CASE REPORT

Vision Therapy for Convergence and Accommodative Insufficiency in Post-Concussion Syndrome

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ABSTRACT

Background
Accommodative and convergence insufficiencies are commonly found in post-concussion syndrome. Retrospective studies have determined the prevalence of these conditions as well as the effectiveness of neuro-optometric rehabilitative therapy (NORT).

Method
The criteria for a successful individualized vision therapy program for patients diagnosed with post-concussion syndrome is outlined. This post-concussion syndrome vision therapy program was developed based on our experience and those of our colleagues, supported by evidence-based practices in vision therapy.

Results
Treatment includes the use of prisms, lenses, and balance boards, along with eye-tracking technology, as illustrated through a case report. Emphasis is on integration of accommodation, convergence, and vestibular systems. Specific activities and their levels of difficulty are included, that can be customized to the need of individual patients.

Conclusion
The case report presented is consistent with the success of NORT through retrospective studies. It is anticipated that prospective studies will shed further light on a standardized protocol of vision therapy for post-concussion syndrome.

INTRODUCTION

The visual system is an intricate network of nerves that travel throughout the brain to process what we see and perceive where we are in space. A disruption in communication caused by trauma to the brain in the form of a concussion can drastically shift an individual’s way of life. Concussions are a type of traumatic brain injury caused by whiplash or a sudden blow to the head mostly seen in sports, motor vehicle accidents, and home accidents.1 The force on the brain causes a shearing of the axons which can lead to a large spectrum of symptoms known as post-concussion syndrome. The most common visual symptoms of post-concussion syndrome include blur, headaches, diplopia, eye fatigue, balance, light sensitivity, and difficulty with prolonged near tasks including reading and working on the computer.1 Studies show that the most common vision disorders are Convergence Insufficiency and Accommodative Insufficiency.1 Treatment includes vision therapy/neuro-optometric

Keywords: Accommodative insufficiency, concussion, convergence insufficiency, mTBI, NORT, vision therapy
rehabilitation where prisms and therapeutic lenses are integrated with activities to develop those neural connections necessary to improve quality of function and quality of life.

BACKGROUND
Fusional and Accommodative Vergence

Fusional vergence is activated when there is image disparity between the two eyes that stimulates an equal innervation of disconjugate eye movements to maintain binocularity. Accommodative vergence occurs when a stimulus needs to remain in focus in addition to maintaining binocularity. There is also evidence of areas throughout the brain that contribute to vergence including the midbrain, pons, parietal lobe and frontal eye fields. When vergence occurs, signals are sent to the lateral rectus by the abducens nerve and the medial rectus by the oculomotor nerve. The speed and amplitude required for these vergence movements are determined by the midbrain reticular formation.

Patients with convergence insufficiency due to a concussion have been shown to have reduced speed and amplitude when viewing near objects. The Oculomotor Nerve and Near Triad

The Oculomotor nerve is the third cranial nerve that originates from the oculomotor nuclei within the midbrain. It travels through the cavernous sinus and enters the orbit through the supraorbital fissure innervating the superior, medial and inferior recti as well as the inferior oblique muscles and upper eyelid. The oculomotor nerve is also involved with the near triad and the pupil reflex. The near triad begins with the stimulus of a near target sending information to the Edinger-Westphal nucleus and from the nucleus the signal travels via the third cranial nerve to innervate the pupil, ciliary nerve, and extraocular muscles. The result is miosis, accommodation and convergence. Patients with post-concussion syndrome have complaints affecting all parts of this triad.

Post-Concussion Vision Disorders

The most common vision disorders associated with a mild traumatic brain injury are convergence insufficiency and accommodative insufficiency. The cause of convergence insufficiency is unknown but is observed as a difficulty with eye teaming. Gallaway et al diagnosed convergence insufficiency (CI) as having a near point convergence more remote than 6 cm, exophoria of at least 4 prism diopters greater than at distance, and reduced positive fusional vergence at near. Symptoms for CI include losing place when reading, eyestrain, headaches, diplopia and blurry vision at near. Accommodative insufficiency (AI) is seen when there is a reduced amplitude of accommodation based on age and difficulty clearing minus lenses at near monocularly. Symptoms for AI include eye fatigue, headaches, blurry vision at near, difficulty concentrating.

