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ORIGINAL ARTICLE

Improvement in Academic Behaviors After Successful Treatment of Convergence Insufficiency

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ABSTRACT

Purpose. To determine whether treatment of symptomatic convergence insufficiency (CI) has an effect on Academic Behavior Survey (ABS) scores.

Methods. The ABS is a six-item survey developed by the Convergence Insufficiency Treatment Trial Group that quantifies the frequency of adverse school behaviors and parental concern about school performance on an ordinal scale from 0 (never) to 4 (always) with total scores ranging from 0 to 24. The ABS was administered at baseline and after 12 weeks of treatment to the parents of 218 children aged 9 to 17 years with symptomatic CI, who were enrolled in the Convergence Insufficiency Treatment Trial and randomized into (1) home-based pencil push-ups; (2) home-based computer vergence/accommodative therapy and pencil push-ups; (3) office-based vergence/accommodative therapy with home reinforcement; and (4) office-based placebo therapy with home reinforcement. Participants were classified as successful (n = 42), improved (n = 60), or non-responder (n = 116) at the completion of 12 weeks of treatment using a composite measure of the symptom score, nearpoint of convergence, and positive fusional vergence. Analysis of covariance methods were used to compare the mean change in ABS between response to treatment groups while controlling for the ABS score at baseline.

Results. The mean ABS score for the entire group at baseline was 12.85 (SD = 6.3). The mean ABS score decreased (improved) in those categorized as successful, improved, and non-responder by 4.0, 2.9, and 1.3 points, respectively. The improvement in the ABS score was significantly related to treatment outcome ($p < 0.0001$), with the ABS score being significantly lower (better) for children who were successful or improved after treatment as compared to children who were non-responders ($p = 0.002$ and 0.043, respectively).

Conclusions. A successful or improved outcome after CI treatment was associated with a reduction in the frequency of adverse academic behaviors and parental concern associated with reading and school work as reported by parents.
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Key Words: convergence insufficiency, exophoria, symptoms, vision therapy, orthoptics, reading, attention deficit hyperactivity disorder

Convergence insufficiency (CI) is a common vision disorder that affects about 5% of school-aged children and is associated with symptoms such as visual fatigue, headaches, and double vision when reading and studying.[1–4] These types of symptoms, as measured by the Convergence Insufficiency Symptom Survey (CISS), are significantly more frequent in children with CI compared with children with normal binocular vision.[5,6]

In addition to symptoms reported by children with CI on the CISS, their parents have reported a significantly greater level of adverse school behaviors on the Academic Behavior Survey (ABS) when compared with parents of children with normal binocular vision.[7] The parents of children with CI are more likely than parents of children with normal binocular vision to report the presence of difficulty in completing school work, avoiding reading and

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studying, and inattentiveness or distraction during reading. In addition, parents of children with CI report that they worry more about their child's school performance when compared with parents of children with normal binocular vision.

Two recent multicenter clinical trials comparing various treatments for school-aged children with CI demonstrated a clinically significant reduction in symptoms after successful treatment of CI.[8,9] However, previous studies have not investigated whether the improvements in child reported symptoms are accompanied by a decrease in parental report of adverse school behaviors and parental worry. Parental report of adverse behaviors related to school work in children with symptomatic CI could have potential implications for the diagnosis of disorders that rely on parent observations of children's behaviors. For example, recent studies have suggested a possible relationship between CI and Attention Deficit Hyperactivity Disorder (ADHD).[7,10–12] Borsting et al.[12] noted that a number of symptoms frequently reported by children with CI (e.g., loss of concentration when reading or reading slowly) are similar to behaviors that are commonly reported in the inattentive type of ADHD (e.g., failure to complete assignments and trouble concentrating in class).[13,14]

This study used the ABS to determine parents' perceptions of the frequency of adverse behaviors exhibited by their children when reading or performing school work and overall parental concern about the child's academic performance after the successful treatment of symptomatic CI in school-aged children.

METHODS

The study was supported through a cooperative agreement with the National Eye Institute of the National Institutes of Health and conducted by the Convergence Insufficiency Treatment Trial (CITT) Group at nine clinical sites (see Acknowledgments). The respective institutional review boards approved the protocol and HIPAA-compliant informed consent forms. The parent or legal guardian of each study subject gave written informed consent, and written assent was obtained from each child. Study oversight was provided by an independent data and safety monitoring committee appointed by the National Eye Institute. The CITT was registered at clinicaltrials.gov under identifier NCT00338611.

