Article ▸ The Optometric Care of Vision Problems After Concussion: A Clinical Guide

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ABSTRACT

Over the past decade, there has been a surge in the diagnosis of sports-related concussions. The etiology of this increase may be the cultural emphasis placed on physical activity, the heightened awareness of the signs and symptoms of concussion leading to better, more accurate diagnosis, or a combination of these two factors. Regardless, there is increased recognition that a number of concussion patients retain persistent symptoms which do not resolve within three months, resulting in the diagnosis of Post-Concussion Syndrome. Often, many of the lingering symptoms are visual in nature, with patients having difficulty with visual attention, decreased reading speed and comprehension, headaches, asthenopia, photophobia, and difficulty processing in busy visual environments. Research over the past ten years provides evidence that post-concussion patients have accommodative, vergence, oculomotor, and visual-vestibular dysfunctions to correlate with these symptoms; research has further classified this type of traumatic brain injury as Post-Traumatic Vision Syndrome (PTVS). Awareness of this syndrome is in its infancy, and there is a paucity of clinical information to help optometrists provide care for these patients. The goal of this paper is to be a clinical guide to the identification, treatment, and management of patients with PTVS.

Keywords: concussion, Post-Concussion Syndrome (PCS), Post-Traumatic Vision Syndrome (PTVS), vision rehabilitation, vision therapy

A concussion is classified as a mild traumatic brain injury (mTBI) caused by a bump, blow, or jolt to the head that can cause a disturbance of cerebral function.[1] It is estimated that 1.5-3.8 million concussions happen annually, with 200,000 of those being sports-related.[1] This number is only an estimate, as concussions are often under-diagnosed and under-reported.[2] All athletic activities pose some risk of a concussive injury, but studies show that football for males and soccer for females pose the highest risk.[1]

Concussion Effects

A concussion is caused by a blow to the head or body with a force strong enough for the brain to displace the cerebrospinal fluid, hitting one side of the skull then rebounding to the opposite side. This is known as the coup/contra-coup reaction. The primary injury during the coup/contra-coup force is the diffuse shearing, stretching, and twisting of the brain's axons, which slows signal transmission.[3] Secondary injury occurs days to weeks following the initial injury, resulting from neurotoxins that have been released and a subsequent biochemical cascade, which further slows and interrupts normal communication within the brain.[3]

It should be noted that because most of the effects of concussion are biochemical in nature, there is often no sign of brain damage on a standard MRI. However, Inglese et al. show that special imaging techniques, such as diffusion tensor imaging, may be used as early indicators and prognostic measures of subsequent brain damage.[4] With the continued advancement in technology, these tests will eventually allow for better, more accurate diagnosis of concussion.

Post-Concussion Syndrome and Post-Traumatic Vision Syndrome

Post-Concussion Syndrome (PCS) is a diagnosis that is given when symptoms of a concussion persist and become pervasive in a patient's life for a period of greater than three months.[5,6] These symptoms often include headaches, cognitive and emotional issues, nausea, dizziness, visual disturbances, and loss of balance.[6] Post-Traumatic Vision Syndrome (PTVS) is a sequela of any acquired brain injury that is diagnosed when the symptoms are largely visual in nature.[7,8] The high prevalence of convergence insufficiency (30-42.5%),[9-11] deficits in saccades (19.6-51.3%),[9,11] and deficits in accommodation (21.7-41%)[9-12] within this population are well documented. Seglaeter et al.[13] also reveal that 26% of mTBI patients manifest an abnormal horizontal distance phoria, while Hellerstein et al.[14] find that approximately 37% of mild traumatic brain injury patients have reduced negative fusional ranges in the distance. These clinical vision syndromes correlate with the most common PTVS symptoms described in Table 1.[8]

Clinical Management

Patients with PCS suffer with symptoms that can be grouped into the following categories: somatic, emotional/behavioral, and cognitive.[7] Success in the evaluation of these patients will be based on the consideration that this population

