Seasonal Variation in Myopia Progression and Ocular Elongation

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ABSTRACT: Purpose. To evaluate possible seasonal variations in myopia progression and ocular elongation in school children. Methods. Seventy-one children who were enrolled in a clinical trial of bifocals were examined every 6 months for 30 months. Three 6-month intervals (“winters”) included none of the summer vacation from school, and two intervals (“summers”) included all of the summer vacation. Myopia was evaluated, after cycloplegia with 2 drops of 1% tropicamide, by automated refractor, and changes in axial length and in vitreous chamber depth were measured by A-scan ultrasonography. Data from left and right eyes were averaged because there was no evidence of a significant eye-visit interaction. Analysis of variance with a planned contrast was used to evaluate differences between the observed rates of change over the two summers compared with expected rates assuming no seasonal effect. Results. For 37 children in single-vision lenses, myopia progression rates over the two summers averaged 0.15 D compared with 0.32 D over the three winters. For 34 children in bifocal glasses, summer rates averaged 0.07 D compared with 0.30 D for winters. Analysis of variance showed that seasonal effects on myopia progression were significant (p < 0.025) for both groups for the first summer and approached significance for the second summer. Increases in vitreous chamber depth were also slower during the summer, significantly so (p < 0.01) for both summers in the single-vision group and for the second summer only in the bifocal group. Changes in axial length were somewhat slower in the summer, but the effect of season reached statistical significance in that variable only for the second summer in the bifocal group (p = 0.031). Conclusion. Myopia progression rates were slower during the 6-month periods that included all of the summer vacation than would be expected assuming no seasonal effect. Ocular growth was also slower in the summer; but that trend, in most cases, was statistically significant only for changes in vitreous chamber depth and not for axial length. (Optom Vis Sci 2002;79:46–51)

Key Words: myopia, seasonal variation, near work, vitreous chamber depth, axial length

Identification of factors that affect the rate of myopia progression would be useful in understanding myopia development and in finding remedies to slow myopic progression and ultimately to prevent its initial development. Grosvenor and Goss,1 in their review of the literature on myopia progression, identified the following factors that have been shown to be associated with more rapid progression: earlier onset age, greater time spent reading, shorter reading distance, less time spent outdoors, higher intraocular pressure, presence of a temporal crescent, and esophoria at near. In addition, Parssinen and Lyyra2 reported that the progression rate increased with the number of myopic parents.

Most children in North America have an extended period of vacation in the summer months when they do not attend school. This vacation period generally lasts 12 weeks and begins after mid-May and ends before mid-September. Knowledge of how the rate of myopia progression might vary between months of intense near work and months of less intense near work would help to establish a causal link between myopia and near work. Two longitudinal studies of myopia progression, conducted in North America, reported a marked slowing of myopia progression during the 6-month period that included all of the summer vacation compared with the other 6-month period that included none of the summer vacation.3, 4

Tan et al.5 reported a seasonal effect on myopia progression in Singaporean children. They performed cycloplegic refractions on 168 children from three age groups five times over a 10-month period and found that myopia progressed more rapidly in the
period just after final school examinations. The effect reached statistical significance for the youngest myopic children.

Herein we report on the effects of season on myopia progression for 37 children wearing single-vision glasses and 34 children wearing bifocals over a 30-month period. Seasonal effects on eye growth are also presented.

METHODS
The Myopia Progression Study, a collaborative study with the National Eye Institute, is a clinical trial examining the efficacy of bifocal glasses to slow myopia progression. An independent Data and Safety Monitoring Committee provided study oversight. Protocols were approved by the institutional review board of Northeastern State University. All subjects and their parents signed an informed consent form. Methods and results dealing with the treatment effect have been published. A brief description of the methods follows.

Subjects
Eighty-two myopic children, with ages ranging from 6.8 to 12.9 years (mean 10.7, SD 1.34), were enrolled and randomized to correction with eyeglasses either having single-vision lenses or bifocal lenses with a +1.50 D add. As an inclusion criterion, all children showed esophoria when tested with the von Graefe technique at 40 cm at the baseline examination. This report is based on the 71 children who attended all six examinations. Some children attended the first and last examination but missed some of the intermediate examinations because they moved out of state.

Study Procedures
All children were enrolled onto the study and were given baseline examinations in the fall between mid-August, after the school year had begun, and November. All children were given their first follow-up examination in the spring, between mid-February and April, 6 months after their baseline examination. Examinations were repeated every 6 months for a 30-month period. The intervals between the fall and spring examinations are referred to as “winters” and the spring-fall intervals as “summers.” Summers included all of the 12-week summer vacation as well as 14 weeks of school. During the winters, children attended school each of the 26 weeks except for a Christmas vacation that was approximately 2 weeks long. The 30-month follow-up period reported on here consisted of three winters and two summers. Fig. 1 is a timeline showing the school schedule and clinic visits for data collection.

