OPO OPHTHALMIC AND PHYSIOLOGICAL OPTICS
THE JOURNAL OF THE COLLEGE OF OPTOMETRISTS

Ophthalmic & Physiological Optics ISSN 0275-5408

Effectiveness of vision therapy for convergence dysfunctions and long-term stability after vision therapy

Hoy Sun Shin[1], Sang Chul Park[2] and Willis C Maples[3]

[1]Department of Ophthalmic Optics, Yangsan College, Yangsan, South Korea, [2]Department of Ophthalmic Optics, Busan College of Information Technology, Busan, South Korea, and [3]Southern College of Optometry, Memphis, USA

Citation information: Shin HS, Park SC & Maples WC. Effectiveness of vision therapy for convergence dysfunctions and long-term stability after vision therapy. *Ophthalmic Physiol Opt* 2011, **31**, 180–189. doi: 10.1111/j.1475-1313.2011.00821.x

Keywords: accommodative insufficiency, convergence insufficiency, quality of life questionnaire, vision therapy

Correspondence: Sang Chul Park
E-mail address:
eyecareopto@yahoo.co.kr

Received: 10 May 2010; Accepted: 3 January 2011

Abstract

Background: Symptomatic convergence insufficiency (CI) is a common binocular dysfunction. It is often associated with accommodative insufficiency (AI). Optimum therapy for this condition was recently shown to be in-clinic vision therapy (VT). More scientific studies are needed to assess the effectiveness of VT and verify these evidence-based results.

Methods: Fifty-seven children aged 9–13 years were diagnosed with symptomatic CI ($n = 27$) or combined symptomatic CI and AI ($n = 30$). They were independently divided into a treatment and a control group, matched by age and gender. The treatment group received 12 weeks of VT while the control group received no therapy. A quality of life instrument documented the symptomatic patients and charted improvement in symptoms after therapy. Clinical aspects were also assessed to determine the treatment effects on clinical findings. Twenty children in the treatment group completed a 1 year follow-up examination.

Results: Symptom scores and clinical measures of the treatment and control groups were not significantly different at baseline ($p > 0.05$), but showed significant differences after completion of 12 weeks of treatment ($p < 0.001$). No significant changes of either symptoms or signs were evident for the control group. One year follow-up examination revealed that most children maintained the improved symptom and clinical measures after VT.

Conclusion: This study supports the notion that VT is a successful method of treating CI and CI combined with AI.

Introduction

Convergence insufficiency (CI) is a common binocular vision anomaly among school children[1–4] and is frequently associated with accommodative insufficiency (AI).[4–7] An individual with CI alone or combined with AI may report symptoms such as headache, blurred vision, ocular discomfort, diplopia or loss of concentration when performing near activities.[2,3,8] These symptoms can have a negative effect on the quality of life (QOL)[9,10] and school performance.[10–13] Symptomatic primary school children with binocular vision anomalies can exhibit significantly impaired academic performance.[4]

The College of Optmetrists in Vision Development (COVD)-QOL questionnaire was designed to document the changes in symptoms before and after vision therapy (VT).[14] This instrument has been a useful tool to measure improved QOL changes after VT.[9,15] The COVD-QOL short form, 19-item questionnaire has good test-retest reliability[16] in measuring subjects' visual symptoms. A numerical score is assigned to each item ('never' = 0 points, 'seldom' = 1 point, 'occasional' = 2 points, 'frequently' = 3 points, and 'always' = 4 points). The summed scores of the 19 items represent the visual symptoms score and is considered to represent accommodative, vergence, ocular motor and perceptual/cognitive

skills. A total score ≥20 is of concern, and further evaluation is indicated.[16]

The COVD-QOL questionnaire was previously independently given to 1031 parents and their children aged 9–13 years to identify symptomatic children.[4] The survey identified 327 symptomatic children based either on the response of the child or their parents. Of these, 136 children met our eligibility criteria and 96 of these children showed accommodative and/or vergence anomalies upon the completion of comprehensive eye examinations. Eligible symptomatic children were those without amblyopia, strabismus and ocular and/or systemic pathology, and who did not wear contact lenses. Children were also excluded if their visual acuity was poorer than 20/25 in either eye, presence of vertical phoria of >1 prism dioptre or presence of stereopsis >60 s (Titmus Stereo Fly; Bernell Corporation, Mishawaka, IN, USA). Fifty-seven of the 96 children who were diagnosed with CI or combined CI and AI were the subjects of this study.

Conventional VT comprises individually prescribed office-based and home-based procedures. It is an important mode of treatment for CI or combined CI with AI.[17,18] Few controlled trials have been reported to support the efficacy of VT for CI. Other than for CI, criticisms by systematically reviewed studies[19–21] claim a lack of scientific evidence to support VT. Recently, the CITT study group[18] reported a masked, placebo-controlled and randomized multi-center clinical trial of 221 children with symptomatic CI. An experimental group in the CITT study underwent 12 weeks of VT and demonstrated significant improvement of both symptoms and clinical signs of near point of convergence and positive fusional vergence measures. Among these 221 subjects, 121 children (55%) were associated with AI even though they were included in the diagnostic criteria of CI.

