J. Phys. Ther. Sci.
26: 223–227, 2014

Improvement of Vergence Movements by Vision Therapy Decreases K-ARS Scores of Symptomatic ADHD Children

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Abstract. [Purpose] To determine whether the improvement of vergence movements by vision therapy can decrease the K-ARS scores of symptomatic ADHD children. [Methods] Eighty-one out of 1,123 children surveyed using the K-ARS, a parents'-reported questionnaire, led to 16 of these 81 children being showed scores of ≥19, and measurement of binocular function diagnosed as having convergence insufficiency. The 16 children were divided equally into a control group and a vision therapy group. [Results] After vision therapy for 12 weeks, near point convergence (4.38±0.69 cm) significantly neared compared to the near point convergence before vision therapy (11.50±2.28 cm), and both the break point (32.38±2.53 Δ) and recovery point (19.75±2.11 Δ) of near positive fusional vergence significantly improved compared to their values before vision therapy (15.88±2.64 Δ, 6.38±6.70 Δ, respectively). Near exophoria after vision therapy (7.81±2.00 Δ BI) significantly decreased compared to its value before vision therapy (12.00±1.16 Δ BI). The K-ARS scores referring to symptomatic ADHD significantly decreased after vision therapy (17.13±2.84) compared to before vision therapy (23.25±1.49). [Conclusions] Convergence insufficiency symptoms are closely related to symptoms screened for ADHD, and vision therapy to improve vergence movements is an effective method of decreasing the K-ARS scores.
Key words: Convergence insufficiency, Vision therapy, ADHD

(This article was submitted Jul. 24, 2013, and was accepted Sep. 1, 2013)

INTRODUCTION

Convergence is one of the most important binocular functions of stereopsis and is a common vision disorder characterized by excess and insufficiency. Convergence insufficiency (CI) has great potential to induce exophoria at near[1, 2)]. The adverse impact of CI, during near viewing, results in typical symptoms including double vision, blurred vision, eye strain, difficulty with concentration, and slow reading[3, 4)]. These symptoms are closely related to attention deficit hyperactivity disorder (ADHD) and the academic achievement of school children[5–7)]. Several investigators have concluded that children with ADHD exhibit more visual and quality-of-life symptoms than children without ADHD. Some of the symptoms of ADHD overlap with those of CI. The symptoms frequently reported in CI such as loss of concentration when reading, or reading slowly, are similar to behaviors associated with ADHD (inattentive type), such as failure to complete assignments, and trouble of concentration in class[8)]. A diagnosis of ADHD for a child has an impact not only on the life of the child, but also on the family, the school, and society as a whole[9)]. For a complete diagnosis, a medical evaluation should be performed. Furthermore, an evaluation of binocular functions should be made, because some visual problems may be the cause of a child's academic underachievement and/or lack of concentration[10, 11)]. Recently, the relationship between CI and ADHD has been investigated[8, 10, 12)], but the effect on ADHD of convergence improvement has rarely been studied. We are confident that symptomatic ADHD with CI can be significantly relieved by continuous and self-conscious training for vergence improvement, because vergence movements are controlled by voluntary motor innervation.

In this study, we selected children with symptomatic ADHD, as reported by their parents on the Korea-ADHD Rating Scale (K-ARS) questionnaire, and CI evaluated by a binocular function test, and investigated whether vision therapy (VT) for improvement of vergence movement can relieve the symptoms of ADHD evaluated by K-ARS.

SUBJECTS AND METHODS

For the selection of children with symptomatic ADHD, a total of 1,123 parents participated in a questionnaire survey using the K-ARS[13, 14)]. Their children, ranging from 8–13 years of age, were attending the 1st, 2nd, 3rd, 4th, 5th, and 6th grades of a public primary school in G City, Korea. A

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child is identified with symptomatic ADHD when their score is ≥19 on the K-ARS questionnaire[15]. The number of subjects reporting K-ARS scores ≥19 totaled 81 children. The binocular functions test found that 16 of these 81 exhibited CI without accommodative dysfunctions. These 16 children were divided equally into a control group and a VT group. Each subject and his or her parent provided informed consent to participation in this study after receiving an oral explanation of its method. The study was conducted in adherence to the ethical principles of the Declaration of Helsinki. All subjects were without physical problems, receiving no medical care, taking no medication, and exhibiting no signs of strabismus, or amblyopia.