Table 1: Common Symptoms of Post-Traumatic Vision Syndrome (PTVS)[11]

Blurred vision, Distance viewing	Face or head turn	Disorientation	Discomfort while reading	Easily distracted	Loss of balance	Dizziness
Blurred vision, Near viewing	Head tilt	Bothered by movement in spatial world	Unable to sustain near work	Decreased attention span	Poor eye-hand coordination	Poor coordination
Slow to shift focus, near to far to near	Covering, closing one eye	Bothered by noises in environment	General fatigue while reading	Reduced concentration ability	Poor handwriting	Clumsiness
Difficulty taking notes			Loss of place while reading	Difficulty recalling what had been read	Poor posture	
Pulling or tugging sensation around eyes			Eyes get tired while reading	Easily distracted		

Table 2: Summary of Examination Elements and Treatment Considerations

Exam Elements	Tests	Treatment Considerations
Quality of Life Survey		
Visual Acuity/Refraction	• Snellen Chart (Projector or Computerized) • ETDRS Chart	• Spectacles
Contrast Sensitivity	• MARS Test • Pelli-Robson • Vistech	• Tints
Vergence System	Distance & Near: • Cover Test • Von Graefe Phorias • Negative/Positive Fusional Ranges Near Only: • Near Point of Convergence (NPC) • Vergence Facility (3BI/12BO)	• Prism • Vision Therapy
Accommodative System	• Minus Lens Accommodative Amplitudes • +/-2.00 Accommodative Facility	• Near Vision Spectacles • Vision Therapy
Oculomotor Skills	Fixation/Saccades/ Pursuits • Gross Observation • Visagraph	• Vision Therapy
Visual Vestibular	•OKN Drum	• Binasal occlusion • Tints • Vision Therapy
Photosensitivity		• Tints

will most likely be suffering from headaches, fatigue, sensitivity to light/noise, and emotional instability. They will often have slowed thinking, slowed response speed, and deficits in executive function.[7] Adapting the speed, environment, and elements of your exam will allow for the most effective patient evaluation and diagnosis.

It is important to recognize that the pervasive effects of concussions often lead to these patients having a team of professionals collaborating towards maximal patient care and rehabilitation. Neuro-optometric rehabilitation is a key element for the patient's care and requires constant communication and correspondence with other medical professionals to ensure comprehensive care of the concussed population.[15]

Methods/ Exam Considerations

To accurately assess the visual system in the concussed and post-concussion syndrome patient, careful consideration of the following should be considered: quality of life surveys, visual acuity, the vergence and accommodative systems, oculomotor function, and the vestibular system. Table 2 gives a broad overview of these, with corresponding diagnostic methods and treatment considerations.

Quality of Life/Activities of Daily Living Surveys

According to Rutherford et al,[16] approximately 10-15% of those with mTBI have post-concussive symptoms persisting beyond one year post-injury. To get a full understanding of the patient's symptoms, a clinically studied quality of life (QOL) or activities of daily living (ADL) survey is beneficial. A commonly used survey is the College of Optometrists in Vision Development (COVD) quality of life questionnaire (COVD-QOL). It has been shown to be statistically accurate in identifying an at-risk population, with a cut-off score of 20. It can also be used as a pre- and post-vision therapy marker.[17]

Additionally, the authors recommend inquiring whether flickering or fluorescent lights are problematic for your patients. Many surveys do not include this question, but a study by Chang et al.[18] showed that the mean critical flicker fusion frequency (CFF) was found to be higher in mild TBI patients who suffered from light and motion sensitivity when compared to those not suffering from mTBI. The etiology of this correlation is perhaps neurological disinhibition as a result of the brain injury, but further studies are needed definitively to address this.[18]

Visual Acuity

Visual acuity should be taken with standard Snellen letters 20 feet from the patient. The authors use a method where visual acuity is assessed as single letter acuity to threshold and then

