

ORIGINAL ARTICLE

Nearpoint of Convergence: Test Procedure, Target Selection, and Normative Data

MITCHELL SCHEIMAN, OD, FAAO, MICHAEL GALLAWAY, OD, FAAO,
KELLY A. FRANTZ, OD, FAAO, ROBERT J. PETERS, OD, FAAO, STANLEY HATCH, OD, FAAO,
MADALYN CUFF, OD, and G. LYNN MITCHELL, MAS, FAAO

Pennsylvania College of Optometry, Philadelphia, Pennsylvania (MS, MG), Illinois College of Optometry, Chicago, Illinois (KAF), Private Practice, Grand Rapids, Michigan (RJP), New England College of Optometry, Boston, Massachusetts (SH), Private Practice, (MC), College of Optometry, The Ohio State University, Columbus, Ohio (GLM)

ABSTRACT: *Background.* The purpose of this study was to help determine the most appropriate target to be used for the assessment of the nearpoint of convergence, normative data for the break and recovery in adults, and the diagnostic value of the red-glass modification and repetition of the nearpoint of convergence. *Methods.* A total of 175 subjects with normal binocular vision and 38 subjects with convergence insufficiency were evaluated. The nearpoint of convergence was measured three ways, with an accommodative target, a penlight, and a penlight with red and green glasses. The nearpoint of convergence was also measured using a penlight for 10 repetitions. *Results.* Results suggest a clinical cutoff value of 5 cm for the nearpoint of convergence break and 7 cm for the nearpoint of convergence recovery with either an accommodative target or a penlight with red and green glasses. *Conclusion.* This study establishes normative data for the nearpoint of convergence break and recovery in the adult population and supports the value of various test modifications when other testing is equivocal. (*Optom Vis Sci* 2003;80:214–225)

Key Words: nearpoint of convergence, convergence insufficiency, binocular vision testing

The assessment of the nearpoint of convergence (NPC) is widely used by eye care practitioners in the routine primary care examination^{1, 2} and is often included as a test procedure for vision screenings.^{3–7} The NPC is also considered an important diagnostic finding in the assessment of convergence insufficiency.^{8–13} For example, Daum¹⁰ reviewed 58 studies of convergence insufficiency and found that 36% of the studies specified a receded nearpoint of convergence as an important criterion for diagnosis of convergence insufficiency. A survey conducted by Rouse et al.¹⁴ determined that the NPC was used in making the diagnosis of convergence insufficiency by 93.8% of optometrists surveyed. Thirty-five percent of the doctors indicated that one criterion was sufficient to diagnose convergence insufficiency, and the most frequently used single diagnostic characteristic was the NPC. Given its widespread use and diagnostic importance, it is surprising that the NPC test procedure, target selection, and normative data have received limited investigation since its introduction as an important routine test procedure in the late 19th and early 20th centuries.^{15, 16}

Although most authors describe the NPC as part of the minimum database for a routine vision examination,^{1, 2, 7, 17–33} our

review of the literature found only one recent study that was designed to determine the normative data for this test. In this study, Hayes et al.³³ suggested expected values for the NPC for school-aged children. We were unable to retrieve any study that systematically investigated the expected values for the NPC in adults. Table 1 is a compilation of recommendations in current textbooks and articles.^{1, 2, 7, 17–33} As the table illustrates, there are a variety of recommendations for target selection, and the recommended expected findings for the break range from 5 to 17.5 cm. More than half of the authors did not include an expected finding for the recovery measurement. The expected findings for those who did report a recovery finding ranged from 8 to 11 cm. Other than the study by Hayes et al.,³³ not one of the other authors provided supportive data or a reference for their suggestions for either the recommended target or expected findings.

We were able to find one article that reported the NPC in adults with normal binocularity and adults with convergence insufficiency.²⁵ This study was not designed specifically to investigate normative data for NPC. However, in the course of studying the relationship between the NPC and vergence amplitudes in convergence insufficiency patients, the authors reported an average break

TABLE 1.
Previous suggestions for NPC target selection and expected findings.^a

Source	Expected Break	Expected Recovery	Target/Method	Based on
Davies ¹⁷	7 cm	NR	Target not specified, suggests repeating test 8–12 times	Not stated
Capobianco ¹⁸	6–10 cm	NR	Penlight, stresses importance of red glass test	Not stated
Carter ¹⁹	5 cm	9 cm	Pencil, pen point, or other small object	Not stated
Duke-Elder ²⁰	10 cm	NR	Target and method not specified	Not stated
Burian and von Noorden ²¹	8–10 cm	NR	Target not specified, stresses importance of red glass modification	Not stated
Hoffman and Rouse ²²	5 cm	8 cm	Target and method not indicated	Not stated
Mohindra and Molinari ²³	6 in	Within 2 in of break	Red glass, repetition suggested	Not stated
Pickwell and Hampshire ²⁴	10 cm	NR	Black vertical line on a white card	Not stated
Cohen et al. ⁷	10 cm	NR	A bell	Not stated
Shippman et al. ²⁵	5 cm	NR	Target and method not indicated	Clinical study
London ²⁶	5 cm	8 cm	Penlight, important to repeat to check for fatigue effects, talks of diagnostic potential of NPC with red glass (suggests that a difference of 3 cm has diagnostic value)	Not stated
Helveston et al. ²⁷	11 cm	NR	Accommodative target	Not stated
Wick ²⁸	NR	NR	Target not indicated, repeat test five or more times	Not stated
Pickwell ²⁹	10–15 cm	NR	Any suitable target	Not stated
Carlson et al. ²	>17.5 cm	Within 7.5 cm of break	Penlight for screening, use accommodative target and red glass/penlight if NPC is greater than 4 in/7 in.	Not stated
London ³⁰	6–10 cm	NR	Accommodative target or penlight, repeat five times	Not stated
Eggers ³¹	10 cm	NR	Target not indicated	Not stated
Griffin and Grisham ³²	8 cm	11 cm	Small detailed target, perform five times	Class notes
Grosvenor ¹	8 cm	NR	Penlight, suggests repeated testing; if NPC is greater than 12–15 cm with repeated testing, it is evidence of a convergence insufficiency.	Not stated
Hayes et al. ³³	6 cm	10 cm	Astron International Accommodative Rule and a 20/30 single column of letters. Examiner moved target at a rate of approximately 1–2 cm/s.	Well-designed study

^a NPC, nearpoint of convergence; NR, not reported.

finding of 5 cm (range, 1 to 15 cm) for a group of 46 adult clinical patients with normal binocular vision. The average break for adults diagnosed with convergence insufficiency was 7.9 cm (range, 1 to 20 cm). The authors did not report the target used for the testing.

The recent study by Hayes et al.³³ was designed to establish normative values for the NPC using a standardized and reliable protocol. They studied 297 schoolchildren in kindergarten, third grade, and sixth grade who had passed a school-based Modified Clinical Technique vision screening. Based on their results, they suggested a clinical cutoff value of 6 cm for the NPC break for schoolchildren using an accommodative target.

