THEME ARTICLE

OT-OD Synergy During Management of the Concussed: A Case Report Illustrating Seamless Care 'Handoffs'

John-Ross Rizzo, MD, MSCI[1,2,3];
Margaret Waskiewicz, OTR/L, MS[1];
Neera Kapoor, OD, MS[1]

[1]*Department of Rehabilitation Medicine, New York University School of Medicine, NYULMC, New York, New York*

[2]*Department of Neurology, New York University School of Medicine, NYULMC, New York, New York*

[3]*Department of Mechanical and Aerospace Engineering, New York Tandon School of Engineering, New York, New York*

Correspondence regarding this article should be emailed to John-Ross Rizzo, MD, MSCI, at johnross.rizzo@nyumc.org.

Rizzo JR, Waskiewicz M, Kapoor N. OT-OD synergy during management of the concussed: A case report illustrating seamless care 'handoffs'. Vision Dev & Rehab 2017;3(3):131-46.

Keywords: Concussion, occupational therapy, neuro-optometry, inter-professional, vision

ABSTRACT

Background: Concussion is a change in brain function following an applied or directed force to the head or body with or without loss of consciousness. Common causes of concussion include falls, motor vehicle accidents, and sport-related accidents. Despite heightened awareness, as well as potential preventative approaches, the occurrence of concussion has increased in the United States and ranges from 1.6-3.8 million persons yearly. Once managed acutely, disposition plus education are pivotal to successful outcomes. Complex pathology and/or poor compliance to post-injury recommendations may prolong symptomatology and require a multi-faceted rehabilitation plan. This may also pose long-term clinical challenges related to function for activities of daily living, many of which are impacted by vision. Therefore, an inter-professional, collaborative treatment team, augmented with vision specialists and inclusive of neuro-optometry (OD), neuro-ophthalmology, and occupational therapy (OT), becomes integral to optimized assessments and therapeutic remediation for visually symptomatic individuals with concussion.

Case Report: In this case report, a 44-year-old female post-concussion is initially managed with an incomplete care team rendering an incomplete recovery. This is followed by an exacerbation of her original clinical manifestations, a functional decompensation, and a return presentation to her care team. In response, a more complete inter-professional care team is assembled, including OT and OD, and a re-tooled management plan is constructed, exemplifying seamless 'handoffs'.

Conclusion: This case demonstrates the importance of appropriately recognizing and managing visual deficits in a patient's post-concussive recovery. Further, the incorporation of an inter-professional vision team, including OT and OD, is highlighted, drawing particular

attention to synergistic skill sets and seamless interplay. If properly coordinated and launched at the start of the care timeline, patients benefit from an expedited and more complete functional recovery. Overall, this case illustrates that the inter-disciplinary vision team is integral to successful concussion management in the setting of visual dysfunction.

BACKGROUND

Concussion is the result of an alteration in brain function subsequent to a force applied or directed to the head or body, producing fresh neurological symptomatology without additional explanations.[1] Disturbances may be evident in somatic manifestations, cognitive deficits, behavioral/emotional irregularities, and/or sleep impairments. While the vast majority of those concussed will recover quickly with a trajectory that 'hits' a premorbid baseline in approximately 1 week, the recovery period may be longer and lead into a chronic course.[2] Mechanistic insights into the ultrastructural changes that occur during neuronal shearing and the microtubular damage of axons, along with the cellular and neurometabolic consequences of traumatic brain injury across the severity spectrum, have shed light on recovery periods and begun to improve our understanding of the post-injury neurobiology.[3-8]

Per annum in the US, there are approximately 1.6-3.8 million sports-related concussions,[9] accounting for a significant percentage of athletic injuries at the high school and collegiate levels, 9% and 6%, respectively.[10-11] The voluminous occurrence leads to repeat injuries; in fact, there is a three-fold increase in a repeat event following the first traumatic insult.[12] Repetitive concussive injuries are associated with a higher symptom burden, protracted recovery epochs, and possible dementia.[13] Hence, sensitive sideline assessments[14-17] focused on the detection of concussion are paramount, fast-tracking formal evaluations by clinicians and triaging athletes to the appropriate care level.

Once diagnosed and acutely managed, the disposition accompanied by education is vital to successful outcomes, and post-injury home management is essential. Poor compliance to post-injury recommendations may lead to protracted symptomatology, posing long-term challenges that can negatively affect patients' health-related quality of life (QOL).[18] Current evidence suggests a short period of rest immediately followed by low-level multimodal physical and cognitive activity that is graded and gradual, titrating intensity, as tolerated.[19,20]

For those who are sighted, many activities of daily living (ADLs) are visually guided, such as reading, writing, computer use, cooking, cleaning, ambulation, and driving. Further, given that a significant amount of the brain's neural 'real estate' is dedicated to vision, including the brainstem, cerebellum, and all four lobes of the cortex, it is not surprising that vision may be impacted following concussion, especially for those with prolonged recovery. Therefore, for visually symptomatic individuals with prolonged post-concussive symptoms, the multi-faceted rehabilitation approach often benefits from a care team that is augmented with vision specialists and ultimately from vision rehabilitation.[21-25] Integrating a vision specialist, such as a neuro-optometrist (OD) or neuro-ophthalmologist, alongside occupational therapy (OT), in the neuro-rehabilitation model has increasingly become the primary approach. This inter-professional vision team ensures optimal assessments and subsequent therapeutic remediation plans for visually symptomatic patients with concussion;[21] this will now be illustrated in a case report.

