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Does home-based vision therapy affect symptoms in young adults with convergence insufficiency?

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The purpose of this study was to investigate the effectiveness of extended home-based vision therapy as a treatment for symptomatic convergence insufficiency (CI) in young exophoric adults. Twenty-four adults with symptomatic exophoria at near with convergence insufficiency were divided into an experimental and a control group. The experimental group received 24 weeks of vision training, while the control group received no therapy. The three major outcome measures were the scores on the convergence insufficiency symptom survey V15 (CISS-V15), the near point of convergence and the positive fusional vergence at near. Only subjects from the experimental group demonstrated statistically and clinically significant changes in the CISS-V15 score (improvement of 20 points), near point of convergence (improvement of 5.5 cm) and positive fusional vergence at near (improvement of 15 Δ). No significant changes of either symptoms or signs were evident for the control group. The results presented in this study showed that extending the time and number of home based therapy techniques might be an effective treatment modality in adult subjects with CI. This therapy might be an alternative way for treatment of symptomatic exophoric CI subjects, who cannot attend office sessions.

Keywords: asthenopia, convergence insufficiency, exophoria, exotropia, eyestrain, symptom survey, vision therapy.

1. Introduction

Convergence insufficiency (CI) is a common and distinct binocular vision disorder [1–5]. Clinically, CI is characterized by exophoria (or exotropia) greater at near than at distance, receded near point of convergence (NPC), and reduced positive fusional vergence (PFV) at near [6]. Symptomatic CI subjects tend to suffer from the following symptoms: eyestrain, headaches, sleepiness, blurred vision, diplopia, problems with concentration, jumping letters while reading, difficulty with comprehension after short-time reading or performing close activities [7, 8].

Studies show that CI occurs in 1.7% of population between 6 and 70 years of age [9]. It is a commonly occurring binocular vision disorder, being reported as high as 4.2 to 6% [9]. Moreover, PICKWELL and STEPHENS [10] found the tendency for CI in

36% of optometry clinic patients examined at the age of 8–80 years (75% of the subjects were over 50-years of age).

Treatment modalities for symptomatic CI include base-in prism reading glasses [11–17], overcorrecting minus lenses [18, 19], active home- or office-based vision therapy [20–32] and extraocular muscle surgery (especially in exotropia) [32–34] but active vision therapy appears the best treatment in subjects with intermittent exotropia and/or exophoria with CI [20, 21]. GRISHAM [21] in his literature review (17 studies, 1931 subjects with CI (phorias and tropias)) found that active vision therapy was effective treatment modality with a cure rate 72%, improved rate of 19% and only a 9% failure rate.

In the randomized clinical trial studies, office-based vision therapy (OBVT) has been found to be a significant more effective type of vision training than home-based vision therapy (HBVT) in exophoric children with CI [35–37]. The evidence of this advantage is less consistent in a mature population because, according to our knowledge, there was only one randomized clinical study in adults with CI [22]. In this paper, SCHEIMAN *et al*. showed that not only in children but also in adults was OBVT much more effective treatment modality than HBVT. However, superiority of OBVT over HBVT found in this study, may result from relevant differences in methodology they used. Their HBVT program included a pencil push-ups technique 15 minutes per day, 5 days a week. While in OBVT program, subjects practiced 11 different training techniques, which gave 60 minutes once a week with 15 minutes, 5 days a week of home training reinforcement. It is considered that specifically, duration of therapy and its intensity [22, 35, 36, 38–40], and types and number of techniques used [25, 35, 38], may play a crucial role in the efficacy of therapy. What is important, contrary to low efficacy of HBVT [22, 23], there are some studies which demonstrated high significant improvement in symptoms and clinical signs after more complex HBVT [24, 26], even in cases of intermittent exotropias [41].

Based on these assumptions, it was hypothesized that a longer time of therapy and more varied types of techniques with HBVT might be a more effective treatment than usual HBVT.