There has also been speculation about modification of the standard procedure to make the test more sensitive and of greater diagnostic and prognostic value. In an entirely anecdotal report in 1952, Capobianco¹⁸ recommended that the NPC be performed twice, once with a penlight and again with a penlight and a red glass in front of one eye. Capobianco refers to this second method as the subjective NPC. She suggests that this modification might potentially yield useful diagnostic and prognostic information. According to Capobianco, in cases in which a convergence insufficiency is suspected but the NPC with a penlight alone is normal, the subjective NPC may be more remote and demonstrate a better correlation with fusional amplitudes. Thus, the red-glass NPC may be a more sensitive diagnostic test. She claims that the test also provides information about progress in treatment because the NPC tested with the red-glass modification improves more rapidly than the NPC tested with the penlight alone. Although several authors recommend that this procedure be incorporated as part of the standard assessment of convergence amplitude,^{2, 21, 23, 26} no research data have been produced to support its use or any of Capobianco's assertions about the value of the test.

Another modification that has been suggested is repetition of the NPC, with the assumption that symptomatic patients will show a greater recession in the NPC with repeated testing compared with normals. Davies,¹⁷ in 1946, appears to be the original source for this recommendation. He advocated repeating the NPC eight to 12 times and suggested that a breakdown would occur at about five to six repetitions and the break would recede to 25 to 30 cm. This would indicate poor convergence reserve. Subsequent authors have suggested that this might be a worthwhile part of the NPC evaluation.^{1, 2, 23, 26, 28, 30, 32} Although this may make intuitive sense, again no supporting data exist. Even if a clinician adopts this approach, the literature is unclear about how much of a change in the NPC with repetition should be considered significant.

Thus, we have a clinical test that is considered part of the minimum database for a primary eye care examination, is often used as a screening procedure for binocular vision problems, and is a key criterion for the diagnosis of convergence insufficiency, yet there is a lack of supportive, clinical research. There is a lack of agreement about the most appropriate target and the expected finding for a normal or abnormal break in adults. In addition, although clinicians have developed several potentially valuable modifications of the NPC test, there are no data to validate the use of these modifications.

The purpose of this study is to investigate these issues and help determine the most appropriate target to be used for the NPC, normative data for the break and recovery in adults, and the clinical value of modifications of the test using filters and repetitions.

METHODS

Two groups of subjects were evaluated. The first group consisted of optometry students (N = 175; age range, 22 to 37 years; average age, 24.9). These subjects received a full eye examination. We orally reviewed the study with each subject and outlined the risks and benefits. After receiving consent, we enrolled subjects in the study. All subjects had 20/20 visual acuity in both eyes (distance and near) with best refraction. We excluded all subjects with a strabismic or nonstrabismic binocular vision problem or an accommodative disorder. We used traditional normative values to determine whether a subject had an accommodative or nonstrabismic binocular vision disorder.^{34, 35}

Group two consisted of clinic patients at The Eye Institute of The Pennsylvania College of Optometry and the Illinois Eye Institute of the Illinois College of Optometry (N = 38; age range, 9 to 52 years; average age, 20.2). We orally reviewed the study with each subject and outlined the risks and benefits. After receiving consent, we enrolled subjects in the study. We excluded subjects with <20/20 visual acuity in each eye with best correction or constant strabismus. All subjects in this group were diagnosed with convergence insufficiency using criteria of exophoria greater at near than at far, receded NPC (we selected a value of 5 cm for the NPC based on the previous work of Shippman et al.²⁵), and reduced positive fusional vergence amplitudes (≥ 1 SD from Morgan's expected findings). The NPC was considered abnormal if the measurement was receded with any of the three targets described below.

We administered an eight-item symptom questionnaire (Table 2) to all subjects. This questionnaire was adapted from a questionnaire developed and used by Cooper et al.³⁶ Each item was scored on a scale of one to five. The lower the score, the less the symptoms. The highest possible symptom score was 40, indicating a very symptomatic subject, and the lowest possible score was eight, indicating no symptoms. This survey has not been tested for reliability and repeatability. A symptom survey (Convergence Insufficiency and Reading Study symptom survey³⁷) is now available that has been shown to be a valid instrument for differentiating convergence insufficiency (CI) children from those with normal binocular vision. However, at the time we performed this study, this symptom survey was not available.

For all subjects, the NPC was assessed by one of the authors using a standard push-up technique with a Bernell Accommodative Rule. We used an instructional set similar to the one first described by Hayes et al.³³ The Accommodative Rule was placed just above the nose at the brow between the two eyes. The target was moved toward the subjects at a rate of about 1 to 2 cm/s. Subjects were encouraged to try to keep the target single. The subjective break and recovery values were measured and recorded in centimeters. If there was no subjective report of diplopia, the points at which the patient objectively lost and regained ocular alignment were recorded as the break and recovery. The NPC was measured once with each of the following: an accommodative target (AT) (single 20/30 letter), a penlight (PL), and with penlight while the subject wore red/green glasses (PLRG). Red and green glasses were used instead of a red glass to free both hands of the examiner so that he could hold the Accommodative Rule with both hands. The order of testing

TABLE 2.
Symptom Questionnaire

-
1. How long can you do nearwork (i.e., reading, writing, computer work, sewing, etc.) without discomfort, headaches, eye ache, burning, stinging, watering, blurriness, double vision, loss of vision, or tiredness?
 1. at least 3 hours
 2. up to 2 hours
 3. up to 1 hour
 4. up to 30 minutes
 5. up to 15 minutes
 2. How often do you get headaches when you do nearwork?
 1. never (0% of the time)
 2. occasionally (approximately 25% of the time)
 3. often (approximately 50% of the time)
 4. very often (approximately 75% of the time)
 5. every time I do nearwork (100% of the time)
 3. If you experience headaches during nearwork how bothersome are these headaches (i.e., to what degree do they interfere with your normal functioning)?
 1. minimally bothersome
 2. mildly bothersome
 3. moderately bothersome
 4. very bothersome
 5. extremely bothersome
 4. Do your eyes pull, ache, or water when you do nearwork?
 1. never (0% of the time)
 2. occasionally (approximately 25% of the time)
 3. often (approximately 50% of the time)
 4. very often (approximately 75% of the time)
 5. every time I do nearwork (100% of the time)
 5. Does the reading material ever become blurry, run together, or jump when you do nearwork?
 1. never (0% of the time)
 2. occasionally (approximately 25% of the time)
 3. often (approximately 50% of the time)
 4. very often (approximately 75% of the time)
 5. every time I do nearwork (100% of the time)
 6. Does reading material ever become double when you do nearwork?
 1. never (0% of the time)
 2. occasionally (approximately 25% of the time)
 3. often (approximately 50% of the time)
 4. very often (approximately 75% of the time)
 5. every time I do nearwork (100% of the time)
 7. Immediately following prolonged nearwork do objects at distance appear blurry for a short period of time?
 1. never (0% of the time)
 2. occasionally (approximately 25% of the time)
 3. often (approximately 50% of the time)
 4. very often (approximately 75% of the time)
 5. every time I do nearwork (100% of the time)
 8. Do your eyes feel tired or do you lose your concentration when doing nearwork?
 1. never (0% of the time)
 2. occasionally (approximately 25% of the time)
 3. often (approximately 50% of the time)
 4. very often (approximately 75% of the time)
 5. every time I do nearwork (100% of the time)
-

with these three targets was randomized. After a 30-s break, the NPC with a penlight was then performed an additional 10 times. Finally, each subject filled out the eight-item symptom questionnaire to assess the presence and severity of asthenopic complaints during nearpoint activities. All testing was performed with full room illumination.

Descriptive statistics (means, standard deviation, medians, etc.)

were generated for both break and recovery measurements obtained using each of the three target types. These calculations were performed separately for normal and convergence insufficiency subjects. Within each group, a repeated-measures analysis of variance was used to compare the mean break and recovery values obtained with each of the targets. *Post hoc* testing was performed using Scheffe's method of multiple comparison. Given the non-

normal distribution of NPC values for both groups, natural log-transformed values were used when performing these analyses.

