

Article ► Effect of Near Work on Binocular Vision Measurements in Adults with Convergence Insufficiency

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ABSTRACT

Background: Convergence insufficiency (CI) is a common binocular vision disorder. A common characteristic of CI is that patients have more symptoms, such as eyestrain and headache, after close work. The purpose of this study was to determine whether 30 minutes of reading affects the binocular and accommodative measurements used in the diagnosis of CI.

Methods: Eighteen normal adult subjects and eighteen adult CI subjects (symptomatic and asymptomatic) were recruited. None of the CI subjects had accommodative insufficiency. The following measurements were made: distance and near cover test, near point of convergence (NPC) with accommodative target (AT), NPC with transilluminator and red lens (RL), near positive fusional vergence (PFV), and accommodative amplitude. Subjects were then asked to read a book for 30 minutes, immediately followed by repeated administration of the above tests by the same examiner. Statistical analysis was performed using a Student's paired t-test to compare the measurements before and after reading.

Results: In the CI group, the mean phoria at near changed from 7.06^Δ exophoria to 6.56^Δ exophoria after reading for 30 minutes. Mean NPC break with AT changed from 9.58 cm to 11.25 cm. With RL, an average increase from 12.56 cm to 13.93 cm occurred for NPC break. Mean PFV break decreased from 17.22^Δ to 15.56^Δ. Mean amplitude of accommodation (OD) changed from 7.46 to 7.56 diopters. Only the change in NPC break with AT after reading was statistically significant ($P = 0.007$). There were minimal changes in clinical measurements after reading in the normal subjects.

Conclusion: Half an hour of reading had a statistically significant effect on the NPC break with AT but not on other binocular vision measurements in subjects with CI. It is unknown whether a longer period of reading would have a greater effect.

Keywords: convergence insufficiency, CISS, near point of convergence, near work, phoria, vergence, visual fatigue

Introduction

Convergence insufficiency (CI) is a common binocular vision disorder with a reported prevalence of 2.5% to 25%.¹⁻⁷ It can cause headache, blurred vision, visual fatigue, eye strain, double vision, and other symptoms.^{8,9} These symptoms commonly

occur or become worse after reading or other types of near work.

Previous studies have investigated the effect of near work on the following binocular vision functions in normal subjects: associated phoria,^{10,11} dissociated phoria,¹⁰ vergence,¹²⁻¹⁴ and accommodation.^{11,13,15-20} The results are

Table 1: Eligibility Criteria**Eligibility criteria for control subjects**

- Visual acuity 20/25 or better in each eye at distance and near with habitual correction using a Snellen chart
- Habitual correction within 0.25 D difference of the manifest refraction
- No strabismus at 3 m or 40 cm by unilateral cover test
- No binocular vision disorder
- Normal NPC (break < 6 cm, recovery < 9 cm) tested with 20/30 size accommodative target
- No accommodative insufficiency as measured by the minus lens method*
- Stereoacuity equal to or better than 500 seconds of arc tested with random dot forms

Eligibility criteria for CI subjects

- Visual acuity 20/25 or better in each eye at distance and near with habitual correction using a Snellen chart
- Habitual correction within 0.25 D difference of the manifest refraction
- No strabismus at 3 m and no constant strabismus at 40 cm by unilateral cover test
- Exodeviation at near at least 4^Δ greater than distance exophoria
- Insufficient positive fusional convergence (failing Sheard's criterion or less than 15^Δ break)
- Receded NPC of greater than 6 cm break with 20/30 size accommodative target
- No accommodative insufficiency as measured by the minus lens method
- Stereoacuity equal to or better than 500 seconds of arc tested with random dot forms

Δ, prism diopters; CI, convergence insufficiency; NPC, near point of convergence.

