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ORIGINAL ARTICLE

Accommodative Training to Reduce Nearwork-Induced Transient Myopia

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ABSTRACT

Purpose. To assess changes in the nearwork-induced transient myopia parameters of initial magnitude and its decay duration, as well as accuracy of the near accommodative steady-state response and clinically based accommodative facility, after 6 weeks of home-based accommodative training in asymptomatic myopes.

Methods. Ten young adult, progressing myopes participated in the study. The experimental paradigm consisted of a baseline session and two follow-up sessions at the end of the third and sixth weeks of training. At the first session, baseline refractive state and selected accommodative functions were assessed. Measurements were repeated at the two follow-up sessions. Home-based vision training included accommodative flippers (±2 D) at near, Hart chart at distance (6 m) and near (40 cm), and prism flipper (6 pd) training at near (40 cm), for a total of 20 minutes a day performed 5 days a week for 6 weeks.

Results. Several dynamic accommodative response functions improved significantly with training. Lens flipper rate increased significantly from 11 to 16 cpm in the OD ($p = 0.04$), 11 to 19 cpm in the OS ($p = 0.03$), and 8 to 11 cpm in the OU ($p = 0.03$). Hart chart rate increased significantly from 22 to 33 cpm in the OD ($p = 0.01$) and from 22 to 31 cpm in the OS ($p = 0.02$). There was a significant negative correlation between lens flipper rate and nearwork-induced transient myopia decay duration after training ($p = 0.02$) with binocular viewing.

Conclusions. Training of the accommodative system in these progressing myopes resulted in improved dynamics in both laboratory and clinical measures. This is consistent with earlier reports in the literature of improvement in symptomatic myopic subjects.

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Key Words: nearwork-induced transient myopia (NITM), accommodative flipper, Hart chart, myopia, accommodative dynamics

NITM refers to a nearwork-related, lenticular-based, accommodative aftereffect.[1] That is, after a period of sustained nearwork, the distance refractive status exhibits a temporary myopic shift because of an inability of the crystalline lens to reduce its power appropriately and rapidly under normal viewing conditions, thus reflecting an accommodative hysteresis phenomenon having neuropharmacologic underpinnings.[1–4] Several studies have assessed the initial magnitude of nearwork-induced transient myopia (NITM), as well as its decay characteristics. The typical initial magnitude of NITM in asymptomatic, visually normal young adults ranges from 0.12 to 0.60 D,[5] with a mean of about 0.30 D.[3] NITM typically decays to baseline in about 60 seconds,[1,5] with a very wide task-dependent range from about 30 seconds[6] to 1 hour or more.[7] The initial magnitude and decay duration of NITM are increased in myopes compared with other refractive groups (see Refs. 4 and 5 for reviews).

Only one study has assessed NITM characteristics in visually abnormal, symptomatic myopic subjects, namely those who reported transient blur (3 seconds or more) at distance after a relatively brief period (15 minutes or less) of sustained nearwork.[8] During testing, the three young adult subjects focused binocularly on high contrast (~90%) black numbers on a white background at a distance of 20 cm for 10 minutes. After this task, they exhibited very large initial posttask NITM (0.4–1.4 D) that exceeded their depth-of-focus because they concurrently reported transient blur. In addition, there was very slow dissipation of the initial NITM (up to 200 seconds), with it manifesting considerable intersubject variability. Presence of either or both of these factors would result in increased retinal defocus, even in the absence of perceived blur.[9]

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The authors suggested that accommodative training in such subjects improved accommodative dynamics and accuracy, with concurrent reduction in symptomatology.

Only one study has reported on the training of accommodation in subjects with visually abnormal, symptomatic NITM.[10] Five myopic optometry students who reported transient blur in the distance for 3 seconds or more after 15 minutes or less of nearwork were tested and trained. On average, they received 8 weeks of home-based optometric vision therapy. The subjects performed the training 5 days each week and then returned to the laboratory every 7 to 10 days for symptom assessment. They performed accommodative facility-based procedures,[11] namely the accommodative lens flippers (±2 D) at 40 cm, and the Hart chart at distance and near, under both monocular and binocular viewing conditions for 3 minutes per procedure for a total of 18 minutes per day. They averaged a total of 12 hours of training during the 8-week period. After therapy, the initial NITM magnitude did not change significantly (0.43 D pretraining and 0.57 D posttraining). The decay time constants subsequent to training revealed mixed results, with only some subjects exhibiting more rapid decay and reduced variability. However, there were consistent and progressive improvements in both the clinical Hart chart and the lens flipper rates in each subject. Furthermore, symptoms reduced markedly in each subject. These results demonstrated subjective, objective, and clinical improvements in NITM in at least some of the subjects after a relatively brief, simple, and only moderately intense period of vision therapy, with a correlated marked reduction in symptoms.

