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ORIGINAL ARTICLE

Vision Therapy for Post-Concussion Vision Disorders

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ABSTRACT

Purpose. To determine the frequency and types of vision disorders associated with concussion, and to determine the success rate of vision therapy for these conditions in two private practice settings.

Methods. All records over an 18-month period of patients referred for post-concussion vision problems were reviewed from two private practices. Diagnoses of vergence, accommodative, or eye movement disorders were based on pre-established, clinical criteria. Vision therapy was recommended based on clinical findings and symptoms.

Results. Two hundred eighteen patient records were found with a diagnosis of concussion. Fifty-six percent of the concussions were related to sports, 20% to automobile accidents, and 24% to school, work, or home-related incidents. The mean age was 20.5 years and 58% were female. Eighty-two percent of the patients had a diagnosis of an oculomotor problem [binocular problems (62%), accommodative problems (54%), eye movement problems (21%)]. The most prevalent diagnoses were convergence insufficiency (CI, 47%) and accommodative insufficiency (AI, 42%). Vision therapy was recommended for 80% of the patients. Forty-six per cent (80/175) either did not pursue treatment or did not complete treatment. Of the 54% (95/175) who completed therapy, 85% of patients with CI were successful and 15% were improved, and with AI, 33% were successful and 67% improved. Clinically and statistically significant changes were measured in symptoms, near point of convergence, positive fusional vergence, and accommodative amplitude.

Conclusions. In this case series, post-concussion vision problems were prevalent and CI and AI were the most common diagnoses. Vision therapy had a successful or improved outcome in the vast majority of cases that completed treatment. Evaluation of patients with a history of concussion should include testing of vergence, accommodative, and eye movement function. Prospective clinical trials are necessary to assess the natural history of concussion-related vision disorders and treatment effectiveness.

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Key Words: vision therapy, vision rehabilitation, concussion, convergence insufficiency, accommodative insufficiency, near point of convergence

Up to 3.6 million concussions are reported annually from causes such as motor vehicle accidents, sports, and household injuries.[1,2] Traumatic brain injury (TBI) from blast injuries was the signature injury of the Iraq and Afghanistan wars. Studies with both military[3–8] and civilian[9–11] populations have found that oculomotor deficits such as convergence insufficiency (CI), accommodative insufficiency (AI), and saccadic dysfunction (SD) occur 30 to 42% of the time after concussion, which is much higher than the 5 to 15% estimated in the general population.[12,13] A recent hospital-based study by Master et al. found very similar prevalence rates in adolescents after concussion, with CI and AI reported in approximately 50% of the sample.[14]

Treatment of concussion-related vision disorders often involves the use of vision therapy/rehabilitation to remediate vergence, accommodation, and versional eye movements. In a retrospective study in a university optometric clinic, Ciuffreda et al. reported that 90% of patients (n = 33) with TBI-related oculomotor abnormalities experienced improvement in signs and symptoms after vision therapy.[15] In a recent placebo-controlled randomized clinical trial, the authors found clinically and statistically significant improvements in vergence, accommodative, and versional findings and visual attention.[16–18]

As awareness of concussion-related vision disorders has grown over the past 5 to 10 years, more optometrists are diagnosing and treating these disorders. Although there is strong evidence for the

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effectiveness of vision therapy for CI and accommodative dysfunction in non-concussed patients,[19–22] there are limited published data on the treatment of concussion-related vision disorders. The purpose of the current study was to assess the frequency and types of concussion-related vision disorders and the effectiveness of treatment for these conditions in a private practice setting.

METHODS

Institutional Review Board approval was obtained to perform this retrospective chart review. A record search (18-month period from January 2012 to July 2013) was completed in two private practice settings that specialize in vision therapy/neuro-optometric rehabilitation. Eligibility criteria included all patients who were referred for visual evaluation after a medical diagnosis of concussion. Referral sources included sports medicine physicians, physiatrists, neurologists, pediatricians, athletic trainers, and physical therapists.

The diagnosis of concussion included a history of a direct or indirect force transmitted to the head causing signs or symptoms of headache, dizziness, nausea, balance problems, fatigue, light and noise sensitivity, sleep problems, cognitive deficits (memory, attention, executive functioning, reaction time), and emotional issues (irritability, sadness, nervousness, anxiety and depression).[23,24] Patients were generally referred to the authors' offices due to visual symptoms such as blur, diplopia, eye fatigue, headaches, and loss of place with reading and close work.

