Myopic Children Show Insufficient Accommodative Response to Blur

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Purpose. The study was performed to establish the relationship between the slope of the accommodative response function and refractive error in children.

Methods. Using an autorefractor, accommodative responses were measured in children under the following conditions. The subjects wore their best subjective refraction to view targets (a 3 X 3 array of 20/100 letters) displayed at seven distances (4.0 to 0.25 m). They viewed letters placed at 4.0 m through a series of negative lenses and letters placed at 0.25 m through a series of positive lenses.

Results. Myopic children accommodate significantly less than emmetropic children for real targets at near distances. Compared with emmetropic subjects, myopic children use blur poorly to increase accommodation, as shown by shallow slopes of the accommodative response functions for negative lenses. However, with positive lenses, requiring relaxation of accommodation, there is no significant difference in slope between myopic and emmetropic children.


Speculation abounds regarding the relationship between intensive near work and myopia. Prolonged chronic accommodation during close work has been said to cause myopia, but there are few data from well-controlled studies to support this hypothesis. Epidemiologic studies have shown correlations between myopia and near visual tasks that require accommodation.1 However, a reduced ability to accommodate for close targets has been implicated in the development of myopia.2 It is known that adults with myopia of recent onset accommodate significantly less than emmetropic subjects when viewing close targets,4,5 which is not the case for adults in whom myopia developed when they were children.6 These findings and reported differences in tonic accommodation between late-onset and early-onset myopic subjects in some studies have led to the suggestion of a separate cause for these two classes of myopia.

When blur is the main stimulus driving the accommodative system, accommodative response functions of practiced adult observers typically show a small lead for low dioptric stimuli and a small lag for high dioptric ones. This results in a steep slope, at least over a range of from 0–4 D.5 Some subjects, however, accommodate poorly to blur produced by negative lenses.7 When the accommodative responses to blurred targets was measured in 20 subjects 14–25 yr of age, it was found that 7 of the 20 accommodated minimally to blur produced by minus lenses.8 In a study of 69 college students who viewed a high-contrast target in a Maxwellian-view system, the mean slope of the accommodative response function was 0.57, with almost 15% of the subjects having slopes lower than 0.3.7 Refractive errors of the subjects were not reported, but to anticipate our results, it is probably safe to conclude that there were some newly myopic ones among the 69 college students and they were the poor accommodations.

Taken together, these claims present a paradox. How do we reconcile the assertion that intensive near work with habitual accommodation leads to myopia with the evidence indicating that myopic subjects have poor accommodation? One possibility is that near work for those with reduced accommodation results in chronic blur and that it is the blur, not the accommodative effort, that induces myopia. In this scenario, reduced accommodation precedes the onset of myopia, although the chronologic coupling of and the causal relationship between accommodative deficiencies and myopia are not yet known.

In the current study, accommodative responses were measured in newly myopic and emmetropic children under three conditions. The age of onset of myopia was known from our longitudinal study of refraction in children. We related the slope of the accommodative response function to refractive error in a subgroup of these children with known refraction histories.
METHODS. Sixty-four children, 31 boys and 33 girls (age range, 5–17 yr; mean, 11.7 yr) were tested. The age distribution was as follows: 5–6 yr, 7 subjects; 7–8 yr, 9; 9–10 yr, 13; 11–12 yr, 12; 13–14 yr, 10; and 15–17 yr, 13. Informed consent of the parents was obtained before undertaking any testing. The research was approved by the Massachusetts Institute of Technology Committee on the Use of Humans as Experimental Subjects, and it followed the tenets of the Declaration of Helsinki.

Before the measurement of accommodative responses, all children were refracted with noncycloplegic distance retinoscopy for a target at 4.0 m. No child had an astigmatism greater than 1.0 D, and 97% of the children had cylinder values less than or equal to 0.5 D. No child had anisometropia, defined as a difference in spherical equivalent between the two eyes greater than 1.0 D, and 83% of the children had differences less than or equal to 0.25 D. Forty-eight of the children were emmetropic, with spherical equivalents between −0.25 and +0.50 D (mean, 0.0 D plano). Sixteen children were myopic, with spherical equivalents between −0.50 and −6.25 D (mean, −1.94 D). For all accommodative response measures, the subjects wore their best subjective refraction (most plus) within 0.25 D.

Accommodative responses were measured using a Canon R-1 Autorefractor (Canon Europa N.V., Amstelveen, The Netherlands), an optometer that allows targets to be viewed at any distance through an infra-red reflecting mirror. All testing was performed monocularly, on the right eye only. An occluder covered the left eye. The child’s right eye was lined up in the autorefractor with the use of a chin and forehead rest. All children were tested with a 3 × 3 array of 20/100 letters, and 18 of the children also were tested with an array of 20/30 letters in the negative lens series. Before any measurements were made, the child viewed the target for 5–10 sec. The time between readings varied from 5–30 sec, depending on the behavior of the child. All children, regardless of refractive error, were instructed to keep the target as clear as possible and to report if it became blurred. Periodically, each subject was asked to read a row or column. A minimum of three readings was taken for each condition.

