HHS Public Access

Author manuscript

Ophthalmic Physiol Opt. Author manuscript; available in PMC 2023 September 29.

Published in final edited form as:

Ophthalmic Physiol Opt. 2022 January ; 42(1): 59–70. doi:10.1111/opo.12911.

Does coexisting accommodative dysfunction impact clinical convergence measures, symptoms, and treatment success for symptomatic convergence insufficiency in children?

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Abstract

Purpose: To determine whether coexisting accommodative dysfunction in children with symptomatic convergence insufficiency (CI) impacts presenting clinical convergence measures, symptoms, and treatment success for CI.

Methods: Secondary data analyses of monocular accommodative amplitude (AA; push-up method), monocular accommodative facility (AF; ±2.00D lens flippers), and symptoms (CI Symptom Survey [CISS]) in children with symptomatic CI from the Convergence Insufficiency Treatment Trial (N=218) and CITT-Attention and Reading Trial (N=302) were conducted. Decreased AA was defined as more than 2D below the minimum expected amplitude for age (15 - ¼ age); those with AA<5D were excluded. Decreased AF was defined as <6 cycles per minute. Mean near point of convergence (NPC), near positive fusional vergence (PFV), and symptoms (CISS) were compared between those with and without accommodative dysfunction using analysis of variance and independent samples t-testing. Logistic regression was used to compare the effect of baseline accommodative function on treatment success [defined using a composite of improvements in 1) clinical convergence measures and symptoms (NPC, PFV, and CISS scores) or 2) solely convergence measures (NPC and PFV)].

Results: Accommodative dysfunction was common in children with symptomatic CI (55% had decreased AA; 34% had decreased AF). NPC was significantly worse in those with decreased AA (mean difference=6.1cm; P<.001). Mean baseline CISS scores were slightly worse in children with coexisting accommodative dysfunction (decreased AA or AF) (30.2 points) than those with

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normal accommodation (26.9 points) (mean difference=3.3 points; P<.001). Neither baseline accommodative function (P≥.12 for all) nor interaction of baseline accommodative function and treatment (P≥.5) were related to treatment success based on the two composite outcomes.

Conclusions: A coexisting accommodative dysfunction in children with symptomatic CI is associated with worse NPC, but it does not impact the severity of symptoms in a clinically meaningful way. Concurrent accommodative dysfunction does not impact treatment response for CI.

Keywords

Ocular Accommodation; Convergence Insufficiency; Symptoms; Accommodative Insufficiency; Accommodative Facility; Children

Mutual interactions between vergence and accommodation are well known,[1,2] and it is commonly accepted that patients often have concurrent dysfunction in both systems.[3–9] Clinically, convergence insufficiency and accommodative dysfunction are associated with symptoms that occur when reading or performing other near work, such as blurred vision, headaches, asthenopia, frequent loss of place, or poor concentration.[3,4,10–23] The impact of coexisting accommodative dysfunction on clinical convergence measures (near point of convergence and/or positive fusional vergence) has been investigated previously, but only in small numbers of patients with coexisting convergence and accommodative insufficiency.[24,25] Controversy exists regarding the relative contribution of convergence insufficiency and accommodative insufficiency to patient symptoms when concurrently present.[24,26,27] Vergence/accommodative therapy has been shown to be effective in improving the clinical convergence measures and accommodation (amplitude, facility) in children with symptomatic convergence insufficiency.[6,7,25,28–32] However, the impact of associated accommodative dysfunction on treatment response for convergence insufficiency is unknown. This study used data from two large clinical trials and investigated whether the presence of accommodative dysfunction (decreased accommodative amplitude and/or accommodative facility) in children with symptomatic convergence insufficiency was associated with the severity of presenting clinical convergence measures, symptoms, and/or treatment success.

Methods

This study was a secondary analysis of prospectively collected accommodative measures (amplitude and facility), convergence measures (near point of convergence and positive fusional vergence at near), and symptoms (CI Symptom Survey [CISS]) from two large randomized clinical trials - the Convergence Insufficiency Treatment Trial (CITT)[34] and Convergence Insufficiency Treatment Trial – Attention and Reading Trial (CITT-ART).[33] Both studies followed the tenets of the Declaration of Helsinki, and the institutional review boards of all participating centers approved the protocol and informed consent forms. The parent or guardian of each study participant provided written informed consent and Health Insurance Portability and Accountability Act (HIPAA) authorization, and each participant provided written assent. An independent data and safety monitoring committee provided

oversight. These studies are registered at ClinicalTrials.gov under identifiers NCT00338611 and NCT02207517.