Refractive error was measured with an automated refractor (Nidek ARK 900; Marco, Jacksonville, FL) 30 min after instilling two drops of 1% tropicamide, spaced 3 min apart, in each eye. Ten readings were taken of each eye, and the spherical equivalent of the “selected value” calculated by the instrument was used. Biometry, performed by A-scan ultrasonography (model 820 Biometer; Humphrey Instruments, San Leandro, CA) immediately after automated refraction, gave estimates of axial length, anterior chamber depth, and lens thickness. Vitreous chamber depth was calculated by subtracting lens thickness and anterior chamber depth from axial length. The A-scan probe was hand-held. During biometry of one eye, children were asked to look with the other eye at the wall across the room 2 to 4 m away. All procedures were performed on the right eye first. Five biometry readings were taken of each eye and were averaged.

Data Analysis
Data from the two treatment groups, i.e., eyeglass corrections with either single-vision lenses or bifocal lenses with a +1.50 D add, were subjected to separate but parallel analysis because bifocals appeared to slow myopia progression as reported earlier.

Children randomized to wear bifocals had somewhat less myopia and shorter axial length at baseline than children assigned to single-vision glasses. As pointed out in the previous report on treatment results, those slight differences were not statistically significant and did not seem to affect the rate of myopia progression.

Data from the left and right eyes were averaged to provide a single set of outcome variables for each subject. Justification for using averages across eyes was based on the results of the following analysis. Within each treatment group and for each of the three variables, a two-factor analysis of variance with repeated measures on both EYE and VISIT factors was used to examine the differences among the 12 means. A total of six such analyses were per-

![FIGURE 1](image-url)
Timeline showing when clinic visits and summer vacation from school occurred in relation to the two 6-month intervisit intervals referred to as “summer” and “winter.”

formed, one for each of three variables (myopia, axial length, and vitreous chamber depth) for each of two subject groups (single vision and bifocals). None of those six procedures yielded a significant EYE-VISIT interaction, indicating no evidence of any difference between OD and OS in the pattern of change over time (Table 1). Such a result justified the use of OD-OS averages for variables that deal with change over time, a procedure that greatly simplified data presentation.

Myopia progression during each 6-month interval was calculated by subtracting the spherical equivalent refractive error at the end of the interval from the value at the beginning. A positive number therefore indicates myopia progression. For axial length and vitreous chamber depth, the initial value was subtracted from the later value, therefore, a positive number also indicates an increase over that interval.

The strength of any possible effect of season on change rates was measured for each summer as the difference between the observed rate of change during the summer and the average of the change rates during the previous and subsequent winters. The value of that computation is defined as the seasonal effect for the first summer or second summer. A positive value indicates slower change during the summer. If progression rates changed in a linear manner over time, the summer rate would equal the mean of the rates during the previous and following winters, and the value of seasonal effect would be zero. Because the mean of each seasonal effect may be expressed as a contrast of the marginal means, each mean of the seasonal effect was tested for difference from zero as a planned contrast associated with the corresponding repeated-measure analysis of variance.

We examined whether age might affect the strength of any seasonal effect observed by computing the correlation coefficient between the subjects’ initial age and the seasonal effect for each summer as defined above.

There was considerable variation in the time interval between when the school year began and when the fall examinations occurred because subjects were recruited and received their first examinations over approximately a 3-month period. Thus, some subjects received their fall examinations during the first week or two of the school year; others had their fall examination 2 months after school started. To examine whether the date of the fall examination had any effect on the strength of the seasonal effect, we calculated the correlation coefficient between seasonal effect during the first summer and the number of days the third examination was held after August 1.

### RESULTS

Fig. 2 shows the mean for each parameter (myopia, vitreous chamber depth, and axial length) at each visit for children in single-vision and bifocal glasses. For myopia, the slope of the line is flatter during the 6-month intervals that are shaded (summers) than during the unshaded intervals (winters). A similar pattern can be noted for vitreous chamber depth and, in second summer only, for axial length. Fig. 3 shows the rate of change for each parameter during each of the five 6-month intervals. Myopia progression and change in vitreous chamber depth appeared to be less during the two summers than during the three winters. Table 2 gives the means for observations made at each visit and for the changes observed during each 6-month interval along with the associated standard deviations.