Measurements of binocular functions are as follows. The examiner corrected refractive errors by subjective refraction with a phoropter (CV-3000, Topcon, Japan) using a decimal visual chart (ACP-7, Topcon, Japan) at 5 m (25–35 lux of interior illuminance and 110–120 lux of chart illuminance). The near point of convergence (NPC) was measured using a fixation stick (Bernell, Indiana, USA) and a ruler. The examiner moved (1–2 cm/sec) the target toward the midpoint of the subject's eyes from 40 cm away. When the subject reported a double target or one eye lost target fixation, the distance measured from the midpoint of eyes to target was recorded as NPC. The fusional vergence facility (FVF) was measured using flipper lenses mounted 3 Δ base in (BI)/12 Δ base out (BO) and Vectogram 9 (Bernell, Indiana, USA) at 40 cm. The examiner placed the 12 Δ BO lenses in front of subject's eyes and as soon as the subject reported that the print became single and clear, flipped the lenses to 3 Δ BI. The number of full cycles that consisted of both the BI and BO lenses in 60 seconds was recorded as FVF. A 6 Δ base up (BU) was placed over the left eye and a 12 Δ BI was placed over the right eye in the subject who was seated behind the phoropter. A vertical arrow target was held at 40 cm from the subject by the examiner. Subjects were instructed to keep the target clear at all times. If subjects didn't see target dissociation vertically, the examiner adjusted the Risley prism over the left eye until dissociation occurred. The examiner then checked the relative direction of the upper target to the lower one, right or left. The horizontal prism over the right eye was slowly moved until the subject said that two targets were aligned vertically. At this point, prism power and base direction were recorded as horizontal phoria. The horizontal vergence at near and at distance was measured using an isolated vertical line of 0.7 letters with subjects seated behind the phoropter. Risley prisms set to zero were placed before both eyes. The examiner instructed the subject to look at the target and try to keep it clear, and introduced the BI prism before both eyes at a speed of approximately 1 prism diopter per second. As prism is added, the total amount of prism before the two eyes was noted when the subject reported the line of letters had broken into two (break point of negative fusional vergence; NFV). After overshooting the break point slightly by adding a little more prism in the same direction, the examiner instructed the subject to acknowledge when the target became single again, and reduced prism until the subject reported the target was single (recovery point). The total amount of prism before both eyes was noted. The examiner repeated the measurement with the BO prism before both eyes (positive fusional vergence; PFV).

Table 1. The program of vision therapy for children having symptomatic ADHD and convergence insufficiency

Phase 1
Office based
Block string and Barrel card: convergence and accommodation exercise
Vectograms and Tranaglyphs: convergence exercise
Synoptiscope: convergence and divergence exercise
Home based
Block string and Barrel card: convergence and accommodation exercise
HTS: convergence and divergence exercise
Phase 2
Office based
Vectograms, Tranaglyphs, and Aperture rule: convergence exercise
Synoptiscope and Prism flipper: convergence and divergence exercise
Home based
HTS and Prism flipper: convergence and divergence exercise
Phase 3
Office based
Aperture rule, Life saver cards, and Eccentric circles: convergence exercise
Prism flipper: convergence and divergence exercise
Home based
Life saver cards and Eccentric circles: convergence exercise
HTS and Prism flipper: convergence and divergence exercise

HTS, home therapy system

Major eligibility criteria for VT were: high exophoria at near (6 Δ or greater), exophoria at near at least 4 Δ greater than at distance, a receded NPC break (6 cm or greater), or insufficient PFV at near; or failing Sheard's criterion (PFV less than twice the near phoria[16]), or minimum PFV ≤ 15 Δ BO blur or break. The program of VT was composed of three phases lasting for 12 weeks, which were divided into home-based VT and office-based VT (Table 1), and three optical practitioners conducted the VT. Each subject in the VT group was instructed how to perform their therapy both at home and with a practitioner every week, and performed 30 minutes of the program, five days a week, at home and at the practitioner's office. To arouse the children's interest in VT, different types of tools were used for the same training. The subjects in the control group continued living their typical day-to-day lives without VT. After VT for 12 weeks, the questionnaire survey using K-ARS was answered again by the children's parents.

Data analysis was performed using SPSS for Windows (SPSS Inc., Chicago, USA). The Mann-Whitney U test was used to compare the mean difference of binocular functions before and after VT, and ANCOVA was used to compare the mean difference of symptomatic ADHD by K-ARS

Table 2. Changes of near point of convergence and fusional vergence facility after vision therapy for children having symptomatic ADHD and CI

Parameters	Control group (8)		VT group (8)	
	Before VT	After VT	Before VT	After VT
NPC (cm)	13.59±2.12	11.20±1.75	11.50±2.28	4.38±0.69*
FVF (cycles/min)	7.38±1.69	8.13±1.77	12.75±1.81	14.75±0.92