CLINICAL STUDIES
Retrospective Studies

Two retrospective studies discussed below look at the occurrence of vision disorders and the outcome of vision therapy treatment. Ciuffreda et al’s retrospective analysis found that out of 160 patients from the age of 8 to 91, 41.1% had an accommodative insufficiency, and 56.3% had a convergence insufficiency. The diagnosis of accommodative insufficiency were only considered for those under 40 years old, which were 19 out of 51 people total. The study by Gallaway et al looks at the occurrence and efficacy of vision therapy for vision problems that occur after a concussion. The study found that out of the 218 patients diagnosed with a concussion, 47.5% had a CI and 41.9% had an AI. Vision therapy was done on 54.3% of the total patients recommended for therapy. Therapy was comprised of a combination of in-office and home therapy with activities including balance and head movements, saccades, and pursuits, as well as procedures that were similar to the Convergence Insufficiency Treatment Trial. According to their outlined criteria, 85% had a successful outcome while 15% had an improved outcome for treatment for CI. For treatment of AI, 33% had a successful outcome and 67% had an improved outcome for AI. The retrospective study found patients to have
an improvement in positive fusional vergence and amplitude of accommodation.

**Prospective Clinical Studies**

Prospective clinical studies have been conducted, but are limited to a relatively small sample size, difficulty with creating a standard vision therapy program, and measurement variability.\(^\text{12}\) A meta-analytical review of the literature by Merezhinskaya et al identified accommodative dysfunction, convergence insufficiency, and visual field loss as the most common visual disorders found in patients who have a TBI, with visual field loss occurring more frequently in moderate to severe TBI as opposed to mTBI.\(^\text{11}\) A prospective longitudinal trial with a systematic approach can provide more insight on the short- and long-term visual effects on TBI, and ultimately on how best to relieve the symptoms that decrease the patient’s quality of life.

**In-Office and Home Vision Therapy**

Creating a successful vision therapy program involves an integration of convergence, accommodation, saccades, visual planning and balance activities while engaging peripheral vision. When activities involve multiple components of vision, it gives the brain new opportunities to learn. In order to have a successful session, the patient must be motivated and the activities assigned must be tailor-made based on the patient’s goals. The vision therapy program should include both in-office therapy and home therapy that solidifies the concepts covered in session. The aim for each session should be to introduce something new to the patient, even if the materials used are similar. Materials needed include prisms, therapeutic lenses, vectograms, tranaglyphs. The use of technology such as Virtual Reality (VR) and Eye Tracking software such as Optics Trainer have also been shown to be effective in improving symptoms.\(^\text{4}\) Activities that include the use of vectograms and tranaglyphs increase the demand on vergence on the visual system. The addition of walking and balance activities to the demand on vergence are very useful for concussion patients since the vestibular system is usually affected as well with patient complaints of vertigo and balance difficulty.\(^\text{1}\) Emphasis on engaging peripheral vision and control is essential to expanding vergence ranges on each activity.\(^\text{5}\) Beginning with monocular activities using flippers and therapeutic lenses allows both eyes to have an opportunity to stimulate and relax accommodation. The progression from monocular activities to bi-ocular and binocular activities allow the patient to involve vergence as well in order to best replicate the demands that patients face in their work and school. Prisms can be used in most activities to shift the view of the patient’s target, as well as stimulate or relax accommodation and vergence based on the base direction.\(^\text{5}\) The ability to learn a task with each activity introduced as well as the repeatability of that task help to engage the areas of the brain affected in a traumatic brain injury. This has shown to cause neuroplasticity changes, including axonal sprouting, where new axons have been shown to grow in structures involved with the visual system.\(^\text{14}\) The study by Alvarez et al showed how this growth can result in neurophysiological changes leading to an improvement in the overall rate and function of the fusional system.\(^\text{15}\)

Appendix 1 contains several representative activities that allow patients who have had concussions to repair the neural connections damaged due to injury. It is important to observe how the patient adapts to each level of an activity before proceeding to the next level of difficulty. It is best to approach each new level after it is evident that the patient can handle the lower level without experiencing adverse side effects. Evaluating progress throughout the program is crucial in determining the necessary changes to create a successful outcome for the patient.

**CASE STUDY**

Below is a case example of a patient who was seen at Appelbaum Vision with a history of concussion. The patient experienced a successful outcome based on incorporating the principles presented above and activities contained in Appendix 1.
HISTORY
A 19-year-old Asian male experienced two concussions after falling off a rental scooter on two separate occasions within a one month period of time. The patient presented with chief complaints of headache, trouble reading, in headaches, foggy and blurry vision. A college student, the patient’s symptomology resulted difficulty completing academic assignments. His medications consisted of Magnesium 400mg BID and Vitamin C. The patient has never worn glasses and did not have a history of strabismus, amblyopia, ocular surgeries, or prior vision therapy. Prior to attending college, the patient reported that he experienced an estimated total of four concussions including two concussions from high school football.