Children aged 9 to 17 years with symptomatic CI were recruited at participating CITT clinical centers. Major eligibility criteria for the trial included exodeviation at near at least 4Δ greater than at far, a receded nearpoint of convergence (NPC) break (6 cm or greater), insufficient positive fusional vergence (PFV) at near (i.e., failing Sheard's criterion [PFV] less than twice the near phoria[15] or minimum PFV ≤15Δ base-out blur or break), and a CISS score of 16 or higher. A detailed description of eligibility criteria is provided elsewhere.[8,16]

Eligible children were randomly assigned with equal probability to one of four treatment groups: (1) home-based pencil push-ups (HBPP): (2) home-based computer vergence/accommodative therapy and pencil push-ups (HBCVAT+); (3) office-based vergence/accommodative therapy with home reinforcement (OBVAT); and (4) office-based placebo therapy with home reinforcement (OBPT). Each child then completed 12 weeks of active therapy in his/her assigned treatment group. Outcome measures included the CISS score, nearpoint of convergence (NPC), and positive fusional vergence (PFV) and were measured by an examiner who was masked to the child's treatment group. A subject's treatment outcome was classified as "successful," "improved," or "non-responder" based on the CISS score, NPC, and PFV measurements at the 12-week outcome examination. Successfully treated CI was defined as a score <16 on the CISS, a normal NPC (i.e., <6 cm), and normal PFV (i.e., >15Δ and passing Sheard's criterion). Improved CI was defined as a score <16 or a 10-point or more decrease in the CISS score, and at least one of the following: normal NPC, an improvement in NPC of 4 cm or more, and normal PFV or an increase in PFV of more than 10Δ. A subject was classified as a non-responder when the criteria for "successful" or "improved" were not met.

The ABS was developed by the CITT Study Group to query parents regarding behaviors that a parent could easily observe, such as avoiding near work and problems with completing schoolwork.[7] Previous research has shown that parent and child agreement is better for behaviors that are easily observable (such as walking up and down stairs), as opposed to reporting on somatic issues (such as amount of pain) which are more subjective.[17–19] A list of potential questions was field tested by the CITT investigators, and six questions were chosen for the final survey. Five questions relate to observable behaviors and one question addresses the parent's level of concern about school performance (Table 3). Each item is scored on an ordinal scale as follows: 0 (Never), 1 (infrequently), 2 (sometimes), 3 (fairly often), and 4 (Always), with total scores ranging from 0 to 24.[5,20]

The following instructions are contained on the ABS form: "Please rate each item according to your child's behavior during the last school month. If your child was not in school last month, think about during the last month he/she was in school. For each item, ask yourself 'How much of a problem has this been in the last month?' and check the best answer for each one. Please respond to all 6 items." The parent was not allowed to consult with the child during completion of the survey.

Data Analysis

The ABS was designed as a secondary outcome measure in the CITT and as such the study was not powered to find differences in the mean ABS score between the four treatment modalities. In addition a score on the ABS was not an inclusion criteria for the study. Thus, we evaluated the relationship between change in ABS score (baseline score − week 12 score) and response to treatment (i.e., successful, improved, or non-responder) rather than comparing treatment groups.

All descriptive statistics for the characteristics of the sample at baseline are reported as means and SDs. Estimates for mean change in ABS score (baseline score − week 12 score) are presented along with 95% confidence intervals. The confidence intervals allow the reader to assess the statistical significance of the change observed and to compare change between treatment response groups. That is, if a confidence interval contains zero, then there is no significant change in ABS score and if two confidence intervals overlap, then there is likely no significant difference between the two groups. A formal comparison of the mean change in ABS score for each treatment response groups (successful, improved, or non-responder) was achieved using analysis of covariance methods. The

baseline ABS score was included as a covariate because of its high correlation with the observed change ($r = 0.44$, $p < 0.0001$) and the slight, non-significant ($p = 0.50$) differences at baseline between outcome response categories. The error rate for post hoc pair-wise comparisons was controlled using the method of Tukey. Given the ordinal nature of the data, the Kruskal-Wallis test was used to compare the mean change in response for each item of the ABS between children classified as successful, improved, or non-responder. Pearson correlation coefficients were used to assess the relationship between the change in ABS score and changes in signs (NPC and PFV) and symptoms (CISS) of CI. SAS version 9.2 (Cary, NC) was used for analysis.