Participants

Major eligibility criteria in the CITT and the CITT-ART included: near exophoria at least 4Δ greater than at distance, a receded near point of convergence break (≥6 cm), and insufficient positive fusional vergence at near (i.e., failing Sheard's criterion[34] [positive fusional vergence less than twice the near phoria] or positive fusional vergence break value of ≤15Δ); a CISS score of ≥16; and a monocular amplitude of accommodation of ≥5.00 diopters (D).[33,35] Children with an amplitude of accommodation <5.00 D were excluded because of prior reports of poor treatment outcomes in children with severe accommodative insufficiency.[25,36] Participants were ages 9 to <18 years in the CITT and 9 to <15 years in the CITT-ART. The complete listings of eligibility and exclusion criteria for each study have been published previously.[33,35]

Assessment of Accommodative Function and Symptoms

The clinical procedures for the assessment of accommodative amplitude, accommodative facility, clinical convergence measures (near point of convergence and near positive fusional vergence), and symptoms (CISS) have been described previously in detail.[6,33,35] Briefly, a printed Gulden fixation target (Gulden Ophthalmics, Elkins Park, PA) consisting of a single column of 20/30 letters was used for all assessments of accommodation and convergence. All measurements were made with participants wearing their habitual optical corrections.

Amplitude of accommodation was measured monocularly in the right eye by the push-up method. The participant was asked to keep the letters clear as long as possible. The examiner moved the target toward the participant at approximately 1 to 2 cm/sec using a sliding near point rule (Gulden Ophthalmics, Elkins Park, PA). When blur was reported, the examiner stopped moving the target and asked if the letters remained blurry or became clear. If the letters became clear, the examiner continued moving the target until the participant reported sustained blur. The distance at which first sustained blur was reported was measured to the nearest half-centimeter and then converted into diopters.

Monocular accommodative facility was measured in the right eye only. The speed at which the participant reported seeing the single column of 20/30-sized letters clearly at 40cm while alternately looking through +2.00D and −2.00D lenses in one minute was measured in cycles per minute. One cycle was the ability to clear the plus lens followed by the minus lens.

To measure near point of convergence break, the examiner moved the target toward the participant at approximately 1 to 2 cm/sec using a sliding near point rule. The participant was asked to keep the letters single as long as possible but to report when the letters doubled or broke into two. When diplopia was reported, the examiner stopped moving the target and asked if the letters remained double or became single. If the letters became single, the examiner continued moving the target closer to the participant until the participant reported sustained diplopia. The distance (to the nearest half-centimeter) at which sustained diplopia

was reported (or loss of fusion was observed by the examiner) was recorded as the break value.

Positive fusional vergence was measured using a horizontal prism bar (B-16, Gulden Ophthalmics, Elkins Park, PA). The participant was asked to report when the letters became blurred or double, but to try to keep the target single as long as possible as the magnitude of base-out prism was increased at approximately 2 prism diopters/second. At each prism increment, the examiner confirmed that the target was “single and clear” or once blurred, that the target was “single.” When diplopia was reported, the examiner stopped increasing the prism and asked if the letters remained double or became single. If the letters became single, the examiner continued increasing the prism until the participant reported sustained diplopia. The magnitude of prism at which blur and break were reported (or the examiner observed loss of fusion) was recorded.

Symptoms were assessed using the CISS.[11,12] Each of the 15 questions was read verbatim to the participant, who selected among five response options (never, not very often, sometimes, often, always) using a response card. Responses of never, not very often (infrequently), sometimes, fairly often, and always were scored as 0 through 4, respectively. Thus, the participant-reported symptom scores could range from 0 to 60 points.

Treatment

In the CITT, participants were randomly assigned to a 12-week program of office-based placebo therapy or one of three active treatments – office-based vergence/accommodative therapy, home-based pencil push-ups, or home-based computer-based vergence/accommodative therapy and pencil push-ups. Details of the treatment protocols can be found at https://u.osu.edu/citt/. CITT-ART participants were randomly assigned in a 2:1 ratio to a 16-week program of office-based vergence/accommodative or office-based placebo therapy. Treatment protocol details can be found at https://u.osu.edu/cittart/.