CASE REPORT

History

Patient A was a 44-year-old female with past medical history of Lupus and osteoarthritis affecting her knees, hips, shoulders and back. She presented to the emergency department

(ED) seven hours after being in a motor vehicle accident (MVA), in which she was rear-ended. She reported that she was wearing her seat belt, but that the accident caused her head to "snap forward". While she did not report any direct impact to her head nor loss of consciousness, she did report feeling "fuzzy" and nauseous. She drove from the scene of the accident to seek medical attention, but has no recollection of that drive. While at the ED, a computerized tomography (CT) scan of the brain was performed and found to be unremarkable. With no salient findings on clinical examination, the patient was diagnosed with a concussion and discharged to her home with recommendations to follow up with a neurologist. During this post-care epoch, she reported tingling on the left side of her face and neck, as well as feeling hazy and confused.

Two days after the accident, she presented to the recommended neurologist who performed an electroencephalogram (EEG) to assess for unusual epileptiform or epileptiform-like activity. The EEG was found to be without events and, therefore, unremarkable. Although the patient returned to work, she experienced significant difficulty reading, as well as an overwhelmed and dizzy sensation when working in her busy office environment. She was conservatively managed by Neurology with a referral for vestibular rehabilitation, addressing balance and disequilibrium, which commenced 2 months after the MVA, and for occupational therapy (OT), addressing her vision symptoms and their functional significance, which commenced 3 months after the MVA. The physical and medicine rehabilitation doctor (physiatrist) joined the inter-professional team 5 months after the MVA, following the initiation of therapy services.

Regarding the patient's performance in her overall therapy regimen, her work-related hours and associated symptoms require consideration. She initially returned to work full-time a few days after the accident and experienced significant symptoms, which caused her to divide her work duties between home and office, maintaining her full-time status. While this was stressful for her, she continued with this approach until the initial evaluation with physiatry at the 5-month post-injury date. One of physiatry's primary suggestions was an immediate work reduction with a graded return. She acquiesced initially, but was recalcitrant and gradually increased her hours back to full-time as the management regimen progressed, her signs normalized, and her symptoms reduced, per patient report. The formal recommendations started with workload reductions to 4 hours per day /5 days weekly divided between an in-office and home office settings, using compensatory strategies and workplace modifications. This was to be gradually titrated up one hour per weekday every 1 to 2 months while ensuring a minimal increase in symptoms. While time elapsed, the clinicians involved in her management sensed an extreme amount of work-related pressure; this external stressor was repeatedly noted by the care team and may have influenced the reported subjective impressions of her recovery.

During the first course of therapy, the patient received OT once weekly for a total of 39 sessions (see Table 1). Concurrently, she received a course of vestibular physical therapy to address her dizziness and balance issues. After several sessions of OT, a recommendation was made to integrate neuro-optometry into the care team. Unfortunately, the patient did not follow through with this recommendation due to scheduling conflicts. Upon discharge at 16 months post-MVA, the DEM was within normal limits with no functional complaints and her tolerance to both reading and computer use had significantly improved (see Table 2). Although she reported minimal, if any, functional complaints, with independence achieved in areas of ADLs, including those required for "work" and leisure, there was question as to the authenticity of her subjective

Table 1. OT Interventions (Initial Course of Therapy)

Phase 1 (Sessions 1-11)	Phase 2 (Sessions 11-25)	Phase 3 (Sessions 25-39)
• Monocular strengthening: o Functional pursuits-tracking larger objects, moving to smaller objects o Functional saccades-smaller and larger angled saccades, eventual use of metronome • Word/letter cancellations without distraction; eventual distraction added to increase complexity of information being provided • Education on symptom management • Scapular mobilization to assist with pain and posture • Deep breathing techniques for relaxation • Introduction of straw-piercing and Brock string	• Binocular functional strengthening through use of straw-piercing and Brock string • Implementation of computer-related activities for working on binocular tracking and saccadic eye movement • Implementation of eye/hand coordination activities: use of Vision Coach, Biometrics. • Continuation of working on saccades and pursuits in more complex way (additional stimulation provided, performed in more dynamic positions-i.e. sitting on therapy ball, standing, standing on foam) • Continued education on modifications and rest break implementation	• Work simulation activities • Modification recommendations for computer/office and for travel situations • Continued education on strategies for symptom management in stressful situations • Outdoor excursions (i.e., to grocery store, with and without list during a busy time of day)

ratings given the increase in external pressures, specifically those related to her current job.

Return to Physiatry

Approximately 18 months after completing her initial OT program, which corresponded to 2 years and 10 months after her MVA, she presented again to her physiatrist. She reported having discontinued her home exercise program (HEP) about a year prior and had been functioning well at home and work until returning to 'full-time' hours at work 2 years following her MVA. At that point, she noted a marked increase in difficulty at work, primarily related to reading for prolonged time periods being accompanied by increased headaches and eyestrain. During this period, while working over 40 hours a week, her compensatory strategies and workplace modifications were no longer assisting her symptom management. As she denied any other recent or pertinent histories of illness or head impacts that could explain her findings, her referring physiatrist diagnosed a chronic concussive injury and prescribed a second OT evaluation and treatment regimen, as well as an onsite neuro-optometry consultation. The physiatrist's plan was for conservative, multi-disciplinary neuro-rehabilitation treatment to address her vision symptoms; this would start with a comprehensive vision assessment by OD and then a coordinated handoff with cooperative management from OT, striving for seamless interplay.