Decreasing distance series. The child fixated the letter array at distances from 4.0 to 0.25 m in seven steps. The physical size of the letters was varied to keep the visual angle constant. Children wore their best subjective refraction for 4.0 m, thereby producing zero accommodative demand for the 4.0-m target. The luminance of the 4.0-m target was 10 cd/m², and it was slightly less for the closer targets. This luminance value was chosen so that the targets would be bright enough for the subjects to have good acuity but dim enough for the pupils to dilate, yielding a small depth of focus.

Negative lens series. Lenses from plano to between −3.0 and −4.0 D in 0.5-D steps in a sequence from the least to the most minus lens were placed in front of the right eye as the child fixated the target at 4.0 m. If the child had a refractive error, the lens series was adjusted to use that refractive error as the zero point for the added lenses. Trial lenses were placed in lens cells fitted to spectacle frames at a forward tilt of 15° in order for the autorefractor to make a correct reading. Tilting the lens induced a small astigmatism, which may have reduced the accommodative demand by 6% at most.

Positive lens series. Lenses from 0–+4.0 in 0.5-D steps sequenced from the least to the most plus were placed in front of the right eye as the child fixated the target at 0.25 m. Again, the starting lens was adjusted for the child’s refractive error.

Data analysis is described in the appendix.

RESULTS. Both myopic and emmetropic children accommodated accurately to real targets at far distances, and they showed the typical lag of accommodation with near targets (Fig. 1). However, the mean slope for myopic children (0.78) was significantly less than that for emmetropic children (0.88, t = 2.4, degrees of freedom = 31, P < 0.05, by two-tailed t test). In addition, for the two closest target distances myopic children accommodated significantly less than emmetropic children (2.00 versus 2.22 D at 0.33 m and 2.95 versus 3.34 D at 0.25 m, respectively).

With negative lenses, the mean slope for myopic
eyes (0.20) was much shallower than the mean slope for emmetropic eyes (0.61, Fig. 2). These mean slopes were significantly different (t = 4.9, degrees of freedom = 62, P < 0.00001). For accommodative demand greater than 0.5 D, myopic children accommodated significantly less than emmetropic children for all values. For example, with a demand of 3.0 D, myopic eyes accommodated 0.75 D versus 1.66 D for emmetropic eyes. With a demand of 3.5 D, myopic children accommodated 0.69 D versus 1.89 D for emmetropic children. The mean slope for the 18 subjects tested with both 20/100 and 20/30 letters was significantly steeper with the larger letters (t = 2.08, degrees of freedom = 17, P < 0.05). The mean slope for the 20/100 letters was 0.42 compared with 0.29 for the 20/30 letters. With positive lenses and 20/100 letters, the mean slope for myopic children (0.64) was not significantly different from that for emmetropic children (0.69, Fig. 3).

Three typical functions are the steep (characteristic of most emmetropic eyes), the shallow, and the up and down, with the latter two found mainly in myopic children (Fig. 4). Seventy-nine percent of the emmetropic children had slopes greater than 0.5; the distribution was reversed for the myopic eyes, with 75% having slopes less than 0.5. The probability of finding this distribution by chance was small (chi-square = 13.3, degrees of freedom = 1, P < 0.001).

DISCUSSION. Our results indicate that negative lens-induced blur is much less effective in producing accommodative responses in myopic than in emmetropic children. With 3.00 and 3.50 D accommodative demands, the myopic children, on average, had 0.91 and 1.20 D more blur than the emmetropic children.
However, this testing condition, monocular with negative lenses, is not the way children normally view the world. With real targets at near distances and monocular viewing, the myopic children have 0.40 D more blur than the emmetropic children. This small but real difference may reflect the inability of myopic eyes to use blur cues for accommodation, although the powerful proximity cues are equally effective for both myopic and emmetropic subjects. The chronic blur may induce myopia, analogously to the pattern deprivation that induces myopia in infant chicks, tree shrews, and monkeys.9

With proximity cues provided by real targets at near distances, the slopes of the accommodative response functions are steeper for both myopic and emmetropic eyes than those obtained by purely lens-induced change in optical demand. We intend to investigate systematically cues, such as parallax, knowledge of the dimensions of the testing room and targets, and others that might contribute to increased slopes.

Although newly myopic children use blur poorly for increasing accommodation, they can use blur as well as emmetropic children for relaxing accommodation. According to some clinicians, patients may have difficulty relaxing accommodation at a later stage in the development of myopia.10 Regular testing of a longitudinal sample of children should provide information about the time course of both accommodative problems and development of myopia.

We were surprised that the slopes of the accommodative response functions were significantly steeper with 20/100 compared with 20/30 letters. However, it has been shown that the strongest drive for clearing a blurred image is provided by intermediate spatial frequencies.11 Although the smaller letters provide a more demanding signal (they cannot be recognized without good accommodation), the spatial frequency spectrum they provide is weaker and narrower than that for the large letters.