The most important factor in evaluating the real effects of VT is to measure improved symptoms and clinical measures. Improvements should also be long-lasting. The CITT study group[22] recently reported the long-term stability of the treatment effect for children with CI. This was a continuation of their previous work[18] that was conducted 1 year later. They reported most subjects who were asymptomatic after 12 weeks of VT maintained both improved symptoms and signs 1 year after completion of the VT program. The long-term maintenance of the treatment effect was consistent with earlier studies,[23,24] which reported little or no regression of symptoms or signs for CI subjects assessed 9 months to 2 years post VT, after being initially classified as cured. Certainly, more studies assessing the effectiveness of VT for CI or combined CI with AI should be conducted to verify these evidence-based results. Therefore, the goal of this project was to develop and conduct a controlled study of the effects of in-clinic VT for children with symptomatic CI with and without AI.

Methods

Subjects and examination

Fifty-seven children aged 9–13 years who were diagnosed in our previous study[4] with symptomatic CI ($n = 27$) or combined symptomatic CI and AI ($n = 30$) participated in the study. One female subject with combined CI and AI assigned to the treatment group was lost due to a family problem, leaving 29 CI and AI subjects. The children were divided into treatment and control groups that were matched for age and gender. More subjects were assigned to the treatment group after we considered the possibility of subject loss during the course of treatment. Relevant demographic and clinical data are summarized in *Table 1*. Of the 33 children assigned to the treatment group, nine were diagnosed with CI and 11 were diagnosed with combined CI and AI. Twenty of the 33 children were available for re-examination 1 year post-VT. Of the remaining 13

Table 1. Demographics and clinical characteristics of the study subjects

	Mean ± S.D.	
Classification	**Treatment group**	**Control group**
Convergence insufficiency		
Characteristic		
n (male/female)	15 (8/7)	12 (6/6)
Age, years	10.4 ± 1.6	11.2 ± 1.8
Distance horizontal phoria[a], Δ	0.7 ± 1.8	1.1 ± 1.2
Near exophoria, Δ	9.1 ± 1.5	9.1 ± 1.7
Near vertical phoria[b], Δ	0.2 ± 0.4	0.2 ± 0.4
Stereopsis, s	41.3 ± 5.2	45.0 ± 8.0
MAA, D	13.3 ± 2.6	12.2 ± 3.0
MAF, cpm	6.2 ± 1.9	6.7 ± 2.9
Combined convergence and accommodative insufficiency		
Characteristic		
n (male/female)	18 (10/8)	11 (6/5)
Age, years	11.9 ± 1.1	11.5 ± 1.0
Distance horizontal phoria[a], Δ	1.3 ± 1.9	1.6 ± 1.9
Near exophoria, Δ	9.3 ± 1.6	9.4 ± 1.8
Near vertical phoria[b], Δ	0.1 ± 0.3	0.1 ± 0.3
Stereopsis, s	46.1 ± 8.5	44.6 ± 8.2
MAA, D	7.5 ± 1.9	8.4 ± 1.4
MAF, cpm	1.8 ± 1.7	2.3 ± 1.4

[a]Distance horizontal phoria was expressed as an absolute value of exo- and eso-phoria.

[b]Near vertical phoria was expressed as an absolute value of hyper- and hypo-phoria.

MAA, monocular accommodative amplitude; D, dioptre; MAF, monocular accommodative facility; cpm, cycles per minute; Δ, prism dioptre; S.D., standard deviation.

children, two were lost to contact, two had moved, and nine had conflicts in scheduling as they had since enrolled in higher education institutes. The study protocol and consent form were approved by the Institutional Review Board of Keimyung University. Informed consent and assent was obtained from both the subjects and their parents after explaining the course of treatments to be performed.

Examinations were performed using a standardized protocol in a school clinic between October and December 2007. Clinical tests were divided into three stations and each station was consistently assigned to the same examiner to avoid examiner bias. All measurements were repeated three times and the average measurement was used for the analysis. The near point of convergence (NPC) was measured in free space with a Fixation Stick (Bernell Corporation, Mishawaka, IN, USA) and a millimeter ruler. The distance and near lateral and vertical phorias, and near positive fusional vergence (PFV) were measured by the von Graefe technique with a single line of 20/30 letter target using a model CDR-3100 digital refractor (Huvitz, Gyeonggi, South Korea) and Predio CDC-4000 chart (Huvitz). Monocular accommodative amplitude (MAA) was measured in free space by Donder's Push-up method using a single line of 20/30 reduced Snellen target and a millimeter ruler. Monocular accommodative facility (MAF) was measured with ±2.00 D flipper lenses and a 20/30 letter line.

