Effect of Vision Therapy on Measures of Oculomotor Function in Patients Presenting with Post-Concussion Syndrome

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Abstract

Oculomotor dysfunction is a common symptom of post-concussion syndrome (PCS). In this study, the efficacy of Vision Therapy (VT) for the treatment of PCS-related symptoms of the visual system was investigated retrospectively. Overall, 56 patients were selected, all of whom presented with clinical impairment of at least one measure of oculomotor functioning. Activities related to VT were wide-ranging and case-dependent, but all aimed to improve one of the five main areas of visual function. Following the completion of VT, all patients demonstrated statistically or clinically significant improvements, as defined by the use of Morgan's norms, in at least one measure of oculomotor functioning related to PCS. In general, improvements in measures of oculomotor functioning were greatest for near point of convergence, vergence facility and accommodative facility. Patients who received 20 sessions of VT had improved and less variable outcomes than those who received 5-10 sessions of VT. In addition, VT improved symptoms of visual discomfort in patients presenting with PCS. The results of this retrospective analysis demonstrate significant improvements in measured outcomes for all patients who received VT, and support VT as a treatment option for symptoms of PCS.

INTRODUCTION

Mild traumatic brain injury (TBI), such as that sustained due to a blow to the head, violent shaking or movement of the head or body, can lead to symptoms of concussion.[1] Following injury, symptoms of a concussion generally manifest in the first 7-10 days and can persist for up to one year or more. Symptoms of a concussion are referred to collectively as post-concussion syndrome (PCS).[1] Symptoms of PCS include, but are not limited to, headaches, dizziness, fatigue, noise and light sensitivity, and issues associated with the visual system. In particular, between 11% and 54% of patients in cohort studies of soldiers or patients of auto accidents presenting with symptoms of TBI have been diagnosed with one or more oculomotor dysfunctions including convergence insufficiency, accommodative insufficiency, impaired version movement, and minor ocular alignment issues.[2-10] In addition, 46% of adolescents presenting with symptoms of a concussion had more than one vision-related diagnosis such as accommodative disorder, convergence insufficiency or saccadic dysfunction.[11] Convergence insufficiency is a prevalent vision disorder characterized by reduced fusional convergence amplitude and receded near point of convergence, which can manifest as blurred vision, eye strain and headaches when engaging in near work.[12-14] Previous work has suggested that symptoms of convergence insufficiency and related oculomotor issues are likely due to excessive convergence compensation for large exophoric postures in near vision.[15]

Optometric vision therapy (VT) has emerged as a promising treatment option for patients presenting with symptoms of PCS or TBI.[4,5] For example, in a retrospective study, 90% of participants receiving VT for an acquired brain injury demonstrated complete or significant improvements in at least one of the recorded symptoms of acquired brain injury, and these changes

persisted when measured 2 months or more following completion of VT.[16] In addition, similar improvements in measures of oculomotor functioning have been observed in most patients receiving VT for PCS or TBI.[4,5,17–20] Furthermore, VT has been demonstrated to improve measures of concentration, memory and comprehension in patients presenting with symptoms of PCS or TBI.[20] By use of the convergence insufficiency treatment trial symptom survey (CISS), Alvarez et al.[21] demonstrated significant improvements in patients presenting with convergence insufficiency following 18 h of vergence training, and their scores were similar to those in control patients. In addition, the work by Alvarez et al.[21] further supports the notion that convergence insufficiency is due to significantly reduced convergence peak velocity, and vergence training leads to increased functional activity. Furthermore, Scheiman and Wick.[15] demonstrated that office-based vergence and accommodative therapy with home practice can result in sustained improvements in symptoms of convergence insufficiency.

Although there exists evidence to support VT in the treatment of PCS- or TBI-related symptoms, additional data to support a positive role for VT in the treatment of traumatic brain injury would be timely.[4,22] Therefore, in this work, we present the results of a retrospective analysis of the efficacy of VT treatment for improving various oculomotor functions in patients presenting with symptoms of PCS.

METHODS
Patients provided their express consent before treatment for oculomotor dysfunction was initiated.

PATIENT EVALUATION
Patients diagnosed with PCS by a physician were given a thorough oculo-visual assessment. Vision testing relevant to this study included assessments of near point of convergence (NPC), vergence facility (12 Base Out and 3 Base In), accommodative facility by use of + / - 2.00D lens power (age-dependent), stereopsis measures at near (40cm) and distance (6 metres) by use of Randot Stereopsis testing, King-Devick Saccadic Testing, positive fusional vergence ranges at near (40cm) and distance (6 metres), negative fusional vergence ranges at near (40cm) and distance (6 metres) and completion of CISS before and one week following treatment. All tests were performed as described by Elliott.[23] Patients presenting with nerve palsies, extraocular muscle restrictions, elevated intraocular pressure or gross visual field loss as determined by confrontation were excluded from the study.