Briefly, office-based therapy was administered by a therapist during weekly, 60-minute office visits with home therapy prescribed to be performed for 15 minutes per day, 5 days per week. The office-based vergence/accommodative therapy consisted of a specific sequence of standard vergence and accommodative procedures. The office-based placebo therapy group received a sequence of placebo therapy procedures designed to look like real vergence/accommodative therapy, but not to stimulate vergence, accommodation, or fine saccadic eye movements beyond usual near activities. The home-based pencil push-ups group (CITT study only) was prescribed pencil push-ups using 20/60 reduced Snellen letters on a pencil as the target for 15 minutes per day, 5 days per week. Those assigned to home-based computer vergence/accommodative therapy and pencil push-ups therapy (CITT study only) performed fusional vergence and accommodative therapy procedures using the Home Therapy System (HTS/CVS) (www.visiontherapysolutions.com) computer software (performed throughout the therapy program or until the therapy goals were met) and pencil push-ups 5 minutes per day, 5 days a week.

Definitions for Accommodative Dysfunction (Decreased Amplitude of Accommodation, Decreased Accommodative Facility) and Treatment Success for Symptomatic Convergence Insufficiency

Consistent with prior studies of symptoms in accommodative and convergence insufficiency, decreased amplitude of accommodation was defined as monocular amplitude of accommodation that was more than 2D below the minimum expected amplitude based on the participant's age (15 - ¼ age).[6,24,26,37,38] Decreased accommodative facility was defined as <6 cycles per minute, which is 1 SD below the normative value of 11 cpm for school-age children.[6,7,39,40]

Treatment success for all groups was determined using two composite outcomes. The first composite outcome was comprised of both clinical convergence measures (NPC and PFV) and symptoms, while the second composite outcome only consisted of the clinical convergence measures. There were three possible outcomes ("successful," "improved," or "failure)" for the first composite outcome (convergence and symptoms). "Successful" was defined as meeting normal levels for each measure (near point of convergence break <6 cm, positive fusional vergence greater than 15Δ and meeting Sheard's criterion, and CISS score <16). "Improved" was a CISS score of <16 *or* a ≥10-point decrease in score, *and* at least one of the following: normal near point of convergence (<6 cm), improvement in near point of convergence of ≥ 4 cm, normal positive fusional vergence (>15Δ and passing Sheard's criterion), or an increase in positive fusional vergence of ≥ 10Δ. Those who did not meet "successful" or "improved" criteria met the "failure" category. For the second composite outcome (convergence measures only), both a normal near point of convergence *and* normal positive fusional vergence were required to be classified as a success; otherwise it was a failure.

Statistical Methods

All data were analyzed using SAS software, version 9.4 (SAS Inc., Cary, NC). Analyses were limited to participants from CITT and CITT-ART with complete outcome data at the final visit (CITT = 218 and CITT-ART = 302). Independent samples t tests were performed to compare mean differences in presenting (at study entry) near point of convergence break values, positive fusional vergence blur findings (break if no blur), and CISS scores between those with and without decreased accommodative function (decreased amplitude or facility). To assess whether there were differences in presenting near point of convergence, positive fusional vergence, or CISS findings by the presence of accommodative dysfunction (none, either decreased accommodative amplitude or facility, or both), an ANOVA of each variable was performed. T tests of mean differences for each item were performed to explore whether CISS score differences were present at the item level. For pairwise comparisons of the three accommodative function groups (none, one, or both) and CISS item testing, p values were adjusted for multiple comparisons using the Holm–Bonferroni stepdown method.[41] For the analyses of presenting clinical convergence measures (near point of convergence, positive fusional vergence) and CISS scores, the findings at study entry from the CITT and CITT-ART were combined.

Logistic regression models were used to examine the effect of baseline accommodative function (age-normal or decreased amplitude or facility) and treatment on the composite outcomes of 1) clinical convergence measures (near point of convergence, positive fusional vergence) and symptoms (CISS score) and 2) the clinical convergence measures only. The regressions modeled the odds of a successful or improved outcome. Model predictors were treatment group, baseline accommodative function, and the interaction of baseline accommodative function and treatment. The regressions used data from all treatment groups. Because these analyses were not limited to baseline data, separate analyses were performed for CITT and CITT-ART.