In contrast to the above, not all myopes are symptomatic after the completion of sustained nearwork. However, they typically exhibit increased initial NITM magnitude, with extended NITM decay durations.[12–15] Presence of either or both of these factors would result in increased retinal defocus, compared with a subject manifesting less initial NITM magnitude and rapid decay.[4,12,13,15] It has been speculated that any residual, non-decayed NITM may alter the magnitude of retinal defocus[4,9,15] in such a way as to increase the risk of myopia and its progression.[9,16–18] Hence, one potentially important preventative aspect of a vision training–based, myopia control program would be directed at reducing NITM immediately after nearwork.

Hence, the aims of the current investigation were threefold with respect to dynamic accommodative training in progressing asymptomatic, myopic, young adults. First, to assess for any reduction in the NITM parameters of initial magnitude and its decay duration. Second, to assess for any decrease in the steady-state accommodative error to a near target. Finally, to assess for any increase in flipper and Hart chart rate reflecting the underlying accommodative dynamics.

METHODS

Subjects

Ten optometry students were recruited from the SUNY State College of Optometry. They ranged in age from 21 to 26 years, with a mean of 23.6 (±2.2) years. All had self-reported normal vision function. Subjects who were symptomatic after a near task of 30 minutes or more and/or had received prior vision therapy for accommodative and/or vergence dysfunction were excluded. They were prescreened from a larger test population, using a standard NITM protocol,[3] to exhibit larger magnitudes of initial NITM, which ranged from 0.37 to 0.84 D, in this larger initial population. Non-cycloplegic refractive state was obtained using an objective, open-field, infrared autorefractor to ensure accuracy of the habitual refractive error correction (Canon R-1, Lake Success, NY). The refractive correction of these progressing myopic subjects, as determined using subjective refraction, ranged from −0.5 to −4.5 D, with a mean of −2.16 D (±0.1.6 D). There was self-reported progression of at least 0.5 D in the last 2 years based on their previous refractive correction. The cylindrical component ranged from plano to −0.50 D, with a mean of −0.23 D (±0.14 D). The cylinder axis ranged from 58 to 170°, with a mean of 120° (±38°). All subjects were habitually corrected with soft contact lenses, which resulted in distance and near visual acuity of 20/20 or better both monocularly and binocularly. Informed consent was obtained from each subject after explaining the nature and possible consequences of the study. The research followed the tenets of the Declaration of Helsinki and was approved by the internal review board of SUNY State College of Optometry.

Instrumentation

All measurements of refractive state (OD only) were obtained objectively under binocular viewing conditions using the Canon R-1, which has been widely used for vision research.[19] This instrument provides rapid measurements (about every 2 seconds) of refractive state. Its power range is ±15 DS and −7 DC, with a dioptric resolution of 0.12 D; cylindrical axis resolution is 1° (see Ref. 19 for a detailed explanation).

Procedures

The experimental paradigm consisted of three components: clinical testing of accommodation pre- and posttraining, assessment of NITM pre- and posttraining, and the home-based vision training.

Clinical Tests of Accommodation and Vergence

All clinical testing was performed at the first and last session. These included accommodative facility, the near point of convergence, near phoria, negative relative accommodation, positive relative accommodation, and the binocular amplitude of accommodation, to assess normalcy of these parameters before inclusion in the study and to assess for any posttraining effects.

NITM Testing

The NITM experimental paradigm was performed at each session. It included pretask, near task, and posttask testing, as described below.

Pretask

Subjects were seated in total darkness for 3 minutes to allow for the dissipation of any transient accommodative aftereffects.[20] Then the autorefractor measurements were initiated under binocular viewing conditions in subdued room illumination (~20 ft-candles). The distance refractive state was assessed objectively in the OD while the subject focused on 20/30 Snellen letters (7.5-minute arc) at 6 m, with measurements every 2 seconds for a period of 20 seconds. They then focused on the 20/30 letters (7.5-minute arc) of the reduced Snellen chart at 30 cm along the line of sight of the OD with full overhead room illumination, and measurements of the steady-state accommodative response were obtained every 2 seconds during a 20-second interval. During all test periods, contact lenses were worn by the subjects to correct their distance refractive state to avoid spectacle reflections that might interfere with the measurements.[21]

Near Task

Subjects focused on a small (2.5°), medium contrast (35%), Maltese cross-mounted on the Canon autorefractor at a distance of 10 cm (10 D) from the corneal apex for 10 minutes. This very near target was used to stimulate a high level of accommodation to maximize the subsequent NITM magnitude,[3] with its medium contrast nature to ensure better accommodative accuracy.[1]

Posttask

Immediately after the 10-minute near task, the distance refractive state was reassessed in the autorefractor every 2 seconds for a period of 120 seconds. Subjects were queried about target clarity periodically to ensure that they were focusing accurately.