RESULTS

Subjects

Between July 2005 and October 2006, 221 patients were enrolled in the study. Study retention was excellent with 218 completing the 12 week of treatment. The mean (SD) age of the patients was 11.8 (2.3) years; 59% were female, 55% were white, 30% were Black, and 34% reported Hispanic or Latino ethnicity. Descriptive statistics for selected findings at baseline are shown in Table 1. Other clinical characteristics have been previously reported.[8,16] The mean ABS score at baseline was 12.8 (6.3). Of the 218 children who completed the study, 42 (19%) were classified as successful, 60 (28%) as improved, and 116 (53%) as non-responders to treatment. The mean ABS score at the outcome visit was 10.6 (6.0) which was significantly lower (better) than the score at baseline ($p < 0.0001$).

Comparisons Based on Treatment Outcome

The distribution of ABS scores at baseline and week 12 for participants classified as successful, improved, and non-responders are shown in Fig. 1. Comparisons of changes in ABS scores between the three groups were performed after controlling for the ABS score at baseline. An interaction term between ABS at baseline and treatment response group was included in the initial model. As shown on Fig. 2, the relationship between change in ABS (baseline score − week 12 score) and treatment response was the same regardless of ABS score at baseline (p-value for interaction between group and ABS at baseline = 0.25). The mean ABS score decreased (improved) after 12 weeks of treatment in those categorized as successful, improved, and non-responder by 4.01, 2.94, and 1.27 points, respectively (p-values <0.001, Table 2). Post hoc testing indicated that the ABS score was significantly lower (better) for subjects classified as either successful or improved compared with non-responders ($p = 0.002$ and 0.043, respectively). There was no significant difference in improvement between subjects classified as successful or improved ($p = 0.44$).

We can estimate whether the findings above are clinically meaningful by calculating the effect size (Cohen's d) of the change in score from baseline to week 12 for each treatment response group.[21] A four-point change (as found in the successful treatment group) would translate into an effect size of 0.9. A 2.9-point change (as found in those who improved) translates into an effect size of 0.7.

To better understand the effect of treatment outcome on ABS score, comparisons of the change in response to each of the six questions of the ABS were made between the children classified as successful, improved, and non-responders (Table 3). For each question, the amount of change (improvement) was greatest in those who were successful, less in those improved, and least in the non-responders. Given the non-significant difference in total score between the successful and improved groups, these two groups were combined for comparison with the non-responders. Significant differences in the change in response were observed for "Worry about school performance" ($p = 0.004$) and "Fails to give attention to detail" ($p = 0.043$). For both of these questions, the change in average item response for subjects who were successful or improved after treatment was more than double that observed in the non-responders. In fact, there was no appreciable change in the response to "Worry about school performance" among the parents of children who were non-responders to treatment.

Relationship with CI Signs and Symptoms

As shown in Fig. 3, improvement in the ABS score was significantly correlated with reduction in symptom level as determined by the CISS ($r = 0.29$, $p < 0.0001$). A 15-point decrease on the CISS (as observed in the OBVAT group after treatment) was associated with a 2.1-point reduction in ABS score. The change in ABS score (baseline score − week 12 score) was not, however, correlated with changes in NPC break ($r = 0.081$, $p = 0.23$), changes in PFV ($r = 0.002$, $p = 0.97$), or the ratio of change in PFV to change in near phoria ($R = -0.004$, $p = 0.96$).

DISCUSSION

Improved and successful outcomes after treatment for symptomatic CI in school-aged children were associated with an overall reduction in the frequency of adverse behaviors and parental concern associated with reading and school work as measured by the ABS. There was also a significant positive relationship between the reduction in ABS score and the CISS score.

Although the differences in overall ABS score between those who were successful or improved vs. non-responders were statistically significant, the question arises as to the clinical significance of the reduction in the frequency of adverse behaviors. We estimated whether the finding is clinically meaningful by calculating the effect size (Cohen's d) of the change in score from baseline to week 12. According to Cohen, effect sizes >0.50 are considered medium effects, while values >0.80 are considered large effects.