This paper presents the results of study designed to explore the potential benefit of extending the time of home-based vision therapy which was conducted with the number of training techniques employed. We called it extended home-based vision therapy (EHBVT) and reported its efficacy on young exophoric adults with CI.

2. Material and methods

2.1. Subject selection

24 young adults with symptomatic exophoria at near with CI participated in the study. They were recruited from 40 CI university students and patients of the Laboratory of Vision Science and Optometry of Adam Mickiewicz University in Poznań, Poland. The ages ranged from 18 to 35 years with a mean age of 25.1, SD 5.4 years. Experimental group (EG) was composed of 12 subjects who decided to join the extend-

ed home-based vision therapy (EHBVT). Control group (CG) consisted of 12 subjects who refused any active (vision training) or passive (prisms) treatment modality. Other individuals who chose the office-based therapy (7 subjects) or prisms (9 subjects) were not included in further analysis of the study. Both groups (EG and CG) of our study were matched for age and gender. They were not significantly different from one another, either in clinical signs or symptom scores at the beginning of the study.

The research followed the tenets of the *Declaration of Helsinki*. A consent form was completed by the subjects after explanation of the nature and possible consequences of the study.

All participants' refractive conditions were corrected with spectacles that were worn for at least 1 month before the eligibility examination. Diagnosis was made using a standarized list of clinical signs of symptomatic CI [27, 36]. Eligibility criteria were: *i*) exophoria at near at least 4 Δ greater than at far, *ii*) receded near point of convergence (NPC) break (≥ 6 cm), *iii*) insufficient positive fusional vergence (PFV) at near (failing Sheard's criterion (PFV less than twice the near phoria) [42] or minimum PFV of 15 Δ base-out blur or break), *iv*) convergence insufficiency symptom survey V15 (CISS-V15) [43, 44] score of 21 or greater. Coexisting accommodative

T a b l e 1. Eligibility and exclusion criteria.

Eligibility criteria
Age 18–32 inclusive
Best corrected visual acuity of 20/25 in both eyes at distance and near
Exophoria at near at least 4 Δ greater than at far
Insufficient positive fusional vergence (*i.e.*, less than 15 Δ fusion break or failing Sheard's criterion)
Receded near point of convergence of greater than or equal to 6 cm for fusion break
At least 500 seconds of arc on the Stereo Fly Test at near
CISS-V15 score greater than or equal to 21 points
Informed consent and willingness to participate in the therapy program
Exclusion criteria
CI previously treated with any type of home-based or office-based vision therapy
Amblyopia
Constant strabismus
Strabismus or refractive surgery
Anisometropia > 1.50 D difference between eyes
Vertical heterophoria greater than 1 Δ
Systemic diseases known to affect accommodation, vergence and ocular motility
Any ocular or systemic medication known to affect accommodation, vergence or ocular motility
Monocular accommodative amplitude less than 4 D in either eye as measured by the pushup method
Manifest or latent nystagmus
Any eye diseases
Any eye care professional, ophthalmic technician, medical or optometry student

Δ – prism diopter, D – diopter.

insufficiency found in 6 subjects in EG and 4 in CG was not an excluding criterion. The criteria of CI with AI included all the eligibility criteria of CI and, in addition, a reduced accommodative amplitude, less than Hofstetter's calculation for minimum amplitude of accommodation (15 D – 0.25×age).

Table 1 presents all eligibility and exclusion criteria.

2.2. Program of treatment

After subjects were diagnosed, they were informed of their vision disorder as well as all known treatment possibilities with special consideration of vision therapy (VT).

If the subject had agreed to perform home-based vision training, she/he was attached to EG. Information concerning some relaxing vision techniques was provided to those subjects, who did not desire to participate in any treatment modality and they were enrolled as the CG. They were advised to take a short break (*ca*. 30 s) every 20–30 minutes while doing close work. During the break they were to close their eyes, bow their head, try to relax and then look into the distance, making sure that everything is clear and single. Saccadic, vergence and pursuit eye movements were also proposed from time to time. They were also informed that symptoms could be reduced with these procedures. They were asked also to come back for the follow up examination after about 6 months. EHBVT program for EG had a frequency rate similar to that of typical HBVT, but was extended from 12 to 24 weeks. The EHBVT included many techniques usually employed in OBVT. Each training technique was presented to the subjects during visits and practiced by them. Moreover, handouts with instructions and their therapy program schedule were given to each subject.