Seasonal effects were positive, indicating slower change during the summer, for all variables in both summers and in both groups of subjects. Table 3 shows summary statistics and the results of the testing of contrast for seasonal effects. For myopia progression, seasonal effects were significant for both groups of subjects during the first summer (p = 0.022 for single vision and p = 0.016 for bifocals) and approached significance (p = 0.070) for the bifocal group during the second summer. For vitreous chamber depth, seasonal effects were significant during both summers (p = 0.004, p = 0.001) in the single-vision group and during the second summer (p = 0.005) in the bifocal group. Seasonal effects were less evident in axial length; changes were significant (p = 0.032) only during the second summer in children wearing bifocals.

Most but not all children showed slower progression of myopia during summer. The distributions of seasonal effects in myopia progression are shown in Fig. 4. In the first summer, six of the 37 children from the single-vision group and three from the 34 in the bifocal group had a negative seasonal effect, i.e., they showed faster myopia progression in the summer than would be expected if progression had been linear over the first 18 months. In the second summer, nine children wearing single-vision glasses and eight wearing bifocals had a negative seasonal effect.

The correlation coefficients between initial age and the degree of the seasonal effect on myopia progression were close to zero and not statistically significant in any case, ranging from −0.06 (p = 0.718) to −0.13 (p = 0.430). Results for the changes in the vitreous chamber were similar.

The third examination occurred an average of 52.5 days (SD = 20.8) after August 1, 15 days after the typical start of the school year. Correlation coefficients between that index of how much of the school year had elapsed before the third examination in the fall of the second year and the strength of the seasonal effect in myopia progression and eye growth during the first summer are shown in Table 4. Statistically significant (p < 0.05) negative correlations were found in all cases except for single-vision children during the summer.

### TABLE 1.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Treatment</th>
<th>Eye</th>
<th>Visit</th>
<th>Eye × Visit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myopia progression</td>
<td>Single V</td>
<td>0.520</td>
<td>&lt;0.001</td>
<td>0.220</td>
</tr>
<tr>
<td>Axial change</td>
<td>Single V</td>
<td>0.800</td>
<td>&lt;0.001</td>
<td>0.270</td>
</tr>
<tr>
<td></td>
<td>Bifocals</td>
<td>0.090</td>
<td>0.120</td>
<td>0.110</td>
</tr>
<tr>
<td>Vitreous change</td>
<td>Single V</td>
<td>0.900</td>
<td>0.003</td>
<td>0.170</td>
</tr>
<tr>
<td></td>
<td>Bifocals</td>
<td>0.074</td>
<td>&lt;0.001</td>
<td>0.970</td>
</tr>
</tbody>
</table>

*The response variables were change in myopia progression, change in axial length, or change in vitreous chamber depth, and factors were follow-up visit (one through five) and eye (right or left).*
first year, indicating that an examination late in the fall was associated with changes over the first summer at a rate that deviated less from the expected linear rate than if the examination had been earlier in the fall.

**DISCUSSION**

The rate of myopia progression was clearly slower during the first summer than expected if there had been no seasonal effect. Of
all myopia progression in an average year, 33.5% occurred in summers for the single-vision group. For the bifocal group, 18% occurred in the summers. The 6-month period we refer to as summer actually contained about 3 months of summer vacation and 3 months of school. The proportion of the total myopic progression that occurred during the actual summer vacation could have been less than indicated above. It is possible that no progression at all occurred during the summer vacation from school.

The most obvious explanation for those seasonal differences is that myopia progression is stimulated by reading or studying, activities that are more frequently engaged in during the school year than during the summer vacation. Other explanations are possible. Those would include some sort of seasonal effect on ocular growth cued to day length or to other environmental factors that change with the seasons. We know of no evidence suggesting the existence of seasonal effects on ocular growth. In Singapore, myopia progression was faster in January just after the annual school examinations. That seasonal effect could not be due variations in day length because Singapore is near the equator.

Children whose fall examination was several weeks after the school year had started showed a weaker seasonal effect that those examined earlier in the school year. Regardless of when the fall examination occurred, all children had the same number of weeks of schooling that occurred during the 6-month period called summer. The correlations noted above could be explained by the first weeks of school having a stronger myopogenic effect than the last weeks of school in the spring. Another explanatory hypothesis is that the time delay between the start of more intense near work and the appearance of the myopic effect is greater than the time it takes for the effect to dissipate after the near work decreases.