Mixed model analysis was used to model the repeated measurements obtained for both NPC break and recovery as a function of measurement number. In addition, indicator variables were included in the model to determine whether the slope of the line relating break or recovery to measurement number was consistent across the entire range of repeats. Akiake's Information Criterion values were used to judge model fit. Due to the non-normal distribution of break and recovery values, natural log transformed data was used in all analyses. These analyses were performed separately for CI and normal subjects.

RESULTS

Normative Data and Target Selection

Descriptive statistics for both break and recovery values obtained from the normal subjects are summarized in Table 3. The mean break for both the AT and PLRG targets is about 2.5 cm. The mean break value for the PL target is slightly lower at 2.0 cm. The mean recovery for the AT and PLRG targets was also similar at 4.35 cm and larger than the mean for PL at 3.74 cm. Repeated-measures analysis of variance (ANOVA) indicated a significant difference in the mean break measurements obtained via the three targets ($p < 0.0001$). *Post hoc* testing indicated a significant difference in AT and PL ($p \leq 0.0001$), AT and PLRG ($p = 0.0033$), and PL and PLRG ($p = 0.0018$). The actual differences, however, were < 0.5 cm and are not considered clinically meaningful. A significant difference in mean NPC recovery for the three targets was also found ($p < 0.0001$) using the repeated-measures ANOVA. The mean recovery for AT and PL were significant different ($p = 0.0001$) along with the means for PL and PLRG ($p = 0.0001$). As with the break values, the differences, although statis-

tically significant, were < 0.7 cm and therefore not clinically meaningful. For clinical testing purposes, the break and recovery data for normal subjects are essentially identical for each of the three target types.

The distribution of break and recovery values for each of the three targets is shown in Figs. 1 and 2. Cumulative distributions are shown in Fig. 3. Break values for each of the three targets are unimodal and right skewed with a concentration of measurements in the 0.5- to 3.0-cm range (Fig. 1). In fact, slightly more than 70% of the subjects had break values of ≤ 3 cm with AT (Fig. 3). The percentage of subjects with values of ≤ 3 cm increases to 75% using PL and exceeds 80% using PLRG. More than 90% of subjects had break values in the range of 0.5 to 5.0 cm regardless of the target.

As with break, the distributions of NPC recovery values are unimodal and skewed to the right (Fig. 2). As indicated by the median values in Table 3, more than 50% of the recovery measurements were ≤ 4.0 cm for each of the three targets. Recovery measurements of ≤ 10 cm were observed in over 90% of the subjects using each target.

Also included in Table 3 are descriptive statistics for the NPC break and recovery measurements obtained from subjects with convergence insufficiency. The mean break for AT is lowest at just over 9 cm, increasing to almost 12 cm with PL and almost 15 cm with PLRG. AT also produced the lowest mean recovery at 12.5 cm, followed by PL with a mean of just over 17.5 cm. As with break, the mean recovery for PLRG was largest at slightly more than 20.5 cm. The repeated-measures ANOVA indicated a significant difference in the mean break measurements obtained via the three targets ($p < 0.0001$). *Post hoc* testing indicated a significant difference in AT and PL ($p = 0.0104$) and AT and PLRG ($p < 0.0001$). Unlike normal subjects, the statistically significant differences in break values obtained with the three targets were also clinically meaningful. A significant difference in mean NPC recov-

TABLE 3.

Descriptive statistics for NPC break and recovery by method obtained and study group.^a

Method Obtained	Mean	SD	Minimum	Median	Maximum
CI subjects (N = 38)					
Break					
Accommodative target	9.32	6.74	0.5	7.75	31.0
Penlight	11.86	8.40	2.0	10.0	41.0
Penlight with R/G glasses	14.75	10.0	2.0	11.0	41.0
Recovery					
Accommodative target	12.47	7.89	1.0	10.5	36.0
Penlight	17.68	11.24	4.0	14.25	51.0
Penlight with R/G glasses	20.59	12.32	5.0	15.5	56.0
Normal binocular vision subjects (N = 175)					
Break					
Accommodative target	2.49	1.74	0.5	2.0	7.0
Penlight	2.06	1.85	0.5	1.5	10.0
Penlight with R/G glasses	2.38	2.11	0.5	2.0	11.0
Recovery					
Accommodative target	4.35	2.74	1.0	4.0	11.0
Penlight	3.74	2.87	0.5	3.0	14.0
Penlight with R/G glasses	4.35	3.26	1.0	4.0	17.0

^a NPC, nearpoint of convergence; CI, convergence insufficiency; R/G, red and green.

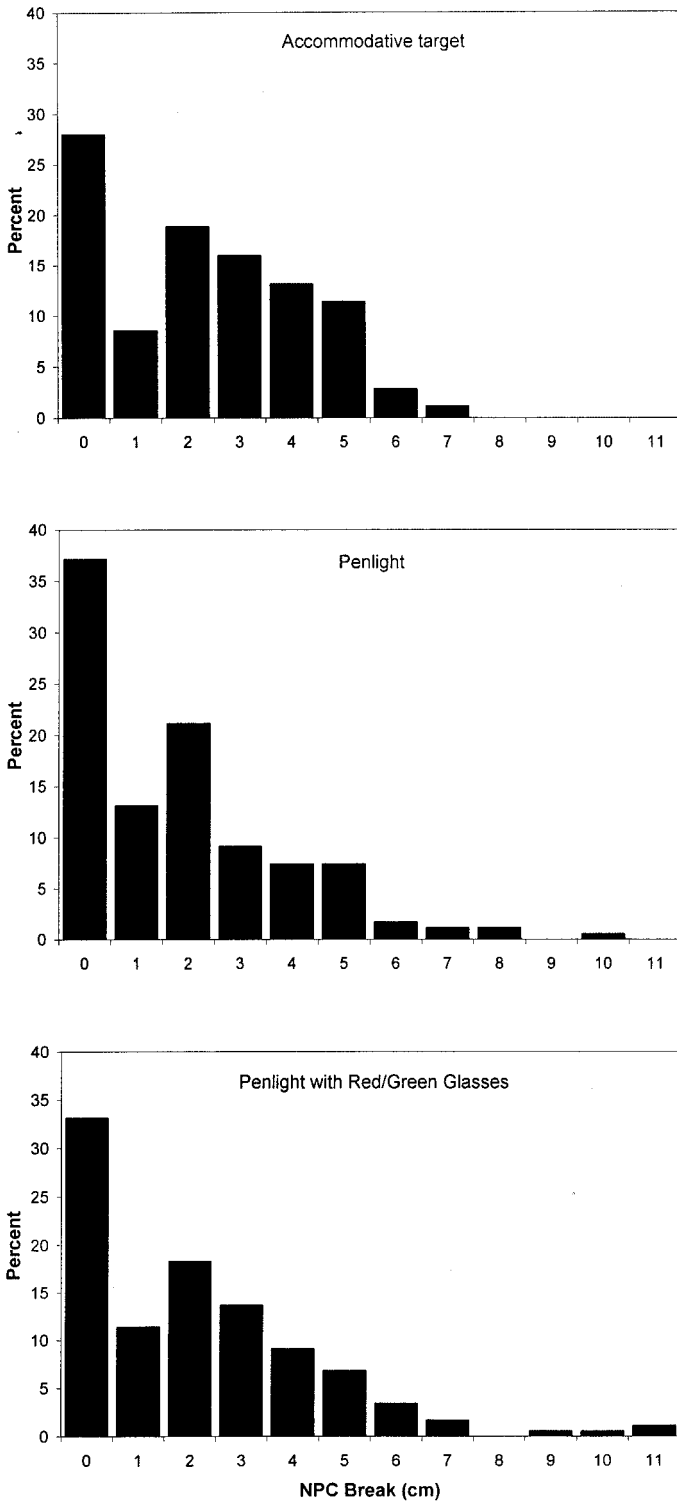


FIGURE 1. Distribution of nearpoint of convergence (NPC) break values for normal subjects by measurement method.