Results

Of the 520 participants in the two studies at baseline, a decreased amplitude of accommodation was present in 55% (CITT:55%; CITT-ART:55%) and decreased accommodative facility was present in 39% (CITT:46%; CITT-ART:34%) of participants (see Tables 1 and 2).

Is Associated Accommodative Dysfunction (Decreased Accommodative Amplitude or Facility) Related to Severity of Presenting Clinical Convergence Measures (Near Point of Convergence or Positive Fusional Vergence values) in Children with Convergence Insufficiency?

Mean near point of convergence was significantly more receded in the group with a decreased amplitude of accommodation (17cm) than in those with an age-normal amplitude of accommodation (10.9cm) (mean difference 6.1cm; P<.001) (Table 3). A large effect size (.85) as measured by Cohen's d[42,43] was associated with the 6.1 cm difference in near point of convergence. Mean near point of convergence was also more receded in those with decreased accommodative facility (15.2cm) than in those with normal accommodative facility (13.7cm) (mean difference 1.5cm; P=.03), but the effect size was small (.20). Positive fusional vergence was significantly lower (worse) in those with accommodative dysfunction than in those without, with a moderate effect size (.4) for decreased accommodative amplitude and a small effect size (.21) for decreased accommodative facility, although the mean differences were less than 2Δ (Table 3).

Clinical convergence measures (near point of convergence, positive fusional vergence) were worse for those with either decreased amplitude or facility as compared to those with no accommodative dysfunction. In addition, those with both decreased amplitude and facility had worse clinical convergence measures than those with no accommodative dysfunction or those with only one type of accommodative dysfunction (P≤.03 for all comparisons) (Table 4).

Is Associated Accommodative Dysfunction (Decreased Accommodative Amplitude or Facility) Related to Presenting Symptoms in Children with Convergence Insufficiency?

Mean CISS scores in those with versus without decreased accommodative amplitude were 30.9 and 27.9 points, respectively (mean difference of 3.0 points; 95% CI: 1.5, 4.4; P<.001). Mean CISS scores in those with versus without decreased accommodative

facility, respectively, were 30.9 and 28.7 points (mean difference of 2.2 points; 95% CI: 0.7, 3.7; P=.006) (Table 3). Mean CISS score in participants with either accommodative dysfunction (decreased accommodative amplitude or decreased accommodative facility) was 30.2 compared with 26.9 in those with no accommodative dysfunction (mean difference of 3.3 points; 95% CI: 1.6, 5.1; P<.001). The mean CISS score in those with both types of accommodative dysfunction (31.4) was not significantly different from those with either accommodative dysfunction (30.2) (mean difference of 1.2 points; 95% CI: −0.7, 3.0; P=0.21) (Table 4).

Tables 5 and 6 show the mean responses for each of the 15 CISS items at study entry for those with versus without decreased accommodative amplitude (Table 5) and decreased accommodative facility (Table 6) in CITT and CITT-ART. Compared with the group with age-normal accommodative amplitude, the group with decreased accommodative amplitude reported a significantly higher mean frequency of the following symptoms: 1) having double vision, 2) seeing the words move, jump, swim or appear to float on the page, and 3) noticing words blurring or coming in and out of focus (mean differences of 0.5 to 0.6 points; $p < .001$ for each comparison) (Table 5). On average, symptoms of double vision or blurred vision were reported to occur infrequently to sometimes in those with age-normal accommodative amplitude, and sometimes to fairly often in those with decreased amplitude of accommodation. Symptoms of words moving were reported infrequently to sometimes in those with or without decreased accommodative amplitude. There were no significant differences in the mean reported frequency of other symptom items ($p \geq 0.11$ for all 12 comparisons) (Table 5). Only the mean reported frequency of eyes feeling tired (p=0.049) was significantly different for the group of children with versus without decreased accommodative facility (Table 6).

Regardless of whether or not an accommodative dysfunction was present, the most frequently reported symptoms when reading or doing near work were having to re-read, loss of place, and loss of concentration. Other commonly reported symptoms when reading or doing near work included trouble remembering what was read, feeling sleepy, feeling as if reading slowly, eyes feeling tired, words blurring, and double vision.

