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## Relationship between Clinical Signs and Symptoms of Convergence Insufficiency

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### Abstract

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**Purpose**—The percentage of children who are symptomatic has been shown to increase with the number of signs of convergence insufficiency (CI). Our goal was to investigate whether there is a relationship between the severity of the clinical signs of CI and symptom level reported in children with 3-sign symptomatic CI.

**Methods**—The Convergence Insufficiency Treatment Trial (CITT) enrolled 221 children with symptomatic CI from ages 9 to 17 years. Inclusion criteria included the following three signs of CI: (1) exophoria at near at least  $4\Delta$  greater than at distance, (2) insufficient positive fusional vergence (PFV) at near, and (3) a receded near point of convergence (NPC) of  $\geq 6$ cm break. The relationships between the severity of each sign of CI (mild, moderate and severe) and the level of symptoms as measured by the Convergence Insufficiency Symptom Survey (CISS) at baseline were evaluated.

**Results**—Mean CISS scores were not significantly different between mild, moderate or severe exophoria ( $p=0.60$ ), PFV blur ( $p=0.99$ ), Sheard's criterion ( $p=0.89$ ) or NPC break ( $p=0.84$ ). There was also no difference in the frequency of subjects scoring at mild, moderate or severe levels on the CISS and the severity of each sign of CI. Correlations between individual clinical signs and the CISS score were very low and not statistically significant.

**Conclusions**—Among symptomatic children with a CISS score  $\geq 16$  and three clinical signs of CI, there is no further association between the severity of the clinical signs and their level of symptoms.

### Keywords

convergence insufficiency; vision therapy; orthoptics; vergence/accommodative therapy; home-based computer therapy; exophoria; convergence insufficiency symptom survey; Sheard's criterion

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Convergence insufficiency (CI) is a common binocular vision disorder in children and is associated with symptoms such as eye fatigue, headaches and double vision during reading and close work.<sup>1-6</sup> CI is typically characterized as a syndrome of clinical signs most often defined by exophoria at near, a receded near point of convergence (NPC), and reduced positive fusional vergence (PFV) at near.<sup>3,4</sup> The Convergence Insufficiency Symptom Survey (CISS), a validated CI-specific symptom assessment instrument, has shown that individuals with CI are much more likely to be symptomatic than those with normal binocular vision.<sup>6,7</sup> Cohen et al found modest correlations between symptoms and clinical signs of CI (NPC and PFV)<sup>8</sup>, but they did not classify the severity of the CI. Rouse has reported that children having all three clinical signs of CI (exophoria at near, receded NPC, and reduced PFV) are more symptomatic than children who exhibit only one or two of the clinical signs.<sup>4</sup> Despite the common clinical impression that symptoms are worse in more severe cases of CI, the relationship between the severity of the clinical signs of CI and level of presenting symptoms in children is unknown.

We recently completed the Convergence Insufficiency Treatment Trial (CITT), a randomized multi-center clinical trial that evaluated different modes of treatment for symptomatic CI in childhood.<sup>9</sup> Symptoms were quantified in a standardized manner at baseline using the CISS. These data provide an opportunity to gain a better understanding of the relationship between the severity of these three clinical measures and level of symptoms in children with 3- sign, symptomatic CI. The aim of this study was to investigate the relationship between the severity of clinical signs of CI and symptom level in children with all three signs and symptomatic CI.

## Methods

The study was supported through a cooperative agreement with the National Eye Institute of the National Institutes of Health and was conducted by the CITT Group at nine clinic sites. The protocol and Health Insurance Portability and Accountability Act compliant informed consent forms were approved by the respective institutional review boards. A parent or guardian of each study subject gave written informed consent and each subject gave assent as required. An independent Data Safety Monitoring Committee provided study oversight. The study is registered at [www.clinicaltrials.gov](http://www.clinicaltrials.gov), identifier NCT00338611. The complete manual of procedures is available on the CITT website at <http://optometry.osu.edu/research/CITT/8581.cfm>, (accessed March 9, 2012).