*Accommodative insufficiency is defined as accommodative amplitude 2.00 D lower than the minimum amplitude using the formula: 15-0.25 x age.

contradictory, and the most recent studies showed that near work had no significant impact on binocular vision function.^{11,12,16,17} The fact that CI subjects complain more after near work indicates that visual system function in CI patients may be affected by visual fatigue induced by prolonged near work. If this is the case, it would be wise to evaluate binocular vision after visual fatigue in patients who are suspected to have CI. In particular, the borderline CI patients may have normal clinical findings before visual fatigue. To the best of our knowledge, there has been no study done to determine if visual fatigue induced by close work affects visual system function in young adults with CI.

The purpose of this study was to determine whether binocular and accommodative measurements were affected by 30 minutes

of reading in both young adults with normal binocular vision and those with asymptomatic or symptomatic CI. In addition, we investigated the association between CI symptoms and clinical measurements.

Methods**Study Population and Eligibility**

Optometry students from the Illinois College of Optometry (ICO) were recruited for the study. The study followed the tenets of the Declaration of Helsinki and was approved by the ICO Institutional Review Board, and informed consent was obtained from all subjects in the study.

Students were screened by one of the authors (YP) in a standard eye examination room. The first 36 students who met the criteria (Table 1) for control or CI were invited to participate in the study, with 18 subjects in each group. An effort was made to recruit an equal number of subjects for both groups.

Data Collection and Data Analysis

The Convergence Insufficiency Symptom Survey-V15 (CISS) was self-administered by each subject. The survey has been developed and validated by the Convergence Insufficiency Treatment Trial Study Group and has 15 questions, which are scored from 0 to 4 based on the severity of the symptom.^{21,22} The following clinical measurements were taken by a masked examiner. All subjects wore their habitual correction during testing.

- Distance and near phoria by cover test
- NPC break and recovery with accommodative target (AT)
- NPC break and recovery with transilluminator and red lens (RL)
- Near positive fusional vergence (PFV) with Risley prisms (blur, break, and recovery values)
- Accommodative amplitude by minus lens method (OD and OS)

A Bernell Accommodative Rule, which is commonly used in research, was utilized to measure NPC.^{23,24} One end of the Accommodative Rule was placed just above the nose at the brow, between the two eyes. The target, a single 20/30 letter or transilluminator positioned just below the Accommodative Rule, was started 30 cm from the subject and moved toward the subject at a rate of 1 cm/sec.²⁵ The target was stopped when the subject's eyes were observed to fail to converge or when the subject reported diplopia.^{25,26} Then, the target was moved away from the subject at the same speed until the eyes were observed to reestablish bifixation or the subject reported a single image. An isolated vertical line of 20/30 letters was used to test near PFV with Risley prisms,²⁷ and a row of 20/30 letters was used to measure accommodative amplitude by minus lens method.²⁸

Following these measurements, subjects were asked to read the book *Harry Potter and the Order of the Phoenix* (11-point Arial Font) for 30 minutes with their habitual spectacles or contact lenses. Subjects were allowed to read the book at their habitual reading distance. Immediately following this period of reading, the above clinical measurements were administered again in the same test order. To ensure the attention of subjects, they were informed that they would be asked to answer questions based on the reading material at the end of reading.

All data were analyzed using Statistical Package for Social Sciences (SPSS version 17.0; SPSS Inc., Chicago, IL). The distributions of binocular and accommodative measurements were confirmed as normally distributed by the Kolmogorov-Smirnov test. The clinical measurements used for CI diagnosis were compared before and after reading using the student paired t-test: near phoria, NPC break tested with AT,²⁹ NPC break tested with RL, PFV break,²⁹ and accommodative amplitude for the right eye (OD). Pearson correlation was

performed to test the association between CISS scores and change in the above five clinical measurements before and after reading. To account for multiple comparisons of binocular and accommodative measurements, $p < 0.01$ was considered statistically significant.³⁰⁻³²

No formal sample size calculations were performed a priori because one of the goals of the study was to determine which clinical measurements were affected by reading, and there was a question as to which of those measurements should be used for sample size calculation. A pilot study was conducted³³ (n=14), and NPC break with AT in the CI group was the only measurement that was statistically significantly affected by reading; the other measurements were not close to reaching statistical significance. Thus, the difference in NPC break with AT, before and after reading, for the CI group from the pilot study was used to determine the sample size, which resulted in n=18. Four more subjects were enrolled to reach the sample size of 18. The calculations were performed using Power and Sample Size Program (Version 3.0, Nashville, TN) with $\alpha = 0.05$, assuming a 2-sided test.

