

Baseline Refractive Error, Habitual Accommodative Tone, and Its Association With Myopia in Children: The Lhasa Childhood Eye Study

Fei Luo,¹ Jie Hao,¹ Lei Li,¹ Jiawen Liu,² Weiwei Chen,¹ Jing Fu,¹ and Nathan Congdon^{3,4}

¹Beijing Tongren Eye Center, Beijing Tongren Hospital, Capital Medical University; Beijing Key Laboratory of Ophthalmology & Visual Sciences, Beijing, China

²Industrial Engineering and Operations Research, University of California, Berkeley, California, United States

³School of Medicine, Dentistry and Biomedical Sciences, Queen's University, Belfast, United Kingdom

⁴Orbis International, New York, New York, United States

Correspondence: Jing Fu, Beijing Tongren Hospital, Capital Medical University, No. 1, Dong Jiao Min Xiang Street, Dongcheng District, Beijing Tongren Hospital, Beijing 100730, China; fu_jing@126.com.

FL and JH contributed equally to this work and should be regarded as co-first authors.

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PURPOSE. The purpose of this study was to describe the baseline refractive error, habitual accommodative tone (HAT) in Tibetan children and its longitudinal association with incident myopia and myopia progression.

METHODS. This was a prospective cohort study. From 7 elementary schools, 1440 children with mean age of 6.83 ± 0.46 years were included with full noncycloplegic and cycloplegic refraction data at baseline, 1-year and 2-year follow-up in the Lhasa Childhood Eye Study. Noncycloplegic and cycloplegic automated refraction were performed at baseline and annually over the next 2 years. HAT was measured as the difference in spherical equivalent (DSE) between noncycloplegic and cycloplegic refraction.

RESULTS. The mean HAT decreased from a baseline value of 0.92 ± 0.82 diopters (D) to 0.55 ± 0.65 D, $P < 0.0001$ at 2 years. In multivariable logistic regression models, only baseline spherical equivalent (SE; $P < 0.0001$) was significantly (negatively) associated with 1- and 2-year incident myopia. Among 1386 children without myopia at baseline, 271 developed myopia over 2 years. For hyperopic children, baseline HAT was significantly associated with the incidence of myopia over 2 years (odds ratio [OR] = 0.43, $P < 0.001$), and the incidence of myopia was significantly lower with baseline HAT ≥ 0.5 D, compared to children < 0.5 D. For 54 (3.75%) children who were myopic at baseline, SE was significant positively associated with myopic progression in univariable ($P = 0.03$) and multivariable general mixed linear regression analysis ($P = 0.03$).

CONCLUSIONS. Baseline SE was an independent influencing factor for the incidence of myopia and its progression. The incidence of myopia was significantly higher with lower baseline HAT among hyperopic children, indicating that lower HAT was potentially associated with myopic development.

Keywords: noncycloplegic refraction, cycloplegic refraction, accommodation, myopia, ciliary muscle

Global myopia prevalence is dramatically increasing.^{1,2} In a recent cross-sectional study among urban Chinese school-going children, at age 6 to 8 years, 25.0% were myopic,³ whereas the prevalence increased to 63.1% by age 12 years,⁴ and 95% by 16 years.⁵ In urban east Asia, up to 90% of teenagers and young adults are myopic,⁶ a condition predicted to affect nearly 50% of the world's population by 2050.^{7,8} Myopia is etiologically heterogeneous, consisting of genetic mutations, and environmental risk factors,^{7,9,10} all of which lead to specific ocular biometry features. Of them, the role of accommodation has been debated for years. The relationship between accommodation and myopia development and progression has remained controversial.¹¹

Previous reports on the association between accommodation and myopia have produced contradictory findings, and studies have varied in design, type of accommoda-

tive stimulus, and age range and refractive error of participants.^{12–14} However, most studies have focused on exploring the link between myopia and altered dynamics of the accommodation response, but few have assessed the relationship between myopia and accommodation over a substantial period of follow-up.