Eligibility criteria for a diagnosis of CI were COVD-QOL scores ≥20, near exophoria >6 Δ and ≥4 Δ greater exophoria than the far, a receded NPC ≥6 cm break, and a reduced PFV (failing Sheard's criterion or, minimum normative positive fusional vergence of ≤12 Δ base out blur or ≤15 Δ base out recovery). Two additional eligibility criteria were defined for the combined CI and AI category. The criteria included all the eligibility criteria of CI and, in addition, a reduced push-up accommodative amplitude ≤2 D than Hofstetter's calculation for minimum amplitude (15 D−0.25 × age) and failure of MAF ≤4.5 cpm. The values of the minimum normative positive fusional vergence at near were eventually not considered for either category, since all of the subjects failed Sheard's criterion.

VT protocol

Children with CI and CI with AI underwent 12 weeks of a treatment program between January and March, 2008, after the school day was completed. Training procedures were supervised by clinicians not assigned to the measurements phase except for one (HSS) who measured the PFV and who was also involved in the treatment phase. Children assigned to the treatment group were scheduled to visit the school clinic two times per week for 1 h each treatment session and additionally were prescribed home support procedures to be performed for 15–25 min a day during the week. To negate the Hawthorne effect,[25] no symptom measurement or clinical measures were performed during the treatment phase, except for the scheduled evaluations. The specific accommodative and vergence procedures performed at school clinic and at home are shown in the Appendix. These techniques have been described in detail elsewhere.[17,26,27] The therapy followed the protocol through the phases. The clinician had the responsibility to advance the therapy from one phase to the other, as deemed necessary. No one was discharged before 12 weeks. Consequently, all subjects were phase 3 at the end of 12 weeks, but a few were unable to reach the goal for some of the procedures. Before the therapy program began, children in the treatment group and their parents were invited to a VT presentation to elicit active home participation. During this presentation, nothing was mentioned that would affect treatment outcome results. The clinicians who administered the therapy also evaluated each subject's progress. Each subject began with the first phase of VT listed in the Appendix and was judged by the clinician to be competent in that phase before she/he was promoted to the next higher phase. Children assigned to the control group were not given any of the VT procedures.

Follow-up measures

The evaluation of both symptoms and clinical tests were conducted after 6 weeks (12 h) and 12 weeks (24 h) of treatment, and again 1 year from the completion of the treatment program. The control group was re-examined at week 12. These findings were considered as follow-up data for the control group. The follow-up clinical tests were performed by the same designated examiner who originally performed the baseline measurement. The COVD-QOL questionnaire was administered with each evaluation to document any changes in the visual symptoms. The clinical measurements at each follow-up examination included NPC, PFV, MAA and MAF. Neither maintenance nor re-enforcement therapy was performed after the completion of 12 weeks of therapy.

Success criteria for treatment

Children who completed at least 20 treatment sessions (20 total hours) were categorized as either *cured* or *improved*. *Cured* criteria for children with CI were the following: the COVD-QOL scores decreased to <20, NPC improved to <6 cm break and PFV improved to at least twice the amount of the phoria based on Sheard's

criterion. *Improved* criteria were designated as COVD-QOL scores decreased to <20 and normal values were obtained in either the NPC or the PFV.

The *cured* criteria for children with combined CI and AI were the following: the COVD-QOL scores decreased to <20, NPC improved to <6 cm break, PFV improved to at least twice the amount of the phoria based on Sheard's criterion, MAA improved to ≥Hofstetter's calculation for minimum amplitude (D), and MAF increased to a minimum score of ≥7 cpm. The *improved* criteria for this combined category were that the COVD-QOL scores decreased to <20 and three of the following characteristics: NPC of <6 cm break, PFV to meet Sheard's criterion, MAA to satisfy Hofstetter's minimal requirement, and MAF of at least ≥7 cpm. We also considered the child was *improved* if the COVD-QOL was met with either one of the vergence or accommodative findings being adequate. That is, the subject was considered improved if either an adequate MAA or an adequate MAF (accommodative aspect) was measured; along with either a normal NPC or a normal PFV (vergence aspect).

Data analyses

Some of the data were not normally distributed, therefore, non-parametric tests were used for analyses using SPSS 12.0K for Windows. The intra-examiner repeatability for clinical measures during each phase was assessed using intra-class correlation coefficient (ICC). ICC values of 0.61–0.80 were interpreted to indicate good repeatability and 0.81–1.00 to indicate very good repeatability. Comparisons of symptom scores and clinical measures between the treatment and control groups were calculated by Mann–Whitney *U*-tests. Changes in symptom scores and clinical measures before and after 6 and 12 weeks for the treatment group were calculated by Friedman tests. Wilcoxon signed rank tests were used for before and after treatment for the control group, and to compare changes occurring by 1 year after completion of treatment for the treatment group. A level of $p < 0.05$ was considered statistically significant.