Results

The characteristics of subjects in the control and CI groups are listed in Table 2. Table 3 shows the clinical measurements before and following 30 minutes of reading for both control and CI groups. There was no significant change in any of the parameters for the control group. In the CI group, the changes in the phoria, PFV break, and amplitude of accommodation (OD) were minimal after reading. Although the NPC break values tested with either AT or RL had a tendency to be more receded following reading, only the change in NPC break with AT (1.67 cm) was statistically significant ($t = -3.05$, $df = 17$, $p = 0.007$). Figure 1 shows the NPC break values tested with AT for each subject before and after reading. NPC was more receded

Table 2: Characteristics of Subjects in the Control and Convergence Insufficiency (CI) Groups (n=36)

Characteristic	Control (n=18)	CI (n=18)
Gender		
Female	12	12
Male	6	6
Race		
Caucasian	17	10
Asian	1	8
Age (years)		
Mean	24.77	24.65
SD	1.17	2.82
Range	22-28	23-28
CISS Score		
Mean	13.94	16.56
SD	5.51	7.62
Range	2-23	3 - 36

[Asymptomatic (CISS<21): 13 subjects Symptomatic: 5 subjects]
SD, standard deviation; CI, convergence insufficiency.

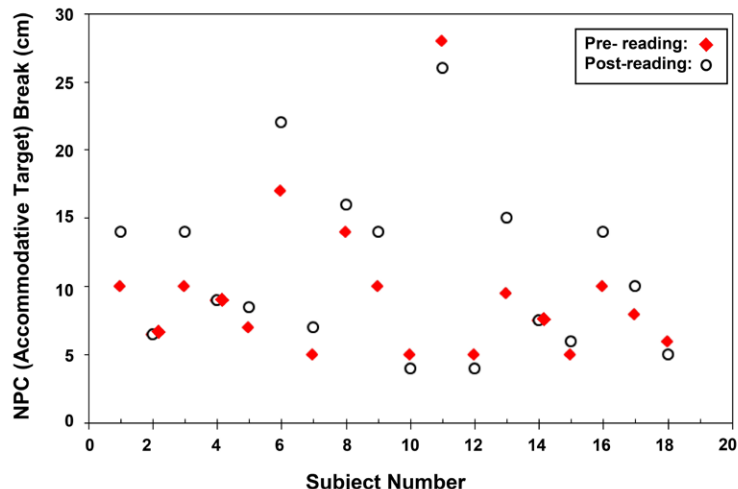


Figure 1: Break values for near point of convergence tested with accommodative target before and following 30 minutes of reading.

after reading in 11 of 18 total subjects, with no change in 3 subjects and improvement in 4 subjects.

No difference was identified in CISS scores between control and CI subjects ($p=0.25$). There was no correlation between CISS scores and the differences in clinical measurements before and after reading.

Discussion

This study was designed to identify whether binocular and accommodative measurements in both normal young adults and those with asymptomatic or symptomatic

Table 3: Clinical measurements before and after reading in control and convergence insufficiency subjects.