In children, the ocular dimensions undergo considerable changes at the time of myopia onset, with a rapid decrease in spherical equivalent (SE) refraction and a corresponding increase in axial growth rate, and even a slowing or cessation of loss of crystalline lens power.¹⁵ Cycloplegia paralyzes accommodation and thus affects measured crystalline lens power during autorefractometry.¹⁶ In recent years, studies on noncycloplegic compared with cycloplegic refraction have been undertaken in school-based populations.^{16–18} Three quarters of school-aged participants had < 1 diopters (D)

of myopic SE difference between noncycloplegic and cycloplegic autorefraction.¹⁶ The difference in spherical equivalent (DSE) refractive power was calculated as the noncycloplegic SE subtracted from the cycloplegic SE,^{19–22} reflecting the amount of habitual accommodative tone (HAT).

HAT has been defined as the habitual state of relaxation or contraction of the ciliary muscles, varying from person to person, and within an individual over time. Previously suggested parameters (accommodative response, amplitude of accommodation, and accommodative facility) have provided only a snapshot of the accommodative response, whereas HAT describes long-term, age-related changes of habitual accommodative tone. As is widely understood, HAT decreases with increasing age, but the prevalence of myopia increases with aging.^{4,21} Whether HAT is a risk factor for myopic development and progression remains unclear, in large part due to the lack of longitudinal data. Although the potential mechanism could be explored from laboratory-based studies, a large-scale longitudinal study can provide stronger evidence to address the question, compared to a smaller laboratory-based study. The purpose of the present study is to observe the baseline refractive error, HAT, and its longitudinal association with incident myopia and myopia progression. The hypothesis that low HAT is a risk factor for myopia onset and progression will be explored in this study.

METHODS

Study Population

The Lhasa Childhood Eye Study (LCES)²³ was a school-based longitudinal cohort study designed to document the occurrence and development of different ocular diseases, especially myopia, in children. From September to October 2019, 1856 participants (mean age = 6.83 ± 0.46 years, response rate = 97.6%) completed all baseline examinations. Identical examinations were repeated at 12-month intervals over 2 years. Ethics approval was obtained from the Institutional Review Board of Beijing Tongren Hospital, Capital Medical University (TRECKY2019-146). Written informed consent was provided by the parents of all participants, and the principles of the Declaration of Helsinki were followed throughout.

Procedures

All examinations and questionnaires were completed at the Health Examination Station of Lhasa Maternal and Child Health Care Center. Ophthalmic examinations included assessment of visual acuity, slit lamp biomicroscopy, noncycloplegic and cycloplegic autorefraction, measurement of intraocular pressure, evaluation of stereopsis, cover testing, documentation of ocular movements, and optical coherence tomography.

As described elsewhere in detail,¹⁷ refraction was measured before and after cycloplegia using an autorefractor (KR-800, Topcon). Three repeated measurements were averaged and required to be at most 0.50 D apart in both the spherical and cylinder components; the measurements were repeated whenever this could not be accomplished. Slit lamp examination was performed by an experienced ophthalmologist to find children with angle closure. After ensuring that there was no risk of angle closure, cycloplegia medication was applied. Cycloplegia was induced using the

following procedure: 5 minutes after a single drop of topical anesthetic agent (Alcaine, Alcon, s.a. ALCON-COUVREUR n.v., Belgium) was instilled, 2 drops of 1% cyclopentolate (Alcon, s.a. ALCON-COUVREUR n.v., Belgium), and one drop of tropicamide phenylephrine (0.5% tropicamide and 0.5% phenylephrine; Santen Pharmaceutical CO. LTD., Japan) were administered at 5-minute intervals. Thirty minutes after the last drop, a third drop of 1% cyclopentolate was administered whenever the pupillary light reflex was still present or if the pupil diameter remained <6.0 mm, and the autorefractor measurement was repeated 15 minutes later. If complete cycloplegia was not achieved after the third drop of cyclopentolate, subjects did not undergo cycloplegic refraction.

Definitions

The SE was defined as the spherical power added to half the cylindrical power. The HAT was the difference in SE between the noncycloplegic and cycloplegic refractive power (DSE), calculated as the noncycloplegic SE subtracted from the cycloplegic SE. The change in HAT between baseline and follow-up was calculated as baseline HAT subtracted from follow-up HAT. Myopia was defined as $SE \leq -0.5$ D, emmetropia as $-0.5 \text{ D} < SE < 0.5 \text{ D}$, and hyperopia as $SE \geq 0.5 \text{ D}$ after cycloplegia. Incident myopia was defined as myopia at the follow-up in a child with emmetropia or hyperopia at baseline. Myopic progression was calculated as baseline cycloplegic SE subtracted from follow-up cycloplegic SE among baseline myopic children.