Vision testing included well-established clinical measures of accommodation, vergence, and ocular motility.[25] Ocular alignment/phoria was measured with the cover test at distance and near with prism bar neutralization. Near point of convergence (NPC) break and recovery were measured with a 20/30 accommodative target and an accommodative convergence rule from the patient's mid-brow. Step vergences to assess positive and negative fusional vergence blur, break, and recovery at 40 cm were performed with a prism bar. Vergence facility was assessed at 40 cm with a 12BO/3BI prism. Accommodative amplitude was measured with a push-up technique and 20/30 target to first sustained blur. Accommodative facility was assessed monocularly and binocularly with +2.00/−2.00 lens flippers. Saccadic speed and accuracy was measured with the Developmental Eye Movement Test (DEM), a timed visual-verbal test. In addition, the Convergence Insufficiency Symptoms Survey (CISS)[26,27] was administered to monitor changes in symptoms with patients who were subsequently treated with vision therapy.

Diagnosis of vision disorders was based on the criteria listed in Table 1. Some patients had more than one diagnosis. Patients with convergence excess or accommodative insufficiency without CI were offered a reading prescription in addition to vision therapy.

Vision therapy consisted of once or twice weekly, 45-minute in-office sessions with approximately 15 min/day and 3 to 5 days per week of home activities. Therapy procedures were similar to those used in the Convergence Insufficiency Treatment Trials (CITT)[19,21,22,28] with the addition of saccadic and pursuit activities such as Hart Chart, thumb rotations, rotating pegboard, and the Sanet Vision Integrator (SVI).[25] Balance and head movements were added as needed for vestibular and VOR stimulation. Criteria for success or improvement in signs and symptoms are listed in Table 2.

Statistical analyses were completed using SAS version 9.3 and SPSS version 21. One-sample *t*-tests were used to compare treatment improvements to zero. The area under the receiver-operator characteristic (ROC) curve is used as an indicator of the accuracy of the given patient characteristic to identify a patient with any vision disorder. It is constructed by plotting the value of sensitivity versus specificity for all possible cut-points for a given

TABLE 1.

Diagnostic criteria for binocular vision, accommodative, and eye movement disorders

Convergence insufficiency
(A) 3-Sign CI
Requires: 1, 2 plus at least 1 finding from 3–4
1. Near point of convergence of ≥6 cm break
2. Exophoria at near at least 4 pd greater than at distance
3. Reduced positive fusional vergence at near (<20 pd or fails Sheard's criterion)
4. Vergence facility (D or N) ≤9 cpm with difficulty with base-out
(B) 2-Sign CI
Requires: 1, plus at least 1 finding from 2–4
1. Near point of convergence of ≥6 cm break
2. Exophoria at near at least 4 pd greater than at distance
3. Reduced positive fusional vergence at near (<20 pd or fails Sheard's criterion)
4. Vergence facility (D or N) ≤9 cpm with difficulty with base-out
Convergence excess
Requires: 1 plus at least 1 finding from 2–3
1. ≥3 pd esophoria at near
2. Reduced negative fusional vergence at near (<8 pd or fails Sheard's criterion)
3. Vergence facility (D or N) ≤9 cpm with difficulty with base-in
Fusional vergence dysfunction
Requires: 1 and 2, or 3
1. Reduced negative fusional vergence at near (<8 pd or fails Sheard's criterion)
2. Reduced positive fusional vergence at near (<20 pd or fails Sheard's criterion)
3. Vergence facility (D or N) ≤9 cpm with difficulty with both base-in and base-out
Accommodative insufficiency
Requires: 1 or 2
1. Amplitude of accommodation ≥2 D below mean for age (15–1/4 age)
2. Monocular accommodative facility ≤6 cpm (difficulty with minus lenses)
Accommodative excess
Requires: 1
1. Monocular accommodative facility ≤6 cpm (difficulty with plus lenses)
Accommodative infacility
Requires: 1
1. Monocular accommodative facility ≤6 cpm (difficulty with plus AND minus lenses)
Saccadic dysfunction
Requires: 1 or 2
1. Ratio score: 1 SD or more below the mean on DEM
2. Error score: 1 SD or more below the mean on DEM

TABLE 2.

Criteria for success with vision therapy

Convergence insufficiency	
Success: (all 3) NPC <6 cm, BO >20 or pass Sheard's criteria, and CISS <16	
Improved: improved CISS by 10 or more, and either improved NPC >4 cm or normal or improved BO >10	
Accommodative insufficiency	
Success: (all 3) Normal accommodative amplitude (15–1/4 age), MAF/BAF >6, CISS <16 or improved by >10	
Improved: (1 or 2) Normal accommodative amplitude (15–1/4 age), or MAF/BAF >6	
Saccadic dysfunction	
Success: Both ratio and error scores ≥50th percentile	
Improved: Either ratio or error scores ≥50th percentile	

characteristic. An area of 1.0 represents a perfect test whereas an area of 0.50 represents a test no better than flipping a fair coin. Commonly used classification schemes characterize values over 0.90 as excellent, 0.80 to 0.90 as good, 0.70 to 0.80 as fair, 0.60 to 0.70 as poor, and values less than 0.60 as failure to discriminate.[29] The ability of combinations of patient characteristics to discriminate was completed by first using a logistic regression to calculate the probability of vision disorder. These probabilities were then used to construct the ROC curve.