Occupational Therapy (OT) Intervention Post-Exacerbation

Once scheduled, Patient A commenced with OT, for her second course, 2 years and 11 months following her MVA, which was 6 weeks prior to neuro-optometry. The OT evaluation preceded the neuro-optometry consultation due to a scheduling backlog, as neuro-optometry was only onsite for outpatient care one day weekly at that time. Ocular motility, fixation, saccades, and pursuit, as well as vergence were evaluated by OT, along with visual performance skills. During the evaluation, objective assessments and patient symptoms were noted (see Table 3), short- and long-term goals were established with the patient (see Table 4), and a treatment strategy with selected techniques was delineated (see Table 5). Please note that Table 5 summarizes the results of the OT re-initiation, comparing the initial to discharge performance.

Table 2. OT Objective Assessments/Symptoms: First Round of Therapy

	Initial Evaluation	Re-evaluation: Visit 10	Re-evaluation: Visit 20	Discharge: Visit 39
DEM Score	Subtest C: 29.44 seconds, with the ***patient reporting nausea and headache***	Subtest C 35 seconds, with the ***patient reporting increased work stress and reduced number of hours sleeping***	Subtest C improved to 26.1 seconds, ***with no reported symptoms***	Subtest C improved to 21.31 seconds, ***with no reported symptoms***
Subjective Symptoms/ Complaints	• Lightheadedness • Occasional vertigo • Feeling foggy • Difficulty processing complex information • Movement in stationary objects • Sensitivity to visual motion	• Nausea with reading • Lightheadedness • Fatigue • Movement in stationary objects	Head pressure when focusing	Head pressure when stressed
Self-Care Limitations	*Dizziness when washing hair and during lower body dressing	*Dizziness when washing hair	#Patient reported resolution of symptoms	#Patient reported resolution of symptoms
Home Management Limitations	Not performing home management due to subjective symptoms	• Began performing light home management-simple meal prep with moderate difficulty finding items in cabinet • Not performing house cleaning or grocery shopping due to dizziness and eye strain	Managing household tasks independently; level of difficulty depended on fatigue	**Independent**
Work Limitations	Modified work schedule: working a few half days weekly in the office	Continued modified work schedule, added working from home 1-2 half days when not in the office	Had taken 1 week off from work per physiatrist recommendations; was feeling overall better, still on modified work schedule, and starting to travel minimally for work	• Working 4 days/week: patient had to return to work on a more full-time basis due to fear of losing her job • Noted overall increased stress and fatigue-attributed to work
Reading Tolerance	15 minutes, the patient was noted to have difficulty functionally converging	• 45 minutes: was able to read for this length of time, but she noted decreased comprehension and multiple rest breaks • Convergence: 11cm, but it was difficult to maintain	• 45 minutes: was able to read for this length of time, but she was appreciating increased comprehension and required less rest breaks • Convergence: 8cm, and she was able to maintain converging at this distance for up to 5 seconds • Able to read a book for leisure	• 45 minutes with rest breaks, but she was unable to read for longer due to work stressors and fatigue • Convergence 5-6 cm, and she was able to maintain converging at this distance for 5 seconds
Computer Tolerance	Less than 15 minutes, prior to evident increase in errors, decrease in comprehension, and increase in subjective symptoms	Up to 20 minutes, prior to evident increase in errors, decrease in comprehension, and increase in subjective symptoms	Up to 30 minutes, prior to evident increase in errors, decrease in comprehension, and increase in subjective symptoms	Up to 45-50 minutes with improved comprehension, subjective symptoms only noted when work stressors were high

(*) indicates that the patient did not subjectively complain of difficulty with self-care activities throughout the course of OT. However, there were times that the patient appeared to minimize symptoms due to other life stressors (pressure to return to work, family stressors etc.).

(#) indicates that the patient appeared to be minimizing symptoms towards the end of therapy, as she was trying to handle mounting external pressure from work and was demonstrating increased levels of stress, which was very apparent to the treatment team.

Anticipating a delay for the OD evaluation, after this second round's OT evaluation, neuro-optometry was contacted for recommendations for the treatment strategy prior to the patient's actual consultation with OD. The recommendation (referred to in Table 5) was provided by neuro-optometry and involved the Brock string, with the application and sequencing being tailored to the patient's presentation based upon OT's second initial evaluation.