TABLE 1.
Descriptive statistics for clinical findings at baseline

Characteristic	Mean	SD	Range
Distance phoria (Δ)	1.9 exo	2.8	15 exo, 4 eso
Near phoria (Δ)	9.3 exo	4.4	2 exo, 25 exo
NPC break (cm)	14.3	7.6	6.0, 49.3
NPC recovery (cm)	17.9	8.2	7.5, 52.0
PFV break (Δ)	12.7	4.7	2.3, 31.7
PFV recovery (Δ)	8.8	4.5	0.0, 24.0
CISS	29.9	8.9	16, 58

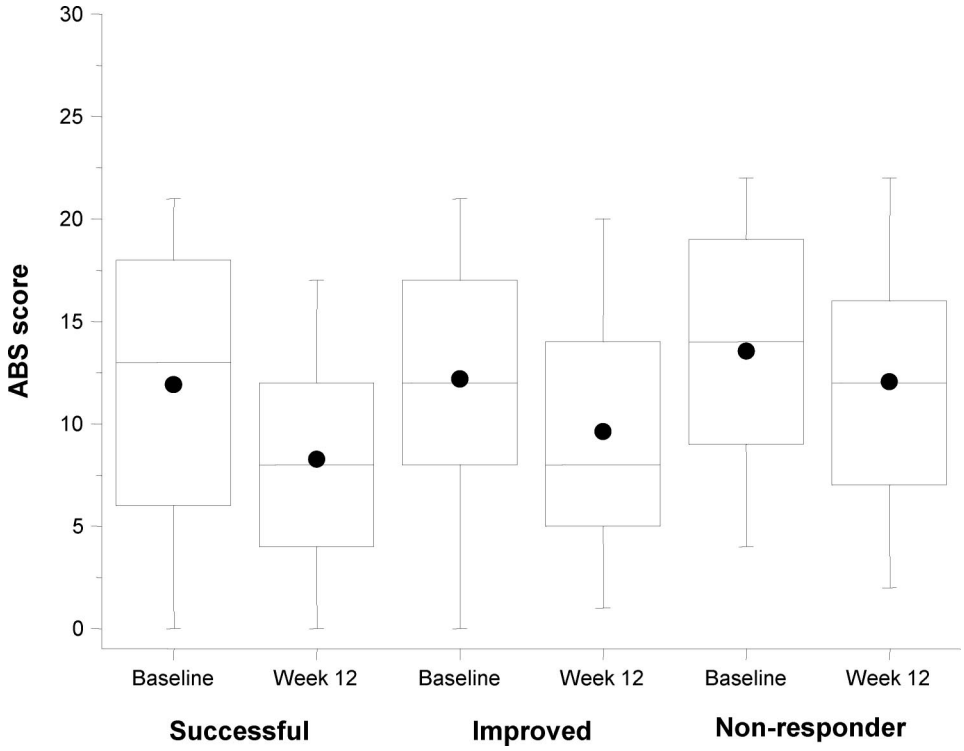

FIGURE 1.

Box plots for the ABS at Baseline and the 12-week outcome visit, by treatment outcome. The outer limits of each box represent the 25th and 75th percentiles of the distribution. The median is shown as the line within each box, whereas the mean is represented by the dot within each box.