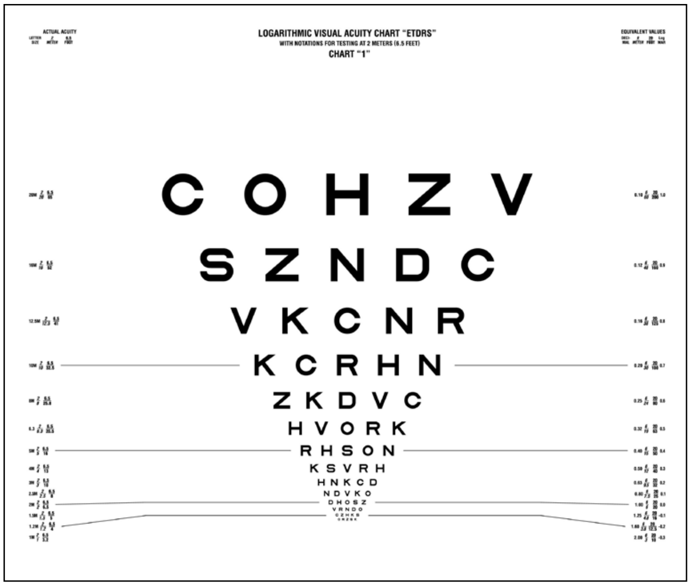

Figure 1. *Early Treatment Diabetic Retinopathy Study (ETDRS) Chart[19] (Precision Vision, La Salle, Illinois)*