VISION THERAPY TREATMENT REGIMEN
Following assessment, the number of sessions required was selected on a per-patient basis based on best judgement, previous literature and occasionally by approval from 3rd-party payors.[2,15,24] Vision therapy consisted of weekly one-hour sessions at the clinic performed by trained vision therapists and prescribed daily sessions of 15 minutes at home. Activities prescribed were wide-ranging and case-dependent, but all aimed to improve one of five main areas of visual function: central-peripheral visual integration (spatial awareness), eye teaming (converging and diverging), eye focusing (accommodation), eye tracking (smooth pursuits and saccades), and motion processing (tracking of moving objects within a busy visual scene). The details of the procedures used throughout therapy have been described previously.[15,25]

STATISTICAL ANALYSIS
Patient data were collected between January 1, 2017, and December 31, 2017, from all patients receiving vision therapy for PCS (n=56). Individual scores of the 56 patients were averaged across all measured outcomes and values before (pre-) and after (post-) VT intervention were compared. Patient outcomes pre- and post-VT were compared by use of the dependent t-test ($p < 0.05$). Endpoints that did not meet the assumptions of normality or equal variance were compared by use of the Wilcoxon signed rank test as suggested by Rosner et al.[26] To assess the clinical significance of patient outcomes, measured or recorded values were compared with the relevant literature, namely Morgan's table of norms.[15]

RESULTS
Data overview
Overall, 56 patients were included in the retrospective analysis and descriptive statistics are presented in Table 1. Patients experienced a range of events resulting in the presence of PCS, including motor vehicle accidents in 38, sport-related injuries in 10 and falls in 8. Patient age ranged between 12 and 62 years (mean ± SD; 42.6 ± 13.8) and patients received between 5 and 20 sessions of VT (13.8 ± 4.70) to treat symptoms of PCS. The average patient program duration (15.2 weeks) was greater than the number of sessions of VT (13.8 sessions) and reflects the impact of patient appointment cancellation or delays in treatment from week-to-week on program duration. In addition, patients generally began VT treatment one month following assessment.

Measured patient outcomes

In general, treatment of symptoms of PCS with VT resulted in significant improvements of all measured oculomotor functions (Table 2). All patients included in this study demonstrated improvement in at least one measure of oculomotor functioning. Forty-six patients presented with clinically impaired NPC and, following VT, 86% of patients demonstrated clinically relevant improvements (Table 2). Fifty-five patients presented with clinically impaired vergence facility (Table 2) and, following VT, all patients demonstrated improved vergence facility; this improvement was clinically relevant in 36 (65%). When assessed for accommodative facility, 20 of 22 patients presented clinically relevant impairment and, following treatment, 90% of patients demonstrated clinically significant improvements. When measured by use of the King-Devick Test, 43 patients presented clinically impaired saccadic movement and, following treatment, 26 patients (60%) demonstrated clinically significant improvements (Table 2).

Forty-six patients presented with clinically relevant impairment of stereopsis when tested at distance. All patients but 3 experienced average score improvements of 50%, and these improvements were clinically relevant in 23 (50%). When stereopsis was assessed at near distances, 40 patients demonstrated clinically relevant impairment. Following treatment, average improvements of 45% were observed, and 30 patients (75%) had clinically significant outcomes. Fifty-three patients had CISS symptom survey scores greater than 22. Following treatment, all patients showed average score improvements of 48%, and these improvements were clinically significant in 35 (66%) (Table 2).

Patient convergence and divergence test scores

Both positive and negative fusional vergence ranges (PFV/NFV) were assessed at distance (6 metres) and near (40cm). When PFV at distance was measured, 51 patients presented with clinically impaired convergence break. Forty-nine patients had an average improvement of 11D in positive fusional break scores, and these improvements were clinically relevant in 26 (53%). When assessed for PFV recovery at distance, 46 patients presented with clinically impaired scores. Following treatment, all but one patient had improved scores, and these improvements were clinically significant in 32 (69%) (Table 2). When NFV at distance was assessed, 52 patients presented with clinically relevant impairment when assessed for divergence break. Following treatment, 47 patients had an observed average score improvement of 4.7 D, and this improvement was clinically significant in 35 (67%). When assessed for NFV recovery at distance, 42 patients presented with clinically relevant impairment. All but one patient demonstrated improvements in score following VT, and these improvements were clinically significant in 40 (95%) (Table 2).

