

# Prospective Data from a RANDOMIZED LONGITUDINAL STUDY of ACCOMMODATION & CONVERGENCE TRAINING as a Potential Method of Myopia Control in Children

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## Abstract

Contemporary theories of myopia etiology incorporate nearwork and aspects of visual function at nearpoint. This paper reports the results of a small prospective longitudinal study of accommodation and vergence training as a method of myopia control. Twenty-one subjects were randomized into the control group and 22 subjects into the training group, but only 10 trainees completed the three years of the study. Both control group subjects and training subjects wore single vision spectacle lenses equal in power to the subjective refraction. Training subjects performed standard home procedures to improve accommodation and vergence function. Rates of myopia progression were calculated by dividing the change in autorefractive spherical equivalent by time in the study. Nott dynamic retinoscopy was performed at the annual examinations with a 40 cm test distance and the subject viewing through a +1.00D add, the subjective refraction, and a -1.00D add. There was a high drop-out rate in the vision training group, undoubtedly due to the time commitment. The rates of myopia progression were not significantly different between the control group and

the training group. The regimen of accommodation and convergence training used in this study did not reduce the rate of childhood myopia progression. Studies using individualized vision therapy programs or using vision therapy programs designed to treat specific anomalies of the vision system related to myopia progression may have more positive results.

## Key Words

accommodation, convergence, myopia, vision therapy, vision training.

## INTRODUCTION

Recent theories of myopia etiology often suggest a role of retinal image defocus.<sup>1-4</sup> If retinal image defocus plays a role in myopia development in humans, then training to improve accommodation and vergence would be a reasonable approach for myopia control. People with myopia have been found to have greater lags of accommodation than persons with emmetropia.<sup>5-8</sup> If accommodation training could reduce the lag of accommodation, perhaps retinal image defocus could be reduced enough to slow myopia progression. To our knowledge, there are no previously published studies on vision training (VT) as a method of lowering myopia progression rates.

While no studies on VT as a method of controlling myopia progression have been published, there have been several studies on VT for reducing the existing amount of myopia. A variety of different training methods have been shown to improve unaided visual acuity in subjects with myopia, with little or no reduction in average amount of myopia.<sup>9-23</sup>

The purpose of this paper is to present prospective data from a small preliminary study

on accommodation/convergence training as a potential method of myopia control.

## METHODS

This study was conducted at Indiana University in Bloomington, Indiana. Study protocols were approved by the Indiana University Human Subjects Committee. Eligibility criteria were: (a) at least 0.50D of myopia in both principal meridians of both eyes as measured by the manifest subjective refraction to best visual acuity; (b) five to 13 years of age; (c) corrected distance visual acuity of at least 20/25 in each eye; (d) no strabismus; (e) no ocular disease; (f) no history of systemic disease or systemic drug use with potential ocular effects; and (g) no previous contact lens wear. Subjects were randomized to one of four groups using a random number table. The four groups were: single vision lens control group, bifocal lens group, progressive addition lens group, and accommodation and vergence training group. The results of the bifocal lens and progressive lens treatments are discussed in a separate paper in this issue of this *Journal*.<sup>24</sup> The exception to the randomization procedure was if a sibling of a child in the training group was also assigned to the training group. The reason for this exception was that non-training group subjects might try the training procedures done by their siblings. Subjects in the training and the non-training groups wore single vision lenses equal in power to the manifest binocular maximum plus subjective refraction to best visual acuity. All subjective refractions were performed by the same investigator (BBR). If the spherical equivalent of a subject's subjective refraction increased in minus in either eye by 0.50D or more, a new pair of spectacles was provided. Subjects were

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advised to wear their glasses full-time. Spectacles, study examinations, and training equipment were provided to subjects at no charge.

A subject in the non-training control group who stayed in the study for the full three years had a minimum of eight study visits: a comprehensive baseline examination, a spectacle dispensing visit, three six-month progress checks, and three yearly comprehensive examinations. Subjects who had changes in spectacles had additional spectacle dispensing visits. Subjects in the training group had all of those visits plus additional two-month progress checks to monitor their training activities. Fourth year optometry student interns assisted in the yearly eye and vision examinations by performing entrance tests and ocular health tests.

Training group subjects did daily home training for three weeks following each two month visit. All training subjects underwent a similar therapy program. The training procedures used are common methods used in VT for the improvement of accommodation and vergence. The procedures were assigned without regard to an individual subject's accommodation or vergence function. We used the same training approach for all subjects to theoretically keep the number of variables to a minimum.