Data are expressed as mean±SD.
*p<0.05: significantly different in the same group according to the Mann-Whitney U test
The number of subjects is in parentheses.
VT, vision therapy; NPC, near point of convergence; FVF, fusional vergence facility

Table 3. Changes of binocular vergence and horizontal phoria at near after vision therapy for children having symptomatic ADHD and CI

Parameters	Control group (8)		VT group (8)	
	Before VT	After VT	Before VT	After VT
PFV break point (Δ)	16.13±1.20	15.25±2.00	15.88±2.64	32.38±2.53**
PFV recovery point (Δ)	6.13±2.08	5.75±2.68	6.38±6.70	19.75±2.11**
NFV break point (Δ)	21.88±1.11	20.63±0.75	19.50±1.63	26.25±1.81**
NFV recovery point (Δ)	16.50±1.48	12.88±0.83	15.38±2.11	18.50±2.53
Horizontal phoria (Δ)	−9.19±1.04	−8.81±1.16	−12.00±1.16	−7.81±2.00*

Data are expressed as mean±SD.
*p<0.05, **p<0.01: significantly different in the same group according to the Mann-Whitney U test
The number of subjects is in parentheses.
Minus sign denotes exophoria in phoria measurement.
VT, vision therapy; PFV, positive fusional vergence; NFV, negative fusional vergence

Table 4. Changes of binocular vergence and horizontal phoria at distance after vision therapy for children having symptomatic ADHD and CI

Parameters	Control group (8)		VT group (8)	
	Before VT	After VT	Before VT	After VT
PFV break point (Δ)	11.25±1.06	10.13±1.57	15.50±3.40	27.25±1.94**
PFV recovery point (Δ)	2.38±1.87	2.63±1.66	3.38±0.65	15.00±2.65**
NFV break point (Δ)	7.38±1.07	8.00±0.98	10.88±2.86	12.38±2.54
NFV recovery point (Δ)	3.25±0.37	3.13±0.35	6.25±2.55	7.63±2.34
Horizontal phoria (Δ)	−1.31±0.63	−1.13±0.58	−2.38±0.74	−2.75±0.89

Data are expressed as mean±SD.
**p<0.01: significantly different in the same group according to the Mann-Whitney U test
The number of subjects is in parentheses.
Minus sign denotes exophoria in phoria measurement.
VT, vision therapy; PFV, positive fusional vergence; NFV, negative fusional vergence

scores before and after VT while adjusting for differences at baseline. The two tests were analyzed using a 95% confidence level.

RESULTS

The changes of NPC and FVF after VT over 12 weeks are given in Table 2. NPC of 11.50±2.28 cm before VT significantly neared ($p<0.05$) to 4.38±0.69 cm after VT. FVF after VT increased by 2 cycles compared to before VT, but the difference was not significant.

The changes of vergence functions at near such as PFV, NFV, and horizontal phoria after VT are given in Table 3. The prism diopters in both the break point and recovery point of PFV after VT significantly increased ($p<0.01$) compared to before VT. The break point was measured as 32.38±2.53 Δ, an increase of BO 16.5 Δ, and the recovery point was measured as 19.75±2.11 Δ, an increase of BO 13.4 Δ. In NFV, though both the break point and recovery point showed increases of BI prism diopters, only the break point showed a significantly increase ($p<0.01$) of BI 6.8 Δ. Horizontal phoria, measured as 12.0 Δ of exophoria before VT, significantly decreased ($p<0.05$) to 7.8 Δ of exophoria after VT.

The changes of vergence functions at distance after VT are given in Table 4. The change pattern of all functions was

similar to that of at near. After VT, the break point of PFV was measured as 27.25±1.94 Δ, a significant increase of BO 11.8 Δ ($p<0.01$), and the recovery point of PFV was measured as 15.00±2.65 Δ, a significant increase of BO 11.6 Δ ($p<0.01$). However, horizontal phoria showed no significant difference between before and after VT.

The scores of symptomatic ADHD as assessed by the K-ARS questionnaire are given in Table 5. The score before VT was 23.25±1.49, and it significantly decreased ($p<0.05$) to 17.13±2.84 after VT.

