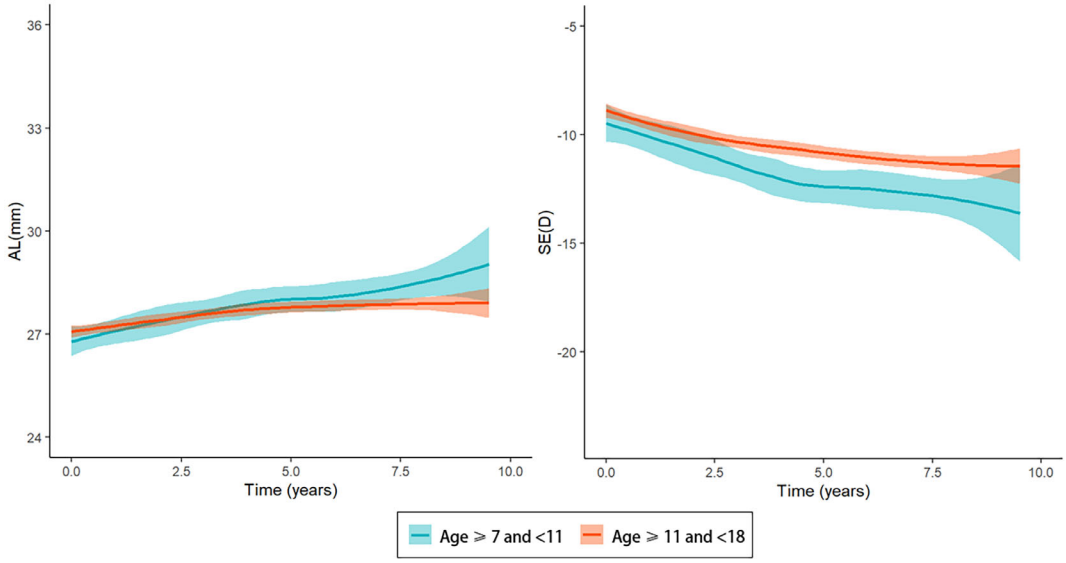

Figure 3. LOWESS-smoothed SE progression and AL elongation by different ages with 95% CIs.