The vergence therapy paradigm, which commenced at the first OT treatment session, involved performing the Brock string in

Table 3. OT Objective Assessments/Symptoms (2nd Course of Therapy)

	Initial Evaluation	Re-evaluation/Discharge (Visit 10)
A-DEM Score – *Performed DEM, however it was not challenging patient's deficits enough during second course of therapy*	Test A: 24.75 seconds Test B: 26.38 seconds Test C: 56.07 seconds ***(reported nausea and eye strain after performing)***	Test A: 22.22 seconds Test B: 23.66 seconds Test C: 48.97 seconds ***No reported symptoms***
Subjective Symptoms/ Complaints	• Headaches • Nausea • Fatigue • Eye strain/eye "heaviness" (constant) • Inability to concentrate at work for long • periods of time	• Occasional nausea (triggered more by visual movement specifically when driving for long periods of time) • Eye strain (intermittent and more noticeable when rest breaks were not taken)
Self-Care Limitations	Independent	Independent
Home Management Limitations	• Requires minimal assistance from husband with meal preparation, grocery shopping and bill paying due to increased headaches and fatigue. • Patient also with reported difficulty being passenger in car for long periods of time and using maps when driving	Independent, with an example being that the patient was able to perform all home management, including the additional task of completing applications for her child.
Work Limitations	Working full-time (7-8 hours/5 days weekly) with reported headaches and increased eye strain	Working full-time with decreased symptom report
Reading Tolerance	Only reading for work (she is yet not reading for leisure purposes); tolerating 20 minutes before needing a break	Reading minimally for leisure, and she was able to tolerate reading for up to 45 minutes with rest breaks
Computer Tolerance	Approximately 30 minutes before requiring a break due to headache and fatigue	Up to 60 minutes with rest breaks
Functional Convergence	7cm	7cm

Table 4. OT Goals

OT Goals
<u>Short Term Goals (set to be achieved within 6 sessions):</u> 1. <u>Convergence:</u> Consistently maintain accurate fusion on brock string for up to 5 seconds at near distance (from 1-2 seconds) to improve ability to focus on near work. (Goal Met) *Patient was able to consistently maintain accurate fusion on the brock string (using the standard size target) for 5-7 seconds. She reported improved ability to focus at work, although she continued to benefit from consistent rest breaks throughout the day.* 2. <u>Reading:</u> Perform A-DEM without increase in symptoms (from mild nausea) to improve reading tolerance. (Goal met) *Patient was able to perform this objective measure without a significant change in her symptoms and reported an overall improvement in her tolerance to reading.* 3. <u>Map Reading:</u> Improved ability to read maps on phone and navigate in clinic environment without difficulty in preparation for navigation while driving. (Goal met) *Patient was able to use map applications on her phone (she preferred Waze) when navigating in the car; she found that she would occasionally become overwhelmed when traveling to a new place to the first time so she would pre-plan the route.*
<u>Long Term Goals (set to be achieved by discharge):</u> 1. <u>Work:</u> Tolerate full work duty without increase in symptoms (from moderate difficulty) to improve efficiency. (Goal met) Patient was working full time and traveling for work without difficulty (from a visual standpoint); she was having more difficulty due to her joint pain which limited her from sitting for long periods of time. 2. <u>Driving:</u> Patient will be able to navigate self/others with use of maps in car without difficulty (from moderate difficulty). (Goal partially met) Goal was met when patient was driving to familiar places; if she was going to a new place she would occasionally feel symptomatic when driving, which she sometimes attributed to stress. 3. <u>Childcare:</u> Patient will be able to participate in childcare without increase in symptoms in busy environments (from moderate difficulty). (Goal met) Patient was able to care for her 12-year-old and did not experience any change or increase in symptoms. She reported only feeling fatigued at the end of the day, but it was not different than what she felt prior to the concussion.

Table 5. OT Interventions

Visit 1: Initial Evaluation	Visit 2-9	Visit 10: Discharge
• Obtained history of concussion and previously received therapy and recommendations • Performed functional vision screen • Performed outcome measures (see Table 3) • Functional goal setting (see Table 4)	A collaborative, function-based set of techniques was recommended and implemented: ***Scanning/Saccades/Tracking*** • Word Searches • Visual tracking tube • Vision Coach • Scrabble • Multi-matrix ***Functional Convergence*** • Brock string: performed in both dynamic and static environments, with and without background visual stimulation • Jenga • Straw-piercing ***Education*** • Symptom management • Planning rest breaks • Sleep hygiene ***iPhone application exploration for navigation while driving and in the community***	• Performed re-evaluation of objective measures • Performed re-evaluation of relevant parts of functional vision screen • Reviewed goals • Reviewed home exercise program (HEP) • Reviewed previously provided education

primary gaze, right gaze, and left gaze using both step and ramp vergence. Concurrently, the number of targets in the background was gradually increased as the patient moved from sitting, standing, standing on foam, and finally marching in place. This approach addressed visual-vestibular symptomatology related to foreground-background issues and equilibrium while ensuring appropriate vergence. Once that was stabilized with minimal symptomatology, the patient was ready to perform the dynamic Brock string (i.e., slow horizontal vestibular ocular reflex with the brock string held under the nose) in front of a non-systematically, visually busy background while marching in place.

Neuro-optometry (OD) Intervention

The patient's initial presentation to neuro-optometry occurred 6 weeks after re-starting with OT. She reported wearing bifocal contact lenses most of the time and experiencing comfortable clarity of vision. She denied itching, tearing, burning, redness, floaters, flashes of light, peripheral vision loss, blurred vision, headache, and double vision. However, she did report three categories of symptoms (see Table 6): nausea when transitioning between stationary objects and tracking objects that are moving quickly, slightly slower reading speed but with good accuracy, and mild disequilibrium with rapid eye/head/body movement and when in multiply visually-stimulating environments.

For this initial evaluation, her corrected visual acuities and sensorimotor findings are noted in Table 7 and were obtained with her bifocal contact lenses in place. The results of confrontation visual field, pupillary, and ocular health assessment were unremarkable for each eye without dilation.