The training procedures are presented in the Appendix. Three of these procedures were assigned to a subject at each two month visit. At the following two month visit the three activities were changed on a random basis. Proper technique of each training procedure was explained to the subjects, and they were instructed to work on each procedure for at least five minutes each day for a total of 15 to 20 minutes of training each day. All explanations and instructions on training procedures were administered by one of the investigators (BBR).

For the purpose of encouraging and monitoring compliance, subjects kept a daily log of their training. The training logs were turned in at each two month visit. All subjects who completed the three years of the study turned in a log for each two month interval. All subjects and parents reported that the procedures were performed on a regular basis over the three-week training period. Occasionally, days were missed because of schoolwork or fatigue, and most subjects reported that the procedures were often tedious and boring, but non-compliance did not seem

**Table 1. Number of subjects in the single vision lens control group and in the accommodation/convergence training group.**

Group	Enrolled	Completed 1 yr	Completed 2 yrs	Completed 3 yrs
Control	25	25	22	21
Training	22	14	10	10

**Table 2. Characteristics of subjects completing three years in the study. (\*mean of the spherical equivalents of the subjective refractions of the two eyes)**

Group	n	Males	Females	No. with ortho or exo at near	No. with eso at near	Mean initial age (SD)	Mean initial myopia (SD)
Control	21	15	6	9	12	10.39 (1.60)	-2.64 (1.71)
Training	10	4	6	3	7	10.49 (2.07)	-2.83 (2.41)

to be a problem. Of course, home therapy was not directly observed or otherwise directly monitored, so reported compliance and actual compliance may have differed at times.

The outcome variable used for analysis was autorefractometry (Nikon NRS5100)<sup>a</sup> after instillation of two drops of 1% tropicamide five minutes apart. This procedure was chosen as the outcome variable because of the good reliability of cycloplegic autorefractometry<sup>25</sup> and because autorefractometry is unlikely to be affected by inadvertent examiner bias as subjective refraction could potentially be. Autorefractometry was done at the baseline examination and at each yearly examination. The refractive error used for analysis was the mean of the spherical equivalents of the two eyes. Rates of myopia progression were calculated in diopters per year (D/yr) by dividing the change in refractive error from the baseline examination to the last yearly examination by years in the study. The number of years in the study was determined to two decimal places using the years, months, and days from the date of the baseline examination to the last study examination.

To provide an assessment of accommodation, Nott dynamic retinoscopy<sup>26,27</sup> was performed at the baseline examination and at each of the yearly examinations by one of the authors (DAG), who was not masked to subject group assignment. The test was performed with the subject viewing through the subjective refraction, then through +1.00D and -1.00D adds over the subjective refraction. The +1.00D add condition was accomplished first, followed by the subjective refraction condition, and lastly the -1.00D add. Thus, the dioptric accommodative stimulus levels were 1.50D, 2.50D, and 3.50D, in that order. The test was done with the subject viewing letters in the J5 paragraph on a

Bernell BC/11981<sup>b</sup> near retinoscopy card set at 40 cm from the spectacle plane. The slope of the accommodative response/accommodative stimulus function was calculated using the +1.00 and -1.00D add conditions.

## SUBJECTS

Twenty-five subjects were enrolled in the single vision lens control group and 22 subjects were enrolled in the vision training group. Retention of subjects in these two groups is shown in Table 1. There was a very high drop-out rate in the training group, undoubtedly due to great time commitment in this group. Moving from the area was the reason for drop out in the control group. All but one of the subjects in the two groups who completed two years in the study remained in the study for the full three years. Data analyses considered only the subjects which completed the three years.

Characteristics of the subjects are given in Table 2. The training group was slightly (0.19D) more myopic than the control group at entry into the study. There were proportionally more nearpoint esophores in the training group. There was one pair of siblings (brothers) in the control group. There was one trio of siblings (two brothers and one sister) and one pair of siblings (sisters) in the training group.

## RESULTS

Rates of myopia progression in the two groups are given in Tables 3 and 4. Mean rates were not significantly different by t-test ( $p>0.40$ ). Mean rates by phoria are given in Table 5.