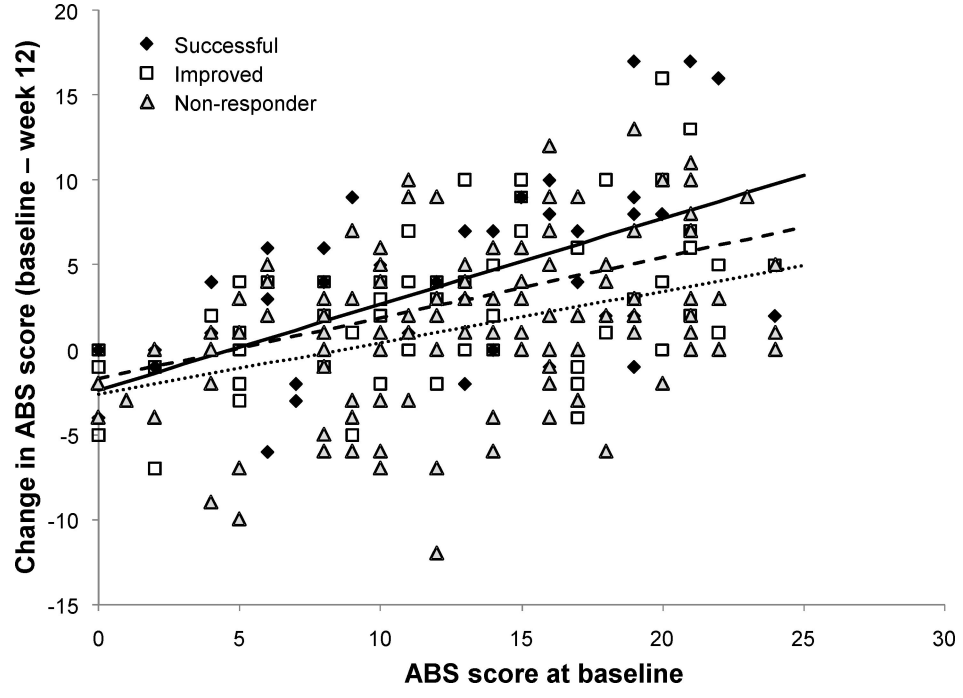

FIGURE 2.

Scatterplot of change in ABS (baseline score − week 12 score) and ABS at baseline by treatment response.

Sloan et al.[22] argues that an effect size of 0.5 is a conservative estimate of a clinically meaningful difference that is scientifically supportable. Our observed effect sizes in the successful and improved groups were 0.9 and 0.7. Thus, the improvement in behavior reported by the parents appears to be a clinically meaningful change.

Strengths of this study include an excellent follow-up rate (98.6%) and masked assessment at the 12-week outcome examination. In addition, the ABS has been shown to have excellent internal consistency with a Cronbach alpha score of 0.92.[7] Limitations are that the ABS is a newly developed instrument and we have not yet assessed the between session reliability or validated the ABS with another survey

TABLE 2.
Mean Academic Behavior Survey scores and 95% confidence interval (CI) at baseline and the 12-week outcome based on treatment outcome in the Convergence Insufficiency Treatment Trial

	Baseline		Week 12		Improvement	
	Mean	95% CI	Mean[a]	95% CI	Mean[a]	95% CI
Successful	11.90	9.8–14.0	8.90	7.6–10.2	4.01	2.7–5.3
Improved	12.18	10.5–13.8	9.96	8.8–11.1	2.94	1.8–4.1
Non-responder	13.54	12.5–14.6	11.64	10.8–12.4	1.27	0.5–2.1
	ANOVA p = 0.22		ANCOVA p = 0.001		ANCOVA p = 0.001	

[a]Mean adjusted for ABS score at baseline.
ANOVA, analysis of variance; ANCOVA, analysis of covariance.

TABLE 3.
Mean improvement in score and 95% confidence interval (CI) for each item of the Academic Behavior Survey by treatment outcome at 12 weeks

	Successful		Improved		Non-responder		
Item	Mean	95% CI	Mean	95% CI	Mean	95% CI	p
How often does your child have difficulty completing assignments at school?	0.55	0.2–0.9	0.47	0.2–0.7	0.28	0.1–0.5	0.32
How often does your child have difficulty completing homework?	0.50	0.2–0.9	0.24	−0.03–0.5	0.21	0.01–0.4	0.43
How often does your child avoid or say he/she does not want to do tasks that require reading or close work?	0.67	0.3–1.1	0.66	0.3–1.0	0.48	0.3–0.7	0.36
How often does your child fail to give attention to details or make careless mistakes in schoolwork or homework?	0.74	0.4–1.1	0.42	0.2–0.7	0.20	0.0–0.4	0.043
How often does your child appear inattentive or easily distracted during reading or close work?	0.62	0.3–1.0	0.53	0.2–0.8	0.35	0.1–0.6	0.16
How often do you worry about your child's school performance?	0.57	0.1–1.1	0.42	0.1–0.8	0.02	−0.2–0.3	0.004

The p values represent comparisons of the successful + improved group to the non-responder group.

instrument. In addition, we were not able to identify whether parents pursued other educational treatments during the 12-week CI treatment intervention which may have impacted the ABS scores. However, we consider it unlikely that the successful and improved groups pursued other forms of care with greater frequency than the non-responder group during the relatively short (12 week) treatment time frame. Finally, due to the ABS being a secondary outcome measure and not powered to find differences between treatment groups, we decided to look at the association between the responses to treatment in CI with changes in ABS scores. With this analysis, we cannot rule out a possible placebo effect resulting from the expectations occurring when the child entered a treatment study. The study did include a placebo treatment arm that controlled for therapist to patient interactions for office-based treatment, but the study did not include corresponding placebo treatment groups for the home-based treatment arms. Despite the above limitations, this study can yield an initial estimate of parental report of improvement in their child's adverse school-related behaviors after treatment for CI.