Table 5. Changes of scores reported by parents answering the K-ARS questionnaire after vision therapy for children having symptomatic ADHD and CI

Groups	Scores of symptomatic ADHD by K-ARS	
	Before VT	After VT
Control group (8)	25.88±1.97	23.38±2.23
VT group (8)	23.25±1.49	17.13±2.84*

Data are expressed as mean±SD.
*$p<0.05$: significantly different in the same group according to ANCOVA
The number of subjects is in parentheses.
VT, vision therapy; ADHD, attention deficit hyperactivity disorder; K-ARS, Korea-ADHD Rating Scale

DISCUSSION

A specific vision condition is closely related to the diagnosis of symptomatic ADHD in children[3]. CI causes symptoms of asthenopia, blurred vision, and the sensation that words and letters run away in reading or near work[17]. Some patients complain of near diplopia, nausea, or occasional headaches[18]. Many cases of CI show poor or delayed reading, or simply lag behind in schoolwork. CI could impede the academic achievements of patients with ADHD. This implies that CI has the possibility of being a comorbid disorder in ADHD patients. Considering that CI is a treatable disorder, management with orthoptic intervention may help patients with ADHD who also suffer from CI[10]. However, it is not obvious that the successful treatment of CI improves symptomatic ADHD. In the present study, we found that improvement of convergence functions significantly decreases the K-ARS scores of children with symptomatic ADHD.

The parents' K-ARS questionnaire for symptomatic ADHD is based on the DSM-IV criteria for ADHD, and 5 of the 9 symptoms of inattention could also be applicable for CI[19]. Our K-ARS questionnaire survey of 1,123 parents found the percentage of children with reported scores of ≥19, suggestive of ADHD symptoms, was 7.2%. Of these, 19.5% had CI without accommodative dysfunctions.

To achieve optimum improvement of CI, clinical guidelines suggest the length of treatment of office-based therapy should generally be 12–24 weeks[20], and the shortest recommended duration is 12 weeks[21]. These suggestions were made for both home-based and office-based treatments, such as computer vergence therapy and pencil push-up, for children with symptomatic CI. In the VT program of this study, the duration of therapy was 12 weeks, and both home-based and office-based therapies were conducted for the subjects. Scheiman et al.[22] found that only office-based vergence/accommodative therapy and home reinforcement resulted in significant improvements in symptoms between visits ($p<0.001$). The rate of improvement was more rapid for clinical signs (NPC and PFV) than for the symptoms of the children undergoing treatment for CI. NPC and PFV improved to within their normal ranges after 12 weeks of VT. Borsting et al.[23] documented that successful treatment of CI induced a significant decrease in exophoria at near ($p<0.001$). The important markers of improvement in CI are NPC, PFV, and exophoria at near. In our results, the NPC after VT (4.38±0.69 cm) significantly neared, compared to before VT (11.50±2.28 cm), to within its normal ranges. The break point (32.38±2.53 Δ) and recovery point (19.75±2.11 Δ) of PFV at near after VT significantly improved compared to before VT (15.88±2.64 Δ, 6.38±6.70 Δ, respectively). The exophoria at near after VT (7.81±2.00 Δ BI) significantly decreased compared to before VT (12.00±1.16 Δ BI). Although the near exophoria after VT remained outside of its normal range, high exophoria >6 Δ, the other criteria, such as PFV less than twice the near phoria, or minimum PFV ≤15 Δ BO blur or break, had improved to within their normal ranges. In the successful treatment conducted by Borsting et al.[23], even when the near exophoria significantly decreased, the mean of exophoria after 12 weeks of treatment was high (8.90 Δ). Thus, our results indicate that CI is improved by a VT program. With these improvements in CI, the K-ARS score of symptomatic ADHD significantly decreased after VT to 17.13±2.84, a score below the level, 19, suggestive of ADHD. Moreover, the significant decrease K-ARS score after VT was not dependent on the relief of a specific symptom, but was based on the relief of various symptoms.

Based on our results, binocular dysfunction should always be considered in conjunction with the questionnaire survey for diagnosis of ADHD symptoms, especially, insufficient convergence, because several questions in the survey of ADHD symptoms could also be used in the diagnosis of symptomatic CI. Though a VT program for successful improvement of CI, including both long-term and maintenance therapy is needed[24], improvements in NPC, PFV, and horizontal phoria were coincident with improvements in symptomatic ADHD of children. Consequently, the results of this study demonstrate the beneficial impact of treating children with CI on symptomatic ADHD based on parental report.