Facility Testing

At the completion of the NITM testing paradigm, dynamic accommodative facility testing was conducted using two standard clinical procedures[11]: the lens flipper and the Hart chart for the OD, OS, and OU viewing conditions were performed in a counterbalanced manner. The lens flipper rate was measured as the subject focused on a standard adult level text (font size = 12) of high contrast (90%) at 40 cm with accommodative flippers of ±2 D positioned in the spectacle plane. Subjects were instructed to alternately view between the plus and minus lenses of the flipper as rapidly as possible while maintaining the target in focus. The number of cycles completed in 60 seconds was measured. This procedure was performed under both monocular and binocular viewing conditions in a counterbalanced manner. The Hart chart rate was also measured. Subjects alternately focused between a distance (6 m) Hart chart (font size = 32) of high contrast (90%) in primary position and a near (40 cm) Hart chart (font size = 6) of high contrast (90%) placed 30° inferiorly. Subjects were asked to read one letter from the near Hart chart, and then shift their focus to the distance Hart chart and read one letter, and so forth across the lines of letters as rapidly as possible. The number of cycles completed in 60 seconds was determined under both monocular and binocular viewing conditions. Flipper and Hart chart rates were assessed before and after the sixth week of training.

After the flipper and Hart chart assessments, subjects were provided instructions for home-based vision training.

Home-Based Vision Training

All subjects underwent 6 weeks of conventional, home-based, optometric vision therapy.[11] Subjects were instructed to perform the training procedures for a total of 20 minutes per day for 5 days a week, thus totaling 10 hours during the entire training period.

This comprised three accommodative training techniques.

Hart Chart Training

This procedure stimulates the accommodative system under relatively naturalistic viewing conditions. When performed under monocular viewing conditions, it incorporates blur-related visual feedback only. However, under binocular conditions, both blur- and vergence-related visual feedback are present and function in an interactive manner, with blur-driven accommodation being primary and vergence-driven accommodation being secondary. The proximal motor contribution is minimal under the closed-loop viewing conditions used in the training[22]; however, its higher-order perceptual contribution is presumably high.[22]

In this technique, subjects alternately focused between a distance (6 m) Hart chart (font size = 32) of high contrast (90%) mounted at eye level and a near (40 cm) Hart chart (font size = 6) of high contrast (90%) placed 30° inferiorly, with both being positioned along the midline. They read four lines from the near Hart chart, then shifted their gaze and focus to the distance Hart chart and read the next four lines, and so forth. This procedure was repeated for a duration of 2 minutes under each viewing condition (OD, OS, and OU) for a total of 6 minutes on each training day.

Lens Flipper

The purpose of this training was similar to that of the Hart chart. It tests the subject's ability to respond to blur both accurately and rapidly. When performed under monocular viewing conditions, it incorporates blur-related visual feedback only. However, under binocular conditions, both blur- and vergence-related visual feedback are present and function in an interactive manner, with blur-driven accommodation being primary and vergence-driven accommodation being secondary. However, unlike the Hart chart, any proximal motor and perceptual contribution is maintained constant, as target distance remains fixed.

In this technique, subjects focused on a standard high contrast (90%), adult-level text (font size = 12) held at 40 cm. They were instructed to alternately view between the plus and minus lenses of the flipper as rapidly as possible while maintaining the target in focus for 2 minutes under each viewing condition (OD, OS, and OU) for a total of 6 minutes.

Loose Prism Training

The purpose of this training under binocular viewing conditions was to train the accommodative system, but now with vergence-driven accommodation being primary and blur-driven accommodation being secondary because it modulates the overall response to obtain a clear retinal image.

In this technique, subjects first placed a base-out prism (6 pd) in front of the OD. It incorporated a Kodak Wratten #29 (Eastman

Kodak, Rochester, NY) red filter as a suppression check. They read four lines of adult-level text (font size = 12) of high contrast (90%) at 40 cm, and then read the next four lines of text without the prism, and so forth, thus stimulating asymmetric disparity vergence, which occurs during most naturalistic viewing conditions. This procedure was performed for 2 minutes, and then it was repeated with a 6 pd BO prism placed over the OS. The procedure described above was then repeated with a 6ΔBI prism. The total training duration was 8 minutes. In addition, subjects were also asked to reduce the target working distance from the initial starting position of 40 cm during the first week to 33, 25, and 20 cm in each subsequent week if they could do so with ease, to increase the level of training difficulty.