Previous studies have indicated that parents of children with CI report more behaviors similar to those observed in ADHD than parents of children with normal binocular vision.[7,23] In addition, Granet et al.[10] found a higher prevalence of ADHD in children diagnosed with CI when conducting a retrospective review of charts. Similarly, Gronlund et al.[11] found one sign of CI (i.e., abnormal NPC) in 24% of the ADHD group but only 6% of the reference group. The results of this study combined with the aforementioned previous studies suggest that impact of treatment on CI should be studied using outcome instruments that assess the behavioral or cognitive aspects of attention (e.g., Connors Ratings Scales or continuous performance tasks).[24,25]

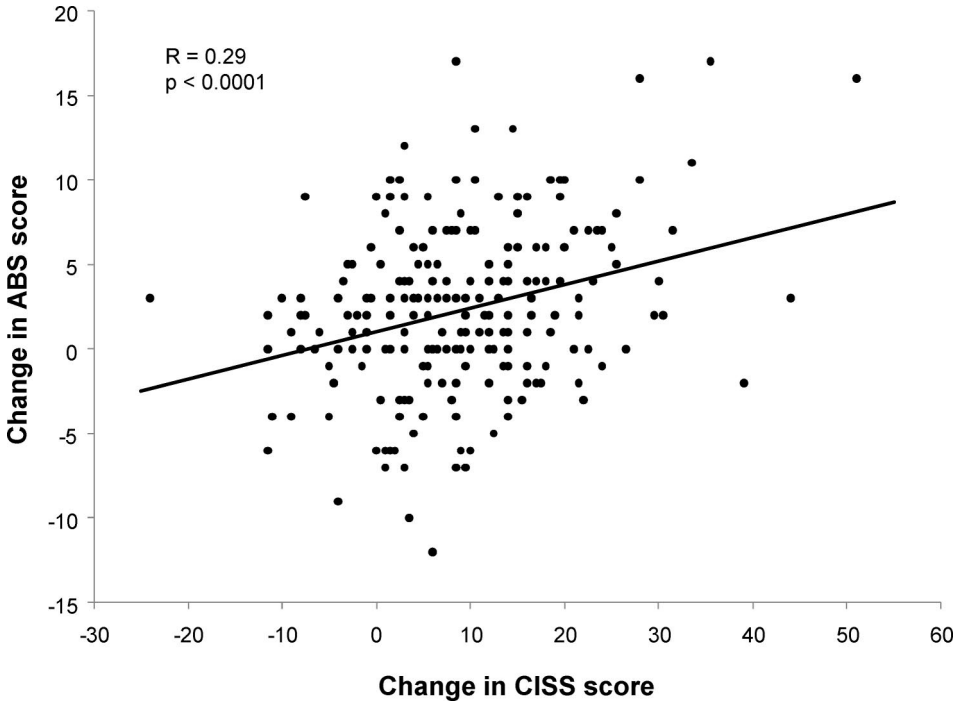

FIGURE 3.
Scatterplot of changes in ABS (baseline score − week 12 score) and CISS from baseline.

To our knowledge, this is the first study that has investigated the impact of treating symptomatic CI in children on parental report of behaviors associated with school work. In translating the results into clinical practice, clinicians can use this information to educate patients/parents about the potential effects of therapy for symptomatic CI in children. These data suggest that parents may report a reduction in the frequency of specific adverse school and may have less overall worry about academic performance after children with symptomatic CI show improvement or are successfully treated.

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Sites are listed in order of the number of patients enrolled in the study with the number of NBV patients enrolled listed in parentheses preceded by the site name and location. Personnel are listed as (PI) for principal investigator, (SC) for coordinator, (E) for examiner, and (VT) for therapist.

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