The extensive program of therapy is presented in Table 2. Subjects practiced only at home about 25–30 min/day, 5–10 min/technique, 5 days a week. A daily therapy program could be performed in 2 sessions (morning and evening) or at one sitting. There was a 2 min break recommended between different techniques. All exercises included in the EHBVT were described by GRIFFIN and GRISHAM [45].

2.3. Outcome measures

The pre-therapy measurements were conducted by one examiner and the post-therapy measurements by the other one. The second examiner had no access to the results from the pre-measurements as well he had no information whether the subject belonged to the EG or CG. Examiners were separated between measurements to avoid researcher bias.

There were 3 major outcome measures determining the subjective and objective condition of subjects before and after therapy. The first outcome measure was the symptom level reported by subjects. It was quantified using the CISS-V15. The second outcome measure was near point of convergence (NPC). The last outcome measurement was positive fusional vergence at near. This was measured with a von Graefe fusional vergence technique using base-out Risley prisms of phoropter. All measurements were repeated three times and the average measurement was used for the analysis.

T a b l e 2. Program of the therapy for experimental group.

Training technique	Purpose of procedure
Phase I. Accommodative procedures, ocular motility	
Eye movements (smooth, pursuit, saccades): with pencil, stickers on the wall or small bricks set on the table Accommodative Tromboning: with small letters on a sheet of paper or/and during reading book or paper Loose lens accommodative rock Monocular and binocular letter chart Accommodative rock Binocular accommodative facility with accommodative flippers	Improve ocular motility (speed, smoothness, accuracy); increase facility, stability and amplitude of accommodation, as well as accommodative response.
Phase II. Eye movement and vergence procedures	
Eye movements (smooth, pursuit, saccades): with pencil, stickers on the wall or small bricks set on the table Pencil push-ups Physiological diplopia and jump fusional vergence with Brock strings	Develop the kinesthetic awareness of converging, diverging and ability to voluntarily converge; normalize the near point of convergence.
Phase III. Fusional vergence procedures	
Single oblique mirror stereoscope Aperture rule Tranaglyphs Vectograms Lifesaver card Eccentric circles	Increase positive and negative fusional vergence amplitudes and stereopsy.

Other examination procedures included: *i*) best-corrected visual acuity at distance and near, *ii*) cover test and phoria measures at distance and near, *iii*) positive and negative fusional vergence at distance, *iv*) near stereoacuity, *v*) monocular accommodative amplitude, *vi*) negative and positive relative accommodation, and *vii*) monocular and binocular accommodative facility.

2.4. Follow-up measures

All subjects were assessed at the beginning and after 6 months of treatment. Additionally, there were 4 follow-up visits (once in a month) within these 6 months only for subjects from EG. During follow-up visits, they were asked about any ailments and about what they liked or disliked about the therapy itself. The following measurements were taken: amplitude of accommodation, accommodative facility, NPC, vergence at near and phoria at near. On the basis of measurements, modifications to training program were implemented, if necessary. When a particular parameter reached the norm, it was included less frequently in the therapy than the one that did not meet norm requirements. Not only were these parameters improved by enlarging the frequency of therapy but they were enhanced by implementing different but still relatively similar techniques. The subject began with the phase I and was evaluated to be competent in that phase before she/he was promoted to the next phase.