Did the presence of accommodative dysfunction affect treatment success?

Logistic regressions to evaluate whether the presence of accommodative dysfunction had an effect on treatment success showed no significant interaction between the presence of accommodative dysfunction (decreased amplitude or facility) and treatment (all $p \geq .35$). In addition, baseline accommodative function did not have a statistically significant effect on treatment success for any treatment group (all $p \geq .12$). The only effect with statistical significance in these models was assigned treatment, with the office-based vergence/accommodative therapy group having significantly greater success (all $p \leq .005$).

Discussion

A coexisting accommodative dysfunction (reduced accommodative amplitude or facility) was commonly present in the children with symptomatic convergence insufficiency enrolled in the CITT and CITT-ART studies. The observation that decreased amplitude

of accommodation often accompanies convergence insufficiency has been reported in other studies as well.[3–5,8]

A decreased amplitude of accommodation was associated with a significantly more receded near point of convergence on average, with a large effect size as measured by Cohen's d.[42,43] Decreased accommodative facility was also associated with a slightly more receded near point of convergence. Decreased amplitude and facility were also associated with somewhat lower (worse) positive fusional vergence ranges on average. Prior studies have reported a more receded near point of convergence[24,25] and slightly lower positive fusional vergence measures[24] in those with convergence insufficiency and coexisting accommodative insufficiency, although these studies included small numbers of participants. To our knowledge, prior studies have not investigated the effect of reduced accommodative facility on near point of convergence or positive fusional vergence.

Symptom scores in those with or without coexisting accommodative dysfunction were similarly high. The frequency of double vision, noticing words blurring or coming in and out of focus, and seeing words move, jump, swim or appear to float on the page was greater in children with decreased accommodative amplitude compared with children with age-normal accommodative amplitude. This is consistent with a report by Borsting and colleagues who noted that college students with visual discomfort may have specific types of symptoms, including text movement and fading, soreness and headaches, and diplopia and blur, based on their factor analysis.[44] It could be that a decreased amplitude of accommodation has a unique contribution to the type of symptoms in children with convergence insufficiency. To our knowledge, prior studies have not investigated the impact of coexisting decreased accommodative facility on presenting symptoms in children with convergence insufficiency.

The present findings are contrary to those from a prior study that reported accommodative insufficiency to be the main cause of symptoms in children with symptomatic convergence insufficiency.[24] The authors reported that participants with convergence insufficiency and no accommodative insufficiency (N=44) had a mean CISS score of 12.9 and those with coexisting convergence and accommodative insufficiency (N=10) had a mean CISS score of 22.8.[24] These CISS scores are much lower (better; less symptomatic) than those found in the present study where children with convergence insufficiency with age-normal accommodation had a mean score of 26.9 and those with coexisting convergence and accommodative insufficiency had a mean score of 30.9. The difference in findings between the studies is likely due to methodologic differences between the studies, with the most important being that the prior study used different diagnostic criteria for convergence insufficiency and administered the CISS using a non-validated method. Furthermore, their small sample size could have contributed to the difference in the results.[27] Our study results clearly show that the presence of an accommodative dysfunction is not necessary for symptoms to be significant in a child with convergence insufficiency. While the mean symptom scores for the children with a coexisting accommodative dysfunction were 2–3 points worse than those of children with convergence insufficiency alone, the differences were not clinically meaningful, with small effect sizes (Cohen's d[42,43]).