### Subject Selection

Major eligibility criteria for the CITT included children aged 9 to 17 years with symptomatic CI defined as (1) an exodeviation at near at least  $4\Delta$  greater than at far, (2) insufficient PFV at near (PFV  $\geq 15\Delta$  base-out blur or break or failing Sheard's criterion [PFV less than twice the near phoria]<sup>10</sup>), (3) a receded NPC break (6 cm or greater), and (4) a symptom score of  $\geq 16$  on the CISS (described below).<sup>9</sup> In addition, children were required to have best-corrected visual acuity at distance and near of 20/25 or better, no constant strabismus, vertical phoria  $\leq 1\Delta$  and monocular accommodative amplitude  $\geq 5$  D. Children with myopia  $\geq 6.00$ D sphere, hyperopia  $\geq 5.00$ D sphere, astigmatism  $\geq 4.00$  D, and  $\geq 2.00$ D of spherical equivalent (SE) anisometropia were excluded. For lesser amounts of refractive error, a refractive correction was required to be worn for a least 2 weeks prior to enrollment when the magnitude of uncorrected refractive error or change in refractive error (as determined by cycloplegic refraction) was equal to or exceeded  $-0.50$  D of SE myopia,  $+1.50$ D of SE hyperopia,  $0.75$  D of astigmatism, or  $1.50$  D of anisometropia in any meridian. Asymmetrical reduction of hyperopia by up to  $1.25$  D was allowed and full correction of myopia was required. A complete listing of eligibility and exclusion criteria has been published previously.<sup>11</sup>

### Examination Procedures

Symptom level was measured using the CISS (Figure 1), a valid and reliable self-report symptom inventory. The CISS uses a Likert-type scale with responses from 15 items summed to obtain an overall CISS score, with symptom severity ranging from 0 (asymptomatic) to 60 (most symptomatic).<sup>6,7</sup> The CISS was administered to each child at baseline, first before and then after clinical testing. To administer the CISS, the examiner read aloud each of the 15 questions while the child viewed a card listing the five possible responses (never, infrequently, sometimes, fairly often, or always). The child responded how often each symptom occurred. Each response option had a corresponding score that ranged from 0 points (never) to 4 points (always); the points from the 15 questions were added to obtain a CISS total score. A score  $\geq 16$  was considered symptomatic.<sup>6,7</sup> The mean CISS score from the two CISS administrations at baseline was used for all data analysis. This is analogous to our protocol of using the average of three measurements of near point of convergence and positive fusional vergence in all data analyses. Previous analyses from our pilot data indicate that using two measurements of CISS ensures a within-person intraclass correlation (ICC) of at least 0.80. In this study, the mean difference between the two administrations at baseline was  $-0.39$  (p-value comparing difference to zero = 0.17) with 95% limits of agreement of  $\pm 8$  points.<sup>12</sup>

Other baseline testing included best-corrected visual acuity at distance and near, cover testing at distance and near, NPC, PFV and negative fusional vergence at near (fusional convergence and divergence amplitudes with a prism bar), near stereoacuity, monocular

accommodative amplitude (push up method), monocular accommodative facility, (the ability to quickly achieve clear vision while alternately viewing 20/30 print through +2 D and -2 D lenses), cycloplegic refraction, and an ocular health evaluation. An accommodative target (20/30 letter(s)) was used for cover testing, NPC, fusional vergence testing, and assessment of accommodative amplitude. CITT trained and certified optometrists or ophthalmologists performed all testing using a previously described standardized protocol,<sup>11</sup> which is available in its entirety at <http://optometry.osu.edu/research/CITT/8581.cfm> (accessed March 7, 2012).