Statistical Analysis

All statistical analyses were performed with SAS software (version 9.4; Statistical Analysis System Institute Inc., Cary, NC, USA). Because of the high correlation between two eyes of the same participant, only data from right eyes were analyzed. Measures are presented as mean $\pm$ SD for continuous variables. ANOVA was used for comparisons of age, SE and HAT among myopes, and emmetropes and hyperopes between baseline, 1-year, and 2-year follow-ups. Logistic regression models and general mixed linear regression model were used to assess potential determinants of incident myopia and myopia progression, respectively. Factors assessed in these models included age, sex, baseline SE, baseline HAT, and 1-year and 2-year HAT change in the univariable analysis. Multivariable regression models included those factors statistically significant in univariable models. All *P* values were two-sided and considered to be statistically significant if < 0.05 .

RESULTS

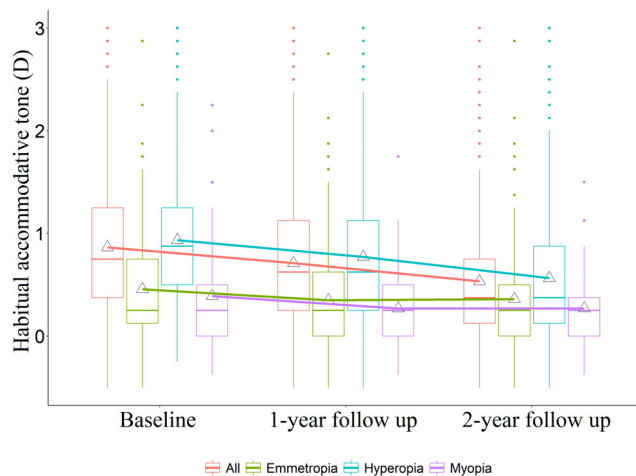
Among 1856 participants with baseline data, 1468 (749 boys [51.0%] and 719 girls [49.0%]; response rate = 79.1%) completed 2-year follow-up, among whom 1440 (77.6%) had full noncycloplegic and cycloplegic refraction data for baseline, 1-year, and 2-year follow-ups. All subsequent analyses refer to these 1440 children, except where indicated.

Table 1 presents the characteristics of children at baseline and follow-up. The 2-year cumulative refractive error change with cycloplegia was -0.90 ± 0.78 D, and the cumulative refractive error change in children with baseline myopia, emmetropia and hyperopia was -1.74 ± 1.30 D,

TABLE 1. The Characteristics of the Children in Baseline and Follow-Up ($n = 1440$)

Variables	Baseline	1 y Follow-Up	2 y Follow-Up	P Value
Age, y	6.83 ± 0.46	7.91 ± 0.46	8.57 ± 0.46	<0.0001
Sex, male/female	731/709	731/709	731/709	–
Noncycloplegic SE (D)				
All	0.16 ± 0.90	−0.16 ± 1.03	−0.36 ± 1.19	<0.0001
Myopia	−1.37 ± 1.09 ($n = 216$)	−1.33 ± 1.11 ($n = 397$)	−1.53 ± 1.19 ($n = 508$)	0.0274
Emmetropia	0.09 ± 0.24 ($n = 649$)	0.04 ± 0.25 ($n = 723$)	0.03 ± 0.24 ($n = 652$)	<0.0001
Hyperopia	0.82 ± 0.45 ($n = 575$)	0.83 ± 0.59 ($n = 320$)	0.83 ± 0.55 ($n = 280$)	0.6770
Cycloplegic SE (D)				
All	1.08 ± 0.92	0.58 ± 1.12	0.18 ± 1.30	<0.0001
Myopia	−1.52 ± 1.30 ($n = 54$)	−1.54 ± 1.34 ($n = 165$)	−1.60 ± 1.28 ($n = 325$)	0.6116
Emmetropia	0.14 ± 0.23 ($n = 149$)	0.10 ± 0.23 ($n = 343$)	0.08 ± 0.25 ($n = 407$)	0.0047
Hyperopia	1.31 ± 0.67 ($n = 1237$)	1.14 ± 0.64 ($n = 932$)	1.06 ± 0.64 ($n = 708$)	<.0001
HAT (D)				
All	0.92 ± 0.82	0.74 ± 0.77	0.55 ± 0.65	<0.0001
Myopia	0.30 ± 0.64 ($n = 54$)	0.18 ± 0.66 ($n = 165$)	0.24 ± 0.51 ($n = 325$)	0.9394
Emmetropia	0.46 ± 0.57 ($n = 149$)	0.43 ± 0.59 ($n = 343$)	0.35 ± 0.52 ($n = 407$)	0.0236
Hyperopia	1.00 ± 0.82 ($n = 1237$)	0.96 ± 0.75 ($n = 932$)	0.80 ± 0.68 ($n = 708$)	<0.0001

