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Myopia Progression in Chinese Children is Slower in Summer Than in Winter

Leslie Donovan^{*}, Padmaja Sankaridurg[†], Arthur Ho[‡], Xiang Chen[§], Zhi Lin^{||}, Varghese Thomas^{||}, Earl L. Smith III[‡], Jian Ge[¶], and Brien Holden[‡]

Brien Holden Vision Institute, Sydney, New South Wales, Australia (LD, PS, AH, VT, BH), Vision Cooperative Research Centre, Sydney, New South Wales, Australia (LD, PS, AH, VT, ELS, BH), College of Optometry, University of Houston, Houston, Texas (ELS), School of Optometry and Vision Science, University of New South Wales, Sydney, New South Wales, Australia (PS, AH, BH), and Zhongshan Ophthalmic Center, Sun Yat-sen University, Guangzhou, China (JG, XC, ZL)

Abstract

Purpose—To characterize seasonal variation in the myopic progression of Chinese children.

Methods—Myopia progression data are presented for a total of 85 Chinese children, aged 6 to 12 years, with baseline myopia of -0.75 D to -3.50 D sphere and astigmatism -1.50 D, who wore traditional single-vision spectacles in two clinical trials (trial A: $n = 37$, trial B: $n = 48$). Refractive error and axial length data were obtained at 6-month intervals using cycloplegic autorefraction and partial coherence interferometry, respectively. Progression rates for right eyes were defined for the first and second 6 months of the studies and classified in terms of “summer,” “autumn,” “winter,” or “spring” based on the mid-point of the 6-month period between visits.

Results—The mean 6-month spherical equivalent progression was -0.31 ± 0.25 D for summer, -0.40 ± 0.27 D for autumn, -0.53 ± 0.29 D for winter, and -0.42 ± 0.20 D for spring ($p < 0.001$). Mean axial elongation was 0.17 ± 0.10 mm for summer, 0.24 ± 0.09 mm for autumn, 0.24 ± 0.09 mm for winter, and 0.15 ± 0.08 mm for spring ($p < 0.001$). Post hoc analysis indicated that data for summer and winter were different from each other at $p < 0.05$ for both myopia progression and axial elongation after adjusting for age.

Conclusions—Myopia progression in summer months was approximately 60% of that seen in winter, and axial elongation was likewise significantly less in summer. It is unclear whether more time spent outdoors in summer vs. winter is a contributing factor, or the difference in progression rates is a result of “seasonal” variations in the intensity or amount of close work performed. These results indicate that studies of potential myopia treatment strategies should be at least 12 months in duration to take seasonal variations into account.

Leslie Donovan, Brien Holden Vision Institute, Level 4 Rupert Myers Building, Gate 14, Barker Street, Kensington NSW, 2033, Australia, l.donovan@brienholdenvision.org.

^{*}BOptom

[†]PhD

[‡]PhD, FAAO

[§]MS

^{||}MSc

[¶]MD

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In their review of published material on myopia progression, Grosvenor and Goss¹ observed that higher rates of progression were characteristically associated with several factors, including less time spent outdoors and more time spent reading, an activity that is generally performed indoors. In many parts of the world, the proportions of time in which a child is typically engaged in outdoor vs. indoor activities are not constant throughout the year. For many children, school vacations are likely to be times when less near work is performed and more time is spent outdoors. Because more hours of reading have been found to be associated with faster myopia progression,² and more hours outdoors appear to provide some protection against myopia development,^{3,4} a period of less reading and more time spent outdoors might be expected to reduce the pace of myopia progression.

Indeed, non-linear intra-year patterns of refractive change in schoolchildren have been reported since the late 1930s.^{5–7} However, the strength of the data in these early reports was compromised by methodological issues; for example, in many cases, the measurements were obtained without cycloplegia. Moreover, there have been inconsistencies between studies. For instance, in contrast to many of the early studies, Hirsch⁸ concluded that the decreases in hyperopia and the increases in myopia observed during the months of the academic year continued unabated throughout the summer vacation. However refraction data for this study were also derived without cycloplegia.