### Classification of Severity of Clinical Signs

Each sign of CI was classified as mild, moderate or severe based on means and standard deviations (SD) from previously published normative studies. For near exophoria, cut-points for mild were  $-8$  exo ( $-1$ SD), moderate  $>8$  exo to  $<13$  exo ( $>1$ SD to  $<2$ SD), and severe  $>13$  exo ( $>2$ SD).<sup>13</sup> For PFV, cut-points for mild were  $-15\Delta$  ( $-1$ SD), moderate  $>7\Delta$  to  $<15\Delta$  ( $>1$ SD to  $<2$ SD), and severe  $>7\Delta$  ( $>2$ SD).<sup>14</sup> For NPC, the cut-points were mild 6 cm to  $<9$  cm ( $-1$ SD to  $<2$ SD), moderate 9 cm to  $<12$  cm ( $-2$ SD to  $<3$ SD), and severe  $>12$  cm ( $>3$ SD).<sup>15</sup> For Sheard's criterion, normative data to establish cut-points are not available. Therefore, we divided the range of findings into three levels. A mild deficit was considered to be PFV  $>1.5 \times$  near phoria, a severe deficit was PFV  $<$  near phoria, and a moderate deficit was values in between these ranges.

### Classification of Symptom Level

Data from two previous studies of children with three clinical signs of CI ( $n=158$ ) were used to define the severity of symptom level.<sup>16,17</sup> All of these children were symptomatic with a CISS score  $\geq 16$ . In these studies, CISS scores ranged from 16 (least symptomatic) to 60 (most symptomatic). Tertiles of the CISS distribution were used because the CISS data is not normally distributed. The cut-points for the level of symptoms were: mild ( $<33^{\text{rd}}$  percentile or a CISS score  $\leq 24$ ), moderate ( $>33^{\text{rd}}$  percentile to  $<67^{\text{th}}$  percentile or CISS scores ranging from 24.5 to 34) and severe ( $>67^{\text{th}}$  percentile or a CISS score  $>34$ ).

### Data Analysis

The relationship between the severity level (mild, moderate or severe) for each clinical sign and symptom level as indicated by the CISS score was examined using analysis of variance models. Mantel Haenszel chi-square tests were used to examine the relationship between severity of clinical signs and symptom level based on tertiles of the CISS distribution. Lastly, Pearson's correlation coefficients were used to assess the association between the individual clinical signs of CI (near exophoria, NPC break, PFV blur, and Sheard's criterion) and the CISS score. Several additional variables that are often associated with CI (e.g. magnitude of difference between the distance and near phorias, NPC recovery, PFV break, and PFV recovery) were also compared to CISS scores. All data analyses were performed using SAS (version 9.1, SAS Institute, Cary, NC).

### Results

Demographic and clinical characteristics of the 221 subjects enrolled into the CITT have been published previously.<sup>9,11</sup> In brief, the mean age was 11.8 years and 59% were female. Race was 55% White, 30% African American, and 15 % other; 34% reported Hispanic ethnicity.

The mean (SD) CISS scores for mild, moderate, and severe levels of exophoria, PFV blur, Sheard's criterion, and NPC break are shown in Table 1. The difference in mean CISS scores between the mild, moderate and severe categorizations for these four clinical signs are not

significantly different (all p-values  $> 0.60$ ). There are 39 subjects in the “mild” category that would pass Sheard's criteria. Exclusion of these subjects, however, does little to the reported mean symptom score changing it from 30.10 to 30.74 (std=8.7, p-value comparing Sheard's Criterion levels=0.75). Table 2 reports the number of subjects in each tertile of CISS score by severity level of the signs of CI. Mantel-Haenszel chi-square analysis showed no significant association between symptom level as measured by the CISS and severity of exophoria (p=0.96), PFV blur (p=0.77), Sheard's criterion (p=0.92), or NPC break (p=0.95). As shown in Table 3, there were no significant correlations between symptom level as measured by the CISS and any of the clinical findings (all r values  $< 0.094$ ; all p values  $> 0.17$ ). This is confirmed by scatter plots of CISS score versus exophoria (Figure 2), versus PFV (Figure 3), and versus NPC (Figure 4).