Results

There was excellent adherence by the study participants. The completion rate was 98%, comprising 27 children with CI and 29 children with combined CI and AI. Genders were combined (male $n = 30$, female $n = 26$) for analysis since there was no significant difference between male and female symptom scores ($p > 0.05$). The mean ± S.D. age for all subjects was 11.11 ± 2.00 years. The mean near exophoria, distance horizontal and near vertical phoria mean was 9.23 ± 1.60 Δ, 1.13 ± 1.73 Δ and 0.14 ± 0.35 Δ, respectively. The stereopsis mean was 44.29 ± 7.59 s. The accommodative findings that distinguished subjects between CI from combined CI and AI were relatively good in the CI group; MAA values were 12.83 ± 2.77 D for CI and 7.84 ± 1.71 D for combined CI and AI, and MAF values were 6.39 ± 2.34 cpm for CI and 1.97 ± 1.59 cpm for combined CI and AI.

The clinical characteristics of the CI group at each phase of the project are described in *Table 2a*. There was very good ICC for the NPC (0.84–0.97) and good repeatability for PFV (0.79–0.95), with a very high degree of statistical significance for both measures ($p < 0.001$). The mean ± S.D. values for the CI group symptom scores and clinical measures for the NPC and PFV are included. These data for both treatment and control group were not significantly different at baseline ($p > 0.05$), but showed significant differences after completion of 12 weeks of treatment program ($p < 0.001$). The mean ± S.D. COVD-QOL symptom score for the VT group was significantly decreased from 27.07 ± 5.09 to 10.40 ± 5.32 ($p < 0.001$). The mean ± S.D. NPC was improved from a pre therapy score of 8.67 ± 3.42 cm to a score immediately after VT of 3.20 ± 1.08 cm. The mean ± S.D. PFV almost doubled the initial measure (13.93 ± 3.15 Δ to 26.80 ± 5.94 Δ; $p < 0.001$), for pre- and post-VT scores, respectively. There were no significant changes between baseline and the 12 weeks follow-up in symptom score and the clinical measures of both NPC and PFV for the control group ($p > 0.05$).

Similar findings were shown for those with combined CI and AI (*Table 2b*). The repeatability for clinical measurements was generally very good: ICC for the NPC (0.87–0.98), PFV (0.78–0.93), MAA (0.88–0.92), and MAF (0.83–0.95) with a very high degree of statistical significance for all measurements ($p < 0.001$). The mean ± S.D. values of the symptom scores and all clinical measures for both treatment and control group were not significantly different at baseline ($p > 0.05$), but showed significant differences after the completion of 12 weeks of VT ($p < 0.001$). The mean ± S.D. symptom score decreased to a clinically significant level of <20 from 28.50 ± 8.35 to 14.06 ± 8.43 after therapy for the treatment group ($p < 0.001$). The right eye measurements for MAA and MAF were used for analyses, since the values were not different from the left eye ($p > 0.05$). All of the clinical measures of the mean ± S.D. for the NPC (from 11.33 ± 5.34 cm to 4.06 ± 1.88 cm), PFV (from 13.44 ± 2.97 Δ to 24.33 ± 6.15 Δ), MAA (from 7.53 ± 1.85 D to 15.19 ± 3.39 D) and MAF (from 1.78 ± 1.68 cpm to 16.50 ± 5.67 cpm) were significantly improved after VT for treatment group ($p < 0.001$). There were no significant changes between baseline and 12 weeks follow-up of the clinical measures of the NPC, PFV and MAA for the

Table 2. Characteristics of convergence dysfunctions

	Mean ± S.D.		
	Treatment group	**Control group**	***p* value[1]**
(a) Convergence insufficiency			
Parameter			
Symptom score			
Baseline	27.1 ± 5.1	24.3 ± 5.5	0.09
6 weeks	17.6 ± 6.4		
12 weeks	10.4 ± 5.3	25.8 ± 7.0	0.001
p value[2]	0.001	0.31	
NPC, cm			
Baseline	8.7 ± 3.4	11.5 ± 4.7	0.07
ICC	0.97***	0.90***	
6 weeks	4.4 ± 1.8		
ICC	0.92***		
12 weeks	3.2 ± 1.1	12.1 ± 4.9	0.001
ICC	0.84***	0.93***	
p value[2]	0.001	0.50	
PFV, Δ			
Baseline	13.9 ± 3.2	13.5 ± 2.7	0.25
ICC	0.81***	0.79***	
6 weeks	23.5 ± 4.3		
ICC	0.87***		
12 weeks	26.8 ± 5.9	14.2 ± 2.2	0.001
ICC	0.95***	0.82***	
p value[2]	0.001	0.31	
(b) Combined convergence and accommodative insufficiency			
Parameter			
Symptom score			
Baseline	28.5 ± 8.4	31.5 ± 9.1	0.46
6 weeks	17.9 ± 8.9		
12 weeks	14.1 ± 8.4	27.7 ± 6.0	0.001
p value[2]	0.001	0.032	
NPC, cm			
Baseline	11.3 ± 5.3	12.4 ± 4.3	0.37
ICC	0.98***	0.94***	
6 weeks	5.6 ± 3.2		
ICC	0.96***		
12 weeks	4.1 ± 1.9	12.9 ± 4.0	0.001
ICC	0.87***	0.95***	
p value[2]	0.001	0.44	
PFV, Δ			
Baseline	13.4 ± 3.0	14.2 ± 3.3	0.54
ICC	0.83***	0.78***	
6 weeks	20.7 ± 5.6		
ICC	0.93***		
12 weeks	24.3 ± 6.2	13.8 ± 2.9	0.001
ICC	0.88***	0.86	
p value[2]	0.001	0.52	
MAA, D			
Baseline	7.5 ± 1.9	8.4 ± 1.7	0.26
ICC	0.88***	0.92***	
6 weeks	12.6 ± 2.7		
ICC	0.91***		
12 weeks	15.2 ± 3.4	8.0 ± 1.7	0.001
ICC	0.90***	0.90***	
p value[2]	0.001	0.28	
MAF, cpm			
Baseline	1.8 ± 1.7	2.3 ± 1.4	0.36
ICC	0.83***	0.86***	
6 weeks	11.4 ± 4.9		
ICC	0.95***		
12 weeks	16.5 ± 5.7	3.6 ± 2.0	0.001
ICC	0.95***	0.83***	
p value[2]	0.001	0.011	