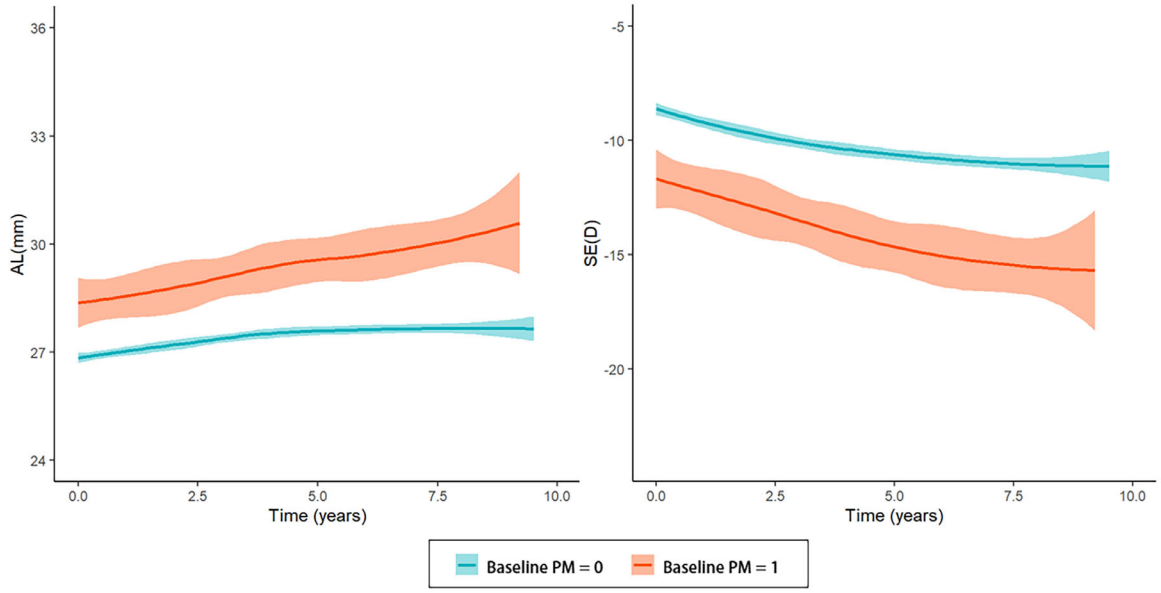

Figure 4. LOWESS-smoothed SE progression and AL elongation by the baseline PM with 95% CIs.

changed over time. Figures 3 and 4 present the LOWESS plots with 95% CI based on age and baseline PM.

Discussion

Using a Chinese children and adolescents aged 7 to 17 years with approximately 7 years of follow-up, we observed that the average annual rates of change in AL and SE were 0.13 mm/y (95% CI, 0.12–0.14 mm/y) and −0.36 D/y (95% CI, −0.39 to −0.34 D/y). Furthermore, less AL elongation and myopic SE progression were related to increasing age and decreasing myopic SE, particularly beyond 11 years of age. This finding suggests that older age and greater initial myopia were associated with slower AL and SE changes. Notably, we found that the AL elongation and myopic SE progression were significantly faster in the subjects that developed PM than in those with normal high myopia.

We report, for the first time, the progression rate of AL and SE in a relatively large sample of highly myopic Chinese children and adolescents with a mean follow-up of 7.09 years. We found that at approximately the age of 11, the AL (0.12 mm/y) and SE (−0.34 D/y) changes were slower than before 11 years (0.21 mm/y; −0.47 D/y). This finding is consistent with those of previous studies on myopia in which the rates of AL and SE change were faster in children and adolescents with myopia before 10 to 12 years of age than after. Chen et al.[14] found, in a 2-year follow-up study of 6353 children and adolescents aged 3 to 15 years, that the progression rates of AL and SE in myopic children were 0.40 mm/y and −0.79 D/y at 2 to 9 years of age, but were significantly lower after the age of 12, reaching 0.21 mm/y and −0.42 D/y,

with a turning point at approximately 10 to 12 years. It was also found that both AL and SE change rates peaked at around the age of 11 in the group of children and adolescents whose parents did not have myopia.[16] Verkicharla et al.[17] examined myopia progression in 6894 myopic individuals aged 1 to 30 years and found that it differed significantly from before the age of 15 to thereafter (−0.45 D/y vs. 0.14 D/y; $P < 0.001$). The fastest progression occurred between 6 and 10 years of age (−0.51 D/y) across all age groups and gradually decreased beyond age 11 (11–15 years, −0.46 D/y; 16–20 years, −0.23 D/y). This result may support the hypothesis that the growth of AL in myopic and highly myopic children and adolescents is mainly driven by excessive growth of the eyes, including the gradual slowdown of physiological growth during physiological emmetropization and the axial elongation of myopia. In addition, it can be inferred that the AL growth rate in children and adolescents with high myopia is not faster than in children and adolescents with myopia and that the rate of SE change seems to be similar. This conclusion needs to be confirmed through controlled longitudinal studies.

We observed that a deeper myopic SE at the baseline visit indicated faster myopia progression. Lanca et al.[18] investigated different refractive states (including nonmyopic, premyopic, low myopic, and high myopic states) in school-age children over a 3-year follow-up period and found that a higher myopic SE at the baseline was associated with greater myopia progression in all the children. Similar findings were reported in some studies that focused on myopia progression in school-age children.[19–21] Du et al.[11] conducted a longitudinal baseline study with a large sample of Japanese adults with high myopia and found that a baseline AL of greater than 28.15 mm was a risk factor for rapid AL growth (≥0.108 mm/y). In this study, baseline AL correlated positively with the rate of AL change in the univariate analysis, but not in the multivariate analysis. This discrepancy may be attributed to the relatively small sample size and the small degrees of change in AL during the follow-up period.