## Discussion

In this study, we investigated the relationship between severity of clinical signs and level of symptoms among children with symptomatic, 3-sign CI. In other words, do children with more severe 3-sign symptomatic CI report more symptoms than children with less severe symptomatic 3-sign CI? We found that mean CISS scores were not significantly different between those with mild, moderate or severe clinical signs (exophoria, PFV, Sheard's phoria/vergence relationship or NPC). Similarly, the percentage of subjects with higher levels of symptoms did not increase as the signs became more severe. Finally, correlations between individual clinical signs and the CISS score were low and not statistically significant. Therefore, the results of this study showed no significant association between symptom level and the severity of individual clinical measures of CI in children with symptomatic CI.

Previous research has shown an association between symptoms and signs when subjects with and without binocular vision problems are included.<sup>5-8</sup> Furthermore, Rouse et al showed that a higher percentage of children with 3-sign CI were symptomatic as compared to those with fewer signs of CI.<sup>4</sup> Therefore, the lack of an association between severity of signs and level of symptoms found in this study, may be attributable to the fact that all children had 3-sign, symptomatic CI. Once children reach a certain threshold level (i.e. three signs of CI), there is no further association between severity of signs and frequency of symptoms. The CITT group has reported that children more frequently report performance-related symptoms (i.e. loss of place with reading, reading slowly, loss of concentration) as compared to eye-related symptoms (i.e. eyes hurt, blurred vision, headaches, diplopia).<sup>18</sup> Also, a high percentage of children with symptomatic, 3-sign CI report that these performance-related symptoms occur fairly often or always. Thus, the lack of any further association between severity of clinical signs and level of symptoms may indicate a plateau in symptoms as measured by the CISS. Another possible explanation is as exophoria increases and/or as convergence ability worsens, some subjects may either develop suppression or avoid near activities to reduce or eliminate symptoms. We did not evaluate suppression, however.

Lastly, the lack of an association between severity of signs and level of symptoms found in this study may be explained by the nature of the data. The CITT did not measure clinical sign or administer the CISS following prolonged near work. It is plausible that signs and symptoms associated with CI may change if testing was performed after the visual system was stressed. Further studies are necessary to determine the effect of visual fatigue on the relationship between the signs and symptoms of CI.

The goal of this study was to determine if worsening signs of CI were related to increases in symptoms. While other researchers have noted a positive correlation between symptom level

and number of signs of CI, there have been no publications examining the association of signs and symptoms among children with 3-sign CI. A significant relationship of symptoms with one or more of the signs of CI might suggest more targeted treatment. For example, if more receded near points of convergence were related to higher symptom levels, then one could argue that even small improvements in near point would result in reductions in symptom. We found no such significant correlations even though we know from previous publications<sup>9,16</sup> that treatments for CI (which coincidentally improve NPC and PFV) have resulted in large reductions in CISS score. Our conclusion, therefore, is that there is a positive relationship between symptom level and the number of signs of CI (0, 1, 2 or 3) but, once the 3-sign threshold has been reached, the wide range of symptom level is not related to severity of any one sign of CI.

## Conclusions

Among symptomatic children with a CISS score  $\geq 16$  and three clinical signs of CI, increased severity of the clinical signs is not associated with a further increase in level of symptoms.