NPC, near point of convergence; PFV, near positive fusional vergence; Δ, prism dioptre; MAA, monocular accommodative amplitude; D, dioptre; MAF, monocular accommodative facility; cpm, cycles per minute; S.D., standard deviation.

p value[1]: Mann–Whitney *U*-test of treatment and control group for before (0 week) and after (12 weeks) treatment; ICC, intra-class correlation coefficient. ***; $p < 0.001$.

p value[2]: Friedman test of 0, 6, and 12 week data for treatment group and Wilcoxon signed rank test of 0 and 12 week data for control group.

control group. The symptoms and MAF showed a small ($p < 0.05$) but clinically insignificant improvement after 12 weeks follow-up.

A comparison of the 12 weeks and 1 year data were made between the 20 subjects that had measurements at both times (*Table 3*). One year after completion of treatment for the CI group, the NPC showed a small regression from 3.00 ± 1.15 cm to 4.17 ± 1.70 cm ($p = 0.011$), but still sustained an acceptable clinical mean of <6 cm. The improved symptom score of 11.56 ± 3.97 and PFV value of 27.11 ± 6.33 Δ after therapy were maintained at the 1 year follow-up measurement: 12.11 ± 5.13 for symptom score and 25.56 ± 3.97 Δ for PFV. Also, for the combined CI and AI group, the improved clinical measures were maintained for at least 1 year after the completion of the 12 weeks of therapy for the NPC (from 4.32 ± 2.32 cm to 4.73 ± 1.84 cm), PFV (from 24.18 ± 6.95 Δ to 24.91 ± 5.39 Δ) and MAA (from 15.14 ± 3.69 D to 14.27 ± 2.61 D). The mean symptoms showed a small regression from 11.09 ± 5.52 to 14.73 ± 6.12 ($p = 0.032$) at the 1 year follow-up, but were still well below the 20 point clinical criteria. MAF showed a small regression from 17.82 ± 3.77 cpm to 15.00 ± 3.95 cpm ($p = 0.01$), but was deemed clinically insignificant since the final measure was still over double the score needed for failure. *Figures 1 and 2* present graphical representations of the symptom and PFV measurements, respectively, at base line, 12 weeks of treatment, and 1 year follow-up using Box-and-Whisker plots. The horizontal

Table 3. Results of Wilcoxon signed rank tests for after 12 weeks of treatment and 1 year follow-up

	Mean ± S.D.	
	CI (*N* = 9)	**Combined CI and AI (*N* = 11)**
Symptom score		
12 weeks	11.5 ± 4.0	11.1 ± 5.5
1 year follow-up	12.1 ± 5.1	14.7 ± 6.1
p value	0.73	0.032
NPC, cm		
12 weeks	3.0 ± 1.2	4.3 ± 2.3
1 year follow-up	4.2 ± 1.7	4.7 ± 1.8
ICC	0.90***	0.88***
p value	0.011	0.32
PFV, Δ		
12 weeks	27.1 ± 6.3	24.2 ± 7.0
1 year follow-up	25.6 ± 4.0	24.9 ± 5.4
ICC	0.84***	0.88***
p value	0.28	0.59
MAA, D		
12 weeks		15.4 ± 3.7
1 year follow-up		14.3 ± 2.6
ICC		0.95***
p value		0.46
MAF, cpm		
12 weeks		17.8 ± 3.8
1 year follow-up		15.0 ± 4.0
ICC		0.90***
p value		0.01

NPC, near point of convergence; PFV, near positive fusional vergence; Δ, prism dioptre; MAA, monocular accommodative amplitude; D, dioptre; MAF, monocular accommodative facility; cpm, cycles per minute; S.D., standard deviation; ICC, intra-class correlation coefficient. ***; $p < 0.001$.

The repeatability for clinical measurements (NPC, PFV, MAA, and MAF), measured after 1 year of treatment, was found to be very good.

line and square inside the box refers to the median and mean value, respectively.