2.5. Statistical analysis

All data analyses were performed using Statistica, version 7.1 (StatSoft Inc., Tulsa, Oklahoma, USA). All parameters with normal distribution (exophoria at near, fusional vergence ranges with base in and base out prisms, CISS-V15 score) were evaluated statistically by repeated measurements analysis of variance (ANOVA) with 2 within-subjects factors: 1) group (experimental and control group), 2) measurement (pre and post). Parameters with abnormal distribution (amplitude of accommodation, accommodative facility, near point of convergence (break and recovery), positive and negative relative accommodation) were evaluated statistically by nonparametric analysis: Wilcoxon signed rank test and U-Mann Whitney test. Measurements were presented in median/mean with standard deviation values. The level of statistical significance was a $p \leq 0.05$.

3. Clinical measurements

All measurements are included in Table 3.

EHBVT influenced the symptoms, which were assessed by CISS-V15. Mean score was definitely higher in pre-measurement (29.1), than it was in post-measurement (17.9) ($F(1,22) = 158.47$, $p = 0.000$). As it is depicted in Fig. 1, mean scores decreased in both groups, but in CG the score reduction was only of 2 points (from 28.2 to 26.4) while in EG mean score decreased strongly from 29.2 to 9.3. The effect

T a b l e 3. Comparison of clinical measures at eligibility and the 24-week outcome examination.

		Pre-measurement		Post-measurement		Difference	
	Characteristic	Median	Mean (SD)[1]	Median	Mean (SD)[1]	Median	Mean (SD)[1]
Experimental group	CISS score	29.9	29.5 (4.4)	9.3	9.0 (3.3)	20.6	20.5 (5.3)*
	Near phoria [Δ]	14.6	14.5 (5.1)	13.0	13.3 (4.9)	1.6	1.2 (1.1)*
	Negative fusional vergence						
	Blur [Δ]	15.6	16.0 (4.2)	18.3	17.0 (4.8)	2.3	1.0 (4.7)
	Break [Δ]	21.5	22.0 (6.4)	22.5	21.0 (5.1)	1.0	–1.0 (2.4)
	Recovery [Δ]	16.3	17.5 (5.3)	17.4	17.5 (3.7)	1.1	0.0 (2.4)
	Positive fusional vergence						
	Blur[2] [Δ]	13.3	12.0 (6.4)	28.4	31.0 (5.9)	15.1	19.0 (6.9)*
	Break [Δ]	16.7	15.0 (8.5)	31.8	31.5 (5.7)	15.1	16.5 (6.8)*
	Recovery [Δ]	6.9	4.5 (7.5)	26.4	27.0 (7.3)	19.5	22.5 (7.1)*
	Near point of convergence						
	Break [cm]	8.8	8.0 (4.0)	2.6	2.5 (1.3)	6.2	5.5 (5.6)*
	Recovery [cm]	12.6	11.5 (5.6)	3.7	2.8 (1.8)	8.9	8.7 (5.7)*
	Monocular accommodative						
	Amplitude [D]	7.7	7.7 (1.0)	10.7	11.0 (1.3)	3.0	3.3 (1.5)*
	Facility [cpm]	8.2	7.3 (3.9)	21.5	19.6 (5.5)	13.3	12.3 (4.1)*
	Binocular accommodative						
	Facility [cpm]		3.3 (4.7)	15.1	15.0 (3.0)	9.6	11.7 (4.3)*
	Relative accommodation						
	Negative [D]	2.3	2.0 (0.5)	2.5	2.4 (0.3)	0.2	0.4 (0.6)
	Positive [D]	3.5	3.4 (1.1)	3.8	3.7 (0.8)	0.3	0.3 (1.0)
Control group	CISS score	28.3	28.0 (3.4)	26.4	26.0 (3.3)	1.9	2.0 (3.2)
	Near phoria [Δ]	14.7	14.5 (5.4)	14.5	13.5 (5.5)	0.1	1.0 (1.5)
	Negative fusional vergence						
	Blur [Δ]	18.6	20.5 (7.0)	19.3	20.0 (5.2)	0.7	–0.5 (4.2)
	Break [Δ]	22.1	21.0 (5.5)	21.3	22.0 (4.2)	–0.8	1.0 (4.7)
	Recovery [Δ]	17.4	17.5 (4.9)	16.7	16.5 (3.9)	–0.7	–1.0 (3.3)
	Positive fusional vergence						
	Blur[2] [Δ]	14.2	13.5 (6.0)	14.7	13.5 (5.9)	0.5	0.0 (3.4)
	Break [Δ]	17.5	19.5 (6.8)	17.8	18.0 (7.0)	0.3	–0.5 (4.2)
	Recovery [Δ]	6.4	6.5 (8.6)	6.8	5.0 (9.9)	0.4	–1.5 (3.4)
	Near point of convergence						
	Break [cm]	10.1	8.5 (3.9)	9.6	9.0 (3.5)	0.5	–0.5 (1.2)
	Recovery [cm]	18.5	16.0 (9.0)	17.8	15.5 (9.2)	0.7	0.5 (3.0)
	Monocular accommodative						
	Amplitude[3] [D]	7.2	7.4 (1.7)	7.2	8.0 (1.7)	0.0	0.6 (1.7)
	Facility [cpm]	8.3	7.0 (4.7)	8.1	8.0 (2.2)	–0.2	1.0 (2.9)