## Acknowledgments

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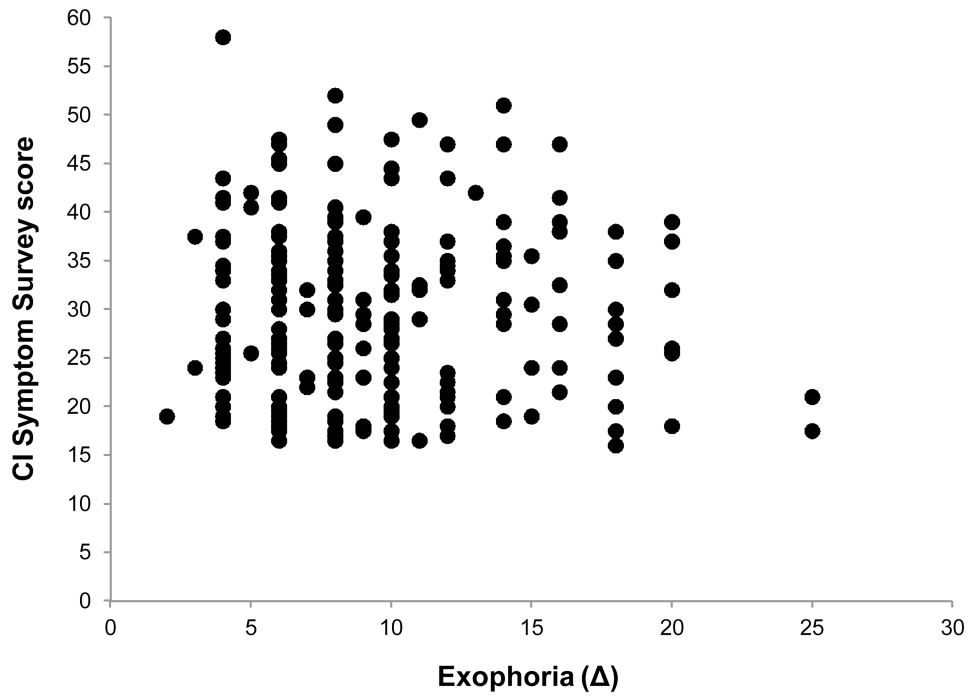
**Clinician instructions:** Read the following subject instructions and then each item exactly as written. If subject responds with "yes" - please qualify with frequency choices. **Do not give examples.**  
**Subject instructions:** Please answer the following questions about how your eyes feel when reading or doing close work. First think about whether or not you have the symptom. If you do, please tell me whether the problem occurs: Infrequently (not very often), Sometimes, Fairly Often, or Always.

		Never	Infrequently	Sometimes	Fairly often	Always
1.	Do your eyes feel tired when reading or doing close work?					
2.	Do your eyes feel uncomfortable when reading or doing close work?					
3.	Do you have headaches when reading or doing close work?					
4.	Do you feel sleepy when reading or doing close work?					
5.	Do you lose concentration when reading or doing close work?					
6.	Do you have trouble remembering what you have read?					
7.	Do you have double vision when reading or doing close work?					
8.	Do you see the words move, jump, swim or appear to float on the page when reading or doing close work?					
9.	Do you feel like you read slowly?					
10.	Do your eyes ever hurt when reading or doing close work?					
11.	Do your eyes ever feel sore when reading or doing close work?					
12.	Do you feel a "pulling" feeling around your eyes when reading or doing close work?					
13.	Do you notice the words blurring or coming in and out of focus when reading or doing close work?					
14.	Do you lose your place while reading or doing close work?					
15.	Do you have to re-read the same line of words when reading?					
To obtain score, total the number of "X"s in each column						
Multiply by the column value		x0	x1	x2	x3	x4
Sum 5 values						