Improvements similar to those at distance were observed for fusional vergence ranges at near. Fifty patients presented with clinically impaired PFV break. Forty-nine patients had average improved scores of 19.6 D, and these improvements were clinically relevant in 46 (94%). When assessed for PFV recovery at near, 47 patients presented with clinically relevant impairment. Overall, patients saw an average improvement of 18.5 D, and these improvements were clinically relevant in 42 (89%) (Table 2). When assessed for NFV ranges at near, 55 patients presented with clinically relevant deficits. Fifty-three patients saw an average improvement of 10.4 D, and these improvements were clinically significant in 30 (55%). When assessed for NFV recovery at near, 45 patients presented with clinically relevant impairment. All but one patient demonstrated an average improvement of 12 D following VT, and these improvements were considered clinically significant in 41 (91%) (Table 2).

Effect of treatment duration

Because patients received between 5 and 20 VT sessions, we wished to compare measures of oculomotor functioning among patient cohorts receiving 5-10, 12-17 or 20 sessions of VT (Table 3). In general, improvements in measures of oculomotor functioning were observed regardless of the duration of treatment. However, patients who received 20 sessions demonstrated greater improvements in scores than patients who received 10 or less sessions of VT. Improvements in vergence facility, stereopsis at distance, and measures of PFV and NFV at both distance and near showed the greatest improvement with a longer treatment duration (Table 3). In addition, measured outcome improvements were compared among age groups, and no trend was observed.

DISCUSSION

The effectiveness of VT in the treatment of PCS-related symptoms of the visual system was investigated retrospectively. Overall, 56 patients were included in this study, all of whom presented with clinical impairment of at least one measure of oculomotor functioning (Table 1; Table 2). Following VT, all patients demonstrated statistically or clinically significant improvements in at least one measure of oculomotor functioning related to PCS (Table 2). In general, improvements in measures of oculomotor functioning were greatest for NPC, vergence facility and accom-

modative facility (Table 2). These results were similar to those of Ciuffreda et al.,[16] who reported that, in multiple studies, 87-100% of patients with an acquired brain injury saw improvements in accommodative dysfunction following VT. More recently, Thiagarajan and Ciuffreda[18] demonstrated the efficacy of VT for improving amplitudes of vergence and accommodation, accuracy of saccadic eye movements, and overall reading in patients with mild TBI.[18] Furthermore, improvements in NPC, PFV at near and distance, and CISS symptom scores were similar to those observed in children and a cohort with an age range similar to that in this study.[22,24]

Interestingly, patients who received 20 sessions of VT had improved and less-variable outcomes than those who received 5-10 sessions of VT (Table 3). These results are similar to those of the Convergence Insufficiency Treatment Trial Study Group,[24] which observed that 12 weeks of VT sessions was insufficient to normalize measures of oculomotor functioning in children with mild TBI. However, it is important to note that, regardless of the program duration, measures of oculomotor functioning, such as convergence and accommodation, can be improved within as little as two to six weeks of VT.[4,27]

Vision therapy was found to improve symptoms of visual discomfort in patients presenting with PCS, as demonstrated by average improvements of 50% in CISS scores, similar to previous results reported by Scheiman and Wick[15] (Table 2). However, although improvements in oculomotor functioning were apparent, no outcomes related to return-to-work or activities of daily living were recorded in this study, and this limits the interpretation of the results. Caution should be exercised in interpretation of these results as there is a tendency for measured oculomotor outcomes, especially near point of convergence, to improve over time in placebo groups.[27] In addition, the effects of motivation and encouragement on patient outcomes cannot be discounted.[27]

CONCLUSION
The results of this retrospective analysis support the findings of previous studies and demonstrate statistically and clinically significant improvements of measured oculomotor functioning in patients presenting with oculomotor deficiencies associated with PCS and support VT as a viable treatment option for associated symptoms. Furthermore, the present results suggest that longer treatment times (20 VT sessions) might improve measured outcomes compared to those in patients who receive 10 or less VT sessions; however, the impact of delayed VT treatment remains unclear. Although no placebo group was available in this study, the results demonstrate significant improvements in measured outcomes for all patients receiving VT and support VT as a treatment option for PCS. ●

DISCLAIMERS
The views expressed in the submitted article are our own and not an official position of an institution or funder.

CONFLICTS OF INTEREST
The authors have no conflicts of interest to declare.