Children completing at least 20 VT sessions were categorized as either *cured* or *improved* according to success criteria (described previously), and were compared at the end of the therapy (*Table 4*). Eleven (73%) of 15 the children diagnosed as CI satisfied the *cured* CI criteria for both the symptom alleviation and normal clinical measures for NPC and PFV. Thirteen (86%) of the 15 children satisfied the *improved* criteria of alleviated symptoms and clinical measures of either NPC or PFV. The success rate for those with combined CI and AI was somewhat lower than for those with CI alone. Eleven (61%) of 18 children satisfied the *cured* criteria of both symptom alleviation and normal clinical measures of NPC, PFV, MAA and MAF. Fourteen (77%) of the 18 children satisfied the *improved* criteria that required the symptoms to be alleviated and some of the clinical measures to be normal.

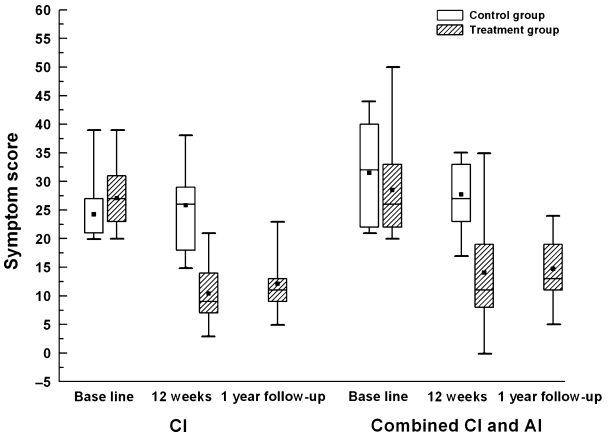

Figure 1. Box-and-Whisker plots of the symptom score at base line, 12 weeks of treatment, and 1 year follow-up for convergence dysfunctions. In this and Figure 2, a comparison of the 12 weeks and 1 year data were made between the subjects that had measurements for both the 12 weeks and 1 year follow-up.

Of the children who completed a follow-up examination after 1 year, only one child with CI showed clinical regression of the NPC (≥6 cm) and a symptom score of ≥20. The symptom score for two children with combined CI and AI had deteriorated to ≥20 on the COVD-QOL and one of these also displayed a regression of the NPC. The improved symptom and clinical signs of seventeen remaining children were maintained.

Discussion

The results demonstrate that in-office VT has a significant positive effect on both the signs and symptoms of CI and CI with AI. This study also documents that

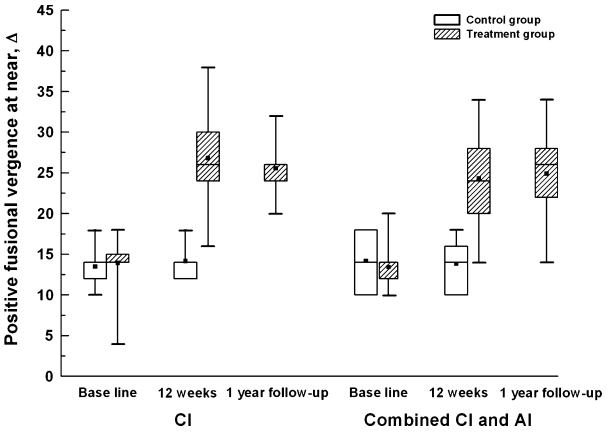

Figure 2. Box-and-Whisker plots of the PFV measurements at base line, 12 weeks of treatment, and 1 year follow-up for convergence dysfunctions.

Table 4. The success rate of VT for 15 children with convergence insufficiency and 18 children with combined convergence and accommodative insufficiency after 12 weeks of treatment

Convergence dysfunctions	After 12 weeks of treatment % (N)
Convergence insufficiency	
Cured rate	73 (11/15)
Improved rate	86 (13/15)
Parameter	
Symptom score, <20	86 (13/15)
NPC, <6 cm	93 (14/15)
PFV, passing Sheard's criterion	93 (14/15)
Combined convergence and accommodative insufficiency	
Cured rate	61 (11/18)
Improved rate	77 (14/18)
Parameter	
Symptom score, <20	77 (14/18)
NPC, <6 cm	88 (16/18)
PFV, passing Sheard's criterion	100 (18/18)
MAA, ≥minimum amplitude	83 (15/18)
MAF, ≥7 cpm	88 (16/18)

positive changes persist, with improvement of both symptoms and signs of CI and AI holding for at least 1 year. Scheiman *et al.*[28] and the CITT Study Group[18] reported that both symptoms and clinical signs are clinically and statistically improved after office-based VT. Symptomatic children with CI who underwent office-based VT displayed improvements in the symptoms and clinical signs of NPC and PFV that were significantly better than the placebo group. These results held for the great majority of the subjects for 1 year.[22] Our study followed a similar protocol to the CITT study, although our study was designed independently and without knowledge of the long term follow-up by the CITT study group.