Changes in Nott dynamic retinoscopy results in the two groups are given in Tables 6 and 7. Accommodative response levels were generally low, with the resultant lag of accommodation (accommodative stimulus minus accommodative response)

Group	n	Mean	SD
Control	21	-0.50	0.34
Training	10	-0.60	0.26

	No. in control group	No. in training group
0 or +	1	0
-0.01 to -0.30	4	1
-0.31 to -0.60	11	4
-0.61 to -1.00	4	4
Faster than -1.00	1	1

Group	n	Mean	SD
<b>Esophoria</b>			
Control	12	-0.49	0.19
Training	7	-0.73	0.20
<b>Exophoria</b>			
Control	9	-0.52	0.48
Training	3	-0.31	0.05

being higher than the normal values generally given in the literature for Nott dynamic retinoscopy.<sup>26-28</sup> The Nott retinoscopy measures did not show statistically significant changes in either the control or the training group over the three years of study.

The mean changes in near von Graefe phoria (minus indicating an exo or divergent shift and plus indicating an eso or convergent shift) were -0.4 prism diopters (n=21, SD=5.8) in the control group and +0.9 prism diopters (n=10, SD=6.0) in the training group. Neither of these means was significantly different from zero.

## DISCUSSION

The number of subjects completing the three-year study was very small, but it appears that the particular form of accommodation/vergence training that we used does not slow myopia progression. We hypothesized that the accommodative response, which is often low in myopia, would be improved with training, and that the increased accommodative response (reduced lag of accommodation) would decrease retinal defocus during reading, which in turn would slow myopia progression. However, the training in this study neither reduced the lag of accom-

	n	Baseline		Three years		Statistical significance
		Mean	SD	Mean	SD	
Response to 2.50 D stimulus	17	1.62	0.22	1.75	0.29	0.070
Slope	17	0.71	0.05	0.69	0.10	0.563

	n	Baseline		Three years		Statistical significance
		Mean	SD	Mean	SD	
Response to 2.50 D stimulus	6	1.58	0.20	1.56	0.17	0.841
Slope	6	0.75	0.06	0.69	0.15	0.370

modation nor reduced the rate of myopia progression.

Accommodative training is highly effective in relieving symptoms of accommodative disorders, in improving relative accommodation test findings, and in improving accommodative facility.<sup>29-43</sup> However, it is not clear that standard accommodative training has a significant effect on lag of accommodation. We have found only one study which reported lag of accommodation before and after patients underwent training. Thirteen patients diagnosed with accommodative dysfunction (ten with accommodation insufficiency and three with accommodative infacility) had a mean lag of 0.27D (SD=0.47) before training and 0.42D (SD=0.29) after training.<sup>32</sup> The difference was not statistically significant.

Some interesting results of this study can be noted when the subjects are separated by nearpoint dissociated phoria (Table 5). Although the findings are suggestive at best because of the very low number of subjects, one may speculate that the training procedures used in this study may have been effective for subjects with exophoria, but not for subjects with esophoria.

While the form of accommodation/convergence training that was used in this study was not successful in controlling myopia progression, it is possible that other vision training or vision therapy regimens may yield positive results. It is possible that it may be necessary to individualize vision therapy programs for myopia control, just as vision therapy for accommodation and vergence disorders. It is also possible that

vision training effects might be enhanced by lens treatments such as near point plus adds of appropriate power for the given patient. While the usual approach in research is to look at one variable at a time, optimal treatment effects are more likely to be achieved by individualized therapy. As more is learned about myopia etiology, vision therapy programs for myopia control may be designed to modify the physiological or functional events leading to myopia progression. Other vision therapy programs proposed for myopia control are available in the literature.<sup>44-46</sup>

## CONCLUSIONS

A program of accommodation and convergence training did not reduce the rate of childhood myopia progression in a small sample of subjects, nor did it have an effect on the lag of accommodation. Studies using individualized vision training programs or vision therapy programs designed to treat specific anomalies of the vision system related to myopia progression may have more positive results.

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## APPENDIX: DESCRIPTION OF ACCOMMODATION/CONVERGENCE TRAINING PROCEDURES

### 1. Push-up accommodative training

The subject viewed a small (20/30 or smaller) letter target at 40 cm monocularly. The target was moved slowly toward the eyes, until it first became blurry. If the subject was unable to clear the target, it was slowly moved away from the eyes until it just became clear. The target was held at this distance, and the subject was instructed to keep the target clear for 10 seconds. After a brief (less than one minute) rest period, the procedure was repeated with the other eye, and this sequence was performed three times per eye. The subject recorded the closest distance at which the target was held each time.