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Table 1: *Summary statistics of treatment regimen and descriptive statistics of patients receiving vision therapy treatments for post-concussion syndrome (n=56).*

Measure	Average	Standard Deviation	Range
Age	42.6	13.8	12 – 62
Months since injury	15.1	14.2	2 – 60
Delay in starting VT (months) following assessment	1.5	2	0 – 12
Sessions of VT	13.8	4.7	5 – 20
Duration of Program (weeks)	15.2	4.9	6 – 24

Table 2: *Summary statistics of optometric data following vision therapy treatment for post-concussion syndrome (n=56).*

Measure	Pre VT		Post VT		Score Improvement		
	avg	std	avg	std	avg	std	range
NPC (cm)	13.0	9.3	3.57*	1.94	65%	2	6.2 – 97%
Vergence Facility (cpm)	2.38	3.92	13.1*	3.18	83%	27	0 – 100%
Accomodative Facility – Binocular (cpm) δ	3.14	3.06	10.6*	1.87	71%	26	17- 100%
King Devick (s)	76.4	41.0	51.4*	18.3	27%	16	0 – 73%
Stereopsis- 40 cm (secs of arc)	79.8	40.6	42.6*	14.3	39%	23	0 – 85%
Stereopsis- 6 metres (secs of arc)	134	125	48.2*	12.8	41%	31	0 – 90%
CISS (Score)	38.2	11.42	20.0*	8.00	49%	14	23 – 100%
Measure	Pre VT		Post VT		Score Improvement		
	avg	std	avg	std	avg	std	range
PFV Break -D (6m)	8.05	5.94	19.4*	7.43	11.4	7.4	0 – 30
PFV Recovery -D (6m)	4.36	4.86	14.8*	6.67	10.4	6.4	0 – 28
NFV Break -D (6m)	3.77	2.36	8.46*	2.98	4.7	3.3	0 – 16
NFV Recovery -D (6m)	1.09	2.51	5.96*	2.27	4.9	3	0 – 15
PFV Break -D (40cm)	11.4	7.25	29.6*	6.98	18.2	8.9	0 – 38
PFV Recovery -D (40cm)	4.46	6.16	21.3*	7.49	16.9	9.1	0 – 38
NFV Break -D (40cm)	11.1	5.99	21.4*	3.30	10.3	6.3	0 – 27
NFV Recovery D (40cm)	6.48	5.37	16.8*	3.45	10.3	6.2	-4 – 22

*Significant improvement in score (p < 0.001).
δn=22, average age of 28.4 ± 10.1

Table 3: *Summary statistics of patient score improvements following vision therapy treatments for post concussion syndrome grouped by number of VT sessions (n=56).*

Number of VT Sessions	5-20		5-10		12-17		20	
Count (n)	**56**		**29**		**10**		**17**	
	avg	std	avg	std	avg	std	avg	std
Months since injury	15.1	14.2	14.3	13.2	14.9	18.6	16.4	13.7
Duration of program (weeks)	15.2	4.86	11.2	2.13	16.0	1.56	21.5	0.94
Percent Score Improvement								
Measure	avg	std	avg	std	avg	std	avg	std
NPC (cm)	65%	20	67%	18	64%	25	62%	21
Vergence Facility (cpm)	83%	27	77%	32	83%	23	94%	12
Accomodative Facility (cpm) δ	71%	26	66%	27	85%	17	72%	31
King Devick (s)	27%	16	23%	16	30%	12	31%	19
Stereopsis- Near	39%	23	34%	22	54%	27	38%	20
Stereopsis- Dist	41%	31	29%	27	61%	33	50%	28
CISS (Score)	49%	14	50%	16	55%	14	46%	9
Score Improvement								
Measure	avg	std	avg	std	avg	std	avg	std
PFV Break D (6m)	11.4	7.42	10.8	8.08	10.0	5.25	13.1	7.36
PFV Recovery - D (6m)	10.4	6.44	10.3	7.43	9.80	4.57	10.9	5.81
NFV Break D (40cm)	4.70	3.35	4.59	3.59	4.60	3.66	4.94	2.88
NFV Recovery- D (40cm)	4.88	3.03	5.10	3.45	3.60	2.84	5.24	2.25
PFV Break- D (40cm)	18.2	8.92	17.2	8.56	16.6	10.8	20.6	8.42
PFV Recovery- D (40cm)Near	16.9	9.13	15.9	9.71	16.4	9.65	18.8	7.95
NFV Break- D (40cm)	10.3	6.33	9.66	5.10	9.60	6.31	11.8	8.14
NFV Recovery- D (40cm)	10.3	6.17	9.93	5.08	8.90	7.34	11.8	7.17

δn=22, average age of 28.4 ± 10.1

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