REFERENCES

1) Borsting E, Rouse MW, Deland PN, et al.: Association of symptoms and convergence and accommodative insufficiency in school-age children. Optometry, 2003, 74: 25–34. [Medline]
2) Rouse MW, Borsting E, Hyman L, et al.: Frequency of convergence insufficiency among fifth and sixth graders. The convergence Insufficiency and Reading Study (CIRS) group. Optom Vis Sci, 1999, 76: 643–649. [Medline] [CrossRef]
3) Borsting E, Rouse MW, De Land PN: Prospective comparison of convergence insufficiency and normal binocular children on CIRS symptom survey. The Convergence Insufficiency and Reading Study (CIRS) Group. Optom Vis Sci, 1999, 76: 221–228. [Medline] [CrossRef]

4) Borsting EJ, Rouse MW, Mitchell GL, et al.: Validity and reliability of the revised convergence insufficiency symptom survey in children aged 9 to 18 years. Optom Vis Sci, 2003, 80: 832–838. [Medline] [CrossRef]
5) Vaughn W, Maples WC, Hoenes R: The association between vision quality of life and academics as measured by the College of Optometrists in Vision Development quality of life questionnaire. Optometry, 2006, 77: 116–123. [Medline] [CrossRef]
6) American Academy of Pediatrics Committee on Children with Disabilities: American Academy of Ophthalmology and American Association for Pediatric Ophthalmology and Strabismus: Learning disabilities, dyslexia, and vision: a subject review. Pediatrics, 1998, 102: 1217–1219. [Medline] [CrossRef]
7) Jiménez R, Pérez MA, García JA, et al.: Statistical normal values of visual parameters that characterize binocular function in children. Ophthalmic Physiol Opt, 2004, 24: 528–542. [Medline] [CrossRef]
8) Borsting E, Rouse M, Chu R: Measuring ADHD behaviors in children with symptomatic accommodative dysfunction or convergence insufficiency: a preliminary study. Optometry, 2005, 76: 588–592. [Medline] [CrossRef]
9) Faraone SV, Biederman J: Neurobiology of attention-deficit hyperactivity disorder. Biol Psychiatry, 1998, 44: 951–958. [Medline] [CrossRef]
10) Granet DB, Gomi CF, Ventura R, et al.: The relationship between convergence insufficiency and ADHD. Strabismus, 2005, 13: 163–168. [Medline] [CrossRef]
11) Rowe FJ: Clinical Orthoptics, 1st ed. Oxford: Blackwell Science, 1997, p 288.
12) Rouse M, Borsting E, Mitchell GL, et al.: Academic behaviors in children with convergence insufficiency with and without parent-reported ADHD. Optom Vis Sci, 2009, 86: 1169–1177. [Medline] [CrossRef]
13) DuPaul GJ: Parent and teacher ratings of ADHD symptoms: psychometric properties in a community-based sample. J Clin Child Psychol, 1991, 20: 245–253. [CrossRef]
14) Kim YS, So YK, Noh JS, et al.: Normative data on the Korean ADHD Rating Scales (K-ARS) for parents and teacher. J Korean Neuropsychiatr Assoc, 2003, 42: 352–359.
15) Kim JW, Park KH, Choi MJ: Screening for attention deficit/hyperactivity disorder in community mental health services for children. J Korean Neuropsychiatr Assoc, 2004, 43: 200–208.
16) Sheard C: Zones of ocular comfort. Am J Optom, 1930, 7: 9–25. [CrossRef]
17) Blondis TA: Motor disorders and attention-deficit/hyperactivity disorder. Pediatr Clin North Am, 1999, 46: 899–913. [Medline] [CrossRef]
18) von Noorden GK, Campos EC: Binocular Vision and Ocular Motility; Theory and Management of Strabismus. St. Louis: Mosby Inc, 2002, pp 502–503.
19) American Psychiatric Association: Diagnostic and Statistical Manual of Mental Disorders/DSM-IV-TR, 4th ed. Washington, DC: American Psychiatric Association, 2000, pp 13–26.
20) Kulp M, Mitchell GL, Borsting E, et al.: Convergence insufficiency treatment trial study group. Effectiveness of placebo therapy for maintaining masking in a clinical trial of vergence/accommodative therapy. Invest Ophthalmol Vis Sci, 2009, 50: 2560–2566. [Medline] [CrossRef]
21) Cooper JS, Burns CR, Cotter SA, et al.: American Optometric Association Clinical Practice Guideline: Care of the Patient with Accommodative and Vergence Dysfunction. St. Louis: American Optometric Association, 1998, pp 1–82.
22) Scheiman M, Kulp MT, Cotter S, et al.: Vision therapy/orthoptics for symptomatic convergence insufficiency in children: treatment kinetics. Optom Vis Sci, 2010, 87: 593–603. [Medline] [CrossRef]
23) Borsting E, Mitchell GL, Kulp MT, et al.: Improvement in academic behaviors after successful treatment of convergence insufficiency. Optom Vis Sci, 2012, 89: 12–18. [Medline] [CrossRef]
24) Convergence Insufficiency Treatment Trial Study Group: Long-term effectiveness of treatments for symptomatic convergence insufficiency in children. Optom Vis Sci, 2009, 86: 1096–1103. [Medline] [CrossRef]