To be continued on the next page.

T a b l e 3. Continued.

		Pre-measurement		Post-measurement		Difference	
	Characteristic	Median	Mean (SD)[1]	Median	Mean (SD)[1]	Median	Mean (SD)[1]
Control group	Binocular accommodative						
	Facility [cpm]	6.4	7.3 (3.9)	5.6	5.5 (2.2)	–0.8	–1.8 (3.6)
	Relative accommodation						
	Negative [D]	2.0	2.0 (0.5)	2.1	2.0 (0.6)	0.1	0.0 (0.1)
	Positive [D]	2.9	2.9 (0.6)	3.0	2.9 (0.9)	0.1	0.0 (0.2)

CISS – convergence insufficiency symptom survey, Δ – prism diopter, D – diopter, cpm – cycles per minute; 1 – when the difference value is not negative it means the parameter was improved after therapy; 2 – the blur finding was used, but if the subject did not report a blur, the break finding was used; 3 – for people (in EG: $n = 6$, 12 eyes; CG: $n = 4$, 8 eyes) with accommodative insufficiency who performed training techniques for amplitude of accommodation; * – $p < 0.05$.

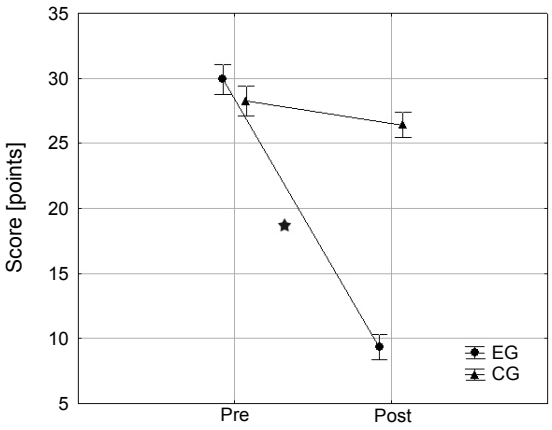

Fig. 1. Changes in mean score of CISS-V15 between groups after duration of 6 months. EG – experimental group, CG – control group. The star reflects significant change between pre- and post-measurements.

of therapy on EG was proved by the highly significant group *x* measurement interaction ($F(1,22) = 110.87$, $p = 0.000$).

Figures 2 and 3 present vergence ranges at near with base-out (BO) prisms. Mean value of fusional blur point (positive fusional vergence – PFV) increased significantly in post-measurement compared to the pre-one (21.5 Δ *vs*. 13.7 Δ) and was confirmed by high significant main effect of measurement ($F(1,22) = 49.6$, $p = 0.000$). The main group effect was significant also showing that the mean PFV was higher for EG (20.9 Δ) than for CG (14.4 Δ) ($F(1,22) = 8.52$, $p = 0.008$). This effect was evoked by the considerable improvement in PFV for EG after the therapy. The change of PFV for EG was more than double 13.3 Δ *vs*. 28.4 Δ for pre- and post-measurement, respectively, with no change for CG (14.2 Δ *vs*. 14.7 Δ for pre- and post-measure-