More recently, several papers have provided more robust evidence of seasonal fluctuations in the rate of myopia progression in North-American schoolchildren.^{9–11} In this article, we document similar temporal or “seasonal” variations in myopia progression in two similar groups of Chinese children in Southeast China.

METHODS

Study Population

Data are presented for the control subject groups who were involved in two clinical trials conducted at Zhongshan Ophthalmic Centre for the Vision Cooperative Research Centre Myopia Control Study. Both trials were carried out in Guangzhou, Peoples’ Republic of China, and all subjects were of Chinese ethnicity, with baseline myopia of -0.75 D to -3.50 D sphere and astigmatism -1.50 D. The control group children, $n = 37$ in trial A and 48 in trial B for a total of 85 subjects, were fit with traditional single-vision spectacles and were encouraged to wear them for all waking hours. Trial A commenced in November 2007 and was 1 year in duration. Although children aged from 6 to 16 years were recruited, only data from the 6- to 12-year olds were used in this analysis. For trial B, which commenced in August 2009, children aged 6 to 12 years were recruited and, although this trial is ongoing, only 12-month data were available at the time of writing. Subject numbers at baseline, mean baseline spherical equivalent myopia, mean age, and gender distribution for the two trials

are shown in Tables 1 and 2. There was no significant difference between the two trials in terms of baseline spherical equivalent ($p = 0.104$), age ($p = 0.454$), and gender ($p = 0.575$).

Data Collection Procedures

The primary outcome measure for both trials was change in spherical equivalent refractive error as determined by cycloplegic autorefraction. After instillation of a topical anesthetic (proparacaine), cycloplegia was achieved with two drops of tropicamide 1% spaced 5 min apart. Thirty minutes after the second tropicamide instillation, refractive data for right and left eyes were obtained by recording the mean of five consecutive readings taken with an open-field instrument (NVision-K5001, Shin-Nippon, Japan). The secondary outcome measure for both trials was the change in axial length as measured by partial coherence interferometry (IOL-Master, Carl Zeiss Meditec, Germany).

Data Normalization

Cycloplegic subjective refraction formed the basis for prescribing a full correction of each subject's myopia, and occurred at the first visit, along with acquisition of the primary and secondary outcome measures. Assigned spectacles were dispensed at visit 2, typically 2 to 3 weeks later, and during this interval, the majority of subjects wore their own single-vision spectacles. At the second visit, baseline data not requiring cycloplegia (e.g., phorias and peripheral refraction with and without assigned spectacles) were collected. The target dates for the 6- and 12-month visits, each with a window period of ± 14 days, were calculated from the day of visit 2. This structure was adopted to minimize the number of times cycloplegic drops were administered in an effort to limit subject dropouts. However, differing times between visits 1 and 2, plus variations caused by attending the 6- and 12-month visits earlier vs. later in the window periods resulted in some variation in the true duration of each "6-month" period.

To address the problem of variations in the precise duration of the first and second "6-month" periods, a procedure was used similar to that previously reported.^{9,10} For each of the subjects, rates of myopia progression for the visit 1 baseline to 6-month visit, and for the 6-month to 12-month visit were calculated by dividing the spherical equivalent changes in autorefraction by the actual number of days in the "6-month" periods, and then multiplying the result by 182.5.