SE, spherical equivalent; HAT, habitual accommodative tone noncycloplegic SE subtracted from cycloplegic SE; ANOVA was used for the comparisons among myopia, emmetropia and hyperopia. The P values were 2-sided and less than 0.05 was considered to be statistically significant.

**FIGURE.** The trends of the habitual accommodative tone changed over years for myopia, emmetropia, hyperopia, and all, respectively.

−1.20 ± 1.09 D, and −0.83 ± 0.66 D, respectively. The prevalence rates of myopia, emmetropia, and hyperopia according to cycloplegic refraction were 3.75%, 10.4% and 85.9% at baseline, 11.5%, 23.8% and 64.7% at 1-year follow-up, and 22.6%, 28.3%, and 49.2% after 2 years, respectively. Seventy-five percent of apparent myopia at baseline on noncycloplegic refraction became emmetropic or hyperopic after cycloplegia, as did 58.4% at 1-year follow-up, and 36.0% at 2 years. Mean HAT for all participants decreased over 2 years and there were significant decreases in HAT over 1 and 2

years for emmetropic and hyperopic, but not myopic children (see the Figure).

We completed parental surveys on wear of correcting lenses at baseline and the follow-up. Among children with hyperopic refractive errors, only five (0.4%) wore corrective lenses full time at baseline. The number increased to 16 (1.7%) at the 1-year follow-up, and decreased to 8 (1.1%) by 2 years. Among children with myopia, the figures at baseline, 1, and 2 years were 2 (3.7%), 10 (6.1%), and 22 (6.8%). These low rates of wear likely had little influence on the accommodative tone. The fluctuation in the numbers of subjects wearing correcting lenses may be attributed to the fact that, at baseline, only a few children had received ophthalmic examinations prior to the study, leading to the lower ratio of wearing correcting lenses. After the study, more children with refractive errors accepted prescriptions from the study. At the 2-year follow-up, the prevalence of hyperopia decreased and myopia increased, which caused a corresponding change in the number of participants wearing corrective lenses.

Baseline HAT, and change in HAT between baseline and 1-year and 2-year follow-up among all participants were taken as dependent variables in regression models. With age, sex, and baseline SE as the independent variables, only baseline SE was significantly associated with baseline HAT ($\beta = 0.42$, $P < 0.0001$), and also with 1-year ($\beta = -0.09$, $P < 0.001$) and 2-year ($\beta = -0.20$, $P < 0.0001$) change in HAT (Table 2).

Risk factors of incident myopia were analyzed using logistic regression, with age, sex, baseline SE, baseline HAT, and 1- and 2-year change in HAT as independent variables. In the univariable regression analysis, baseline SE ($P < 0.0001$)

TABLE 2. The Association Between Habitual Accommodative Tone (HAT) and Various Potential Explanatory Factors in General Mixed Linear Regression Analysis ($n = 1440$)

Variables	Baseline HAT (D)		1-y HAT Change (D)		2-y HAT Change (D)	
	Beta	P Values	Beta	P Values	Beta	P Values
Age, y	0.03	0.51	−0.07	0.16	−0.04	0.40
Sex male/female	0.04	0.36	<−0.01	0.99	−0.01	0.82
Baseline SE (D)	0.42	<0.0001	−0.09	0.0003	−0.20	<0.0001

SE, spherical equivalent; HAT, habitual accommodative tone noncycloplegic SE subtracted from cycloplegic SE; the P values were 2-sided and less than 0.05 was considered to be statistically significant.