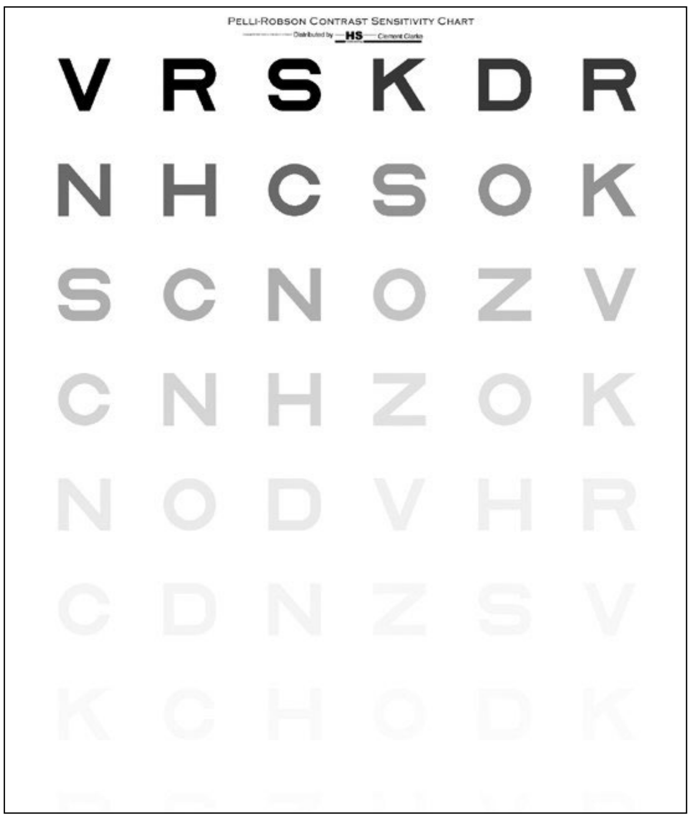

Figure 2. *Pelli-Robson Chart[21]*

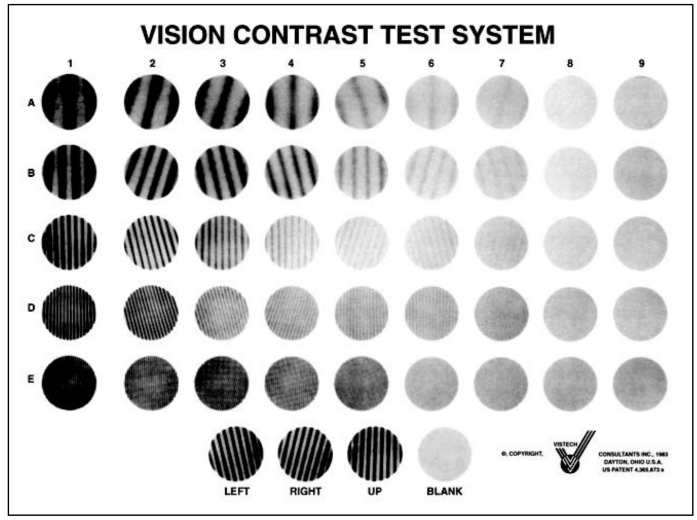

Figure 3. *Vistech Chart[22]*

Figure 4. *MARS[23] (Image courtesy of Mars Perceptix)*

by full-line assessment. This limits the amount of unnecessary distraction early in the exam. Computerized visual acuity systems allow for flexible testing in this manner.

If a computerized system is unavailable or there is concern of reduced contrast sensitivity, a clinician can opt to use the Early Treatment Diabetic Retinopathy Study (ETDRS) Chart (Figure 1). The ETDRS chart is commonly used in large clinical studies because of result consistency. This chart is printed with high-contrast letters, is illuminated from behind, and has the same number of letters on each line (5) that decrease in size based on a mathematical formula. If necessary, this chart can be brought as close as 1 meter to evaluate visual acuity.[19]

Contrast Sensitivity

Many TBI patients present with 20/20 vision but have a series of complaints about the quality of their vision. If this is the case, testing a patient's contrast sensitivity is recommended. In simplest terms, contrast sensitivity is the ability to distinguish an object from its background. Lemke et al.[20] revealed that 21% of mTBI patients suffered from reduced contrast sensitivity, which correlated with poorer results on a quality of life survey.

To test contrast sensitivity, there are three popular options: the Pelli-Robson wall-mounted chart, the Vistech chart, and the hand-held MARS letter tests (Figures 2, 3, and 4).

The Pelli-Robson chart is performed at 40 inches (1 meter), requiring the patient properly to identify the letters in decreasing contrast.[21] The Vistech chart has two test distances of near (16 inches/40cm) and far (10 feet/3.05 meters), but instead of letters, patients have to identify the orientation of the grating bars correctly (vertical, horizontal, or diagonally oriented to the left or right).[22] The MARS letter test has a very similar design to the Pelli-Robson test, using letters of decreasing sensitivity, but this test is portable and is completed at 20 inches (0.5 meters). It should be noted that any of these tests are useful, but the MARS letter contrast sensitivity chart is the most reliable, with a 28% increased precision compared to the Pelli-Robson.[23]

Vergence

Thiagarajan et al.[10] show that 56.3% of the mTBI population has some type of vergence dysfunction. Similarly, Ciuffreda et al.[11] show that 42.5% suffers from signs and symptoms of convergence insufficiency. With the known prevalence of vergence issues in this population, it is essential to perform complete static vergence measurements at both distance and near. Performing at both test distances covers the association of common near findings with visual discomfort, as well as the abnormal distance phoria and reduced fusional capabilities found in mTBI.[13,14]

Testing includes unilateral and alternate cover tests, near point of convergence, von Graefe heterophoria measurements, positive and negative fusional ranges, and vergence facility. All should be performed using standardized clinical test procedures.[24] The near point of convergence should be performed three times, with both accommodative and non-accommodative targets, to allow for the observation of degradation with increased visual stress.

Accommodation

Accommodative dysfunctions in the population are frequent and include insufficiency, excess, and infacility. Accommodative insufficiency, defined as a reduction in amplitude of accommodation to maintain clear near vision, has an incidence between 10-40%.[12] Patients with accommodative excess often report distance vision blur, whereas difficulty with accommodative facility often results in the inability to make quick viewing changes and maintain clear vision.