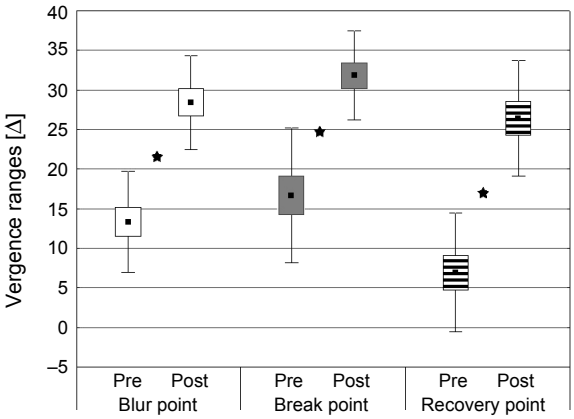

Fig. 2. Mean vergence ranges at near with base-out prism for experimental group (EG) before (pre) and after (post) duration of 6 months. The star reflects a significant change between pre- and post-measurements; Δ – prism diopter.

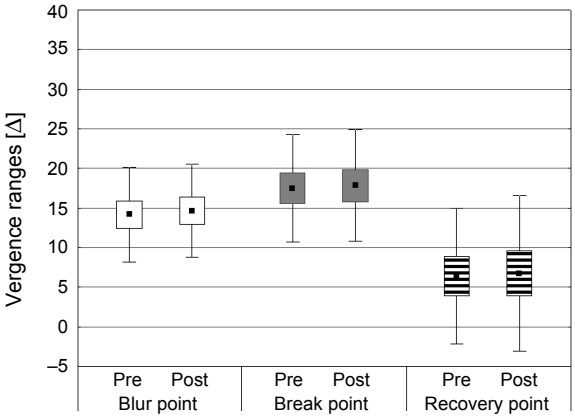

Fig. 3. Mean vergence ranges at near with base-out prism for control group (CG) before (pre) and after (post) duration of 6 months; Δ – prism diopter.

ments). This was confirmed by high statistically significant interaction between group and measurement ($F(1,22) = 43.46$, $p = 0.000$).

An evident impact of vision training on clinical measures was demonstrated with the fusional break point of the BO prism. The mean value of this parameter was changed from 17.1 Δ to 24.8 Δ (main effect of measurement: $F(1,22) = 45.28$, $p = 0.000$), but the statistically significant improvement was observed only for EG (16.7 Δ *vs*. 31.8 Δ for pre- and post-measurements), while the value of break-point remained unchanged for CG (17.5 Δ *vs*. 17.8 Δ for pre- and post-measurements). This difference was demonstrated by the significant interaction between group and measurement ($F(1,22) = 41.47$, $p = 0.000$).

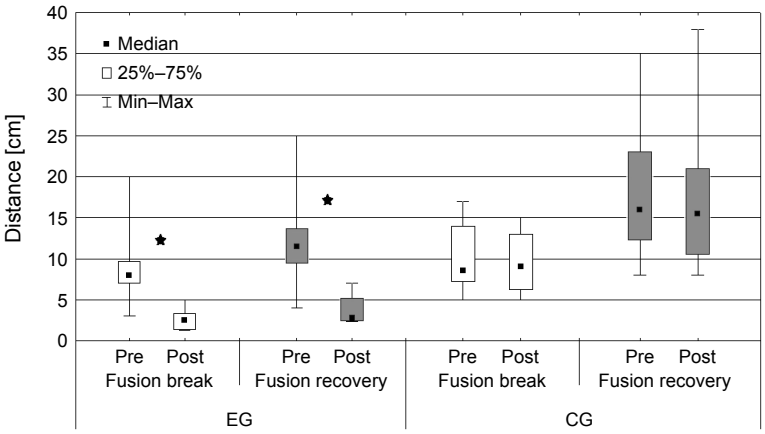

Fig. 4. Median near point of convergence before (pre) and after (post) duration of 6 months. EG indicates experimental group, CG – control group. The star reflects a significant change between pre- and post-measurements.