Statistical Analysis

Progression rates were defined for the first and second 6 months of the 12 months studied. Only right eye data were used. Data were classified in terms of "summer," "autumn," "winter," or "spring," based on the mid-point of the 6-month period between visits. Periods with mid-points falling in the months of June through August were classified as summer, September through November as autumn, December through February as winter, and March through May as spring. As may be seen by inspecting Fig. 1, trial A commenced in mid-autumn and the 6-month data were collected in the following spring. All of winter was included in this period. All of summer was included in the second 6-month period of trial A. Trial B commenced in mid-summer, and the 6-month data were collected in the following winter. Similar proportions of summer and winter were represented in both the first and

second 6-month periods of the trial, with mid-points of each period falling in autumn and spring, respectively. Difference in progression between seasons was analyzed using linear mixed models with subject random intercepts to account for repeat observations within a subject arising from multiple visits and eye-specific data. Age at baseline was added as a covariate in all analyses. Post hoc multiple comparisons were adjusted to an overall 5% level of significance using Bonferroni correction.

RESULTS

Change in Spherical Equivalent

As shown in Table 3, control subjects in trial A exhibited a significantly greater mean myopia progression than those in trial B at the 6-month visit ($p = 0.011$). However, in the ensuing 6 months, mean progression slowed markedly in trial A, while continuing at a similar rate in trial B. At the 12-month visits, mean myopia progression from baseline levels was similar for both trials ($p = 0.680$).

Mean, normalized, 6-month spherical equivalent myopia progression in terms of summer, autumn, winter, and spring months for trial A, trial B, and combined trial A and trial B subjects are shown in Table 4. Note that the bulk of the summer/winter data were obtained from trial A, and the bulk of the autumn/spring data were obtained from trial B. In trial A, mean progression for summer was significantly less than that for winter ($p < 0.001$). In trial B, there was no difference between progression in the four seasons ($p = 0.238$); however, the sample sizes for winter, and particularly for summer, were small. For combined trial A and trial B data, post hoc analysis showed that mean myopia progression in summer was significantly less than for winter months ($p < 0.001$), but there was no difference in progression between that of autumn and that of spring.

Change in Axial Length

As shown in Table 5, there was no significant difference between mean axial length increase in trial A and trial B at the 6-month ($p = 0.190$) or 12-month ($p = 0.639$) visits.

Mean, normalized, 6-month increase in axial length in terms of summer, autumn, winter, and spring months for trial A, trial B, and combined trial A and trial B subjects are shown in Table 6. Again, most of the summer/winter data were obtained from trial A, and most of the autumn/spring data from trial B. In trial A, mean axial elongation for summer was significantly less than that for winter ($p < 0.001$). In trial B, contrasting with the similar changes in spherical equivalent during autumn and spring, post hoc analysis showed mean increase in axial length during spring months was significantly less than that during autumn ($p < 0.001$) and winter ($p = 0.036$). Post hoc analysis for combined trial A and trial B data again showed mean increase in axial length during spring months was similar to that during summer ($p = 1.000$), but significantly less than that during autumn ($p < 0.001$) and winter ($p < 0.001$).

Correlation between Change in Spherical Equivalent Refraction and Axial Length

Figures 2a and b are scatterplots of 6-month change in axial length against 6-month change in spherical equivalent for the first and second 6-month periods of each trial. The coefficients of determination (R^2 , the increase in spherical equivalent myopia that is statistically explained by the increase in axial length) for the first and second 6-month change in trial A were 48% and 33%, respectively. Both were statistically significant ($p < 0.001$). For trial B, the corresponding coefficients were 57% ($p < 0.001$) and 8% ($p = 0.064$). It was also observed that the slopes of the relationship between change in spherical equivalent and change in axial length were different between the two 6-month periods for trial B ($p < 0.001$), but not for trial A ($p = 0.218$).

DISCUSSION

Our finding of increased mean myopia progression rates in winter months as compared with those in summer in conventionally corrected, myopic Chinese schoolchildren is in agreement with recent studies on North-American school-age children wearing single-vision spectacles.^{9–11} Although hours of sunlight, ambient temperature, or some other environmental factors that vary with the seasons could contribute to this phenomenon, the authors of those reports suggest that the most likely explanation was the difference in the amounts of close work performed during these periods. However, the true impact of near work alone is difficult to assess, because most near work is performed indoors, and at illumination levels far lower than those generally encountered during outdoor activities.