The presence of an initial coexisting accommodative dysfunction was not found to be related to treatment outcome for convergence insufficiency. Regardless of baseline accommodative function, the proportion of participants with a successful or improved outcome was significantly greater in the office-based vergence/accommodative therapy group than the other treatment groups. Thus, a coexisting accommodative dysfunction (decreased amplitude [>2D below Hofstetter's minimum age-expected values, but at least 5D] and/or decreased facility [<6 cpm]) does not appear to impact the treatment of symptomatic convergence insufficiency. Prior reports have suggested that an accompanying decreased amplitude of accommodation may represent a more severe presentation of convergence insufficiency and thus may be less responsive to treatment.[25,36] Von Noorden, Brown and Parks[25] (N=9) and Matsuo and Ohtsuki[45] (N=9) reported that very poor amplitudes of accommodation (less than 4D and less than 2D, respectively), were associated with poor treatment outcomes for convergence insufficiency. On the other hand, Mazow et al. reported improvements in symptoms and convergence in patients (N=26) with convergence insufficiency and associated accommodative insufficiency (mean amplitude of accommodation 3D to 6D less than age-normal according to Duane's norms), although patients were treated using a combination of convergence exercises and plus lenses.[46] The study data reported herein from our large cohort of children (N= 520) suggest that accommodative insufficiency (with amplitude of accommodation of at least 5D) or infacility does not impact the treatment success for convergence insufficiency. To our knowledge, no prior studies have investigated the impact of coexisting decreased accommodative facility on treatment success for convergence insufficiency.

Strengths of this study include that the data are from prospective randomized clinical trials that had standardized treatment protocols, examiner masking, and excellent follow-up.[30,47,48] A limitation is that our results cannot be generalized to children with convergence insufficiency who have an amplitude of accommodation less than 5.00 D. Such children had been purposely excluded based on prior reports in the literature[25,36] and clinical opinion of poor treatment outcomes in such children. Nevertheless, we can conclude that children with symptomatic convergence insufficiency with decreased accommodative amplitudes of at least 5.00 D have a similar severity of symptoms and response to treatment regardless of their accommodative function. CITT and CITT-ART were not specifically designed to answer whether an associated accommodative dysfunction affects the clinical convergence measures, symptoms, or response to treatment for symptomatic convergence insufficiency. However, the inclusion of participants with both normal and decreased accommodation allowed us to evaluate the effect of accommodative dysfunction.

Conclusion

A coexisting accommodative dysfunction in children with symptomatic convergence insufficiency was associated with a worse near point of convergence, but did not impact the severity of symptoms in a clinically meaningful way. In addition, the presence of a concurrent accommodative dysfunction did not impact treatment response for convergence insufficiency in children.

Funding/Support:

This work was supported by National Eye Institute of National Institutes of Health, Department of Health and Human Services. The funding organization had no role in the design or conduct of this research.

CITT: EY014713, EY014659, EY014716, EY014715, EY014709, EY014710, EY014676, EY014706, EY014712

(grant number 5U10EY022599 to MMS, 5U10EY022601 to GLM, 5U10EY022595 to SC, 5U10EY022592 to MK, 5U10EY022586 to ES, 5U10EY022600 to RH, 5U10EY022587 to MG, 5U10EY022596 to RC, 5U10EY022594 to KH, and 5U10EY022591 to ST).

ACKNOWLEDGEMENTS

The Convergence Insufficiency Treatment Trial – Attention & Reading Trial Investigator Group Clinical Sites

Sites are listed in order of the number of participants enrolled in the study, with the number enrolled listed in parentheses preceded by the clinical site name and location. Personnel are listed as (PI) for principal investigator, (SC) for coordinator, (ME-ART) for masked examiner or attention and reading testing, (ME-VIS) for masked examiner for visual function testing, (VT) for vision therapist, and (UnM) for unmasked examiners for baseline testing.

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KEY POINTS

1. A coexisting accommodative dysfunction (reduced accommodative amplitude or facility) was commonly present in children with symptomatic convergence insufficiency.
2. Reported symptoms were similarly high in children with symptomatic convergence insufficiency with or without coexisting accommodative dysfunction.
3. The presence of a coexisting accommodative dysfunction did not significantly change the response to treatment in children with symptomatic convergence insufficiency.

Table 1.

Number (percentage) of participants with coexisting convergence insufficiency and accommodative dysfunction within each treatment group in CITT at study entry.

	Office-based		Home-based		Overall (n=218)
Type of Accommodative Dysfunction	**Vergence/ Accommodative n (%)**	**Placebo n (%)**	**Pencil Push-ups n (%)**	**Computer-based Vergence/ Accommodative & Pencil Push-ups n (%)**	
Decreased Amplitude *	35 (59.3%)	28 (51.9%)	27 (50.9%)	29 (55.8%)	119 (54.6%)
Decreased Facility **	23 (39%)	26 (48.1%)	22 (41.5%)	30 (57.7%)	101 (46.3%)
Either Decreased Amplitude or Facility	42 (71.2%)	39 (72.2%)	38 (71.7%)	43 (82.7%)	162 (74.3%)

* more than 2D below the minimum expected amplitude for age (15 - ¼ age)

** less than 6 cycles per minute

Table 2.