Similar effects were found for the fusional recovery point of the BO prism. There was a notable difference between pre- and post-measurements (6.6 Δ *vs*. 16.6 Δ, main effect of measurement: $F(1,22) = 76.06$, $p = 0.000$). However, improvement in fusional recovery was observed only for EG (6.9 Δ *vs*. 26.4 Δ for pre- and post-test), but not for CG (6.4 Δ *vs*. 6.7 Δ for pre- and post-test). This was also confirmed by the significant group and measurement interaction ($F(1,22) = 70.42$, $p = 0.000$).

Near point of convergence (NPC) was the next major outcome (Fig. 4). In the pre--measurement, median values of NPC fusional break point were almost the same between groups: 8 cm in EG and 8.5 cm in CG ($Z = –0.66$, $p = 0.503$). After the period of 6 months, there was no change of this parameter in CG (reduction of 0.5 cm, $Z = 1.42$, $p = 0.155$) but a large significant improvement in NPC in EG was observed (reduction of 5.5 cm, $Z = 2.98$, $p = 0.002$). In the case of NPC fusional recovery point, the value of this parameter was lower in EG group (11.4 cm) than in CG (16 cm) but this difference was not statistically significant ($Z = –1.76$, $p = 0.078$). Similar as in NPC fusional break point, significant reduction was observed in the recovery of fusion point only for EG group (decrease of 8.5 cm, $Z = 2.98$, $p = 0.003$), while no change was found for CG (decrease of 0.5 cm, $Z = 0.51$, $p = 0.610$).

4. Discussion

There is still much controversy on the effectiveness of home-based vision therapy (HBVT) in CI adult individuals. WICK [26] obtained impressive improvement in symptoms in 92% of presbyopic subjects involved in a 12-week multi-technique home therapy. This effect was not confirmed by BIRNBAUM *et al*. [23] in the more controlled research. In that study only 30% of presbyopic participants showed improvement and

this effect was not statistically different from the control group. It is important to note that the efficacy of VT on presbyopic subjects might be limited by accommodative disabilities. Exophoria at near depends on the accommodative lag. Low plasticity of the intraocular lenses could make a limitation in the efficacy of VT in older subjects.

Moreover, the effectiveness of HBVT on younger adults with CI is still an unexplored area. To the best of our knowledge, only one study [24] used multi-technique HBVT in treating CI. After 12-week therapy the data suggested improvement in symptoms (80%) as well as changes in clinical signs. In contrast, SCHEIMAN *et al*. [22] demonstrated that the effectiveness of HBVT was no better than placebo. Even so, this conclusion should not be generalized since only one technique (pencil push-ups) was employed.

The main goal of this study was to investigate the efficacy of multi-techniques, extended in time home-based vision therapy (EHBVT) for adults with symptomatic CI. We suspected that the number of techniques used and the training intensity were further factors to influence the success of therapy. COOPER *et al*. [25] stated that people with CI, unlike normal subjects, may require training involving several methods of vergence stimulation before transferring newly acquired skills from the clinic to home and work environment. Also GALLAWAY and SCHEIMAN [38] and Convergence Insufficiency Treatment Trial (CITT) study group [36] suggested that a wider range of procedures and longer periods of daily home-based therapy might produce better results in HBVT participants.

The first aspect of modification of the present study was the duration of EHBVT. The total time of therapy was extended from 12 to 24 weeks. Thus, EHBVT presented in this study was twice as long as in usual HBVT. Subjects practiced 4–5 times/week, 12–15 minutes 2 times/day (or once a day for approximately 25–30 min). This modification was essential since the numerous vision therapy devices were used. Based on the mechanisms of memory, motor learning and automatization [46–48], it is reasonable to suspect that in order to shift improved vision functions to the automatic level, repeated active visual exercises extended in time are necessary. Thus, the effects of EHBVT have the potential to be more permanent.