Vision Examination
Entering distance vision without correction was 20/20- right eye (OD), 20/25 left eye (OS), and 20/20 both eyes (OU). Cover test showed 1-2 prism diopters of esophoria at distance and 10-12 prism diopters of intermittent alternating exotropia at near. Static retinoscopy revealed +0.50DS right eye (OD) and +0.50-0.50x180 left eye (OS). Subjective refraction resulted in plano for the right eye (OD), and -0.25DS for the left eye (OS).

Near point of convergence was 6cm/10cm. Positive fusional vergence ranges at near (convergence) was 16/14/2 and negative fusional vergence ranges at near (divergence) at near was 18/22/16. NRA was +1.50 and PRA was plano. All other values were within normal limits.

Assessment and Plan
The patient was diagnosed as having post-concussive syndrome including accommodative and convergence insufficiency with fragile binocularity. Low plus lenses were prescribed for near (+0.50DS OU) for the AI and the patient was scheduled to begin vision therapy twice a week to help relieve patient of symptoms. He will also undergo progress evaluations every 24 sessions of therapy. A base-in prism was not recommended since the patient would work on expanding their vergence ranges during therapy.

Management
The patient’s neuro-optometric rehabilitative therapy (NORT) program consisted of 50- minute vision therapy sessions conducted twice weekly. The principal goals for therapy were to alleviate symptoms associated with his concussion, improve accommodation, and improve convergence. Each session is designed to address four key areas of

Table 1: The Four Key Areas of NORT

<table>
<thead>
<tr>
<th>Sample Activities (Total sessions: 52)</th>
<th>Accommodation</th>
<th>Ocular Motility</th>
<th>Binocular Fusion</th>
<th>Visual Planning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample Activities (Total sessions: 52)</td>
<td>Monocular activities with flippers</td>
<td>Infinity Walk</td>
<td>Vectograms</td>
<td>Brock String</td>
</tr>
<tr>
<td>Sample Activities (Total sessions: 52)</td>
<td>Loose lens focus/defocus</td>
<td>Virtual Reality</td>
<td>Tranaglyphs</td>
<td>Long</td>
</tr>
<tr>
<td>Sample Activities (Total sessions: 52)</td>
<td>Split spirangle</td>
<td>Optics Trainer</td>
<td>Addition of Flippers or prism</td>
<td>Short</td>
</tr>
<tr>
<td>Sample Activities (Total sessions: 52)</td>
<td>Monocular fixation in a binocular field</td>
<td>SVI (Sanet Vision Integrator)</td>
<td>WSF</td>
<td>Tangram Puzzle</td>
</tr>
<tr>
<td>Sample Activities (Total sessions: 52)</td>
<td>Red/Green activities</td>
<td>1 (self paced)</td>
<td>15 (Visual Memory)</td>
<td>Geoboards</td>
</tr>
<tr>
<td>Sample Activities (Total sessions: 52)</td>
<td>Target includes: Hart Chart, Groffman Maze</td>
<td>62 (central/peripheral)</td>
<td>16 (Visual Memory fast)</td>
<td>Spatial Arrows</td>
</tr>
<tr>
<td>Sample Activities (Total sessions: 52)</td>
<td>Binocular activities with flippers</td>
<td>15 (Visual Memory fast)</td>
<td>43 (Balance Board)</td>
<td></td>
</tr>
<tr>
<td>Sample Activities (Total sessions: 52)</td>
<td>Beak</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sample Activities (Total sessions: 52)</td>
<td>Polaroid Bars</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sample Activities (Total sessions: 52)</td>
<td>Red/Green Bars</td>
<td></td>
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</tr>
<tr>
<td>Goal</td>
<td>Improve accommodation flexibility and stamina</td>
<td>Improve visual/vestibular integration and eye movements</td>
<td>Expand vergence ranges</td>
<td>Improve mental mapping, decision making and cognition. Smoother eye vergence movements</td>
</tr>
</tbody>
</table>
accommodation, ocular motility, binocular fusion, and visual planning (Table 1).

For the accommodation activities, the first 16 sessions consisted of alternating monocular activities with flippers, loose lens focus/defocus, split spirangle, along with monocular fixation in a binocular field in the form of red/green activities. The level of difficulty was increased for each subsequent session. For the last 8 sessions before his first progress evaluation, the patient began to use the accommodative lens flippers binocularly with polaroid and red/green bars. After 29 sessions, biocular activities were introduced along with the monocular fixation in a binocular field (MFBF) accommodative activities using red/green acetate.