Number (percentage) of participants with coexisting convergence insufficiency and accommodative dysfunction within each treatment group in CITT-ART at study entry.

Type of Accommodative Dysfunction	Office-based Vergence/Accommodative n (%)	Office-based Placebo n (%)	Overall (n=302) n (%)
Decreased Amplitude *	104 (52.5%)	63 (60.6%)	167 (55.3%)
Decreased Facility **	67 (33.8%)	37 (35.6%)	104 (34.4%)
Either Decreased Amplitude or Facility	130 (65.7%)	72 (69.2%)	202 (66.9%)

*more than 2D below the minimum expected amplitude for age (15 - ¼ age)

**less than 6 cycles per minute

Table 3.

Mean differences in Near Point of Convergence, Positive Fusional Vergence, and CI Symptom Survey (CISS) score at study entry for participants with and without accommodative dysfunction in both the CITT and CITT-ART studies.

		Convergence Measures and CISS Scores by Accommodative Function Status						
		Decreased Accommodative Function**		Age-normal Accommodative Function				
Measure	Accommodative Measure	N	Mean (SD)	N	Mean (SD)	Difference Between Means (95% CI)	P Value*	Cohen's d
Near point of convergence (cm)	Amplitude	286	17 (8.2)	234	10.9 (5.8)	6.1 (4.9, 7.4)	<.001	0.85
	Facility	205	15.2 (8.3)	315	13.7 (7.4)	1.5 (0.2, 2.9)	0.03	0.2
Positive fusional vergence (Δ)	Amplitude	286	10.5 (4)	234	12.1 (4)	−1.6 (−2.3, −0.9)	<.001	0.4
	Facility	205	10.7 (4)	315	11.6 (4)	−0.9 (−1.6, −0.2)	0.02	0.21
CISS Score	Amplitude	286	30.9 (8.9)	234	27.9 (8.2)	3 (1.5, 4.4)	<.001	0.34
	Facility	205	30.9 (8.8)	315	28.7 (8.5)	2.2 (0.7, 3.7)	0.006	0.25

*The p values are for independent samples t tests of mean differences.

**Decreased accommodative amplitude was more than 2D below the minimum expected amplitude for age (15 - ¼ age); Decreased accommodative facility was less than 6 cycles per minute

Table 4.

Mean NPC (Near Point of Convergence), PFV (Positive Fusional Vergence), and CI Symptom Survey (CISS) score at study entry for participants in the CITT and CITT-ART studies by accommodative function (both decreased amplitude and facility; one (either) type of dysfunction; neither accommodative dysfunction).

	Accommodative Function (Status of AA and AF)				Decreased AA *or* AF compared to age-normal accommodation		Decreased AA *and* AF compared to age-normal accommodation		Decreased AA *and* AF compared to Decreased AA *or* AF	
Measure	**Both AA *and* AF Decreased (N=127) Mean (SD)**	**Either AA *or* AF Decreased (N=237) Mean (SD)**	**Age-normal accommodation (N=156) Mean (SD)**	**P Value***	**Mean Difference (95% CI)**	**P Value****	**Mean Difference (95% CI)**	**P Value****	**Mean Difference (95% CI)**	**P Value****
NPC (cm)	17.8 (8.6)	14.6 (7.6)	10.9 (5.9)	<.001	3.6 (2.1,5.1)	<.001	6.9 (5.2,8.7)	<.001	3.3 (1.7,4.9)	<.001
PFV (Δ)	10.1 (4.1)	11.2 (3.8)	12.3 (4.1)	<.001	−1.1 (−1.9,−0.3)	0.03	−2.2 (−3.1,−1.3)	<.001	−1.1 (−2,−0.3)	0.03
CISS Score	31.4 (8.9)	30.2 (8.8)	26.9 (7.9)	<.001	3.3 (1.6,5.1)	<.001	4.5 (2.5,6.5)	<.001	1.2 (−0.7,3)	0.21

*The p value from an ANOVA testing for mean differences is displayed after the group means.