At the conclusion of the initial evaluation, the findings were consistent with optometric

Table 6. Neuro-optometric Intervention: Vision Symptoms

Pre-Round 2 OT	Post-Round 2 OT
Nausea when transitioning between stationary objects and following/tracking objects that are moving quickly, which impacts the following negatively: **a) visually focusing when exposed to electronic screens for any longer than 30 minutes consecutively. She has altered her work flow to limit exposure to electronic screens.** **b) reading for longer than 20-30 minutes consecutively** c) focusing on signs over a long period of time while driving which limits her tolerance to prolonged driving activity. This resulted in her limiting the duration of her driving trips	Regarding: **1) eyestrain and nausea for tasks a) and b), moderate symptom reduction was reported relative to pre-round 2 OT** 2) the task duration was reported to be stable for a) through c) before she experiences symptoms
Slightly slower speed of reading, but accuracy is good	**Moderate improvement in speed and accuracy of reading relative to pre-round 2 OT**
Mild disequilibrium with rapid eye/head/body turns and when in multiply visually-stimulating environments (i.e., malls, supermarkets, large stores), accompanied by mild nausea and fatigue	Stable relative to pre-round 2 OT

Table 7. Neuro-optometric Intervention: Vision Signs

Abbreviations: OT=occupational therapy, OD=right eye, OS=left eye, OU=both eyes, DCT=distance cover test, DBI=distance base in, DBO=distance base out, NCT=near cover test, NPC=near point of convergence, cm=centimeters, NBI=near base in, NBO=near base out, EOMs=extraocular motilities, DEM=Developmental Eye Movement test, XP'=exophoria at near, V=vertical time, H=horizontal time, and E=errors.

Data Categories		Pre-Round 2 OT		Post-Round 2 OT	
Corrected distance visual acuities (with bifocal contact lenses: OD set for distance)		OD 20/20 OS 20/30 OU 20/20		OD 20/20 OS 20/25 OU 20/20	
DCT		orthophoria		orthophoria	
DBI	DBO	x/10/4	x/14/10	x/8/4	x/12/6
Corrected near visual acuities (with bifocal contact lenses: OD set for distance)		OD 20/30 OS 20/20 OU 20/20		OD 20/25 OS 20/20 OU 20/20	
NCT	**NPC**	**12-14XP'**	**2.5cm/7.6cm/OD out/ (-) diplopia/ (+) eyestrain/ sluggish reach/ re-grasp/ release**	**8-10XP'**	**5cm/ 10cm/ OD out/ (+) diplopia/ (-) eyestrain/ (+) good reach/ re-grasp/ release**
NBI	NBO	x/18/10	X/16/12	x/20/14	x/14/6
Random Dot Stereopsis		Positive		Positive	
EOMs		Full and comitant OU		Full and comitant OU	
DEM		**V=23sec, H=29sec, E=0 , (+) eyestrain, and (+) difficulty with Test Card C**		**V=23sec, H=25sec, E=0, (-) eyestrain, and (-) difficulty with Test Card C**	

diagnoses of convergence insufficiency, deficits of saccades, dizziness, and bilateral myopia with presbyopia. Convergence insufficiency and deficits of saccades were contributing to her persisting reading symptoms and may have been contributing to her visual-vestibular symptoms, i.e., with regards to her symptomatology 'flares' during eye/head/body movement and in multiply visually-stimulating environments. The initial recommendations included continued use of her current bifocal contact lenses for the bilateral myopia with presbyopia, as well as continued OT for neuro-rehabilitation activities and procedures for convergence insufficiency, deficits of saccades, and dizziness with visual-vestibular symptoms. The vision-related, neuro-rehabilitation activities and procedures were collaboratively agreed upon between OT and neuro-optometry, which provided vergence training paradigms and the associated sequencing of techniques.

Upon undilated re-evaluation with neuro-optometry 2.5 months later, which corresponded to 3 years 3 months after her MVA, she had completed her second round of OT therapy. She reported moderate reduction of eyestrain and nausea with reading on paper, computers, and other electronic devices. She also reported moderate improvement in the speed and accuracy of reading. However, she felt that her fatigue and nausea with visual-vestibular symptoms and focusing on signs while driving for long time periods persisted to a mild degree (see Table 6).

For this re-evaluation, her corrected visual acuities and sensorimotor findings are noted in Table 7 and were obtained with her bifocal contact lenses in place. The results of confrontation visual field, pupillary, and ocular health assessment remained unremarkable for each eye without dilation. While the deficits of saccades were resolved and associated with a normalized Developmental Eye Movement (DEM) test result (complete resolution of symptomatology on testing), she still manifested mild convergence insufficiency with more restricted positive fusional vergence ranges at far and near, albeit with no reported increase in symptoms. However, the patient was less symptomatic (i.e., was not feeling eyestrain, dizziness, furrowing her brow, etc.) during vergence testing at the neuro-optometric re-evaluation and demonstrated noted and significant improvements in dynamic control regarding near point of convergence, as related to reach, re-grasp, and release with no symptoms and resolute tolerance.