The proportion of highly myopic children and adolescents with PM in this cohort reached 12.0%, whereas the prevalence of PM among highly myopic adults in Japan, rural China, and Beijing was approximately 45.9%, 47.6%, and 65%, respectively.[22–24] This result is not surprising considering our relatively young cohort; the development of myopic maculopathy is known to be a cumulative process. We observed that children and adolescents with PM at the baseline showed significant AL and SE progression in the follow-up period. Chen et al.[25] followed 21 children (31 eyes) with PM and found significant AL and SE changes in the 3.90-year follow-up. Our multivariate analysis results also indicate that the presence of PM at the baseline ($\beta = 0.043$, $P = 0.011$; $\beta = -0.097$, $P = 0.025$) had a greater impact on AL elongation and myopic SE progression than had the baseline SE ($\beta = -0.006$, $P = 0.014$, $\beta = 0.017$, $P = 0.005$). This study further demonstrated that AL and SE growth accelerated when PM occurred during childhood and adolescence. Thus, children and adolescents who develop PM are likely to be classified as having infantile-onset myopia, which may have congenital or genetic factors.[26] Infantile-onset myopia is typically characterized by a high degree of initial myopia and rapid myopia progression.[27] These findings suggest that individuals who developed PM at a young age continue to experience disruptive eye growth during adolescence, with no evidence of a slowdown in ocular growth. A relative myopic change in the fundus can be considered an independent factor for predicting future rapid progression of high myopia or PM.[28] This information can be valuable in prioritizing the management of myopia progression in children and adolescents who have already developed PM.

The strengths of this study included its recruitment of rarely reported highly myopic children and adolescents with multiple visits and a mean follow-up period of 7.09 years to explore the nature change of AL and SE. However, our study had several limitations. First, it investigated only a few baseline characteristics and failed to comprehensively identify the risk factors associated with AL and SE variability. The physical parameters, the existence of parental myopia, the age of onset, and environmental factors were not thoroughly investigated. Second, the cohort was drawn from a specialized clinical institution, so the results may not be generalizable to the overall myopic population. Third, the subjects who participated in the fourth follow-up might have been affected by the coronavirus disease 2019 lockdowns in China. To minimize their potential impact, we used data from multiple follow-ups in our analysis. Finally, the number of participants in this study who were younger than 11 years and had PM was limited. Therefore, to gain deeper insights into this special population, more children with PM should be recruit future studies.

In conclusion, our study findings suggest that a younger age (especially <11 years of age), a more myopic SE, and the presence of PM are associated with faster AL elongation and SE progression in the follow-up. Longer-term cohort studies are needed to characterize longitudinal changes in AL and SE in highly myopic children and adolescents, as well as other risk factors related to them.

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References

1. Morgan IG, French AN, Ashby RS, et al. The epidemics of myopia: aetiology and prevention. *Prog Retinal Eye Res*. 2018;62:134–149.
2. Dolgin E. The myopia boom. *Nature*. 2015;519(7543):276–278.
3. Holden BA, Fricke TR, Wilson DA, et al. Global prevalence of myopia and high myopia and temporal trends from 2000 through 2050. *Ophthalmology*. 2016;123(5):1036–1042.
4. Dong L, Kang YK, Li Y, Wei WB, Jonas JB. Prevalence and time trends of myopia in children and adolescents in China: a systemic review and meta-analysis. *Retina*. 2020;40(3):399–411.
5. Morgan I, He M, Rose K. Epidemic of pathologic myopia. *Retina*. 2017;37:989–997.
6. Wong YL, Saw SM. Epidemiology of pathologic myopia in Asia and worldwide. *Asia Pac J Ophthalmol*. 2016;5:394–402.