The accommodative system should be evaluated with various tests, including negative and positive relative accommodation, monocular minus lens amplitudes, a measurement of the lag/lead of accommodation, and accommodative facility with +/-2.00 flippers. Each of these tests should be performed via standardized procedures with the patient wearing their full refractive correction, but adjustment can be made if neccessary.[24]

Eye Movement Evaluation

Fixation

Examination of the stability of the patient's fixation is essential in the assessment of our oculomotor system. The stability of fixation translates into the ability to gather visual information in a concise manner. If, however, there is an unintentional saccade, with a disruption in fixation, this is described as a saccadic intrusion or square-wave jerk.[25] The

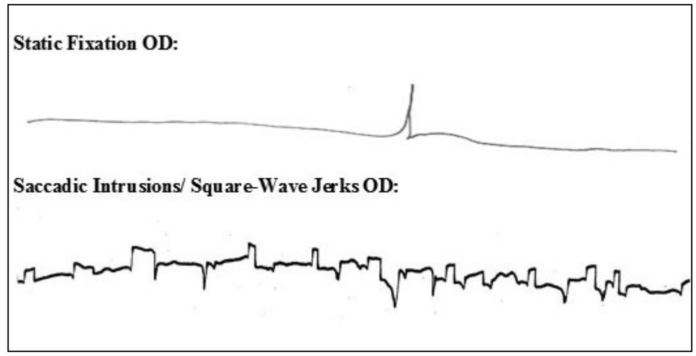

Figure 5. *Measurements taken by Visagraph (Dr. Barry Tannen)*

saccadic intrusions may cause symptoms such as floating/jumping of words, reduced reading speed, and an overall sense of instability in the patient's visual world.[26] Ciuffreda et al.[26] showed that fixation deficits were consistently found in individuals with ABI.

Fixation can be assessed grossly with the observation of both monocular and binocular fixation for ten seconds. There should be no loss of fixation from the target. Findings should be recorded as number of losses/ten seconds.[24]

A more precise measurement of fixation integrity would be to use the 'measurement only' function on the Visagraph/ReadAlyzer. Once the goggles are placed on the patient with their pupils aligned, the patient is encouraged to look back and forth between two objects about twelve inches apart on the observer's command, similar to the NSUCO method of assessing saccadic eye movements.[24] The scans should show steady fixation once the jump has been made. Figure 5 compares steady fixation with unsteady saccadic intrusions noted on Visagraph testing.

Saccades/Pursuits

Saccades are quick eye movements that allow a person to move their eyes from one object to another. Pursuits are the slow tracking eye movements that allow us to fixate and to follow an object. Both eye movements are essential for gathering visual information and maintaining a stable visual environment. Each should be assessed grossly by using standardized measures, such as the NSUCO methodology.[24]

Reading Eye Movements

Many mTBI patients report difficulty with tracking and visual attention and decreased reading comprehension. Ciuffreda et al.[11] report that there is a 90% occurrence of oculomotor dysfunction compared to 20% in the non-ABI symptomatic patients. They propose that if "an oculomotor dysfunction is not found after careful and comprehensive testing, it is unexpected and represents an exception to the rule."

Tools such as the Visagraph or ReadAlyzer are readily available for private practice use. The modified protocol for these instruments that Tannen and Ciuffreda adapted is recommended. This protocol calls for two recordings taken at the patient's independent reading level, with the second one being used for analysis, and one recording taken at least two grade levels below the patient's independent reading level.[27] A comprehension score of at least 70% is required to analyze data. If this level of comprehension is not achieved, the grade level of the text should be dropped until success is achieved. In theory, the grade level efficiency should remain relatively stable over the varying difficulty levels if an oculomotor dysfunction is present (+/-2 grade levels).[27]

Non-computer based methodologies such as King-Devick or Developmental Eye Movement (DEM) testing can also be used to evaluate oculomotor status.[28,29] The authors use the DEM/King-Devick alone for testing children who are unable to read fluently as these tests only require number recognition. These tests are also used as a basis for comparison to the Visagraph/ReadAlyzer to determine whether different types of visual stresses (letters/words vs. numbers) result in dissimilar findings, which contributes to understanding the patient's overall visual/cognitive function.