The fact that myopic children accommodate less than emmetropic children to near targets is also true for adults with recent but not long-term myopia.4 This result suggests that reduced accommodative ability is found for a period after, and perhaps before, the onset of myopia, at whatever age it occurs. From published reports, it is not possible to determine if the slope of the accommodative response function steepens as the myopia stabilizes. To our knowledge, no study has tracked both the accommodative response function and refractive error over time. Clinicians have reported that many recently myopic children have accommodative problems that disappear when the myopia stabilizes, usually by their late teens.10 This assertion from anecdotal reports remains to be tested.

In our sample, a few emmetropic children show reduced accommodative responses. Are these children slated to become myopic? Near work for these subjects may result in chronic blur, and it may be the blur, not the accommodative effort, that induces myopia. It has been proposed that a decrease in retinal image quality accompanying accommodative disorders could play a role in axial elongation and the development of myopia.12 Clues to the mechanism of axial elongation are provided in the animal literature. Continued testing of these children will determine if accommodative deficits predict future myopia.

APPENDIX (DATA ANALYSIS). For each R1 reading, the spherical equivalent was calculated by adding one half the cylinder (in minus lens notation) to the sphere. Then the mean of the spherical equivalent readings for each lens and distance combination was calculated and used as the R1 reading. Accommodative demand and accommodative response were calculated by the following equations.

Accommodative Demand =
\[
\frac{1}{DTE} - LENS + Rx + (DLE*(1/DTE)*(LENS - Rx)) \\
1 - (DLE*(LENS + Rx))
\]

Accommodative Response =
\[
(Rx/(1 - (DLE*Rx)) - (LENS/(1 - (DLE*LENS)))) - R1
\]

where R1 = the R1 reading described above, Rx = best subjective correction for infinity, DTE = the distance from the eye to the target, DLE = the distance from the lens to the eye (13 mm), and LENS = signed dioptric power of the lens.

These equations correct for the effectivity of a spectacle lens placed 13 mm in front of the eye.

In each series (distance, negative lens, and positive lens), the slope of each child's accommodative response function was calculated by linear regression of accommodative response on accommodative demand. Means of these individual slopes were calculated for both myopic and emmetropic eyes and were compared by t tests.

To plot accommodative response functions for both emmetropic and myopic eyes for each lens series (Figs. 2, 3), the mean accommodative response for each nominal lens value was calculated, using the correction for lens effectivity. The correction for effectivity reduced the range of accommodative demand to slightly less than 4.0 D.

Key Words
accommodation, blur, children's vision, myopia, refractive error

References

Modulation of Sodium–Potassium Adenosine Triphosphatase in Cultured Bovine Retinal Pigment Epithelium by Potassium

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Purpose. The aim of the study was to examine the extracellular potassium concentration [K+]o as a modulator of the retinal pigment epithelium (RPE) contribution to ion homeostasis in the subretinal space by measuring sodium–potassium adenosine triphosphatase (Na+/K+ ATPase) pump number and activity in cultured bovine RPE in the presence of different concentrations of extracellular potassium.

Methods. Pump number was quantified by measuring specific binding of 3H-ouabain to bovine RPE exposed to low (0.5–2.5 mmol) or control (5.0 mmol) [K+]o over 72 hr. Na+/K+ ATPase activity in low and control [K+]o was quantified by measurement of 86Rb+ uptake.

Results. Low [K+]o increased RPE pump number in a dose- and time-dependent manner, with lesser effects on denser than on sparser cultures. [K+]o-modulation of pump number was reversible and did not occur in the presence of the cell synthesis inhibitor cycloheximide. In RPE exposed to low [K+]o for 72 hr, pump activity was decreased compared with the control but increased toward control levels when re-exposed to control [K+]o. The total potassium transported per cell was 60% of control in low [K+]o, but increased to slightly above control when re-exposed to control [K+]o.

Conclusions. In cultured RPE cells, both Na+/K+ ATPase pump number and pump activity are affected by changes in [K+]o with greater modulation in sparser cultures. If similar events occur in situ, the sodium pump in RPE may respond to changes in subretinal potassium ion concentration, especially if the RPE cell number is reduced as in aging or disease. Invest Ophthalmol Vis Sci. 1993;34:694–698.

In the retinal pigment epithelium (RPE), sodium–potassium adenosine triphosphatase (Na+/K+ ATPase) pumps are found in an apical location where they apparently contribute to the transport of ions and metabolites across the subretinal space. Previous work has demonstrated a regional variation in Na+/K+ ATPase pumps in the RPE; a lower pump density was observed in posterior cells (including the macular region) versus peripheral cells in human and bovine eyes. It is unknown what regulates the pump number in different regions of eyes, but the topographic variation may reflect regional variation in requirements for ionic regulation.

One regulator of the Na+/K+ ATPase pump number in the RPE in vitro is culture density. We have previously shown that the pump number decreases as the cell density increases and that modulation of the pump number in response to serum is less pronounced in high-density RPE cultures. Another regulator of Na+/K+ ATPase pumps for other cell types is the extracellular potassium concentration ([K+]o). Long-term exposure to low [K+]o has been shown to...