RESULTS

Two hundred eighteen records were found for patients who were referred after a concussion during the 18-month period. The mean age was 20.5 years and 58% were female. Sixty-seven percent of the patients were between the ages of 12 and 19. The causes of concussion were 56% sports-related accidents, 20% motor vehicle accident, 17% home accident, and 7% school or workplace accident. This was the first documented concussion in 70% of the patients. A summary of descriptive statistics for the sample is listed in Table 3.

Eighty-two percent of patients had at least one diagnosis. Sixty-two percent (135/218) of the sample had a binocular vision disorder, 54% (118/218) had an accommodative disorder, and 21.6% (47/218) had saccadic dysfunction. Table 4 lists the specific diagnoses.

TABLE 3.

Descriptive statistics (n = 218)

Mean age	20.5 yrs
Range	6–72 yrs
	67% ages 12–19
Females	58%
Mean no. of concussions	1.5
1 concussion/2/>2	70%/17%/13%
Time since concussion (mean no. of weeks)	31 wks
Range	1 wk to 5 yrs
	83% >4 wks
History of vestibular therapy	78%
Previous vision therapy pre-concussion	5% (11/218)

TABLE 4.

Frequency of specific vision diagnoses

Binocular vision diagnoses	Frequency
Convergence insufficiency	47.5%
Convergence excess	7.8%
Vertical deviations	3.7%
Other	3.3%
Total	62.3%
Accommodative diagnoses	
Accommodative insufficiency	41.9%
Accommodative infacility	11%
Accommodative excess	1.3%
Total	54.2%
Saccadic dysfunction	21.6%

Vision therapy was recommended for 175 of the 218 patients (80%). Of these, 80 (45.7%) either chose not to begin therapy (52) or did not complete therapy (28) (discussed below). Of the 95 patients who completed treatment, the most common diagnoses were CI, AI, and SD. For patients treated for CI, 85% (35/41) had a successful outcome and 15% (6/41) were improved. Among the patients with AI, 33% (13/39) were successful and 67% (26/39) were improved, and for patients treated for SD, 83% (15/18) were successful and 5% (1/16) were improved. The mean number (±SD) of VT sessions for patients who completed treatment was 14.6 (±5). The variability in the number of sessions reflects the variable time course of post-concussion treatment, which is less predictable than with non-concussion accommodative and vergence disorders.

Clinically and statistically significant changes were seen in NPC, positive fusional vergence (base out break and recovery) and CISS for patients with CI, and in accommodative amplitude and CISS in patients with AI (Table 5). Improved speed was seen on the DEM in patients with SD. Data on accommodative facility and vergence facility are not reported because these test results were often recorded as pass/fail and not quantified.

The ability of any one patient characteristic to discriminate those with and without a concussion-related vision disorder varied (Table 6). NPC break and recovery along with accommodative amplitude and DEM ratio percentile have fair accuracy (ROC area between 0.70 and 0.80). For example, the probability of a more receded NPC break observed in a patient with any vision disorder (relative to a patient with normal vision) is 0.79. The accuracy of DEM vertical time percentile and DEM errors is poor (values between 0.60 and 0.70). A combination of NPC break, accommodative amplitude, and DEM ratio percentile offers the greatest ability to discriminate between those with and without a vision disorder with an area under the ROC curve of 0.89 (95% CI 0.84–0.95).

DISCUSSION

The results of this retrospective study provide additional evidence about the prevalence of concussion-related vision disorders in patients referred to optometrists after concussion. The data also indicate an excellent success rate for patients electing to be treated with vision therapy. A recent review article[30] confirmed that

TABLE 5.