ery for the three targets was also found ($p < 0.0001$) using the repeated-measures ANOVA. The mean recovery for AT and PL were significant different ($p = 0.0008$), along with the means for AT and PLRG ($p < 0.0001$). These differences are both statistically significant and clinically meaningful. For clinical testing pur-

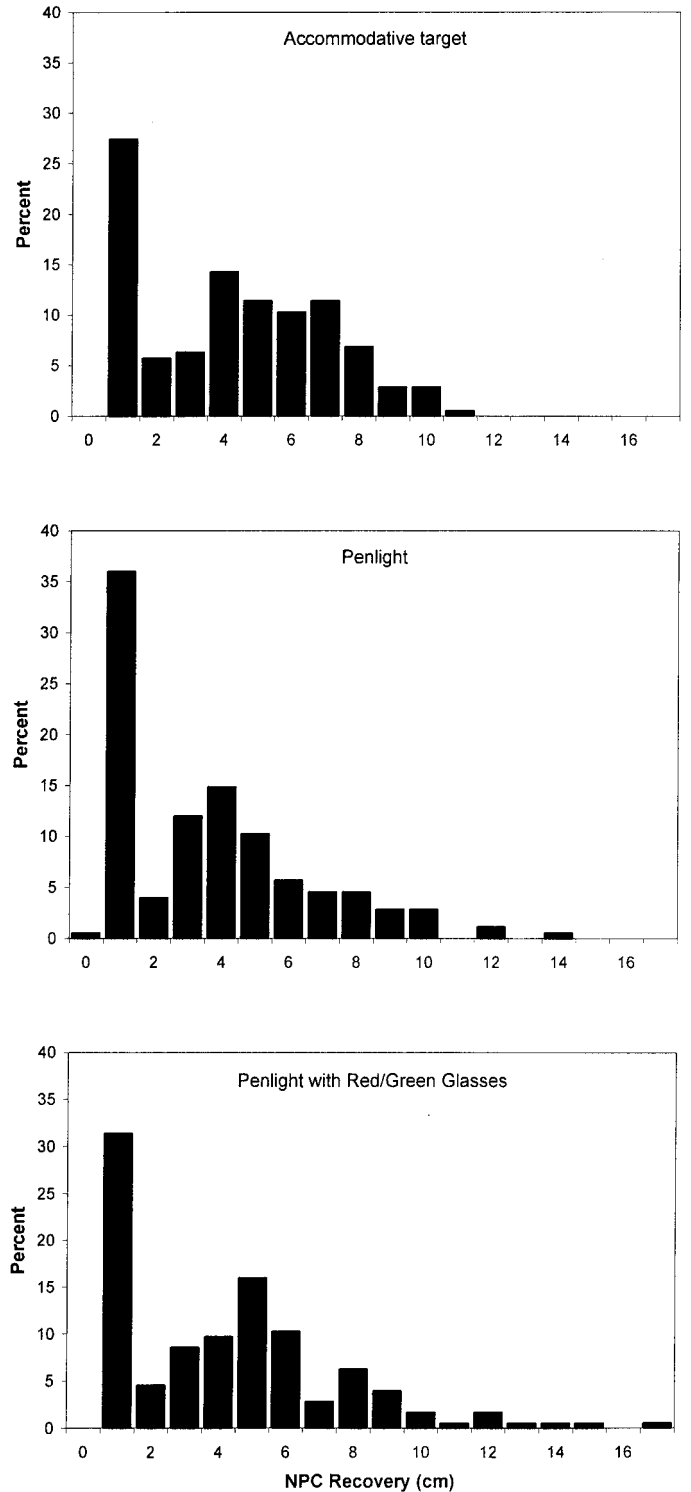


FIGURE 2. Distribution of nearpoint of convergence (NPC) recovery values for normal subjects by measurement method.

poses in patients with convergence insufficiency, it would appear that testing with the AT target results in break and recovery data that are significantly lower than what would be obtained using either PL or PLRG targets.

The distribution of break and recovery values for convergence insufficiency subjects using each of the three targets are shown in

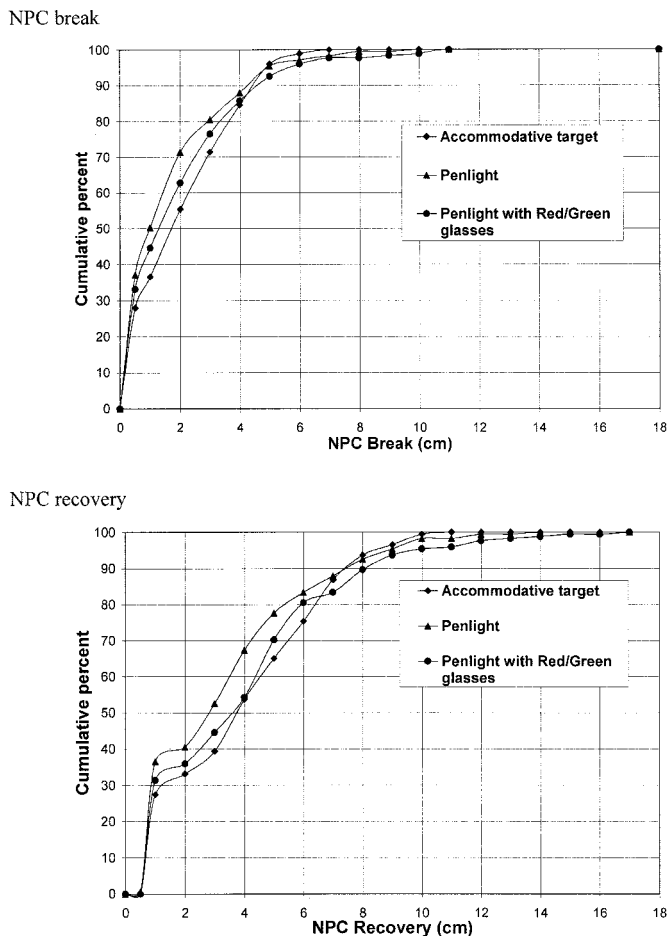


FIGURE 3. Cumulative distribution of nearpoint of convergence (NPC) break and recovery for normal subjects by method of measurements.

Figs. 4 and 5. Cumulative distributions are plotted in Fig. 6. Both AT and PLRG have unimodal NPC break distributions that are skewed to the right. A high proportion (70%) of the break measurements with AT are in the range of 0.5 to 10 cm. PLRG values, although skewed, are not quite as concentrated with <50% in the range of 0.5 to 10 cm. The distribution of break values for PL has three modal values at 8, 10, and 12 cm and appears less skewed than the distribution for the other two targets. In fact, the distribution appears almost uniform in the range of 0.5 to 15 cm.