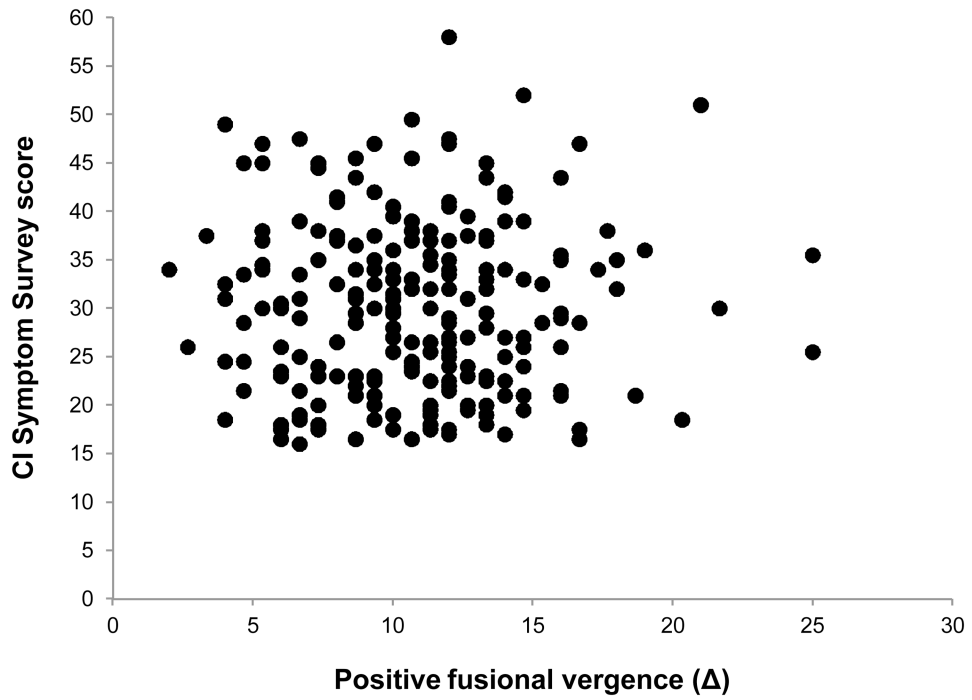
SCORE: \_\_\_\_\_

**Figure 1.**  
 Convergence Insufficiency Symptom Survey.

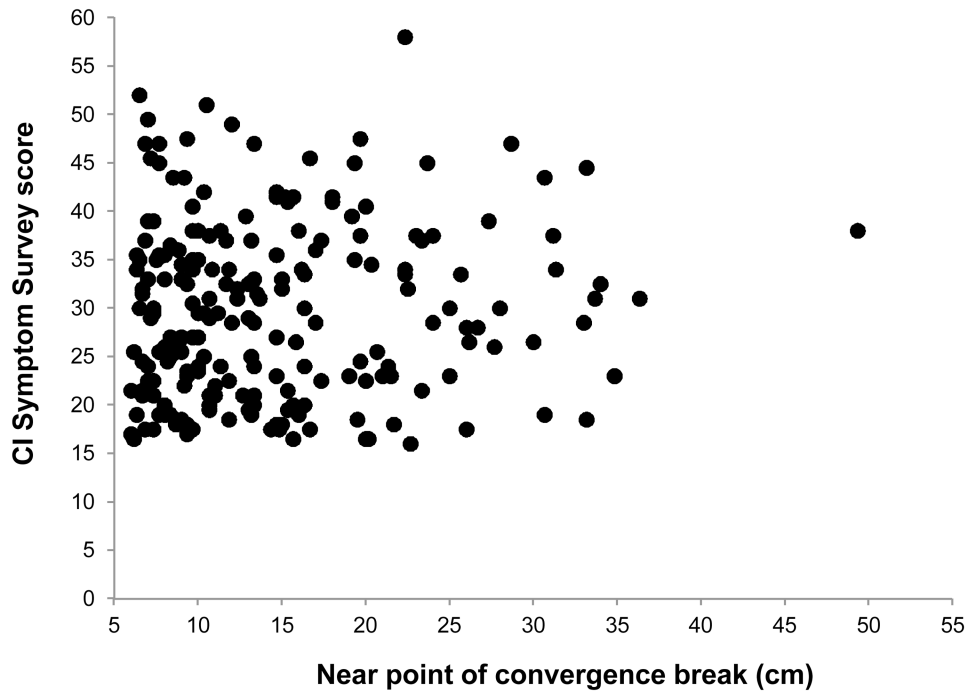




**Figure 2.**  
Scatter plot of CI Symptom Survey score and near phoria.



**Figure 3.**  
Scatter plot of CI Symptom Survey score and positive fusional vergence blur.



**Figure 4.** Scatter plot of CI Symptom Survey score and near point of convergence break.

**Table 1**

Mean and standard deviation (SD) of CISS score, by severity of different clinical measures of CI.