TABLE 3. Univariable and Multivariable Logistic Regression Model for Potential Determinants of Incident Myopia ($n = 1386$) and General Mixed Linear Regression Model for Potential Determinants of Myopia Progression ($n = 54$)

Variables	Incident Myopia ($n = 1386$)				Myopia Progression ($n = 54$)			
	Myopia Onset in 1 y		Myopia Onset in 2 y		Myopia Progression in 1 y		Myopia Progression in 2 y	
	Univariate	Multivariate	Univariate	Multivariate	Univariate	Multivariate	Univariate	Multivariate
	OR (95% CI)	P Value	OR (95% CI)	P Value	Coefficient (95% CI)	P Value	Coefficient (95% CI)	P Value
Age, y	0.85 (0.55~1.32)	0.47	0.87 (0.64~1.16)	0.34	0.11 (−0.51~0.73)	0.71	0.28 (−0.49~1.06)	0.46
Sex, M/F	1.19 (0.80~1.73)	0.40	1.12 (0.85~1.45)	0.42	0.52 (−0.03~1.08)	0.06	0.71 (0.02~1.40)	0.04
Baseline SE (D)	0.03 (0.02~0.05)	<0.0001	0.04 (0.03~0.06)	<0.0001	0.18 (−0.03~0.40)	0.10	0.30 (0.04~0.57)	0.03
Baseline HAT (D)	0.24 (0.16~0.37)	<0.0001	0.32 (0.24~0.42)	<0.0001	−0.07 (−0.52~0.38)	0.76	0.05 (−0.51~0.61)	0.86
1 y HAT change (D)	0.84 (0.67~1.05)	0.12	0.89 (0.76~1.04)	0.15	0.43 (0.07~0.80)	0.02	0.39 (−0.08~0.87)	0.10
2-y HAT change (D)	—	—	1.09 (0.92~1.30)	0.31	—	—	0.33 (−0.20~0.85)	0.21

OR, odds ratio; CI, confidence interval; SE, spherical equivalent; HAT, habitual accommodative tone noncycloplegic SE subtracted from cycloplegic SE; 1-year HAT change, baseline HAT subtracted from HAT of the 1 year follow-up; 2 year HAT change, baseline HAT subtracted from HAT of the 2 year follow-up; univariable and multivariable logistic regression was used to assess potential determinants of the incident myopia. General mixed linear regression was used to assess potential determinants of myopia progression. The P values were 2-sided and less than 0.05 was considered to be statistically significant.

and baseline HAT ($P < 0.0001$) were significantly negatively associated with 1- and 2-year incident myopia, respectively. In the multivariable logistic regression analysis, there was no collinearity between baseline SE and HAT in 1-year (VIF1.03) and 2-year (VIF1.08) analysis. Only baseline SE ($P < 0.0001$) was significantly negatively associated with 1- and 2-year incident myopia, respectively, indicating less hyperopia at baseline was at greater risk for the incident myopia (Table 3).

Of the 1386 nonmyopic children at baseline after cycloplegia, newly developed myopia occurred in 271 participants over 2 years of follow-up. At baseline, there were 54 participants with myopia after cycloplegia. At the 1-year follow-up, the number of participants with myopia increased to 165 after cycloplegia, indicating 111 children became myopic by the end of 1 year. At 2 years, there were 325 children with myopia after cycloplegia, indicating 160 children newly became myopic over the second year of the follow-up. In analyses of the potential determinants of incident myopia, 111 children were included for myopia onset over 1 year and 271 over 2 years. Interestingly, nonmyopic children were stratified to hyperopia and emmetropia for subsample analysis because of the significant association of baseline SE with the incident myopia. Among children with baseline hyperopia, the incidence of myopia was significantly lower with baseline HAT ≥ 0.5 D (9.7%, $n = 949$), compared to children with baseline HAT < 0.5 D (24.3%, $n = 288$, $P < 0.001$). Multivariable logistic regression result found that children who had less baseline SE (odds ratio [OR] = 0.05, 95% confidence interval [CI] = 0.03 to 0.10, $P < 0.0001$), decreased baseline HAT (OR = 0.43, 95% CI = 0.28 to 0.67, $P < 0.001$) and lower 1-year change in HAT (OR = 0.36, 95% CI = 0.23 to 0.54, $P < 0.0001$) had elevated risk in developing myopia over 2 years. There was no collinearity among baseline SE (VIF1.11), baseline HAT (VIF2.84) and 1-year change in HAT (VIF2.66). Among children with baseline emmetropia, there was no significant difference in the incidence of myopia between emmetropic children with baseline HAT ≥ 0.5 D (67.2%, $n = 58$) and < 0.5 D (78.0%, $n = 91$, $P = 0.14$). Multivariable logistic regression result found that only baseline SE (OR = 0.16, 95% CI = 0.02 to 0.92, $P = 0.050$) and lower 1-year change in HAT (OR = 0.56, 95% CI = 0.30 to 0.92, $P = 0.043$) were in borderline significantly associated with the incidence of myopia over 2 years (Supplementary Table S1).