At the conclusion of the neuro-optometric re-evaluation, the findings were consistent with resolved deficits of saccades, persisting mild convergence insufficiency, dizziness, and bilateral myopia with presbyopia. The recommendations included continued use of her current bifocal contact lenses for the bilateral myopia with presbyopia, completing OT for neuro-rehabilitation activities and procedures related to vision, and performing a home-based, visual-vestibular habituation regimen for her visual-vestibular symptoms (see Table 8).

Discharge

Upon discharge from OT and OD, patient was working full-time and was tolerating most aspects of her job with minimal to zero difficulty. She was performing home management activities including grocery shopping, cooking, and cleaning/laundry independently without symptoms. She was also in the process of helping her teenage child apply to high school. While completion of the multiple applications was overwhelming, the patient was asymptomatic during task performance. She consistently performed the integrated HEP provided to her by OT and OD and followed up with her physiatrist and neuro-optometrist prior to discharge.

DISCUSSION

Concussion evaluation and management requires an inter-professional team approach. Vision care specialists should work collaboratively to optimize outcomes for this patient population by tailoring individualized and specific care plans. Domain expertise is always critical and allows discipline-specific assessments and interventions to be performed. Neuro-optometry and neuro-ophthalmology provide vision and eye health examinations, as well as prescribes lenses, tints, prisms, and/or optometric vision therapy. Occupational therapy assesses the vision deficits and relative impact on daily living, as well as vocational needs and desires. For visually symptomatic patients, OT provides neuro-rehabilitation activities and procedures customized for the patient, enhancing the potential for increased functional independence at home and possibly at school and/or work. The inter-professional collaboration amongst occupational therapy,

Table 8. Neuro-optometric Therapeutic Addition of Home-based, Visual-vestibular Habituation Post-Round 2 OT

<table>
<tr><th>Description of Technique</th><th>Sequencing of Intervention</th></tr>
<tr><td>Technique 1-Horizontal Fist Passes: Position yourself 6-8 feet from an empty wall and hold your arm out extended and clench your fist. Keeping your head still and your eyes fixed on your fist, move your fist from 40 degrees left of center slowly across your midline to 40 degrees right of center and back once.</td><td rowspan="4"><u>Week 1:</u>
Do 30 seconds of each of Techniques 1 -4.

<u>Week 2:</u>
Do 30 seconds of each of Techniques 1 -4, with two (BLANK) post-it stickies placed on the wall at eye level and separated horizontally by 2 feet

<u>Week 3:</u>
Do 30 seconds of each of Techniques 1 -4, with two post-it stickies placed on the wall at eye level and separated horizontally by 2 feet and two additional post-it stickies placed on the wall at eye level, which are separated vertically by 2 feet.

<u>Week 4:</u>
Do 30 seconds of each of Techniques 1 -4, with two post-it stickies placed on the wall at eye level separated horizontally by 2 feet, two post-it stickies placed on the wall at eye level separated vertically by 2 feet, and two additional post-it stickies placed on the wall at eye level, which are separated obliquely by 2 feet.

<u>Week 5:</u>
Do 30 seconds of each of Techniques 1-4, with two post-it stickies placed on the wall at eye level separated horizontally by 2 feet, two post-it stickies placed on the wall at eye level separated vertically by 2 feet, two post-it stickies placed on the wall at eye level separated obliquely by 2 feet, and two additional post-it stickies placed on the wall at eye level separated obliquely by 2 feet.

<u>Week 6:</u>
While stading, do 45 seconds of each of Techniques 1-4, with 8 post-it stickies placed on the wall at eye level.

<u>Week 7-8:</u>
While standing, do 30 seconds of each of Techniques 1-4, with 8 post-it stickies placed on the wall at eye level.

<u>Week 9-10:</u>
Do 45 seconds of each of Techniques 1-4, with 8 post-it stickies placed on the wall at eye level.

<u>Week 11:</u>
While marching in place, do 30 seconds of each of Techniques 1-4, with 8 post-it stickies placed on the wall at eye level.

<u>Week 12:</u>
While marching in place, do 45 seconds of each of Techniques 1-4, with 8 post-it stickies placed on the wall at eye level.</td></tr>
<tr><td>Technique 2-Slow Horizontal Head Rotations: Position yourself 6-8 feet from an empty wall and hold your arm out extended along the midline of your body and clench your fist. Keeping your fist still and your eyes fixed on your fist, slowly turn your head from 25-30 degrees left of center to 25-30 degrees right of center and back to straight ahead once.</td></tr>
<tr><td>Technique 3-Vertical Fist Passes: Position yourself 6-8 feet from an empty wall and hold your arm out extended and clench your fist. Keeping your head still and your eyes fixed on your fist, move your fist from 30 degrees above center slowly across your midline to 30 degrees below center and back once.</td></tr>
<tr><td>Technique 4-Slow Vertical Head Rotations: Position yourself 6-8 feet from an empty wall and hold your arm out extended along the midline of your body and clench your fist. Keeping your fist still and your eyes fixed on your fist, slowly turn your head from 25-30 degrees above center to 25-30 degrees below center and back to straight ahead once.</td></tr>
</table>

neuro-optometry and neuro-ophthalmology is essential to an inter-professional vision clinic.[22] The ultimate goal, when possible, for all inter-professional providers is for the patient with concussion to return to their pre-concussive or pre-morbid functional state.