Summer school vacation in North America typically lasts 12 weeks, with a much shorter, 2-week Christmas break during winter. The academic year is broken up somewhat differently in Guangzhou, with 2 months of summer vacation during June and July, and 1 month of winter vacation from mid-January to mid-February. In comparison with the higher latitudes of Indiana and northeastern Oklahoma where the aforementioned North-American studies were conducted, there are comparatively smaller differences in temperature extremes and hours of daylight between the seasons in Guangzhou (Tables 7 and 8). Guangzhou has a more temperate climate in mid-winter, and spending time outdoors in Guangzhou may even be more appealing in the winter vacation than in the summer break. Guangzhou has more daylight hours in midwinter, with the maximum difference in daylight hours between January and June in Guangzhou being roughly half that of Bloomington, with Tahlequah's difference closer to that found in Bloomington.

Myopia progression data from all three North-American studies were presented for 6-month periods classified as "summer" in which all of the summer vacation was included, or as "winter" or "school" in which the children attended school for the entire 26 weeks, with the exception of the 2-week break at Christmas. Separate studies reported progression rates for one summer and two winters,⁹ for two summers and three winters,¹¹ and for a variable number of follow-up seasons.¹⁰ For the purposes of comparison with our Guangzhou data in which a single winter was followed by a single summer, Table 9 presents data only for the first winter and first summer of the three North-American papers. The Goss and Rainey results are from a single report¹⁰ based on pooled data from two longitudinal studies, both of which included some subjects for whom the first 6 months were classified as winter,

whereas for other subjects the first period was summer. Data for those subjects for whom the first winter preceded the first summer are tabulated in the “WS” column, whereas those for which the first summer preceded the first winter are listed under “SW.” The Fulk and Cyert (1996) and Goss and Rainey papers reported summer and winter rates in terms of diopters per year. To facilitate comparisons between studies in Table 9, the reported rates for these studies were divided by a factor of 2.

The percentage calculated for Goss and Rainey “WS” shows substantially less difference in myopia progression for summer vs. winter than do the other North-American results. The reasons for this apparent anomaly are not clear, but possible explanations include both subject and methodological differences. The progression rates for our Chinese children were greater in absolute terms than the rates exhibited by the North American children. In this respect, it may require stronger protective stimuli to slow the faster rates of progression. In addition, the small sample size of the “WS” data and the methods used to monitor progression may have contributed to the observed differences. In the two studies reported by Goss and Rainey, progression data were based on serial changes in subjective refraction, rather than by changes in the means of multiple autorefraction measurements, as was used in the other two North-American studies.^{9,11} Moreover, the decision to not use cycloplegia for the subjective refractions might have been a contributing factor, although for some subjects, cycloplegic retinoscopy was used to verify the subjective findings.

Although our results suggest a decrease in the difference between summer and winter myopia progression rates in our Guangzhou subjects compared with those found in the North-American studies, this does not necessarily strengthen the case for illumination being a factor in larger seasonal differences in myopia progression. A recent report on education in China noted that, as well as in-school education, supplementary academic coaching was becoming the norm, and in 2006, 80% of elementary school students in Guangzhou were receiving extracurricular education.¹² Data on time spent indoors vs. outdoors, or time engaged in near work that relates specifically to the summer and winter school vacations, were not collected for the subjects in our Guangzhou studies. Accordingly, we cannot rule out the possibility that a substantial part of the winter vacation was spent performing indoor, close work, and that our Chinese children spend proportionately the same time outdoors in winter vs. summer as do their North-American counterparts.