The current training paradigm is given scientific validation per the Hung et al.[22] interactive model of accommodation and vergence because the three main active components of accommodation were involved and stimulated to varying degrees, namely blur accommodation, vergence accommodation, and proximal accommodation.

With regard to the statistical analysis, there were two approaches. The first was use of the parametrically based, repeated-measures analysis of variance (ANOVA), which incorporates both the direction and magnitude of the response change. The second approach incorporated a non–parametrically-based analysis because of the relatively small sample size. Thus, if the training were successful, the initial NITM magnitude and its decay duration would decrease.

RESULTS

Initial NITM magnitude was assessed at each test session. Mean initial NITM was 0.52 D (±0.14 D), 0.54 D (±0.22 D), and 0.46 D (±0.12 D) for test sessions 1, 2, and 3, respectively. It ranged from 0.35 to 0.84 D, 0.12 to 0.82 D, and 0.35 to 0.74 D for test sessions 1, 2, and 3, respectively (Fig. 1). A one-way repeated-measures ANOVA was performed to compare the initial NITM magnitude across test sessions. There was lack of a significant effect [$F(2, 27) = 0.597$, $p = 0.55$].

NITM decay duration was assessed at each test session as described in an earlier article.[15] Mean NITM decay duration was 101 seconds (±19 seconds), 89 seconds (±34 seconds), and 74 seconds (±14 seconds) for test sessions 1, 2, and 3, respectively. It ranged from 55 to 125 seconds, 25 to 125 seconds, and 45 to 95 seconds for test sessions 1, 2, and 3, respectively (Fig. 2). A one-way repeated-measures ANOVA was performed to compare the decay duration across test sessions. There was a trend for it to decrease with the training [$F(2, 27) = 3.13$, $p = 0.06$]. Furthermore, and consistent with the above notion of a trend, the non-parametric analysis revealed that posttask NITM decay was significantly decreased direction-wise after the sixth week of training (Wilcoxon signed rank test; df = 9, $p = 0.001$) but not after the third week (Wilcoxon signed rank test; df = 9, $p = 0.58$) of training, for all time durations (e.g., t = 0, t = 10, and t = 20 seconds, etc) (Fig. 3), with the exception of t = 75 seconds.

The steady-state accommodative response to the 30 cm near target (3.3 D) was assessed at each test session. The mean accommodative response was 2.63 D (±0.16 D), 2.70 D (±0.14 D), and

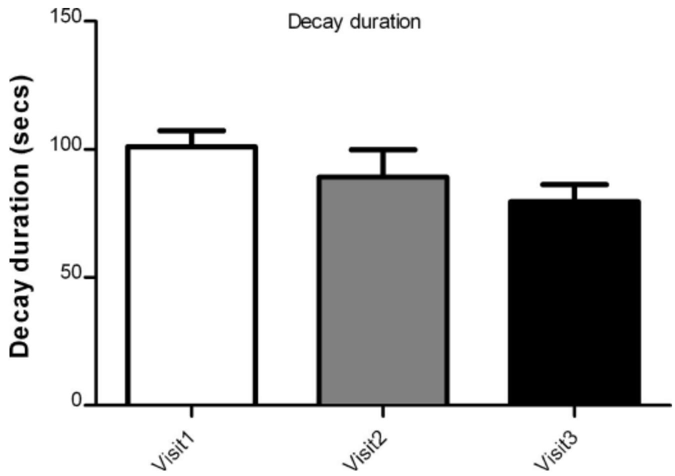

FIGURE 2.
Group NITM overall decay duration for each test session. Plotted is the mean + 1 SEM.

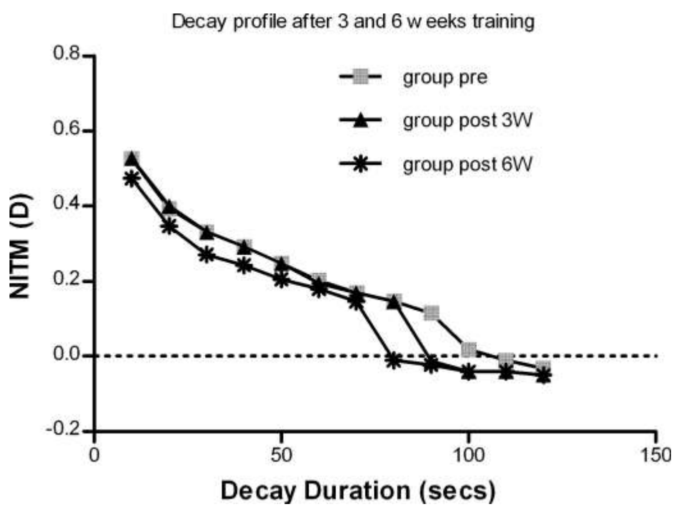

FIGURE 3.
Group NITM decay duration pre- and posttraining of 3 and 6 weeks for each measurement period. Plotted is the mean. The SEM bars were deleted for purposes of clarity.