The second change in the EHBVT was the number of training techniques used. Another important element of EHBVT was weekly telephone calls to enhance the subjects' motivation. They were asked about therapy progress, any problems, doubts or questions. To control and measure therapy progress, the subjects also came in once per month for a follow up examination.

4.1. Impact of EHBVT on clinical signs and symptoms

After therapy all subjects from EG did not complain about any annoying asthenopic signs, which was confirmed in CISS-V15 survey score (reduction in symptoms from 29.2 to 9.3). Significant changes in clinical measurements were also observed. A large increase in PFV was found. The analysis of the median values between pre-

and post-therapy demonstrated a significant improvement in the NPC. After EHBVT all subjects reached a normal NPC with both the break and recovery measures. Apart from these 3 major outcome measures (CISS-V15 score, PFV and NPC), several other outcome clinical parameters were considered (Tab. 3).

It is important to stress that 4 EG subjects did not meet Sheard's criterion after the therapy. It has been stated that patients who meet this standard are not likely to report symptoms [49]. We noted that meeting Sheard's criterion was not necessary for comfortable binocular single vision for these particular individuals. Each of the four EG subjects that did not meat Sheard's criteria measured around 18 Δ of exophoria. To pass Sheard's criterion, it would have been necessary for these subjects to have obtained a minimum 36 Δ of PFV. These 4 subjects did not reach this high level of vergence ranges yet they achieved low scores on the CISS-V15 and all were asymptomatic after EHBVT. This might suggest that in cases of subjects with high exophoria, it is not necessary to pass Sheard's criterion to obtain comfortable, single binocular vision. However, based on only 4 subjects we cannot confirm this hypothesis.

4.2. Limitations of the study and future directions

This study demonstrated that the EHBVT, extended in time and techniques, could be an effective alternative way to treat CI. However, there are some limitations that must be considered when interpreting the results of this study. First, the sample size of 12 subjects of experimental group was quite small and this could have affected the accuracy of our therapy results. To confirm the effect of EHBVT, more participants in future studies are necessary. It is crucial to examine the length of EHBVT needed to be effective and optimize improvements for an extended time. Future studies should identify therapy techniques and time factors that are most effective in optimizing the success of vision therapy. Furthermore, we cannot assess whether symptoms recurred in our subjects from the experimental group after successful EHBVT. Nevertheless, it has been reported that recurrence is rare when normal convergence and fusion are achieved [21, 50].

It is hard to predict whether EHBVT would be effective with large eye deviation as intermittent or constant CI exotropia. It has been demonstrated that extraocular surgery could bring a positive/desired effect in subjects with high angle exotropia [34, 50–54]. However, as MARUO *et al*. communicated [34], after the eye muscle surgery some angle of eye deviation (from +2 deg to –10 deg) is usually observed. It is important to highlight that even small eye misalignments can affect the development of central binocular vision that is extremely sensitive to retinal disparity. No more than 0.5 deg is tolerated to obtain fusion [45, 55]. If there is small angle exotropia after surgery, this can evoke central suppression, a lack of the central stereopsis and/or asthenopia. COOPER and MEDOW [56] suggest that vision therapy should be considered part of the treatment regimen for patients who receive surgery. In these cases, EHBVT might be the effective way to develop vision abilities and eliminate eyestrain. Thus, active in office or home vision therapy might be considered as the treatment

modality with patients who exhibit primary exophoria and as a support treatment in exotropia.

5. Conclusions

Although the office-based vision therapy in children with small angle exophoria with convergence insufficiency seems to be the best treatment modality, it should not be considered the only one effective way to reduce symptoms in children and adults with CI. This paper suggests that multi-techniques and an elongated program of home-based vision therapy (EHBVT) could be an acceptable approach to manage symptomatic CI in adults, if adherence is maintained.

If future studies confirm the effectiveness of EHBVT, it would be an alternative way to perform vision therapy in people with CI who cannot participate in office-based vision therapy.

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