Vestibular System

The visual and vestibular systems are closely intertwined with the task of keeping a person's visual world stable. It is common for TBI patients to have a mismatch between these two systems, resulting in symptoms such as dizziness, blurred vision, difficulty with dynamic moving environments (i.e. supermarkets), and constant nausea.[30] To measure the mismatch between the visual and vestibular systems, a modification of the optokinetic drum proposed by Ciuffreda is used. It is recommended that testing should be done with the drum spinning slowly directly in front of the patient's fixation. Have the patient rate the level of discomfort on a scale of 1-10, with 10 eliciting severe vertigo-like symptoms. Repeat this procedure about 30 degrees to the left, to the right, above, and below eye level to assess the interaction fully and to ascertain whether there is one quadrant more bothersome.[31] The authors theorize that patients who suffer from visual-vestibular dysfunctions rely on visual information more than vestibular-proprioceptive cues, which results in an overwhelming vertigo-like response to visual environments. It is not fully understood why some quadrants are more bothersome to some patients than others, but it may be related to the type and area of the sustained injury. In non-TBI populations, the OKN drum should not elicit any symptoms.[31]

Treatment Options

Spectacles

We have found that TBI patients often have an increased sensitivity to small refractive errors. It is essential to do a careful refraction, keeping in mind that mild astigmatic, myopic, and hyperopic corrections may result in subjective improvement. These prescriptions often have a two-fold benefit: 1) the correction of these small refractive errors gives the patient an extra bit of clarity and boldness that improves decreased contrast sensitivity, and 2) correcting for these small errors allows for the visual system to be balanced accommodatively, which removes this as a disruption to binocularity. However, one must be careful about pseudo-myopes who may subjectively take extra minus. Remember only to prescribe these small refractive errors when a patient's objective and subjective findings correlate. The consideration for near vision only spectacles should be made when a patient is suffering from a symptomatic accommodative insufficiency. When prescribing for near with the mTBI population, it is recommended for the prescriber to consider all objective and subjective information and to trial frame the proposed prescription to ensure that the patient will accept the added plus at near. If there is a mismatch between objective and subjective findings, two options present themselves: recheck the patient at a follow-up visit, or prescribe based on professional judgment.

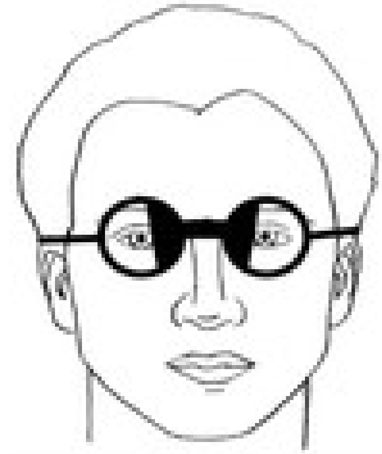

Figure 6. *Binasal occlusion (Image from VisionHelpBlog)*

Prism

Depending on the case, yoked or compensatory prism may be indicated to help alleviate symptoms and to encourage binocularity. We have found that patients with a larger-angle convergence insufficiency or a small vertical deviation respond well to low amounts of compensatory prism. The authors recommend an in-office trial of prism to evaluate patient response.

Tints

Photosensitivity is a prevalent problem in this population (57.8%).[32,33] People who suffer from PCS often retain sensitivity to light past the common healing time of 6 months.[34,35] Common brown and gray polarized tints may be added to lenses for outdoor use. For difficulty with fluorescent lights or motion sensitivity, a blue-ish purple tint from BPI (Omega) may alleviate symptoms.[35]

Binasal Occlusion

Patients who suffer from severe motion sensitivity/vestibular dysfunction may benefit from binasal occlusion.