Measurements	Pre-reading (Mean \pm SD)	Post-reading (Mean \pm SD)	Difference (Post - Pre; Mean)	P Value
Control (n=18)				
Near Phoria (Δ)	-0.82 \pm 1.67	-1.41 \pm 2.29	-0.59	0.21
NPC-AT Break (cm)	3.32 \pm 1.36	3.71 \pm 1.94	0.38	0.15
NPC-RL Break (cm)	6.76 \pm 2.51	7.09 \pm 3.55	0.34	0.67
PFV Break (Δ)	38.82 \pm 7.19	39.12 \pm 6.90	0.29	0.88
Accommodative Amp. (OD)	8.15 \pm 1.96	8.13 \pm 1.74	0.07	0.95
Convergence Insufficiency (n=18)				
Near Phoria (Δ)	-7.06 \pm 3.70	-6.56 \pm 3.93	0.50	0.17
NPC-AT Break (cm)	9.58 \pm 5.61	11.25 \pm 6.14	1.67	0.007*
NPC-RL Break (cm)	12.56 \pm 8.52	13.93 \pm 6.90	1.39	0.17
PFV Break (Δ)	17.22 \pm 9.83	15.56 \pm 9.89	-1.67	0.28
Accommodative Amp. (OD)	7.46 \pm 1.61	7.56 \pm 1.44	0.10	0.66

* indicates statistical significance; NPC, near point of convergence; AT, accommodative target; RL, transilluminator with a red lens; PFV, positive fusional vergence; minus values for near phoria indicate exophoria and plus values indicate esophoria.

CI were affected by 30 minutes of reading. We found that reading had little effect on those measurements in normal adults and had minimal effect on near phoria, PFV break, NPC break with RL, and accommodative amplitude (OD) in subjects with CI. However, NPC break with AT was more receded following reading, a change that was statistically significant.

Binocular vision function following near work has been studied previously in subjects with normal binocular vision function. Collier and Rosenfield measured the associated phoria and accommodative response during 30 minutes of sustained computer work in 20 normal young adults.¹¹ No significant difference in associated phoria or accommodative response was observed. In 30 young adults with normal binocular vision (optometry students), Feldman et al. found that the asthenopia and PFV (both break and recovery values) did not change after 3 minutes of continuous alternating convergent and divergent fusional vergence.¹² Vilupuru et al. tested accommodative amplitude in two young adults during a 30-minute period of 6-diopter stimuli presented in step fashion

and observed that accommodative amplitude did not reduce over time.¹⁶ Wolffsohn et al. reported that accommodative amplitude and accommodative accuracy did not change following a 30-minute reading task in 21 young adults.¹⁷ Our results are consistent with the previous studies in that we did not find significant change in near phoria, NPC, PFV, or accommodative amplitude in our subjects with normal binocular vision. On the other hand, Berens and Sells observed a reduction in accommodative amplitude following repeatedly testing the amplitude over a 30-minute period with a 2-second rest after each measurement.¹⁸ Thiagarajan and Ciuffreda reported that the accommodative system exhibited a consistent fatigue effect on accommodative steady-state response but not on accommodative amplitude, time constant, or peak velocity.¹⁹ Iribarren et al. stated that accommodative facility was negatively correlated with cumulative near work time, which was calculated based on a survey of 87 young adults. Thus, they suggested measuring dynamic accommodation such as accommodative facility instead of static accommodation.¹⁵

Although our results and those of most recent studies show that near work did not change binocular and accommodative measurements in young adults with normal binocular vision, one could argue that binocular vision function in CI subjects is more fragile compared to the normal population. Thus near work might have more impact on binocular and accommodative measurements in CI subjects, especially considering that CI subjects frequently experience more asthenopia after near work. Yekta et al. tested dissociated phoria, associated phoria, and fixation disparity before and after a working day in 21 asymptomatic and 63 symptomatic subjects, all with normal binocular vision (aged 15 to 47 years) and found that all three parameters changed significantly in the symptomatic group but not in the

asymptomatic group.¹⁰ Their study indicates that binocular vision in symptomatic subjects is more prone to the effects of near work. However, with an uncontrolled amount and type of near work and a wide age range, the study by Yetka et al. has some potential weaknesses. Our subjects were all young adults with a very narrow age range. In addition, the reading time and reading material were well controlled. Our results show that in our CI subjects, the majority of whom were asymptomatic, only NPC break tested with AT was more receded following reading, with no significant change in other clinical measurements. This finding suggests that NPC with AT is a more sensitive test than other near tests in CI subjects following near work.