### 2. Brock string

One end of the Brock string was tied to a doorknob, chair, or some other secure object at least 10 feet from the subject. The other end was held against the subject's nose. The closest bead was moved slowly toward the nose until it first doubled. This bead was then moved away from the nose about six inches. The other two beads were positioned such that the beads were about 2 feet apart. Physiological diplopia was explained to the subject, and the subject was told to make sure two strings were seen at all times. The subject then fixated the far bead for 10 seconds, making sure to see two strings. Fixation was slowly moved along the string to the middle bead, as if following a "bug on a string." Fixation was held on the middle bead for 10 seconds, keeping the bead clear and single while appreciating physiological diplopia. The subject then slowly moved fixation to the nearest bead in a similar manner, holding fixation there for 10 seconds. After a brief (less than one minute) rest period, the sequence was repeated 2 more times. The subject recorded the distance of the nearest bead from the nose. The subject was encouraged to try and move the nearest bead closer over the three-week training period.

### 3. Hart chart accommodative facility

A distance chart consisting of 10 rows of 20/40 letters, with 10 letters per line separated by one letter width, was placed on a wall 10 feet from the subject. A near chart with the same sequence of letters, 20/30 size, was held at 40 cm. The subject was instructed to view the distance target binocularly, and call out the first letter aloud when it became clear. The subject then immediately changed fixation to the second letter on the near chart, and called out that letter aloud when it became clear. This sequence was repeated, with the third letter of the distance chart called out, then the fourth letter of the near chart, and so on. The subject stopped after calling out all the letters on the chart. This procedure was performed twice, and the subject recorded the time it took to get through the entire chart each time.

### 4. Lens flipper accommodative facility

The same near chart as the one used in the Hart chart accommodative facility procedure was used for the lens flipper accommodative training. The chart was held at 40 cm. The subject was instructed to view the target binocularly through one side of the flipper lenses, and call out the first letter aloud when it became clear. The subject then immediately flipped to the other side of lenses on the flipper bar, and changed fixation to the second letter on the near chart, calling out that letter aloud when it became clear. This sequence was repeated, with the third letter of the chart called out after flipping lenses, then the fourth letter of the near chart, and so on. The subject stopped after calling out all the letters on the chart. This procedure was performed twice, and the subject recorded the time it took to get through the entire chart each time. Lens flippers of various powers were used, with lens powers increasing after each three-week period if a facility of more than 15 cycles per minute was reached. Each subject started with +/- 1.00 D flippers, then +/- 1.50 D flippers, and, finally, +/- 2.00 D flippers.

### 5. Tranaglyph and vectogram fusional vergence training

Subjects wore red and green filter glasses when using tranaglyphs (red lens over the right eye), and polarized glasses when using vectograms. The two halves of the picture were positioned with the scale on the bottom row at 0. The "R" and "L" suppression checks were explained, and the subject was told to make sure both letters were seen at all times while doing the procedures. The pictures were slowly pulled apart, and the subject was told to keep the target clear and single at all times. If the target blurred or doubled, the pictures were moved closer together until the target first became clear and single again. The target was held at this distance, and the subject was instructed to keep the target clear and single for 10 seconds. After a brief (less than one minute) rest period, the procedure was repeated while sliding the targets apart in the opposite direction, and this sequence was performed three times per direction. The subject recorded the highest number or letter on the scale at which the target was held and kept clear and single each time. A different tranaglyph or vectogram target was used during each 3 week training period.

### 6. Free space fusion cards

Opaque and transparent cards were used. Subjects were instructed on the fusion technique for these cards, and had to demonstrate understanding of the procedure before being given the cards for home use. Anti-suppression checks, and the appreciation of depth were described to ensure the patient was fusing targets and not suppressing an eye. The target card consisted of four pairs of fusion circles that were different distances apart. The subjects started with the circles that were closest together, and were told to keep the target clear and single while viewing the suppression checks for 10 seconds. Then the next set of circles was fused and so on. Once all four sets of circles were fused, and after a brief (less than one minute) rest period, this sequence was repeated until the procedure was performed three times. Only opaque cards were used during the first assigned three-week training period, and both opaque and transparent cards were used during subsequent periods. If the subject was able to perform the procedure easily and without effort, the target was moved closer to increase the difficulty.