The treatment and control groups of our study were carefully matched for age and gender at baseline and were not significantly different from one another, either in symptom measures or clinical signs at the beginning of the study. After 12 weeks of VT (24 total hours of in-office VT), the symptoms and clinical measures showed improvement in the VT group over the control group. These children significantly improved in both symptoms and clinical signs, as with the CITT study. Likewise, the results held for at least 1 year. A placebo effect, however, may have been at play in our study, since the children assigned to the control group were not given any sham treatment. Therefore, more attention was given to the children assigned to the VT group both at the clinic and at home, where their parents guided individual home-prescribed procedures. It is possible that this extra attention might have impacted the children's improved symptoms through a Hawthorne effect.[25]

Another concern with this study was that one clinician was partially masked while conducting clinical measurements and training procedures. Clinician HSS performed the PFV testing as well as being involved in the therapeutic aspects of this study. This might have influenced the result of measurements. However, only one examiner was engaged for both treatments and measurements. All other examiners were strictly separated between the examination phase and the training phase. The clinical tests were performed three consecutive times with a standardized protocol that showed good to very good repeatability. Each test was conducted by a specifically designated examiner throughout the tests. We feel that this protocol helped to avoid examiner bias, thereby minimizing the error of measurements.

The sustainability of the improvement in signs and symptoms warrants discussion. The objective findings of those 20 children who completed VT in the present study were considered after 1 year. Only one child (5%) initially diagnosed with CI had regressed in signs (NPC >6 cm) and symptoms (>20). The symptoms score for two children with combined CI and AI had deteriorated to ≥20. One of these also measured a regression of the NPC. The improved symptoms and clinical signs of the 17 remaining children with CI and CI with AI were maintained. Eighty-five percent of these children maintained the gains for at least 1 year.

The CITT study group[22] supported the efficacy of VT over an extended period. Both the CITT study and our study demonstrate the benefit of VT for CI. The CITT group reported that 16% of the in-office VT group regressed with either signs and/or symptoms after 1 year. The asymptomatic percent (84%) agreed almost exactly with our 85% asymptomatic sample. We were not able to measure 1 year symptoms with the control group, although symptoms have been reported as stable in a majority of college students over a 1 year period.[29]

The NPC for the CI group as well as the symptoms and MAF for combined CI and AI group mean showed a regression in a minor number of subjects, these changes were not considered clinically relevant. Both the symptoms and clinical measures for CI and CI combined with AI showed a small mean regression at the 1 year follow-up. Most of these changes were not significantly different from the 12 weeks post-therapy measures. These small regressions might represent a natural change in long-term adaptation. One would expect highest treatment effects immediately after 12 weeks of treatment. The regressions could be due to an insufficient treatment time for some subjects; the VT protocol proposed that all subjects should be at phase 3 at the end of 12 weeks, but a few were unable to reach the goal for some of the procedures. It is possible that a 12-week VT program may not

have been sufficient for every subject. Certainly, these regressions could also be impacted by as yet unidentified factors.

There was a slight difference in the VT protocol between the two studies. The CITT study therapeutic protocol was 12 weeks of 60 minute in-office therapy, yielding a total time of 12 h of in-office VT combined with home support for 15 min a day on weekdays. Our study also utilized 1 h VT sessions, but for twice a week for 12 weeks for a total of 24 h of in-office VT and home support for 15–25 min a day on weekdays. The higher amount of time for in-office therapy in our study might have influenced the higher success rate. Not all children participated in all 24 h of VT for various reasons. We, therefore, analyzed only the data from children who had participated for at least 20 h of VT. In the study of Scheiman *et al.*,[28] 53% of participants were reported as *cured* and 80% were *improved*, whereas the *cured* and *improved* CI rates in our study were 73% and 86%, respectively. A continuation study[18] reported either successful or improved success outcomes of 73% of CI subjects; although more than half of the subjects were also associated with AI, they were included in the diagnostic criteria of CI. The CITT success rate might have been even lower if more stringent criteria had been considered with combined AI subjects, as was presently done using the additional criteria of MAA and MAF. Even so, our data indicated a *cured* or *improved* rate of 61% and 77%, respectively.

It is curious that the symptoms of one child with CI and two children with combined CI and AI regressed somewhat. A symptom score of ≥15 but <20 was measured after completion of the 12 weeks of therapy for those who regressed. These subjects' symptom scores were, therefore, relatively higher than that of the other successful children. Possibly the relatively insufficient sustained improvement with these children might have been why their symptoms were higher immediately after completion of VT. NPC deteriorated: the NPC for one child with CI and one with combined CI and AI were regressed at the 1 year follow-up. These children were considered border-line when measured immediately after 12 weeks of VT. Overall, we found conventional in-office VT to be an effective treatment method for improving both symptoms and signs of symptomatic children with CI or combined CI and AI.

A logical extension of this study would be that these subjects should be followed for several years. By monitoring their symptoms and clinical measures, one could document if positive findings would be sustained. A much longer term follow-up study should be conducted to answer/clarify this question and to verify any long-term effectiveness of VT.