NPC recovery measurements obtained using the AT target also follow a unimodal distribution with a large concentration in the range of 0.5 to 15 cm. In fact, nearly 80% of the subjects have measurements in this range. The distribution of values for the PL target is also unimodal but appears less skewed than the AT distribution. Only slightly more than one half of the subjects have values of ≤ 15 cm. As with NPC break, the distribution of recovery values for the PLRG target is more evenly spread across the range of values compared with the other two target types. Slightly <50% of the subjects have recovery values of ≤ 15 cm using the PLRG target.

Modification of Test Procedure: Ten Repetitions

The average NPC break for CI subjects was 12.1 cm at the first measurement, but it increased to 15.9 cm at measurement 10. Fig.

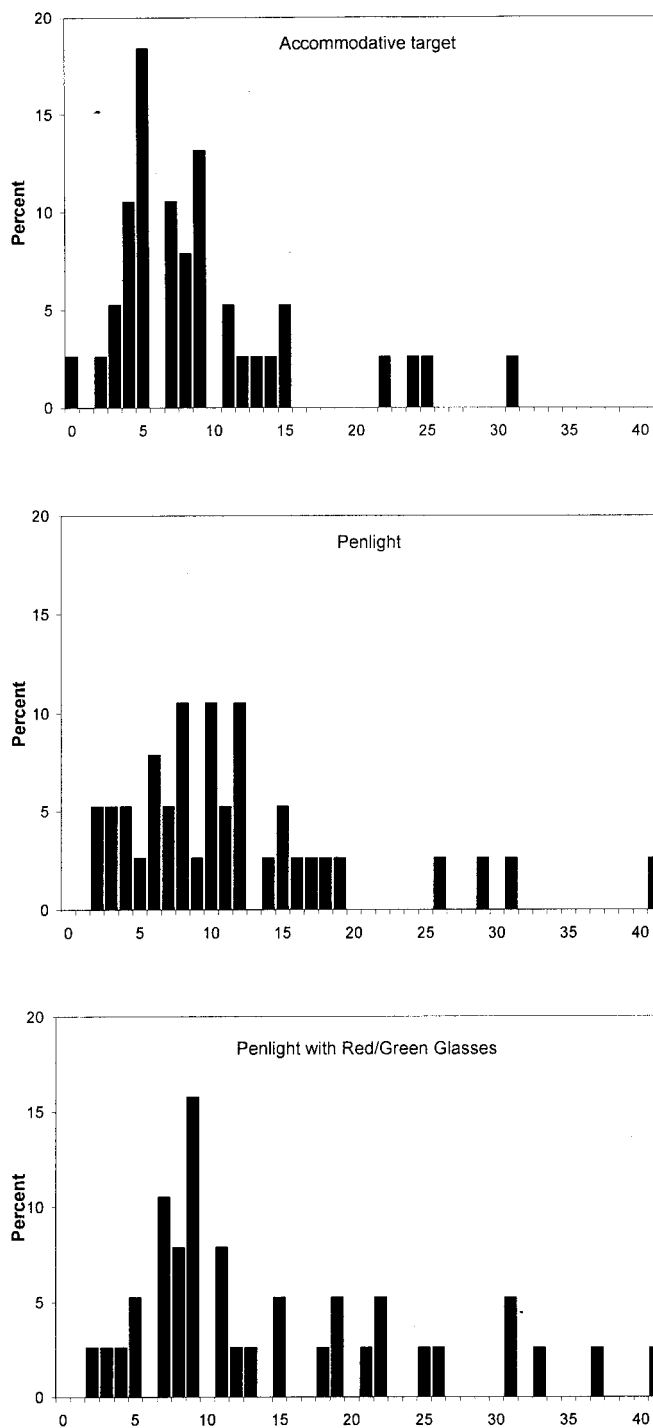


FIGURE 4. Distribution of nearpoint of convergence (NPC) break values for convergence insufficiency subjects by measurement method.

7a shows the change in mean NPC break over the 10 repeated measurements. According to the mixed model analysis, the mean NPC break increases from measurement one to measurement five (p value for slope < 0.0001) but then changes little from measurements six to 10 (p value for slope = 0.0865). The mean NPC recovery increased from 17.7 cm at measurement one to 21.9 at measurement 10 (Fig. 7b). The change, although not remarkable, was more dramatic from measurement one to three (p value for

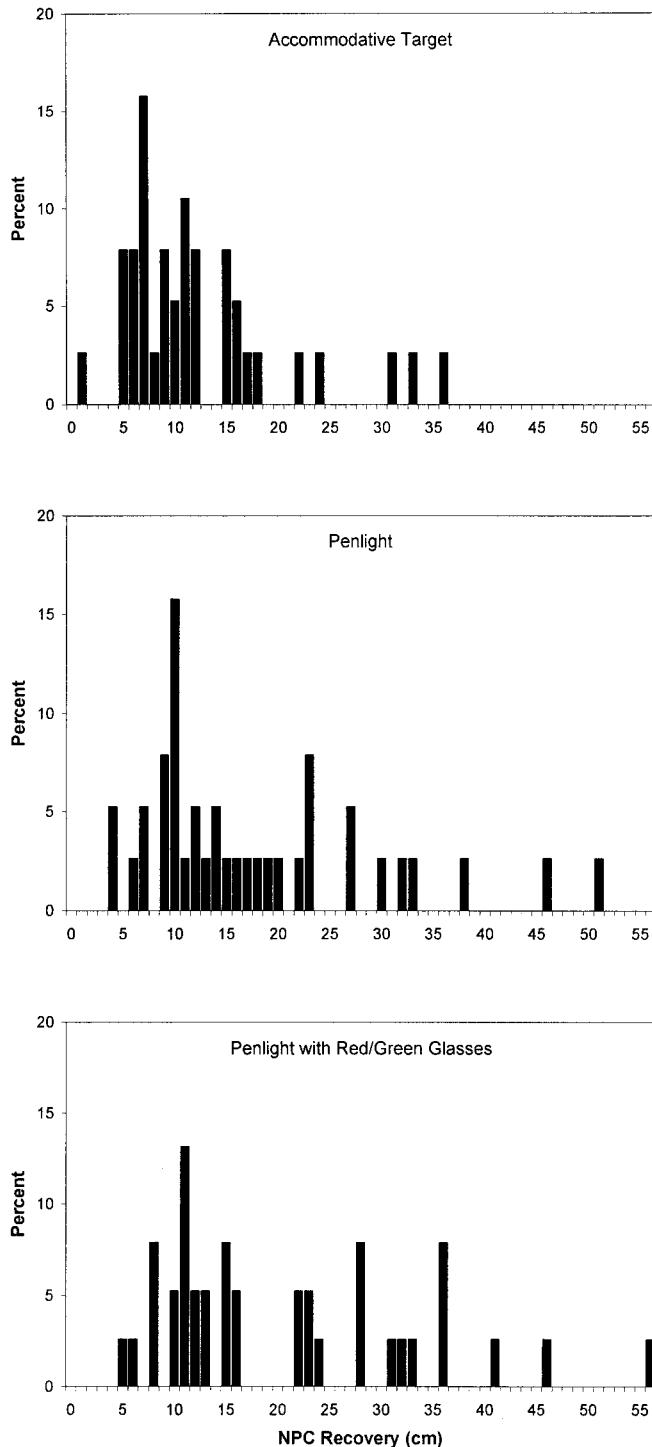


FIGURE 5. Distribution of nearpoint of convergence (NPC) recovery values for convergence insufficiency subjects by measurement method.

slope = 0.0298) than from measurement four to 10 (p value for slope = 0.2543).