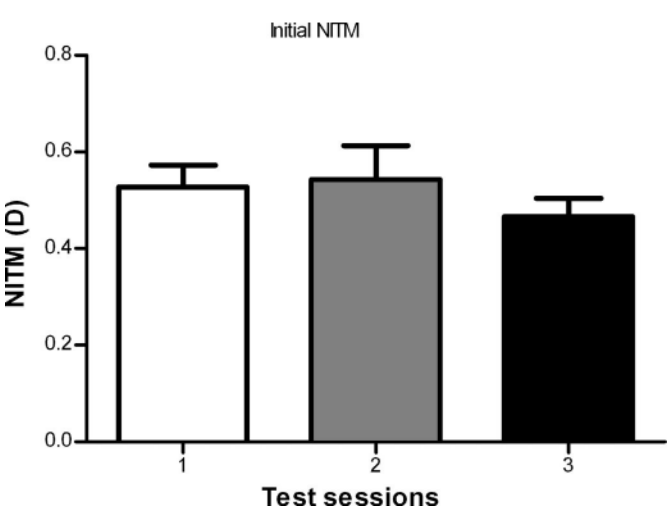

FIGURE 1.
Initial group NITM magnitude for each test session. Plotted is the mean + 1 SEM.

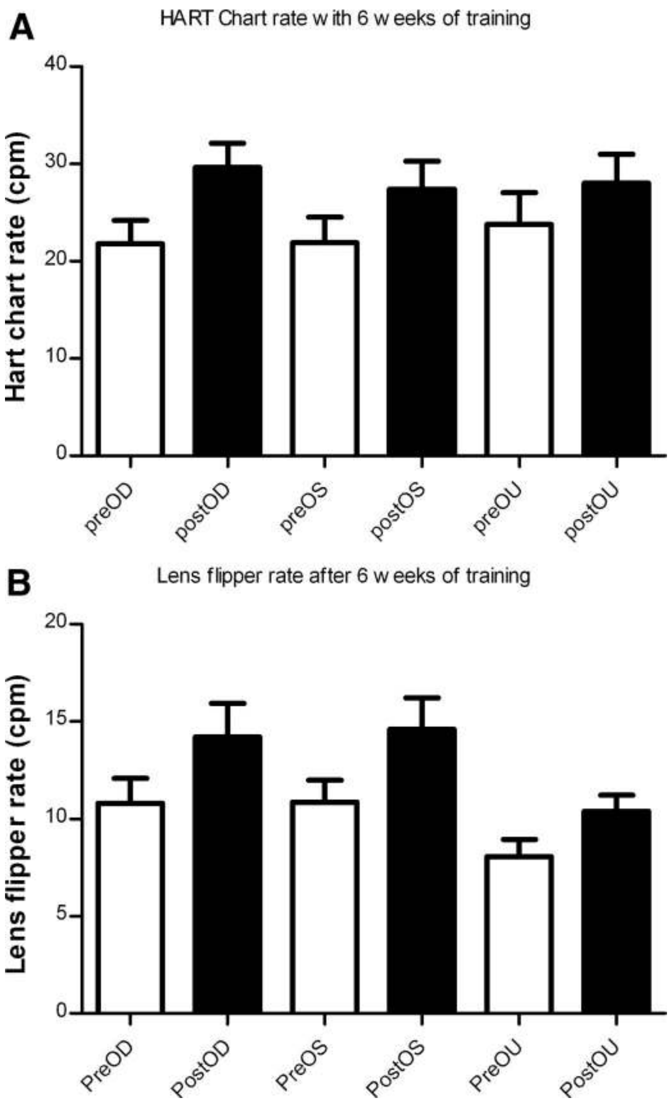

FIGURE 4.
Hart chart (A) and the lens flipper (B) pre- and posttraining for the OD, OS, and OU. Plotted is the group mean + 1 SEM. cpm = cycles per minute.

2.71 D (±0.10 D) for test sessions 1, 2, and 3, respectively. It ranged from 2.36 to 2.82 D, 2.37 to 2.87 D, and 2.58 to 2.9 D for test sessions 1, 2, and 3, respectively. The mean change after training was 0.079 D, with a range from 0.147 to 0.417 D. A one-way repeated-measures ANOVA was performed to compare the accommodative response across the three test sessions. There was lack of a significant effect [F(2,27) = 0.89, p = 0.41].