This study did not perform maintenance therapy after the completion of formal VT. The success rate might have been even higher if such maintenance therapy had been employed. Another area of this study should be to perform maintenance/re-enforcement therapy on the VT group after completion of VT and compare them to subjects who did not undergo maintenance therapy after completion of VT. Such information might identify the most effective treatment for CI and combined CI and AI.

The enhancement of visual functions by eliminating symptoms, while improving vergence and accommodative abilities, is valuable to the patient in its own right. A previous study[4] showed that binocular vision anomalies, CI or combined CI and AI were common among school children. Furthermore, these anomalies were also significantly associated with impaired academic performance. Conceptually, therefore, the improvement should allow children to perform to their maximal learning potential, ultimately promoting a healthy vision and learning system. An issue that is still unresolved and which remains the crux of current criticism about VT is whether academic performance improves once vision skills and conditions are improved. The results of the CITT study group[18,22] and in the present paper show that symptomatic CI and CI combined with AI responds well to VT, with the improvements maintained at least 1 year. The consequence of these improvements on academic performance remains to be investigated in a controlled study.

Conclusions

The results lead us to concur with Scheiman *et al.*[28] and the CITT study group[18,22] that in-office VT is an effective treatment for symptomatic CI and CI combined with AI. The symptomatic individuals assigned to the control group did not change. We further conclude that the beneficial effects of in-office VT are sustained for at least 1 year. Future research should investigate if various administration protocols (longer total VT exposure, use of maintenance VT) would improve the effectiveness of the therapy. Future studies need to assess whether there is a concomitant improvement in symptoms and objective signs for CI and CI combined with AI that is correlated with an improvement in academic performance.

Acknowledgements

We are indebted to M.Y, Kim, H.S. Bae, J.M. Kim and K.H. Park for their assistance with the treatment phase, and to S.H. Lee for his help in carrying out the measurements.

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Appendix

Phase 1		
Gross convergence	PFV	MAF
At school		
Brock String then Barrel Card	Vectograms (Quoits, Clown, Fusion) Then Tranaglyphs (Bunny, Plane)	±1.50 D Lens Flipper
At home		
Brock String then Barrel Card	HTS† Both Base In and Out	±1.50 D Lens Flipper, HTS† Accommodative Rock
Phase 2		
Ramp Fusional Vergence	MAF	
At school		
Vectograms (Quoits, Clown, Basic Fusion) Then Tranaglyphs (Bunny, Plane) Then Prism Flippers Then Synoptophore Both Base In and Out Then Aperture Rule	±2.50 D Lens Flippers	
At home		
Prism Flippers, HTS†Autoslide Vergence	±2.50 D Lens Flippers, HTS† Accommodative Rock	
Phase 3		
Jump Fusional Vergence	BAF	
At school		
Prism Flippers Then Aperture Rule Then Life Saver Card Then Eccentric Circles	±2.50 D Lens Flippers	
At home		
Life Saver Card Then Eccentric Circles, HTS† Jump Ductions	±2.50 D Lens Flippers, HTS† Accommodative Rock	

†Home Therapy System (HTS) procedures were performed before the conventional procedures at home training.

Goals

Brock String: No suppression, no hyper phoria projection, immediate control of string crossing to 2 inches from the nose (Phase 1).

Barrel Card: Immediate ability to fuse each position to 1 inch from the nose (Phase 1).

Vectograms: Develop a vergence range of 15 Δ BI/30 Δ BO (Phase 1). Increase ranges of BI/BO vergence and develop immediate facility of BI/BO jump duction, SILO (Phase 2).

Tranaglyphs: Develop a vergence range of 15 Δ BI/30 Δ BO (Phase 1). Increase ranges of BI/BO vergence and develop immediate facility of BI/BO jump duction, SILO (Phase 2).

Lens Flipper: Ability to clear 20 cpm of the 20/30 Accommodative Rock Card with monocular condition (Phase 1 and 2) and binocular condition (Phase 3).

HTS Both Base In and Out: Automatic demand of both Base In and Out vergences at the computer (Phase 1).

HTS Accommodative Rock: Automatic demand of different level of ± power lenses at the computer (Phase 1–3).

Prism Flippers: Develop vergence facility with 8 Δ BI/8 Δ BO lenses (Gross target and Fine target being used at Phase 2 and Phase 3 respectively).

Synoptophore: Increase ranges of BI/BO vergence and develop immediate facility of BI/BO jump duction (Phase 2).

Aperture Rule: Fuse all cards (12 cards) on the single aperture settings and to card 6 on the double aperture setting (Phases 2 to 3).

HTS Autoslide Vergence: Automatic demand of different BI/BO vergences at the computer (Phase 2).

Lifesaver Card: Facility of fusion of different targets vertically and at different distances. SILO (Phase 3).

Eccentric Circles: Facility of fusion at different distances (Phase 3).

HTS Jump Ductions: Automatic demand of BI/BO jump duction at the computer (Phase 3).