The Discipline of OT and Inter-professional Integration on the Neuro-rehabilitation Care Team

Achieving health, well-being, and participation in life through engagement in occupation is the primary statement that describes the domain and process of OT in its fullest.[23] Traditionally, when working with concussion patients, the role of OT has been limited, focusing mainly on symptoms on the physical, cognitive and emotional axes.[24] In addition to the traditionally reported symptoms, individuals who have sustained a concussion often experience changes in their vision, which significantly impact overall function, specifically ADLs, resulting in QOL 'impact'. OT provides integral aspects of a tailored and optimized functional recovery plan to bridge the gap between remediation and the return to functional independence.

For individuals with concussion, OTs perform a comprehensive evaluation, during which, among other sensorimotor skills, ocular motor and other visual performance skills are screened. OTs develop core aspects to the care plan and aid the treatment team in their ability to employ therapeutic approaches that link specific visual performance deficits to challenging functional activities. Progressive treatment plans are tailored to the individual on a patient-by-patient basis and center on assessments and evaluative platforms for all instrumental activities of daily life. Since visual skills rely on many underlying body structures, OT treats broad aspects of sensorimotor function. OT-related interventions involve compensatory and restorative approaches that are multimodal and patient-specific, often answering occupational-based performance needs. In addition, OTs provide patients with comprehensive education about managing symptoms and modifying ADLs in a graded fashion to monitor step-by-step progress and, ultimately, expedite achieving the patient's self-selected goals.

Ocular motor skills, including smooth pursuits, saccades and visual fixation, are assessed both through observation, a functional vision screen, and through the use of standardized assessments, such as the Developmental Eye Movement Test (DEM)[25] and the King-Devick (KD) Test.[26] In order to determine a baseline of visual complaints, the Convergence Insufficiency Symptom Survey (CISS) is used prior to completing any screening. The CISS is a validated 15-point questionnaire that was originally developed to assess changes in visual symptoms following convergence insufficiency treatment. Recently this tool has been used and studied in broader applications as a screening tool to detect visual dysfunction in patients who have suffered from a concussion.[27] The functional vision screen includes assessment of near and far acuity, assessment of the quality of both pursuit and saccadic eye movement, along with gross assessment of eye alignment, depth perception and vergence. The CISS, along with the functional screen, enables OT to link detected visual deficits to functional limitations that patients are noting in their daily ADLs, home management and work routine. Often deficits are noted and a referral to neuro-optometry will occur, as with our patient described in this case report, resulting in a collaborative care team.

Patients with a concussion very often report a functional difficulty with reading; this may manifest as a focusing difficulty, as well as increased eyestrain, headache and fatigue.[28] Difficulty with reading can easily be observed with occupational performance challenges through many functional activities including: driving, use of digital devices, such as computers and/or smart phones, and performing other home management and employment-related activities. Additionally, individuals may experience impairments in executive function, attention and memory, which can be associated with compromised saccadic function,[29] affecting performance in all types of occupations, basic and instrumental ADLs, rest/sleep, education, and leisure activities. OT is a unique profession, focusing on the complex and dynamic interaction among client factors, performance skills, performance patterns and contexts, and global environments.

The Discipline of Neuro-Optometry and Integration with the Inter-professional Neuro-rehabilitation Care Team

For concussion, as with any other health condition, accurate diagnoses, including for vision function, drive effective management. Vision diagnoses following concussion, from a structure to function approach, are typically determined by optometry (or neuro-optometry), ophthalmology, and/or neuro-ophthalmology.

In terms of optometry, neuro-optometry provides a comprehensive assessment of ocular motor, accommodative, visuomotor, binocular, vestibular, visual-perceptual information processing, and specific ocular sequelae of acquired brain injury (ABI), which encompasses concussion. Neuro-optometrists employ standard optometric modalities such as prescribing corrective lenses, prisms, tints, coatings, varying degrees of occlusion, and optometric visual therapy to manage visually symptomatic patients with neurological compromise.

Within a rehabilitation medicine setting, neuro-optometrists may collaborate with other members of the inter-professional neuro-rehabilitation care team, including physiatry, neurology, sports medicine, occupational therapy, physical therapy, speech and language therapy, as well as cognitive therapy. When concussed patients present with frequent blurred vision, diplopia, reading difficulties, visual-vestibular symptoms, photophobia, and visual information processing deficits, neuro-optometry is often involved for evaluation and management. Neuro-optometry prescribes lenses, prisms, and tints to reduce blurred vision, diplopia, photophobia, and visual motion sensitivity. Consequently, prescription of lenses, prisms, and tints may also favorably impact QOL by improving a patient's visual function for performance in other rehabilitation regimens. Suggestions and recommendations for other therapists regarding vision limitations and therapeutic technique sequencing are means by which neuro-optometry collaborates with members of the inter-professional neuro-rehabilitation healthcare team.

Interaction Between OD and OT

At our center, neuro-rehabilitation activities and procedures provided by OT address vision conditions using techniques without lenses, tints, or prisms. Optometric vision therapy addresses vision conditions with techniques that can incorporate lenses, tints, and prism. While both disciplines link treatment techniques to basic activities of daily living, OT is more oriented to tailoring techniques to a given patient's instrumental activities of daily living, as well as school-related, avocation-related, and/or work-related activities. Having both OD and OT onsite at our center provides greater and simpler communication amongst the patient, OD, and OT.