Because our subjects were asked to read fiction for 30 minutes, our findings of no change in other clinical measurements could be due to the following reasons. First, the period of reading time, 30 minutes, was not long enough to induce visual fatigue for those CI subjects, although it is very common clinically for CI patients to complain of visual fatigue following 30 minutes or even shorter periods of reading. It is possible that a longer period of reading may have more impact on binocular and accommodative measurements. Second, the reading material we utilized in this study produced low mental stress. Adding cognitive stress by using different reading material, such as a scientific paper or course notes, may induce more visual fatigue. However, the same reading material can induce varying degrees of cognitive stress depending on the subject, which would bring variability to the study. Although cognitively demanding tasks have been shown not to induce asthenopic symptoms in young adults with normal vision,³⁴ it is unknown whether adding cognitive stress would affect binocular vision more in CI subjects.

The validity and reliability of the CISS have been established in both children and adults.^{22,35} A score of 21 or higher is suggested to differentiate adults with CI from normal adults.²² In our study, the average CISS score for CI subjects (16.56) was lower than 21. Suppression might have reduced our subjects' symptoms for near tasks and may explain the lack of correlation between the CISS scores and the change in clinical measurements before and after reading in our CI subjects. Incidentally, in two other studies by one of the authors (YP),^{6,7} similar results were found in that clinical measurements were not correlated with the CISS score. In addition, high CISS score was not associated with high phoria at near, high NPC value, and low PFV value. Thus, based on our study purpose, we chose to include both symptomatic and asymptomatic (high and low CISS scores) CI subjects because some of the subjects with low CISS scores had worse binocular vision measurements, and it was interesting to determine the effect of near work on those subjects. Interestingly, NPC break tested with AT, but not with RL, was more receded following near work. Our previous work has shown that NPC with RL was more receded than NPC with AT in CI subjects, and we have suggested that NPC with RL is a more sensitive method to identify abnormal findings and assist in diagnosing CI compared to using AT.^{5,23} NPC with AT measures convergence including the following 4 components: tonic, accommodative, fusional, and proximal. NPC with RL measures all components of convergence except the accommodative one. Thus, our results suggest that near work affected the NPC break through the mechanism of accommodative convergence. Accommodative amplitude was measured in our subjects, and no change was found after near work. Iribarren et al. have suggested

measuring dynamic accommodation such as accommodative facility rather than a static test such as accommodative amplitude.¹⁵ Thus, it could be that the accommodative system was affected by near work in our study but the measurement of accommodative amplitude was not sensitive enough to detect the change.

There are some limitations to our study. First, although the examiner was masked to the subjects' diagnosis (CI versus normal binocular vision), the examiner was not masked to the reading status. However, the examiner made no attempt to remember the subjects and their findings and was unaware of the subjects' scheduling (post-reading subjects were mixed with pre-reading subjects). Thus, it is unlikely that the examiner was aware of the reading status of our subjects; however, the unmasked reading status could induce potential bias from the examiner. Second, because most of our subjects were asymptomatic (lower CISS score), our findings may not apply to symptomatic CI patients. This was addressed in a previous paragraph. Third, our sample size was small. Finally, our subjects were optometry students, a convenience sample, which may limit the ability to generalize the results to the general population.

Conclusion

To the best of our knowledge, this is the first study to determine whether near work impacts binocular and accommodative measurements in subjects with CI. We found that NPC break tested with AT was more receded after reading, but there was no significant change in the other clinical measurements. It is unknown whether a longer period of reading would have a greater effect. Our findings also indicate that clinicians should consider the effect of visual fatigue on NPC when diagnosing CI and monitoring CI treatment progress.

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