For 54 children myopic at baseline after cycloplegia, the average myopia progression was -0.50 D over 1 year and -0.90 D over 2 years. With children's myopia progression as the dependent variable, univariable and multivariable general mixed linear regression were used to assess potential determinants including age, sex, baseline SE, baseline HAT, and HAT change as the independent variables. Unlike with incident myopia, only the 1-year HAT change was significant positively correlated with 1-year myopia progression in the univariate model. However, over 2 years, baseline SE was significant positively associated with myopia progression in univariable ($P = 0.03$) and multivariable regression analysis ($P = 0.03$), and boys progressed significantly more than girls ($P = 0.04$; see Table 3).

DISCUSSION

This study supported the hypothesis that being less hyperopic at baseline predicted myopia.^{24,25} The incidence of myopia was higher in children who had less hyperopic baseline refraction.²⁶ In a recent study, the incidence of myopia

was 92.0% among children a baseline SE of 0.00 to -0.50 D, whereas less than 50% of those with baseline SE of $+1.50$ D to $> +1.00$ D progressed to myopia, and the incident was even lower among children who had a baseline SE of $> +2.00$ D.²⁶ Consistent with previous studies, our analysis demonstrated incident myopia was significantly associated with baseline refraction, showing those with less hyperopic baseline refraction were at greater risk for developing myopia.^{24–27} In a similar-aged cohort to our own, Zadnik et al. showed children examined with $< +0.75$ D of hyperopia were at increased risk for developing myopia at age 6 years.²⁵ In a study among young schoolchildren, compared to those who remained nonmyopic, participants with incident myopia had significantly lower baseline SE.²⁴ Furthermore, emmetropic children were at more than 19-fold higher risk for developing myopia compared to hyperopic children with baseline SE of $\geq +3.0$ D.

Myopic progression was associated with baseline SE.²⁸ Children with more myopic refraction were significantly more likely to develop myopia.²² In contrast with another study reporting no significant difference in the mean SE progression rates among four baseline SE groups, our data showed baseline SE was significant positively associated with myopic progression.²⁴ Others have reported that SE progression was associated with female sex.²⁸ In a previous study, girls had greater annual myopic shifts than boys during follow-up visits.²⁶ Whereas annual myopia progression rates vary from -0.50 D to -0.90 D, girls had a greater rate of annual progression than boys, by an average of 0.093 D.²⁹ It was speculated that girls may spend more time on near work and less time on outdoor activities.²⁶ However, this female-male difference in progression was inconsistent with our study. In this study, the age of children ranged from 6 to 8 years during follow-up, and our data indicated that boys had greater myopic shifts than girls. In contrast, another study reported faster annual myopia progression in girls than in boys, with the average age at the myopia-onset visit between 10 and 11 years old.²⁹ In the study by Li et al., although the mean age was 7.2 ± 0.3 years at baseline, girls had greater annual myopic shifts than boys only at the third and succeeding follow-up years.²⁶ This illustrates that the studies reporting that girls exhibited faster myopia progression involved children who were closer to puberty than our participants. The potential underlying mechanisms are complex. Zadnik et al. estimated that girls, unlike boys, undergo a small increase in lens thickness beginning at 12 years of age.³⁰ Furthermore, older girls may spend less time on outdoor activities and more time on near work activities, a difference perhaps more apparent later than in the ages between 6 to 8 years in our study. Further longitudinal follow-up observations of our subjects are warranted.