Hart chart rate was assessed both before and after training in the OD, OS, and OU (Fig. 4). Mean Hart chart rate was 22 cpm (±7.5 cpm), 22 cpm (±8.5 cpm), and 24 cpm (±10 cpm) before training, which improved to 33 cpm (±8 cpm), 31 cpm (±9 cpm), and 31.5 cpm (±9.5 cpm) after training, for the OD, OS, and OU, respectively A two-way repeated-measures ANOVA was performed to compare the Hart rate across test sessions under monocular and binocular conditions. There was a significant effect across sessions [F(1,54) = 6.52, p = 0.01] but not between viewing conditions [F(2,54) = 0.11, p = 0.89]. Non-parametric analysis revealed that the posttask flipper rate increased significantly after the sixth week of training in the OD (Wilcoxon signed rank test; df = 9, p = 0.01) and in the OS (Wilcoxon signed rank test; df = 9, p = 0.02) but not for the OU (Wilcoxon signed rank test; df = 9, p = 0.081).

Flipper rate was assessed both before and after training in the OD, OS, and OU (Fig. 4). Mean flipper rate was 11 cpm (±4 cpm), 11 cpm (±3.5 cpm), and 8 cpm (± 3 cpm) before training, which improved to 16 cpm (±5.5 cpm), 19 cpm (±5 cpm), and 11 cpm (±2.5 cpm) after training, for the OD, OS, and OU, respectively. A two-way repeated-measures ANOVA was performed to compare the flipper rate across test sessions under monocular and binocular conditions. There was a significant effect across sessions [F(1,54) = 9.08, p = 0.004] and between viewing conditions [F(2, 54) = 4.63, p = 0.01]. Non-parametric analysis revealed that posttask flipper rate improved significantly after the sixth week of training in the OD (Wilcoxon signed rank test; df = 9, p = 0.04), the OS (Wilcoxon signed rank test; df = 9, p = 0.03), and the OU (Wilcoxon signed rank test; df = 9, p = 0.03). Fig. 5 shows the relation between the magnitude of change in lens flipper rate and NITM decay duration under binocular test conditions before and after 6 weeks of training. There was a significant correlation (r = −0.72, p = 0.02). After training, NITM decay duration decreased, and lens flipper rate increased.

All subjects were also evaluated for clinical accommodative and vergence measurements before and after training to ensure normality. All results were within the normative range (Table 1). The near point of convergence ranged from 5 to 7 cm before training and from 5 to 7 cm after training. The near phoria ranged from 2 to 7 pd exo before training and from 3 to 6 pd exo after training. Negative relative accommodation (NRA) ranged from +1.75 to +2.5 D before training and from +1.75 to +2.5 D after training. Positive relative accommodation ranged from −1.75 to −2.5 D before training and from −1.75 to −2.5 D after training. Binocular amplitude of accommodation ranged from 9 to 12 D before training and from 9 to 11.5 D after training. None of these clinical changes were significant [t(9) = 0.28–1.0, p = 0.34–0.78, ranges given].

DISCUSSION

This is the first investigation directed at training progressing asymptomatic myopes to reduce their nearwork accommodative aftereffects, i.e., the potentially myopigenic, NITM-based retinal defocus at both distance and near.[1,14] There were several interesting findings. Neither the initial NITM magnitude nor the steady-state accommodative response to a near target improved after the course of vision training at a level that was statistically significant. Second, and in contrast, several of the dynamic accommodative responses exhibited significant improvement subsequent to the vision training. These latter findings are consistent with previous studies showing improvement in accommodative dynamics after conventional accommodatively based vision training in both visually normal asymptomatic[23] and visually abnormal symptomatic young adults and children.[23–30]

In the current study, the initial NITM magnitude was found to be statistically similar subsequent to the vision training (mean = 0.52 D pretraining; mean = 0.46 D posttraining). Interestingly, only one previous investigation[10] assessed NITM before and after 8 weeks of accommodatively based vision training. However, this