There was little change in the NPC break values for normal subjects across the 10 measurements. The mean break was 2.2 at measurement one and 2.9 at measurement 10 (Fig. 8a). The mixed model analysis indicated that the small increase in mean break was consistent across the 10 repeated measurements. That is, unlike the

break value for CI subjects, the break values do not change more dramatically at early repeated measurements and then remain relatively constant. In contrast, there does appear to be an initial jump in the NPC recovery values for normal subject from measurement one to measurement two (p value for slope = 0.004), after which the values remain relatively constant (p value for slope = 0.4737). At measurement one the mean NPC recovery is 3.99 cm, but it increases to 4.49 cm at repeat two and is 5.3 cm at the last measurement (Fig. 8b).

Symptoms

On the eight-item symptom questionnaire, the lowest possible score was eight with a maximum of 40. The mean value for normal subjects was 13.06 (range, 8 to 32), and the mean for convergence insufficiency subjects was 22.03 (range, 9 to 32). This difference was statistically significant ($t = 11.80$, $p < 0.0001$). Correlations between symptoms and the NPC findings did vary with target selection. The highest correlation between symptom score and NPC finding ($r = 0.37$) was observed for NPC recovery performed with the PLRG (Table 4).

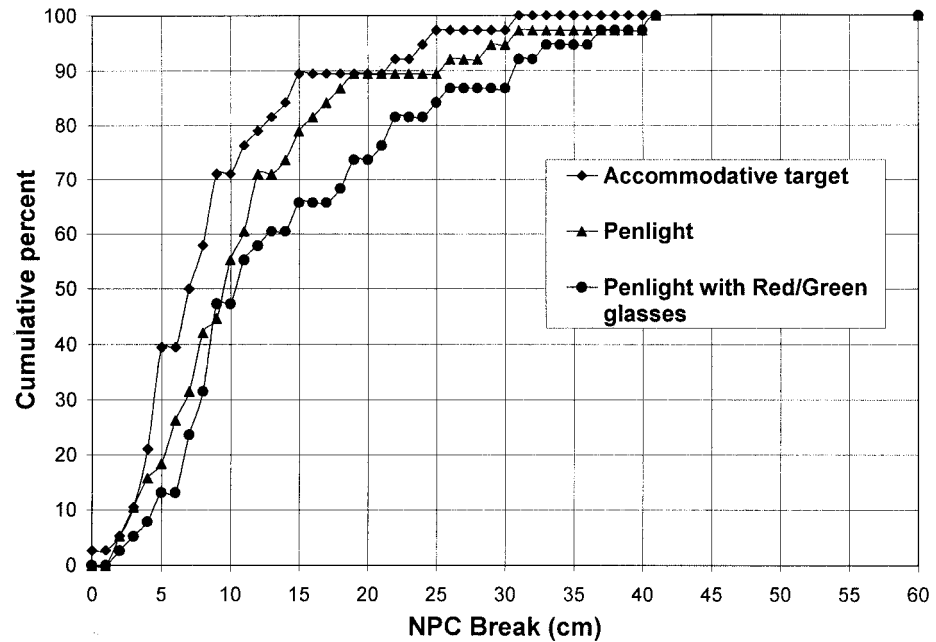
DISCUSSION

This study was designed to determine normative data for the NPC break and recovery in adult subjects, the most appropriate target(s) to be used for the assessment of the NPC, and the diagnostic value of commonly used modifications of the NPC. The distribution of NPC break values showed a concentration for all targets in the 0.5- to 5-cm range. The maximum break value observed with the AT was 7 cm, compared with 10 cm for PL and 11 cm for PLRG. Eighty-five percent of subjects had a break of ≤ 4.5 cm with all targets. In a previous study designed to determine normative values for children, Hayes et al.³³ suggested a clinical cutoff value of 6 cm. In their study, 85% of their subjects had a break of ≤ 6 cm. In our study, 98% of the subjects had a break of ≤ 6 cm with the AT, and 96% had a break of < 6 cm with the PLRG target. Using a similar criterion of 85%, we recommend a value of 4.5 cm. Because clinicians generally do measure the NPC break to the half-centimeter, we suggest rounding the clinical cutoff value for the NPC break to 5 cm.

For the NPC recovery, about 85% of subjects had a recovery of ≤ 7 cm with all targets. Thus, we recommend a clinical cutoff value of 7 cm for the NPC recovery. Others studies have used values ranging from 5 to 11 cm for the break and 8 to 11 cm for the recovery.^{1, 2, 7, 17-33} However, our finding of ≤ 5 cm as the expected break value for normal subjects compares favorably with the expected break value of ≤ 6 cm for children found by Hayes et al.³³

One of the questions we wanted to address was target selection. The results of this study suggest that clinical diagnosis can be made with any of the three targets, although the accommodative target appears to provide the best precision. When evaluating the NPC, we are trying to determine the patient's ability to converge using all aspects of convergence including fusional convergence, proximal convergence, and accommodative convergence. Because the use of an AT maximizes the accommodative demand and accommodative convergence, the NPC should, theoretically, be maximized with this type of target. Ciuffreda³⁸ recommended the use of an

NPC break



NPC recovery

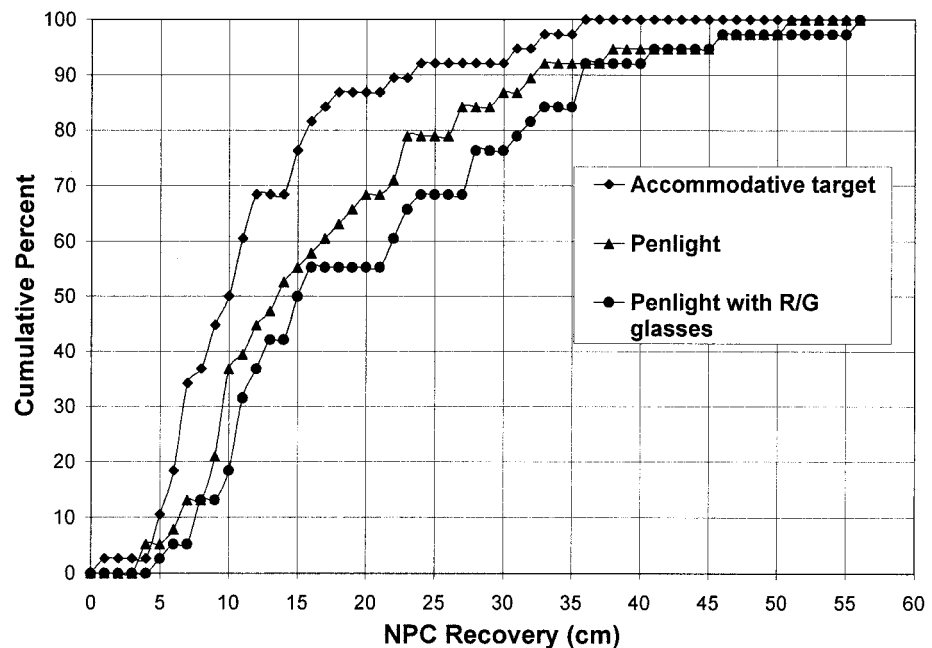


FIGURE 6.

Cumulative distribution of nearpoint of convergence (NPC) break and recovery for convergence insufficiency subjects by method of measurements. R/G, red and green.

AT for another reason. He found less variability in the NPC when measured with an AT vs. a PL. It is important to note, however, that our results suggest that to best discriminate the symptomatic CI, the PLRG break and recovery is most accurate.