Ocular motility activities were incorporated with the goal of stabilizing eye movements and fixation which are usually affected in post-concussion syndrome. The use of Virtual Reality, Optics Trainer activities, Sanet Vision Integrator (SVI), as well as the Wayne Saccadic Fixator (WSF) Lightboard Numbers 1, 15, 16, 43, and 62 were used at various sessions under the ocular motility category. These activities along with the infinity walk described in detail earlier addressed fixations and visual motor integration issues that are commonly affected in patients with post-concussion syndrome.

Binocular fusion activities were programmed to expand the patient’s vergence ranges by using Vectograms, Tranaglyphs as well as the VTS4 vergence and multiple choice vergence software program. Visual planning together with peripheral awareness was addressed through activities such as the Brock String. Both the long (20 foot) and short (10 foot) string were included to increase the dimension of visual space along the Z-axis. The ability to make smooth vergence movements in real space is challenging for post-concussion patients. Activities such as spatial arrows and tangrams were also included to help with mental mapping, decision making, and cognition. These were deemed necessary to achieve transfer of improved visual and mental focus to the academic environment.

Progress Evaluation #1:

After the 24th session, the patient’s first progress evaluation was conducted. He noted fewer headaches, absence of nausea, a reduction in lightheaded sensation, improved ability to look at screens, and the ability to work for long periods of time at near without experiencing eyestrain. NPC improved to 2 cm break and 4 cm recovery. Fusional vergence ranges at near were X/40+ for convergence and X/20/12 for divergence. NRA was +2.75 and PRA was -2.50. All other values were within normal limits. The recommendation was for 24 more sessions of vision therapy with more focus on eye movement control, focus stamina and flexibility as well as visual/vestibular integration.

Progress Evaluation #2:

After his 48th session, the patient’s second progress evaluation was conducted. He noted further improvement in symptomology as compared to his prior progress evaluation, to the point of total resolution of his previous symptoms. His fusional vergence ranges at near were X/24/12 for convergence and X/24/20 for divergence. Although convergence ranges were of lesser magnitude than at the prior progress evaluation, they reflected a better balance with divergence ranges. NRA was +3.00 and PRA was -2.00. All other values were within normal limits. The patient indicated a desire to discontinue therapy, but we recommended four additional therapy sessions to stabilize the outcome before the completion of NORT. The patient complied with our recommendation.

CONCLUSION

Patients who undergo a traumatic brain injury are navigating through life with unprecedented challenges in meeting demands that were once intuitive. They are essentially re-learning how to see
and interpret their world, a lot of which includes work at near or intermediate distances. While visual field loss is more commonly encountered in patients with moderate to severe TBI, presenting problems in orientation, mobility and driving, comparatively more subtle visual deficits in the accommodation and convergence system occurs in mTBI. The latter occurs commonly in younger patients and impacts academic performance, as evident in the case report presented here.

NORT is the treatment of choice, and the neuro-optometric rehabilitation program is individualized to address the patient’s constellation of symptoms associated with post-concussion syndrome. Monitoring progress occurs through a combination of data obtained during each therapy session, observations from the patients, and changes from baseline evident on re-evaluations. Activities proceed through flexibility and integration of subcomponents of the visual system, solidifying and expanding the skills obtained through previous sessions. The end point of therapy typically occurs during a stabilization period, affording transfer of re-acquired skills to the patient’s activities of daily living.

Vision therapy meets patients where they are in their journey and provides rehabilitation to equip post-concussion patients to reclaim their impaired visual skills. Case reports and retrospective studies present a useful road map, while prospective research will provide additional insight into understanding the heterogeneous nature of post-concussion syndrome and its treatment.

REFERENCES


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Dr. Lynette Wray completed her residency in Vision Therapy, Vision Rehabilitation, and Pediatric Optometry with Appelbaum Vision in 2023. She received her undergraduate degree in biological sciences and her masters in biomedical sciences from Rutgers, The State University of New Jersey. Dr. Wray earned her Doctor of Optometry degree from Indiana University School of Optometry in 2021. While attending, she was a member of the National Optometric Student Association and a Student Fellow of the American Academy of Optometry. Dr. Wray continues to be dedicated to meeting the visual needs of her patients through comprehensive clinical care. Her research interests include traumatic brain injury and myopia management.