HAT may play a role in early development of myopia among young hyperopic children. A recent study by Lin et al. showed there was no significant association between DSE (HAT) and newly developed myopia.²¹ They further showed greater DSE was associated with myopia progression among myopic children. Although this longitudinal study found neither HAT nor change in HAT was associated with the incidence or progression of myopia over 2 years, hyperopic children with lower values of HAT were found to be more likely to develop myopia. Because baseline SE was significantly negatively associated with 1- and 2-year incident myopia, we further stratified nonmy-

opic children into those with hyperopia and emmetropia at baseline. This analysis showed baseline HAT to be significantly associated with the incidence of myopia over 2 years for hyperopia, showing hyperopic children with lower values of HAT were at greater risk for incident myopia. It was known that children with higher amounts of hyperopia may need more compensatory accommodation to overcome hyperopic blur, but HAT may not simply reflect the amount of hyperopia. Although there was significant positive correlation between HAT and SE ($r = 0.495$, $P < 0.001$) for hyperopia, showing children with higher amounts of hyperopia were likely to have a greater HAT value, our model demonstrates that both SE and HAT have independent and significant associations with incident myopia. In further important analysis of the collinearity in the multivariable model, there was no collinearity between baseline HAT and SE (VIF = 1.097), indicating that hyperopic children with lower HAT who developed more myopia did not always have lower amounts of hyperopia. This demonstrates that HAT and SE have independent impacts on myopia onset. This may be attributed to the fact that HAT can be affected not only by SE, but also by many other factors, such as age, lag of accommodation, and others.³¹ Moreover, for hyperopia, decreased 1-year change in HAT was also found to be a risk factor for incident myopia. For emmetropia, the numbers were not large enough, making it less likely that any association between change in HAT and incident myopia would reach statistical significance.

The mechanism for decreased HAT being a risk factor for incident myopia remains unclear in hyperopic children. HAT represents usual accommodative tone, which is different from the dynamics of the accommodative response. It essentially reflects the habitual state of relaxation or contraction of the ciliary muscles over a period, typically occurring after a period of sustained near work.²² The ciliary muscles participate actively in the accommodative response, which can be opposed by cycloplegia.³² It has been hypothesized that high lags of accommodation, reflecting accommodative inaccuracies, could lead to the development of myopia.¹¹ Previous studies have showed there was a trend toward low HAT being associated with increased prevalence of myopia,^{4,21,33} which could be explained by decreases in accommodation.^{16,34} We further showed that HAT decreases significantly in emmetropia and hyperopia, but not in myopia. The decrease in HAT implied a change in the refractive error in the direction of myopia, even if the transition into myopia has not yet occurred. In this context, lower HAT need not imply poorly functioning accommodation as a result of either impaired neural signaling or ciliary muscle function. From the standpoint of increasing the accuracy of screening programs to detect children at risk of myopic onset, HAT is potentially useful as a biomarker, irrespective of its underlying cause. Establishing the exact nature of the causal relationship between lower HAT and the risk of myopia is beyond the scope of this epidemiological study.

There were some limitations in this study. First, this longitudinal study covered only 2 years, which may not have been sufficient to elucidate all the potential risk factors for HAT, such as age. Second, axial length was not investigated at baseline. Third, morphologic changes of the ciliary muscle were not evaluated in this study. Further research is necessary to explore whether changes in ciliary muscle shape are causative factors in myopigenesis.

CONCLUSIONS

This study provided evidence that baseline SE was an independent influencing factor for the incidence of myopia and its progression. The study also revealed for hyperopic children aged 6 to 8 years, a link between lower HAT and higher rates of incident myopia, which may be attributed to a reduction in sustained contraction of the ciliary muscle, leading directly or indirectly to the development of myopia. Whether the reduction in HAT was a consequence of the eye tending toward myopia or the cause for it needs to be further explored.

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Data Availability Statement: Data are available upon reasonable request. All data relevant to the study are included in the article.

Ethics Approval: This study was approved by the Institutional Review Board of Beijing Tongren Hospital, Capital Medical University (TRECKY2019-146).

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