A further issue that cannot be addressed by our data is precisely when the pace of myopia progression is decreasing during the period classified as summer. Although it may be intuitive to assume that it occurs during the 2-month summer vacation, a Singaporean study¹³ casts doubt on this notion. Based on cycloplegic autorefraction performed five times over a 10-month period, it was found that, in 7-year olds, there was a significant increase in the rate of myopia progression after the academically important final examinations. This period of increased progression coincided with the summer vacation at the end of the academic year. The authors speculate that the enhanced stimulus for myopia progression generated by the increased pre-examination study load requires time before it manifests as an escalation in the rate of ocular growth. It is reasonable to surmise that the heavy close work load also means that students are spending very little time outdoors while studying, and it is possible that it is this factor, rather than close work per se, that is the catalyst for

subsequent accelerated myopia progression. Thus, it is possible that most of our reported reduction in the summer rate of myopia progression actually occurs during the first month of school after the summer vacation, rather than during the vacation. An inspection of Fig. 1 confirms that such a scenario would still be consistent with our finding of reduced myopia progression in summer months.

The mixed outcome in correlation (significant for trial A and first 6 months of trial B, but not for second 6 months of trial B) between change in spherical equivalent myopia and change in axial length suggests that there are other factors also involved in myopia progression. This is highlighted by the finding that, although there was no difference in the change in spherical equivalent myopia during autumn and spring, there was a significant difference ($p = 0.036$) in axial elongation for autumn (0.24 ± 0.09 mm) compared with that of spring (0.15 ± 0.08 mm). The reason for this apparent anomaly is unclear; however, it may be that there is some mechanism, such as crystalline lens thinning,¹⁴ that attempts to compensate for the sudden increase in axial growth presumably induced by the return to school after the summer vacation.

CONCLUSIONS

Our findings provide additional evidence that temporal variations in the myopia progression of children occur during the course of a school year. Currently, it is unclear whether this phenomenon is a result of seasonal differences in the amount or intensity of close work, or due to factors related to being indoors vs. outdoors, such as differences in ambient light levels. The physiological pathway by which higher ambient light levels might modulate ocular growth is unclear, but increased levels of light-induced retinal dopamine¹⁵ and maintenance of adequate concentrations of cutaneously derived vitamin D in the blood have been hypothesized.¹⁶ Further work is needed to determine the relative influences of these factors, and to define more precisely the temporal patterns of myopia progression. Regardless, the fact that there are seasonal variations in the rate of myopia progression emphasizes that studies of potential myopia treatment strategies should be at least 12 months in duration to take seasonal variations into account. Moreover, determining the optimum timing and duration of such interventions may increase our ability to reduce myopia progression in schoolchildren.

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FIGURE 1.
Overview of the temporal aspects of the two trials from which data were obtained.

FIGURE 2.

Scatterplots of change in axial length against change in spherical equivalent for the first and second 6-month periods of trial A (a) and trial B (b).

TABLE 1

Mean baseline spherical equivalent myopia and mean baseline age

Variable	Trial	N	Mean	SD	p
Baseline cycloplegic	A	37	-2.00 D	0.64	0.104
S.E. autorefraction	B	48	-2.24 D	0.69	
Age at baseline	A	37	10.3 yr	1.8	0.454
	B	48	10.0 yr	1.2	

China Clinical Trial Registry: trial A, ChiCTR-TRC-000000029 (22 Feb 2008); trial B, ChiCTR-TRC-00000476 (12 Aug 2009).

TABLE 2

Gender distribution

Variable	Trial	Female		Male		Total	p
		N	%	N	%		
Gender	A	17	45.9	20	54.1	37	0.575
	B	25	52.1	23	47.9	48	

China Clinical Trial Registry: trial A, ChiCTR-TRC-000000029 (22 Feb 2008); trial B, ChiCTR-TRC-00000476 (12 Aug 2009).