In contrast to Ciuffreda's study, we used traditional, clinical evaluation tools, and in our normal group, and the differences among NPC measurements with various targets were statistically

significant but very small (<1 cm). Although they were statistically significant, due to a large sample size and the repeated-measures design, such differences are not clinically significant. The convergence insufficiency group showed very different results. For the break values in the convergence insufficiency group, statistically and clinically significant differences were found between the AT and the PLRG. For the recovery values, the differences between AT

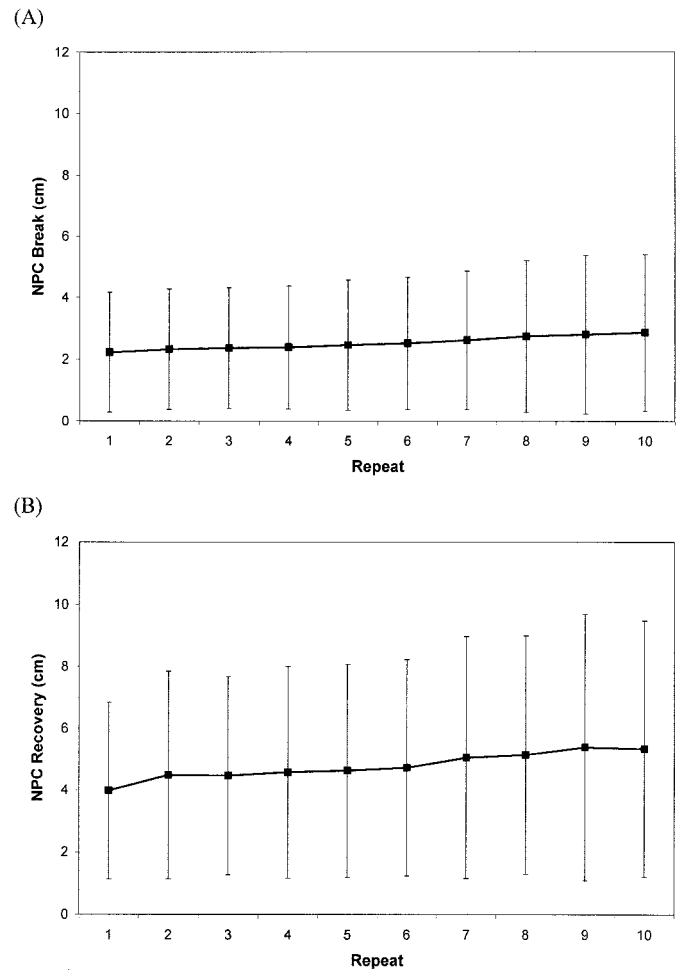
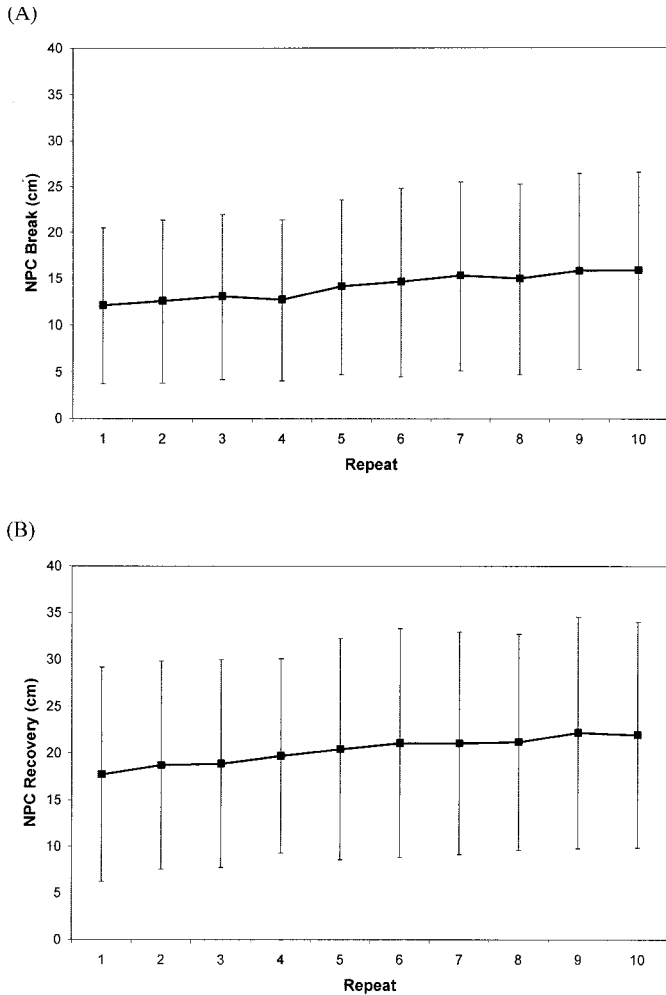


FIGURE 7. Mean nearpoint of convergence (NPC) break and recovery for convergence insufficiency subjects across repeated measurements. Each bar represents 1 SD.

FIGURE 8. Mean nearpoint of convergence (NPC) break and recovery for normal subjects across repeated measurements. Each bar represents 1 SD.

and PL as well as between AT and PLRG were clinically significant. There was also a statistically significant difference between the PL and PLRG, although the mean difference of 2.9 cm between the break with a PLRG and a PL may be too small to be clinically useful. The greatest differences between any two tests were 5.43 cm between the AT break and the PLRG break and 8.17 cm between the AT recovery and the PLRG recovery in the convergence insufficiency group.

Theoretically, the PLRG target not only minimizes the accommodative-convergence component, but also makes binocularity more difficult because of the dissociative factor created by the red and green glasses. Capobianco¹⁸ suggested that the use of two targets (AT followed by a PLRG) might allow clinicians to detect more subtle convergence insufficiency problems. Most clinicians have encountered situations in which diagnostic testing is equivocal, although the history suggests a clinical hypothesis of a binocular problem. The use of the PLRG target may be particularly useful in this situation. Our results suggest that in a patient with normal binocularity, there should be virtually no difference between the break and recovery findings when the NPC is performed with an AT or a PLRG. In this study, patients with convergence

insufficiency had a break that was >5 cm more receded with the PLRG and a recovery >8 cm more receded with the PLRG compared with the AT. Differences approaching these values should alert a clinician to the possibility of a subtle convergence insufficiency. Our data tend to support Capobianco's suggestion.

Of our 38 subjects with convergence insufficiency, 13 had an NPC that was within the expected range for both break and recovery using the AT alone. When the NPC was repeated with a PLRG, all 13 of these subjects were found to have a receded NPC. In 11 of the 13, the NPC was receded with the PL target, and all 13 of these subjects were found to have a receded NPC with the 10-repetition

TABLE 4. Correlations between symptoms and NPC variables for the convergence insufficiency group.^a

	AT Brk	AT Rec	PL-Brk	PL-Rec	PLRG-Brk	PLRG-Rec
Symptom score	r = 0.19	r = 0.21	r = 0.27	r = 0.35 ^b	r = 0.33 ^b	r = 0.37 ^b

^a NPC, nearpoint of convergence; AT, accommodative target; Brk, break; Rec, recovery; PL, penlight; PLRG, penlight while wearing red and green glasses.

^b p < 0.05.

procedure. Thus, the use of the PLRG target or repetition of the NPC appears to be important for the diagnosis of subtle cases of convergence insufficiency. Also, the highest correlation between symptoms and the type of target in this study was with the PLRG (Table 4).