7. Ikuno Y. Overview of the complications of high myopia. *Retina*, 2017;37(12):2347–2351.
8. Morgan IG, Ohno-Matsui K, Myopia Saw S-M. *Lancet*. 2012;379:1739–1748.
9. Ohno-Matsui K, Wu PC, Yamashiro K, et al. IMI pathologic myopia. *Invest Ophthalmol Vis Sci*. 2021;62(5):5.
10. Holden B, Sankaridurg P, Smith E, Aller T, Jong M, He M. Myopia, an underrated global challenge to vision: where the current data takes us on myopia control. *Eye*. 2014;28(2):142–146.
11. Du R, Xie S, Igarashi-Yokoi T, et al. Continued increase of axial length and its risk factors in adults with high myopia. *JAMA Ophthalmol*. 2021;139(10):1096–1103.
12. Lee MW, Lee SE, Lim HB, Kim JY. Longitudinal changes in axial length in high myopia: a 4-year prospective study. *Br J Ophthalmol*. 2020;104(5):600–603.
13. Hu Y, Ding X, Long W, He M, Yang X. Longitudinal changes in spherical equivalent refractive error among children with preschool myopia. *Invest Ophthalmol Vis Sci*. 2019;60(1):154–160.
14. Chen S, Guo Y, Han X, et al. Axial growth driven by physical development and myopia among children: a two-year cohort study. *J Clin Med*. 2022;11(13):3642.
15. Ohno-Matsui K, Kawasaki R, Jonas JB, et al. International photographic classification and grading system for myopic maculopathy. *Am J Ophthalmol*. 2015;159:877–883.
16. Liao C, Ding X, Han X, et al. Role of parental refractive status in myopia progression: 12-year annual observation from the Guangzhou Twin Eye Study. *Invest Ophthalmol Vis Sci*. 2019;60(10):3499–3506.
17. Verkicharla PK, Kammari P, Das AV. Myopia progression varies with age and severity of myopia. *PLoS One*. 2020;15(11):e0241759.
18. Lanca C, Emamian MH, Wong YL, et al. Three-year change in refractive error and its risk factors: results from the Shahroud School Children Eye Cohort Study. *Eye*. 2022;37:1625–1632.
19. Goss DA. Variables related to the rate of childhood myopia progression. *Optom Vis Sci*. 1990;67:631–636.
20. Braun CI, Freidlin V, Sperduto RD, Milton RC, Strahlman ER. The progression of myopia in school age children: data from the Columbia Medical Plan. *Ophthalmic Epidemiol*. 1996;3:13–21.
21. Watanabe S, Yamashita T, Ohba N. A longitudinal study of cycloplegic refraction in a cohort of 350 Japanese schoolchildren. *Ophthalmic Physiol Opt*. 1999;19:22–29
22. Asakuma T, Yasuda M, Ninomiya T, et al. Prevalence and risk factors for myopic retinopathy in a Japanese population: the Hisayama Study. *Ophthalmology*. 2012;119:1760–1765.
23. Gao LQ, Liu W, Liang YB, et al. Prevalence and characteristics of myopic retinopathy in a rural Chinese adult population: the Handan Eye Study. *Arch Ophthalmol*. 2011;129:1199–1204.
24. Liu HH, Xu L, Wang YX, Wang S, You QS, Jonas JB. Prevalence and progression of myopic retinopathy in Chinese adults: the Beijing Eye Study. *Ophthalmology*. 2010;117:1763–1768.
25. Chen M, Yu M, Dai J, Chu R. Long-term natural course of pathologic myopia in Chinese patients. *J Ophthalmol*. 2019;2019:1210398.
26. Ohno-Matsui K, Wu PC, Yamashiro K, Vutipongsatorn K, et al. IMI pathologic myopia. *Invest Ophthalmol Vis Sci*. 2021;62(5):5.
27. Shih YF, Ho TC, Hsiao CK, Lin LL. Long-term visual prognosis of infantile-onset high myopia. *Eye*. 2006;20(8):888–892.
28. Foo LL, Lim GYS, Lanca C, et al. Deep learning system to predict the 5-year risk of high myopia using fundus imaging in children. *NPJ Digit Med*. 2023;6(1):10.

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