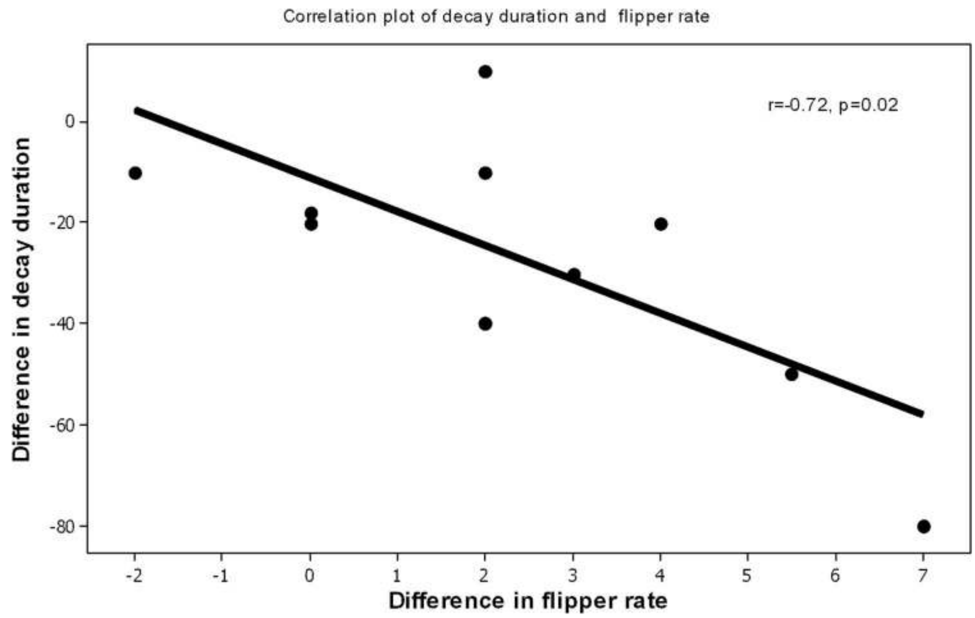

FIGURE 5.

Correlation plot of difference in NITM decay duration (seconds) vs. lens flipper rate (cpm), between post- and pretraining.

TABLE 1.

Summary of group mean clinical accommodative and vergence measurements

	NPC (cm)	Near exophoria (PD)	NRA(D)	PRA(D)	AA(D)
Mean	5.95/6.15	4.20/4.40	2.13/2.10	2.18/2.10	10.55/10.6
SD	0.83/0.67	1.32/0.97	0.32/0.21	0.29/0.29	0.86/0.84
SE	0.26/0.21	0.42/0.31	0.10/0.07	0.09/0.09	0.27/0.26

Each set of these numbers represents corresponding measurements obtained before and after 6 weeks of training, respectively.

NPC, near point of convergence; NRA, negative relative accommodation; PRA, positive relative accommodation; AA, binocular amplitude of accommodation.

was conducted in five symptomatic subjects reporting transient blur at distance after a short period of sustained nearwork. They too found that the initial NITM magnitude remained statistically similar despite considerable changes in their clinically based dynamic accommodative facility functions and correlated marked reduction in symptoms. Hence, it appears that the increased NITM magnitude typically found after nearwork is not readily alterable with vision training in both symptomatic and asymptomatic subjects, at least in those exhibiting moderately increased NITM.

In contrast to its lack of malleability, there was a trend for the NITM decay duration to decrease subsequent to the vision training (i.e., the sixth week) as well as a significant negative correlation between NITM decay duration and lens flipper rate. In the sole previously related investigation,[10] NITM decay duration was assessed before and after a similar vision training paradigm in five symptomatic subjects. However, the results were mixed; only some subjects decreased in decay duration after training, and furthermore, the responses were highly variable. In contrast, in the current study, the data were obtained from 10 asymptomatic subjects. For a sustained period of typical nearwork (e.g., several minutes at 40 cm) in visually normal subjects, a transient increase in myopic shift, i.e., NITM, has been observed especially in myopes.[3] It typically takes only 30 to 60 seconds or so to decay to baseline in these visually normal subjects.[3] In the current study, however, the visually normal asymptomatic subjects focused at a very high accommodative stimulus level (10 D) for 10 minutes, which produced a larger initial NITM magnitude (mean = 0.46 D) compared with that typically found (~0.3 D) for a lower stimulus demand (e.g., 2.5 D).[3] Thus, the occurrence of overall longer decay duration both before (mean = 101 seconds) and after training (mean = 74 seconds) in the current study was evident and in fact expected.