Binasal occlusion can be achieved with black/clear tape or Bangerter foils oriented diagonally at the nasal limbus on the patient's glasses (Figure 6). Padula et al. showed that binasal occlusion helped those suffering from PTVS to organize their peripheral visual processes and aided in the improvement of binocularity and fusion.[36] A recent study by Yadav and Ciuffreda[37] also showed that binasal occlusion in the mTBI population improved VEP findings and also improved visual impressions and sensorimotor tasks in 90% of their subjects.

Vision Therapy

Research in neuroplasticity demonstrates that therapy enhances top-down (cognitive) processing, resulting in the recovery of function and reduction of symptoms.[38] In order to be productive when treating patients with TBI, the approach to vision therapy needs to take into account various processing mechanisms and neuroplasticity.[9] Cohen et al.[9] discuss five components to achieving effective therapy: motivation/goal-directed participation, repetition, feedback to recalibrate, refining encoded responses, and creating a motor match to a sensory mismatch to encourage sensorimotor recalibration and multi-sensory (intermodal) integration. The authors have consolidated the vision therapy sequence into three phases of care.

Phase 1: Visual Stabilization

Initial therapy needs to work on building monocular oculomotor and accommodative skills, while simultaneously stabilizing the vergence system at both distance and near. Activities include basic convergence, Brock string, monocular accommodative rock, near-far Hart chart, Hart chart saccades, Michigan tracking, Marsden ball activities, and PTS II Visual Search and Scan.[39]

Phase 2: Binocular Vision Integration

Once monocular skills have improved, therapy focuses on binocular accommodative and oculomotor tasks, while challenging the vergence system to make quick changes in demand. This level should allow for the basic integration of vergence and accommodation and help to increase the speed and accuracy of all activities. Procedures in this phase include binocular accommodative rock, early BOP/BIM techniques, loaded Brock string with prism flippers, Hart chart saccades, and dynamic reader/visual search and scan with prism and accommodative flippers.[39]

Phase 3: Visual Automaticity

The last phase of therapy helps to ensure that the newly learned visual skills have become fully habituated. Therapy procedures are designed to challenge the patient continually to refine their visual skills, to increase speed of response, and to incorporate the vergence, accommodative, vestibular, and auditory systems. Therapy exercises in this phase are similar to the previous phases but are performed at a higher demand level by challenging further integration of systems. Incorporation of vestibular movements, such as head turns (VOR) and metronomes with higher-level accommodative/vergence procedures, builds and encourages the development of automaticity.[39]

Follow-Up Schedule

If a patient is in active therapy, a progress check is recommended after every 10-12 sessions of therapy to ensure that therapy is addressing all of the patient's symptoms and concerns. After therapy is complete and home maintenance is dispensed, it is our protocol to follow up with the patients six weeks after therapy, then again in three, six, and twelve months post-therapy.

Conclusion

With the growing number of patients who suffer from PCS and PTVS, it is essential as healthcare providers to identify, to diagnose, and to treat these conditions. Understanding the pervasive effects that concussions have and the application of this treatment model will serve as a starting point in providing comprehensive care to this in-need population.

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The online version of this article contains digital enhancements.

Appendix 1

JP- Age 16

A concussion specialist referred JP, a sixteen-year-old male, for a neuro-optometric work-up after he was still suffering symptoms months after his concussion. JP reported that he sustained a concussion from swimming full-speed into a concrete wall during a swim meet. He lost consciousness on the ride to the hospital and experienced amnesia directly following the incident. JP noted that he had a few other minor head injuries, the most notable a fall due to loss of balance two months after the initial concussion. Prior to our exam, JP underwent vestibular, exertional, physical, occupational, and cognitive therapies. Despite all of these therapies, JP still experienced severe eyestrain, headaches, fatigue with near work, nausea with busy visual environments, loss of place while reading, and decreased reading comprehension.

A full optometric exam, performed similarly to the one outline above, revealed that JP suffered from severe accommodative instability. He had reduced amplitude of 4.75/4.25D (target: 12.67D). (Table 3).