**The p values for the group comparisons have been corrected for multiple testing using the Holm–Bonferroni stepdown method.

Decreased accommodative amplitude = more than 2D below the minimum expected amplitude for age (15 - ¼ age); Decreased accommodative facility = less than 6 cycles per minute. Age normal accommodation = Neither AA or AF Decreased

Table 5.

Item-level differences on the Convergence Insufficiency Symptom Survey between participants with convergence insufficiency with and without a coexisting decreased amplitude of accommodation at study entry

Convergence Insufficiency Symptom Survey	Decreased Accommodative Amplitude?			
	No	Yes		
Item	Mean (SD)	Mean (SD)	Corrected p Value*	Cohen's d
1. Do your eyes feel tired?	2 (0.9)	2.3 (1)	.11	.25
2. Do your eyes feel uncomfortable?	1.7 (1)	1.9 (1)	.99	.14
3. Do you have headache?	1.8 (1.2)	1.9 (1.2)	.99	.12
4. Do you feel sleepy?	2.1 (1.1)	2.2 (1.1)	.99	.04
5. Do you lose concentration?	2.3 (1)	2.6 (0.9)	.4	.21
6. Do you have trouble remembering what you have read?	2.2 (1.1)	2.1 (1.2)	.99	.06
7. Do you have double vision?	1.6 (1.2)	2.2 (1.2)	<.001	.49
8. Do you see the words move, jump, swim or appear to float on the page?	1.1 (1.2)	1.6 (1.3)	<.001	.38
9. Do you feel like you read slowly?	2.1 (1.3)	2.2 (1.3)	.99	.13
10. Do your eyes ever hurt?	1.7 (1.1)	1.9 (1.1)	.99	.12
11. Do your eyes ever feel sore?	1.3 (1.1)	1.4 (1.1)	.99	.07
12. Do you feel a "pulling" feeling around your eyes?	1 (1.1)	1.2 (1.1)	.99	.13
13. Do you notice the words blurring or coming in and out of focus?	1.9 (1)	2.4 (0.9)	<.001	.43
14. Do you lose your place?	2.4 (1)	2.6 (0.9)	.99	.17
15. Do you have to re-read the same line of words?	2.4 (1)	2.5 (1)	.99	.09

* The p values for item analyses have been corrected using the Holm–Bonferroni stepdown method.

Table 6 .

Item-level differences on the Convergence Insufficiency Symptom Survey between participants with convergence insufficiency with and without a coexisting decreased accommodative facility at study entry

Convergence Insufficiency Symptom Survey	Decreased Accommodative Facility?			
	No	Yes		
Item	Mean (SD)	Mean (SD)	Corrected p Value*	Cohen's d
1. Do your eyes feel tired?	2.1 (0.9)	2.3 (1)	.049	.28
2. Do your eyes feel uncomfortable?	1.7 (1)	1.9 (1.1)	.99	.17
3. Do you have headache?	1.8 (1.2)	2 (1.2)	.99	.15
4. Do you feel sleepy?	2.1 (1.1)	2.3 (1.1)	.99	.15
5. Do you lose concentration?	2.4 (1)	2.5 (1)	.99	.09
6. Do you have trouble remembering what you have read?	2.1 (1.2)	2.2 (1.1)	.99	.1
7. Do you have double vision?	1.9 (1.2)	2 (1.2)	.99	.14
8. Do you see the words move, jump, swim or appear to float on the page?	1.3 (1.3)	1.5 (1.3)	.99	.12
9. Do you feel like you read slowly?	2.1 (1.3)	2.2 (1.3)	.99	.08
10. Do your eyes ever hurt?	1.7 (1.1)	2 (1.1)	.09	.26
11. Do your eyes ever feel sore?	1.3 (1.1)	1.5 (1.2)	.99	.14
12. Do you feel a "pulling" feeling around your eyes?	1.1 (1.1)	1.1 (1.1)	.99	.06
13. Do you notice the words blurring or coming in and out of focus?	2.1 (1)	2.3 (1)	.99	.16
14. Do you lose your place?	2.5 (1)	2.5 (0.9)	.99	.03
15. Do you have to re-read the same line of words?	2.5 (1)	2.5 (0.9)	.99	.06

* The p values for item analyses have been corrected using the Holm–Bonferroni stepdown method.