Changes in clinical measures after VT for subjects who completed VT

Diagnosis	Test	Mean pre-VT	Mean post-VT(±SD)	Mean change	p-value
CI (n = 43)					
	CISS	31.1	11.0	−21.1 (±8.8)	<0.0001
	NPC break (cm)	13.0	3.3	−9.7 (±10.1)	<0.0001
	NPC recovery (cm)	17.7	5.6	−12.0 (±8.5)	<0.0001
	BO break (pd)	18.1	38.9	20.8 (±8.6)	<0.0001
	BO recovery (pd)	11.2	32.1	20.9 (±7.0)	<0.0001
AI (n = 39)					
	CISS	28.6	8.6	−20.0 (±9.8)	<0.0001
	Accommodative amplitude (cm)	14.1	9.5	−4.6 (±3.6)	<0.0001
SD (n = 23)					
	DEM horizontal speed (sec)	49.9	33.8	−16.1 (±14.3)	<0.0001
	DEM errors	1.82	0.59	−1.24 (3.6)	0.45

CISS, Convergence Insufficiency Symptom Survey; DEM, Developmental Eye Movement Test.

oculomotor abnormalities are much more common after concussion than the prevalence rates in the general population. This may be due to the widespread neural architecture of the visual system, which includes frontal and posterior cortical regions, cerebellum, cranial nerves, and interconnections between these areas. The neurometabolic and structural impacts of concussion in the form of diffuse axonal injury render the visual brain especially vulnerable.[31] As a result, vision therapy is emerging as a treatment modality in concussion treatment, although more data are needed to assess effectiveness.[32]

The most common types of concussion-related vision disorders in this sample were CI, AI, and SD. This finding is consistent with previous literature in military subjects,[3–8] the adult civilian population,[9,33] and children.[14] Other conditions such as convergence excess, comitant vertical deviations, and accommodative infacility were diagnosed less frequently. It is possible that some of these problems were premorbid, and that concussion may have exacerbated symptoms or increased the level of oculomotor dysfunction. It is interesting that there were no cranial nerve palsies in this sample, underscoring the notion that cranial nerve palsies are much more likely to occur from more focal damage seen in moderate or severe TBI.[34]

Seventy-eight percent of the patients reported having previous or concurrent vestibular therapy, reflecting the high prevalence of vestibular disorders after concussion.[23,24] It may also reflect practice patterns in the authors' practice area, where vestibular therapy administered by physical therapists sometimes includes convergence and ocular motor activities. Pre-existing vestibular dysfunction may also have contributed to this high prevalence.

Nearly 46% of patients for whom vision therapy was recommended either did not finish treatment or did not elect treatment in the authors' practices. Some patients may have sought treatment elsewhere (including with physical therapists) or waited to see if resolution or improvement of their problems occurred through natural healing. Some were also prescribed reading glasses that may have lessened symptoms and reduced the motivation for therapy, whereas others may not have been able to afford the cost of vision therapy.

The ROC curve analysis suggests that a combination of NPC break, accommodative amplitude, and DEM ratio score has very good ability to predict the presence of a vision disorder. This information may be helpful for screening purposes for physicians and primary care optometrists.

In our sample, the success rates for vision therapy suggest that cortical neuroplasticity is still present and that treatment can be effective in this population. Strengths of this study were that all patients with concussion-related vision disorders over an 18-month period were included. In addition, the two investigators used similar assessment and treatment methods. Limitations of this study were its retrospective design, the use of unmasked examiners, the high percentage of patients who did not start or complete vision therapy, and a lack of a control group. It is possible that factors such as a placebo effect, regression to the mean, and continued natural healing accounted for some of the treatment effect. Despite these limitations, these data provide insight into the prevalence of vision problems of patients referred to optometrists post-concussion and about the effectiveness of vision therapy for concussion-related vision disorders. Currently, there is only one randomized clinical trial comparing treatments for concussion-related oculomotor problems. In this study by Ciuffreda and colleagues,[16–18] all of the subjects (n = 12) were at least 1 year removed from their brain injury, and they still demonstrated significant ocular motor plasticity as the result of vision therapy. The evidence from the Ciuffreda study, plus the data from this large retrospective study, suggests that vision therapy is a valuable treatment for concussion-related vision disorders and argue for a large, multicenter randomized clinical trial that would be able to minimize factors that introduce bias in study results.

TABLE 6.

Predicting any vision disorder

Characteristic	Area under ROC	95% CI
NPC break	0.79	0.72, 0.86
NPC recovery	0.74	0.67, 0.82
Accommodative amplitude	0.76	0.69, 0.84
DEM vertical time (percentile)	0.61	0.51, 0.72
DEM ratio (percentile)	0.71	0.63, 0.80
DEM errors	0.63	0.53, 0.73

In summary, the high prevalence of concussion-related vision disorders supports the need for appropriate clinical testing of vergence, accommodation, and eye movements. Our data suggest vision therapy can be an effective intervention, but a large-scale randomized clinical trial is warranted to rigorously determine the effectiveness of vision therapy for concussion-related vision disorders and to better understand the time course of natural healing.

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