The repetition modification of the NPC suggested by Davies¹⁷ also appears to be useful in the diagnosis of more subtle cases. A difference of more than 4 cm between the first and 10th repetition suggests a problem. Our data suggest that most of the change occurs from the first to the fifth repetition. However, because of the considerable amount of time required to perform the NPC even five times, this may not be the most practical method for detecting a subtle CI. The PLRG procedure requires less time and also enables the clinician to detect a subtle CI.

Based on these results, we suggest that the NPC should be routinely evaluated with an AT. If the NPC is normal, but there are other signs or symptoms of convergence insufficiency, or if the NPC is borderline (reduced break or recovery or a large difference between the two), the NPC should be repeated with a PLRG.

This study does have a number of limitations. First, the age range of adult subjects used to determine expected clinical values was limited to 22 to 37 years of age. Further investigation is necessary to determine whether our conclusions about normative data and test modifications can be applied to the presbyopic population. In addition, all of our adult subjects used to determine expected values were optometry students, and this may limit the applicability of these data to the general population.

ACKNOWLEDGMENT

Received January 12, 2001; revision received October 2, 2002.

REFERENCES

- Grosvenor TP. Primary Care Optometry: Anomalies of Refraction and Binocular Vision, 3rd ed. Boston: Butterworth-Heinemann, 1996.
- Carlson NB, Kurtz D, Heath DA, Hines C. Clinical Procedures for Ocular Examination. Norwalk, CT: Appleton & Lange, 1990.
- Amigo G, McCarthy A. The "Pooh Corner" vision study. *Am J Optom Physiol Opt* 1976;53:60–5.
- Wong SG. Comparison of vision screening performed by optometrists and nurses. *Am J Optom Physiol Opt* 1978;55:384–9.
- Werner DL, Field S. A mammoth vision screening: public relations and public service. *J Am Optom Assoc* 1982;53:731–7.
- Chernick B. The Seton Study: current concepts and research in vision screenings and child development. *J Optom Vis Dev* 1983;14:3–19.
- Cohen AH, Lieberman S, Stolzberg M, Ritty JM. The NYSOA vision screening battery: a total approach. *J Am Optom Assoc* 1983;54:979–84.
- Duane A. A new classification of the motor anomalies of the eye, based upon physiological principles. *Ann Ophthalmol* 1897;6:84–122, 247–60.
- Grisham JD. Visual therapy results for convergence insufficiency: a literature review. *Am J Optom Physiol Opt* 1988;65:448–54.
- Daum KM. Characteristics of convergence insufficiency. *Am J Optom Physiol Opt* 1988;65:426–38.
- Cooper J, Duckman R. Convergence insufficiency: incidence, diagnosis, and treatment. *J Am Optom Assoc* 1978;49:673–80.
- Daum KM. Convergence insufficiency. *Am J Optom Physiol Opt* 1984;61:16–22.
- Rouse MW, Borsting E, Hyman L, Hussein ME, Cotter SA, Flynn M, Scheiman M, Galloway M, and the Convergence Insufficiency and Reading Study Group (CIRS). Convergence insufficiency and reading ability among fifth and sixth graders. *Invest Ophthalmol Vis Sci* 1997;38:S975.
- Rouse MW, Hyman L, Hussein ME, and the Convergence Insufficiency and Reading Study Group (CIRS). How do you make the diagnosis of convergence insufficiency? survey results. *J Optom Vis Devel* 1997;28:91–97.
- Landolt E. Examination of the eyes. Huntington, NY: Robert E. Krieger, 1979.
- Duane A. A standard test-object for determining the near point and range of accommodation. *Ophthalmol Rec* 1909;18:358–60.
- Davies CE. Orthoptic treatment in convergence insufficiency. *Can Med Assoc J* 1946;55:47–9.
- Capobianco NM. The subjective measurement of the near point of convergence and its significance in the diagnosis of convergence insufficiency. *Am Orthop J* 1952;2:40–2.
- Carter DB. Optometric Examination: Multimedia Center, School of Optometry, University of California, 2nd Ed. Berkeley, CA: University of California, 1973.
- Duke-Elder, S. System of Ophthalmology, Vol. VI. Ocular Motility and Strabismus. London: Henry Kimpton, 1973.
- Burian HM, von Noorden GK. Binocular Vision and Ocular Motility: Theory and Management of Strabismus. St. Louis: Mosby, 1974.
- Hoffman LG, Rouse M. Referral recommendations for binocular function and/or developmental perceptual deficiencies. *J Am Optom Assoc* 1980;51:119–26.
- Mohindra I, Molinari J. Convergence insufficiency: its diagnosis and management - part 1. *Optom Monthly* 1980;71:155–60.
- Pickwell LD, Hampshire R. The significance of inadequate convergence. *Ophthalmic Physiol Opt* 1981;1:13–8.
- Shippman S, Infantino J, Cimbol D, Cohen KR, Wesely AC. Convergence insufficiency with normal parameters. *J Pediatr Ophthalmol Strabismus* 1983;20:158–61.
- London R. Vergence. In: Barresi BJ, ed. Ocular Assessment: the Manual of Diagnosis for Office Practice. Boston: Butterworths, 1984: 136–7.
- Helveston EM, Weber JC, Miller K, Robertson K, Hohberger G, Estes R, Ellis FD, Pick N, Helveston BH. Visual function and academic performance. *Am J Ophthalmol* 1985;99:346–55.
- Wick B. Horizontal deviations. In: Amos JF, ed. Diagnosis and Management in Vision Care. Boston: Butterworths, 1987:473.
- Pickwell D. Binocular Vision Anomalies: Investigation and Treatment. London: Butterworths, 1989.
- London R. Nearpoint of convergence. In: Eskridge JB, Amos JF, Bartlett JD, eds. Clinical Procedures in Optometry. Philadelphia: Lippincott, 1991:66–8.
- Eggers HM. Evaluation of ocular alignment and eye movements. In: Diamond GR, Eggers HM, eds. Strabismus and Pediatric Ophthalmology. St. Louis: Mosby, 1993: section 4.15.
- Griffin JR, Grisham JD. Binocular Anomalies: Diagnosis and Vision Therapy, 3rd ed. Boston: Butterworth-Heinemann, 1995.
- Hayes GJ, Cohen BE, Rouse MW, De Land PN. Normative values for the nearpoint of convergence of elementary schoolchildren. *Optom Vis Sci* 1998;75:506–12.
- Morgan MW. The clinical aspects of accommodation and convergence. *Am J Optom Arch Am Acad Optom* 1944;21:301–13.
- Zellers JA, Alpert TL, Rouse MW. A review of the literature and a

- normative study of accommodative facility. *J Am Optom Assoc* 1984; 55:31–7.
36. Cooper J, Selenow A, Ciuffreda KJ, Feldman J, Faverty J, Hokoda SC, Silver J. Reduction of asthenopia in patients with convergence insufficiency after fusional vergence training. *Am J Optom Physiol Opt* 1983;60:982–9.
37. Borsting E, Rouse MW, De Land PN, and the Convergence Insufficiency and Reading Study (CIRS) Group. Prospective comparison of convergence insufficiency and normal binocular children on CIRS symptom surveys. *Optom Vis Sci* 1999;76:221–8.
38. Ciuffreda, KJ. Near point of convergence as a function of target accommodative demand. *Opt J Rev Optom* 1974;111:9–10.

Mitchell Scheiman

*Pennsylvania College of Optometry
1200 West Godfrey Ave
Philadelphia, PA 19141
e-mail: mscheiman@pco.edu*