### TABLE 3.
Results of a repeated-measure analysis of variance testing the significance of seasonal effects defined as the difference between the observed rate of change during each of two summers and the average of the change rates during the previous and subsequent winters.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Subject Group</th>
<th>Seasonal Effect During First Summer</th>
<th>Seasonal Effect During Second Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mean ± SD</td>
<td>p Value</td>
</tr>
<tr>
<td>Myopia progression</td>
<td>Single vision</td>
<td>0.231 ± 0.253</td>
<td>0.022</td>
</tr>
<tr>
<td></td>
<td>Bifocal</td>
<td>0.263 ± 0.221</td>
<td>0.016</td>
</tr>
<tr>
<td>Change in vitreous chamber depth</td>
<td>Single vision</td>
<td>0.141 ± 0.113</td>
<td>0.004</td>
</tr>
<tr>
<td></td>
<td>Bifocal</td>
<td>0.067 ± 0.192</td>
<td>0.248</td>
</tr>
<tr>
<td>Change in axial length</td>
<td>Single vision</td>
<td>0.030 ± 0.205</td>
<td>0.594</td>
</tr>
<tr>
<td></td>
<td>Bifocal</td>
<td>0.043 ± 0.226</td>
<td>0.514</td>
</tr>
</tbody>
</table>

### FIGURE 4.
Grouped frequency distributions of the seasonal effect in myopia progression over the first summer and second summer for 37 myopic children who wore eyeglasses with single-vision lenses and 34 who wore bifocals.

### TABLE 4.
Correlation coefficients between number of days from August 1 to the date of the third examination and the seasonal effect on the change of each of three variables (myopia, vitreous chamber depth, and axial length) during the first summer.

<table>
<thead>
<tr>
<th>Treatment Group</th>
<th>Myopia</th>
<th>Vitreous Chamber Depth</th>
<th>Axial Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single vision</td>
<td>0.030 (0.860)</td>
<td>−0.350 (0.034)</td>
<td>−0.376 (0.022)</td>
</tr>
<tr>
<td>Bifocals</td>
<td>−0.378 (0.028)</td>
<td>−0.362 (0.036)</td>
<td>−0.376 (0.028)</td>
</tr>
</tbody>
</table>

* p Values are in parentheses.
One of the few longitudinal studies of myopia progression to estimate near work was reported by Parssinen and Lyyra. They showed that progression was faster in children who read more and spent less time playing out-of-doors.

Interpretation of previous studies on myopia and near work is difficult because measures of near work are poor and contaminated with other variables, especially intelligence. If there was a genetic linkage between myopia and intelligence, that linkage could explain many of the apparent associations between near work and myopia without any causal link between the two. Furthermore, increased near work may result from myopia development, instead of causing it, because myopia might make extended periods of near work less difficult.

Our observations that in a single group of children, myopia progressed faster during periods of more continuous schooling than during periods that included a 12-week school vacation provides stronger evidence for a causal link between myopia and near work than studies that compare two different groups of subjects. In studies comparing two groups, it can be argued that differences other than near work exist between the groups and those differences account for the differences in myopia.

We failed to find any association between the age of the child and the strength of the seasonal effect on myopia progression. At first glance, that result might seem contrary to the reports by Goss and Rainey and by Tan et al. The former study, based on children in the U.S. with a study design similar to ours, separated children into three “plot categories” based on the regression of initial age on initial degree of myopia. Children with low initial myopia or/greater initial age (category three) showed a statistically significant seasonal effect, whereas the others did not. The later study, based on Singaporean children and reporting faster progression just after final examinations, found a statistically significant seasonal effect only in the youngest children, i.e., in 7-year-old but not in 9- or 12-year-old children. Our lack of evidence for any age-season interaction vs. the apparent presence of such an interaction in the other studies may be explained by two factors. First, failure to find a statistically significant effect in one group and finding such an effect in another does not necessarily mean that the two groups are different. Type II error, the failure to find a difference when one exists, can be quite large when sample size is small or data variability is large. Second, the seasonal effect may be more difficult to detect in groups that show slower myopia progression as in the oldest children in the Singaporean study if the seasonal effect is proportional to the overall progression rate.

Seasonal differences seemed much larger for the increase in vitreous chamber depth than for axial length increase. That difference may have been caused by differencing relationships those variables have with the two factors that stimulate ocular elongation, namely myopia progression and normal growth. Increase in axial length results both from normal growth and from myopia-associated elongation. Increase in vitreous chamber depth, however, may have been more closely linked to myopia progression alone, as has been suggested by other studies. The observation that myopia progression was very slow, perhaps even zero, during the school vacation may have practical implications. If drugs are developed to slow myopia progression, perhaps their use could be discontinued during the vacation months. Furthermore, careful observations on myopia progression rates in children enrolled in different types of school programs (home schooling or year-around schooling) may lead to instructional methods that would lessen the stimulus to myopia progression.

CONCLUSIONS

Myopia progression and increase in vitreous chamber depth were substantially slower during the 6-month periods that included all of the summer vacation from school than during the other 6 months of the year. Seasonal effects on axial length increase were similar but did not reach statistical significance. We believe the simplest explanation for this observation is that school work stimulates myopia progression in some way.

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