TABLE 3

Mean increase in spherical equivalent myopia (D)

	Visit	Trial	N	Mean	SD	p
Increase in spherical equivalent myopia	6 month	A	37	-0.61	0.35	0.011
		B	48	-0.45	0.27	
	12 month	A	36	-0.90	0.48	0.680
		B	46	-0.87	0.38	

TABLE 4
Mean normalized increase in spherical equivalent myopia in terms of summer, autumn, winter, and spring months

Trial	Season	Progression			p
		N	Mean	SD	
A	Summer (Jun–Aug)	36	−0.32	0.26	<0.001
	Winter (Dec–Feb)	37	−0.54	0.31	
B	Summer (Jun–Aug)	3	−0.25	0.11	0.238
	Autumn (Sep–Nov)	38	−0.40	0.27	
	Winter (Dec–Feb)	10	−0.50	0.23	
	Spring (Mar–May)	43	−0.42	0.20	
A and B combined	Summer (Jun–Aug)	39	−0.31	0.25	<0.001
	Autumn (Sep–Nov)	38	−0.40	0.27	
	Winter (Dec–Feb)	47	−0.53	0.29	
	Spring (Mar–May)	43	−0.42	0.20	

TABLE 5

Mean increase in axial length (mm)

	Visit	Trial	N	Mean	SD	p
Increase in axial length	6 month	A	37	0.29	0.12	0.190
		B	48	0.26	0.10	
	12 month	A	36	0.43	0.20	0.639
		B	46	0.41	0.16	

TABLE 6

Mean normalized increase in axial length in terms of summer, autumn, winter, and spring months

Trial	Season	Progression			p
		N	Mean	SD	
A	Summer (Jun–Aug)	36	0.17	0.10	<0.001
	Winter (Dec–Feb)	37	0.24	0.10	
B	Summer (Jun–Aug)	3	0.23	0.05	<0.001
	Autumn (Sep–Nov)	38	0.24	0.09	
	Winter (Dec–Feb)	10	0.24	0.08	
	Spring (Mar–May)	43	0.15	0.08	
A and B combined	Summer (Jun–Aug)	39	0.17	0.10	<0.001
	Autumn (Sep–Nov)	38	0.24	0.09	
	Winter (Dec–Feb)	47	0.24	0.09	
	Spring (Mar–May)	43	0.15	0.08	

TABLE 7

Mean maximum and minimum mid-winter temperatures

	Guangzhou	Bloomington	Tahlequah
January			
Mean maximum	64.9°F	36.5°F	47.8°F
Mean minimum	49.6°F	19.3°F	25.8°F
July			
Mean maximum	90.9°F	86.0°F	92.0°F
Mean minimum	77.5°F	64.7°F	68.8°F

Source: www.climate-charts.com.

TABLE 8Mid-summer and mid-winter daylight hours^a

	Guangzhou	Bloomington	Tahlequah
Mid January	10:52	9:43	9:59
Mid July	13:25	14:39	14:21

Source: US Naval Oceanography Portal.

^a June and December have the longest and shortest hours of daylight, respectively.

TABLE 9

Summer progression as a percentage of winter progression

Mean progression	Vision CRC	Fulk and Cyert (1996)	Goss and Rainey WS (1998) ^a	Goss and Rainey SW (1998) ^b	Fulk et al. (2002)
First winter	-0.53 ± 0.29 D	-0.34 D	-0.33 D	-0.38 D	-0.38 ± 0.24 D
First summer	-0.31 ± 0.25 D	-0.13 D	-0.255 D	-0.16 D	-0.13 ± 0.18 D
Summer as % of winter	58.5%	38.2%	77.3%	42.1%	34.2%
Sample size	83	14	15	27	37
Sample age range	6–12 yr	-12.99 for girls -13.99 for boys	6–15 yr	6–15 yr	6.8–12.9 yr
Cycloplegia	Yes	Yes	No ^c	No ^c	Yes

^a Data relate to subjects for whom the first winter period preceded the first summer period.^b Data relate to subjects for whom the first summer period preceded the first winter period.^c Cycloplegic retinoscopy was used to confirm non-cycloplegic subjective refractions on some subjects.