Severity	Definition	N (%)	Mean score	SD
<b>Near phoria (<math>\Delta</math>)</b>				
<b>Mild</b> 1SD	8 exophoria	120 (54%)	30.40	9.0
<b>Moderate</b> >1SD - <2SD	> 8 to < 13 exophoria	60 (27%)	28.36	8.7
<b>Severe</b> 2SD	13 exophoria	41 (18%)	30.40	9.1
<b>Positive fusional vergence (PFV) blur (<math>\Delta</math>)</b>				
<b>Mild</b> 1SD	15 $\Delta$	27 (12%)	30.00	8.9
<b>Moderate</b> >1SD - <2SD	> 7 $\Delta$ to < 15 $\Delta$	156 (71%)	29.81	9.0
<b>Severe</b> 2SD	7 $\Delta$	38 (17%)	29.91	9.2
<b>Sheard's criterion</b>				
<b>Mild</b>	PFV blur 1.5 $\times$ near phoria	81 (37%)	30.10	9.0
<b>Moderate</b>	PFV blur near phoria but < 1.5 $\times$ near phoria	75 (34%)	29.45	8.8
<b>Severe</b>	PFV blur < near phoria	65 (29%)	30.00	9.3
<b>Near point of convergence break (cm)</b>				
<b>Mild</b> 1SD - <2SD	6 cm to <9 cm	61 (28%)	29.70	9.2
<b>Moderate</b> 2SD - <3SD	9 cm to <12 cm	53 (24%)	29.32	8.2
<b>Severe</b> 3SD	12 cm or higher	107 (48%)	30.20	9.3

**Table 2**

Number (percentage) of subjects in each category of CI Symptom Survey score, by severity of different clinical measures of CI.

Severity	Definition	CISS score		
		24 Mild	24.5 – 34 Moderate	> 34 Severe
<b>Near phoria (<math>\Delta</math>)</b>				
<b>Mild</b> 1SD	8 exophoria	36 (30.0)	47 (39.2)	37 (30.8)
<b>Moderate</b> >1SD – <2SD	> 8 to < 13 exophoria	25 (41.7)	21 (35.0)	14 (23.3)
<b>Severe</b> 2SD	13 exophoria	13 (31.7)	12 (29.3)	16 (39.0)
<b>Positive fusional vergence (PFV) blur (<math>\Delta</math>)</b>				
<b>Mild</b> 1SD	15 $\Delta$	8 (29.6)	10 (37.0)	9 (33.3)
<b>Moderate</b> >1SD - <2SD	> 7 $\Delta$ to < 15 $\Delta$	55 (35.3)	53 (34.0)	48 (30.8)
<b>Severe</b> 2SD	7 $\Delta$	11 (29.0)	17 (44.7)	10 (26.3)
<b>Sheard's criterion</b>				
<b>Mild</b>	PFV blur 1.5 $\times$ near phoria	25 (30.9)	32 (39.5)	24 (29.6)
<b>Moderate</b>	PFV blur near phoria but < 1.5 $\times$ near phoria	26 (34.7)	27 (36.0)	22 (29.3)
<b>Severe</b>	PFV blur < near phoria	23 (35.4)	21 (32.3)	21 (32.3)
<b>Near point of convergence break (cm)</b>				
<b>Mild</b> 1SD - <2SD	6 cm to <9 cm	19 (31.1)	23 (37.7)	19 (31.1)
<b>Moderate</b> 2SD - <3SD	9 cm to <12 cm	19 (35.9)	20 (37.7)	14 (26.4)
<b>Severe</b> 3SD	12 cm or higher	36 (33.6)	37 (34.6)	34 (31.8)

**Table 3**

Pearson correlation coefficients and p-values describing the relationship between clinical measures of CI and the CISS symptom score.

Clinical measure	Pearson correlation	p-value <sup>†</sup>
Exophoria at near ( $\Delta$ )	0.054	0.42
Positive fusional vergence – blur ( $\Delta$ )	-0.018	0.79
Positive fusional vergence – break ( $\Delta$ )	-0.025	0.71
Positive fusional vergence – recovery ( $\Delta$ )	-0.072	0.28
PFV – blur relative to exophoria at near	-0.00032	0.99
Near point of convergence – break (cm)	0.068	0.32
Near point of convergence – recovery (cm)	0.094	0.17
Difference between distance and near phoria	0.027	0.70

<sup>†</sup> Comparing correlation to zero