His vergence testing revealed a receded near point of convergence of eight inches with reduced compensatory vergence ranges, indicating a large convergence insufficiency. Distance vergence ranges showed fusional instability, with JP's distance positive fusional ranges breaking at 4^{Δ} (19^{Δ} is expected) and recovering at 0^{Δ} (10^{Δ} is expected). His negative fusional ranges were also reduced, indicating a lack of fusional stability.

Oculomotor assessment revealed a small saccadic intrusion on fixation, resulting in two losses of fixation/ten seconds. Visagraph testing also revealed a lower than grade level efficiency of 7.8, when JP was a sophomore (Grade 10) in high school.

JP was diagnosed with convergence insufficiency, fusional instability, oculomotor dysfunction, and accommodative insufficiency, for which neuro-optometric rehabilitative therapy was recommended. After 24 sessions, JP's objective findings improved, but more importantly, his symptoms subsided. Table 4 shows the post-vision therapy findings. The pre and post COVD-QOL questionnaires were 72 and 13, respectively. After 6 months of home vision therapy, JP reported that he felt 'visually normal' again and was able to return to all of his regular activities with no issue.

Table 3. JP Initial Findings-Vision Efficiency and Processing Evaluation

Test	Exam Results	Normal Range	Interpretation
Best Corrected Visual Acuity	RE: 20/20 LE: 20/20	20/20	Normal
Refractive Status	RE: -2.75 DS LE: -2.75 DS	n/a	Mild Myopia
Distance Phoria	2 exophoria	0-2 exophoria	Normal
Near Phoria	6 exophoria	0-6 exophoria	Normal
Nearpoint of Convergence	8 inches	3 inches	Convergence Insufficiency
Near Convergence Range	16 pd	18-24 pd	Convergence Insufficiency
Near Convergence Recovery	8 pd	7-15 pd	Normal
Near Divergence Range	16 pd	18-24 pd	Fusional Instability
Near Divergence Recovery	6	10-16 pd	Normal
Distance Convergence Range	4 pd	14-24 pd	Fusional Instability
Distance Convergence Recovery	0 pd	6-12 pd	Fusional Instability
Distance Divergence Range	4 pd	5-10 pd	Fusional Instability
Distance Divergence Recovery	2 pd	2-6 pd	Normal
Vergence Facility	17 cpm	>15 cpm	Normal
Accommodative Amplitude	RE: 4.75 D LE: 4.25 D	11.00 D	Accommodative Insufficiency
Test of Silent Word Reading Fluency	2.7 %	38th %	Reading Fluency Deficit
Visagraph Reading Eye Movement Test 7th Grade text	7.9 grade level	9.0 or greater grade level	Oculomotor Dysfunction

Table 4. Pre & Post Vision Therapy Evaluation

Test	Initial Evaluation	Re-Evaluation	Interpretation
Best Corrected Visual Acuity	RE: 20/20 LE: 20/20	20/20	Normal
Refractive Status	RE: -2.75 DS LE: -2.75 DS	n/a	Mild Myopia
Distance Phoria	2 exophoria	2 exophoria	Normal
Near Phoria	6 exophoria	6 exophoria	Normal
Nearpoint of Convergence	8 inches	1 inch	Normal
Near Convergence Range	16 pd	36 pd	Normalized
Near Convergence Recovery	8 pd	24 pd	Normalized
Near Divergence Range	16 pd	28 pd	Normalized
Near Divergence Recovery	6 pd	20 pd	Normalized
Distance Convergence Range	4 pd	10 pd	Normalized
Distance Convergence Recovery	0 pd	6 pd	Normalized
Distance Divergence Range	4 pd	22 pd	Normalized
Distance Divergence Recovery	2 pd	16 pd	Normalized
Vergence Facility	17 cpm	19 cpm	Normalized
Accommodative Amplitude	RE: 4.75 D LE: 4.25 D	OD: 11.00 D OS: 12.50 D	Normalized
Test of Silent Word Reading Fluency	2.7 %	79 %	Normalized
Visagraph Reading Eye Movement Test 7th Grade text	7.9 grade level	13.4 or greater grade level	Normalized