Several studies have reported reduced accommodative facility in myopes. O'Leary and Allen[31] assessed accommodative facility at both distance and near in myopes (n = 37) and in emmetropes (n = 42). They reported reduced rates in myopes, but this difference was only significant at distance (9.7 cpm for myopes and 15.7 cpm for emmetropes). A similar result has been reported by Pandian et al.[32] in a large sample of school children (1328 total; 977 emmetropes, 331 hyperopes, and 20 myopes). Furthermore, in a more recent investigation, Allen and O'Leary[33] investigated various accommodative functions to determine the natural progression of refractive error in 64 young adults (30 myopes and 34 non-myopes) during a period of 12 months. They reported that myopes had lower accommodative facility at distance vs. non-myopes (15.95 cpm for myopes and 18.54 cpm for emmetropes), which confirmed their earlier investigation. Moreover, they speculated that accommodative facility might be a good predictor of future myopic progression. More recently, Radhakrishnan et al.[34] reported a similar finding. Thus, taken together, these findings suggest that blur processing at distance may be less effective in myopes, along with slowed near-to-far dynamics. However, none of these investigations incorporated accommodative training in myopic subjects, as was performed in the current study.

Accommodative facility was reassessed after 6 weeks of accommodative training using both the lens flipper and Hart chart procedures. The monocular lens flipper rate (mean 11cpm) in the subjects before training was normal and in accord with the literature (Allen and O'leary[33]; mean = 11.5 cpm). Furthermore, the increases in lens flipper rates were similar to that found by Levine et al.[23] They demonstrated that with only 80 seconds of monocular accommodative facility (±2 D flippers) testing per day during a period of 2 weeks in progressing asymptomatic young adults, a considerable improvement in overall response rate was observed (i.e., up to three times). In the current study, all subjects were myopes, and they universally exhibited increased accommodative facility rates (combined latency and time course dynamics) after training. The present differences in the monocular vs. binocular results may reflect a residual vergence interaction that requires increased training for improvement.

Possible Mechanisms Involved in NITM

There are five possible mechanisms that may be involved in the vision training process related to minimization of NITM and correlated retinal defocus.[1,8,15,35,36] First, NITM could be due to an overall biomechanical hysteresis effect involving the crystalline lens. However, based on their experimental findings on NITM in late-onset myopes, using different interactive vergence and accommodative stimulus demands, Ong and Ciuffreda[1] concluded that this was not a likely contributory factor. That is, the task-induced NITM was related to the presence of the blur-driven, but not the vergence-driven, component of accommodation. Second, it might be due to blur processing related to perceptual learning. However, because these subjects did not complain of blur, especially at distance after nearwork, presence of a blur processing problem per se would not be expected to play a major role, although the absence of symptoms would not necessarily exclude a problem with blur detection itself. Third, the mechanism could be neuromuscular in origin. That is, it may be due to a frank spasm of the ciliary muscle after sustained nearwork, which would reflect an inability to relax the ciliary muscle fibers themselves. However, this too is unlikely to be a factor. Using excised ciliary muscle from the bovine eye, Suzuki[37] reported that an increase in duration and/or frequency of electrical stimulation produced an increased response magnitude but with no change in the time course of its baseline decay. He proposed that ciliary muscle contraction was neuropharmacologically produced and not neuromuscularly mediated via electric potential changes. Fourth, and consistent with the above, it could be related to a neuropharmacologically based mechanism involving the autonomic nervous system. After long and sustained periods of nearwork, the presence of a dysfunction in sympathetic inhibition would result in a relative increase in the activation of accommodation via the parasympathetic system.[38] This would result in increased NITM.[15] Thus, this is a likely factor in the genesis of NITM and its remediation. Finally, motor training could be another factor involved in the improvement after vision training. In normal asymptomatic subjects, repeated sessions of accommodative facility training would produce a powerful motor learning effect.[39] This would lead to an increase in the firing rate of accommodation and vergence neurons (e.g., mid-brain[40]) and more highly correlated synchronization of firing rates in the two neural populations.[41] This would produce increased levels of acetylcholine at the β-2 receptor level, which, in turn, would stimulate the accommodative system with increased and considerable force. This would produce an increased accommodative response, as well as the more rapid processing of blur, thereby resulting in improved dynamic accommodative facility, and hence reduce the potentially myopigenic retinal defocus. In addition, the level of activation of the parasympathetic system will alter the level of activity in the sympathetic system, with resultant time-optimal dynamic accommodative responsivity. In combination, these training-related neurologic and correlated pharmacologic changes will result in a faster near-to-far accommodative responsivity.

Thus, in conclusion, the results of the current study demonstrated consistent improvements in dynamic aspects of NITM with the prescribed training. This is in agreement with a report in a small sample of similarly aged symptomatic myopes.[8] Future investigations should be conducted to determine the efficacy of accommodative training on myopic progression, as has been suggested in theoretical model-based studies of refractive development.[9] One such targeted population would include young school-aged children who are learning to read and write, especially in Asian countries where the early demand is considerable on the developing visual system. A second would include young adults involved in academic pursuit demanding many hours of daily reading extending over a period of several years, such as those in military academies and law schools.

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