To facilitate social intercourse, our center holds formal clinical rounds on a monthly basis to review active or upcoming neuro-rehabilitation cases involving visually symptomatic patients. In addition, individual OTs and the onsite OD communicate frequently about on-going cases, as care is delivered, which is what occurred during the second round of OT with this particular patient. This interplay expedites dynamic adjustments in management plans, maximizing outcomes and demonstrating an appreciation for efficient care administration.

Obstacles in this Case

This case illustrates that, while referring to neuro-optometry, as well as OT, benefits visually symptomatic patients with concussion, external pressures on patients, as well as the accessibility and availability of neuro-optometry, may impact the course of patient care.

For the patient's first round of therapy, she was provided with the contact information for an external facility for neuro-optometry. At that point in her recovery, she was amenable to reducing her work hours to a part-time schedule with workplace modifications and the flexibility to work from home, both of which permitted her to employ compensatory strategies to minimize her symptoms. Since she was feeling more comfortable in a modified work environment, she was not able to perceive and identify persisting symptoms, which may have led to her non-compliance in consulting with another professional and subsequently ramping up her workload in a precipitous fashion.

For her second round of therapy, she was acutely aware of her vision symptoms since she was working full-time and without workplace modifications, the ability to work from home, and recent practice or exposure to her home exercise regimen or clinical recommendations. The intense, full-time work environment with its increased responsibilities and inability to employ her compensatory strategies resulted in a flare-up of her symptomatology, which she could not ignore. Hence, when physiatry referred her to neuro-optometry, as well as OT for treatment with neuro-rehabilitation activities and procedures related to vision, she complied.

While accessibility was not an issue since neuro-optometry was onsite at our center, the availability of neuro-optometry became a limiting factor when scheduling patients since OD was only assigned one day of outpatient care weekly at our center at that time. However, since OT and OD were both at the same location, OT easily communicated with neuro-optometry regarding the case right after the evaluation to develop a collaborative treatment approach to address the patient's needs.

Another concern is the absence of active in-office neuro-optometric rehabilitation therapy (NORT). NORT would most likely have benefited this patient, and potentially all concussion patients at our center, for at least a portion of the overall rehabilitation regimen. However, when this patient was in her first round of therapy, she did not make an appointment with an external neuro-optometrist. When she was in her second round of therapy, neuro-optometry was only onsite one day weekly for outpatient care, which precluded the possibility of the OD providing NORT in her case due to the initial demand of even intake evaluations, let alone therapeutic follow-up.

Moving Towards Seamless Synergy Between OD and OT

OD and OT operate together at our center, which is a large multi-disciplinary rehabilitation teaching hospital that provides both inpatient and outpatient care. In fact, upon hiring neuro-optometry at our center, our inpatient acquired brain injury (ABI) service immediately integrated neuro-optometry evaluations. These evaluations are scheduled following the initial OT evaluation for visually symptomatic patients, enabling the completion of a formal OT-driven screening. When warranted, a neuro-optometric evaluation is performed yielding applicable diagnoses, the provision of lenses/prisms (fusional or yoked), when needed, and comprehensive treatment recommendations for OT. Following this consultation, a clinical dialogue is established with frequent interaction between OD and OT, during which care team members discuss case-pertinent advances and setbacks. This sequenced scheduling approach improves workflows, as well as associated care administration efficiency. From a clinical perspective, this is an additional step towards solving the puzzle of seamless handoffs and synergistic OD-OT management of visually symptomatic individuals with concussion.

Having recognized the benefit of neuro-optometry for the provision of formal vision diagnoses, evaluative intervention with lenses/prisms/tints, as well as guidance for OT and vestibular rehabilitation, our center increased neuro-optometric outpatient care from one day to two and half days weekly. In addition, geographic proximity and accessibility furthers the dialogue between our occupational therapy treatment team and OD, improving communication efficiency and most importantly care outcomes.

CONCLUSIONS

The Art of the Seamless Handoff

As previously described, once a concussion is acutely managed, the disposition, along with education, is paramount to successful outcomes. Lackluster compliance and/or complex pathology may lead to post-concussion symptomatology that poses long-term challenges.[18] For individuals that experience a prolonged recovery following concussion, multi-faceted rehabilitation services are often critical.[31-35] While the integration of a vision specialist, such as a neuro-optometrist or neuro-ophthalmologist, in the rehabilitation model is an integral component of optimal assessment and therapeutic remediation,[21] seamless inter-professional collaboration and communication between occupational therapy and neuro-optometry towards evaluating and managing vision symptoms following concussion is also key.

In an inter-professional setting, the ultimate goal is to create synergy between disciplines, maximizing core skill sets. Recognizing the potential impact of a visual dysfunction, integrating a vision specialist at the 'front-end' of the care timeline, and managing the seamless interplay of clinicians, including vision specialists such as OT and OD, are key components of the neuro-rehabilitative care plan, which often become indispensable in successful concussion management.[21] 'Handoffs' between professionals in an inter-disciplinary setting become seamless when the requisite evaluations and interventions are scheduled in a timely and appropriately sequenced manner. In addition, having OD accessible to the neuro-rehabilitation team, inclusive of OT, facilitates care cooperation. As briefly delineated in this case report, a collaborative OD-OT approach to evaluating and managing visually symptomatic patients with concussion avoids recrudescence and ensures a favorable and resolute recovery.

Acknowledgements

The authors acknowledge and thank the Department Chair of NYU-School of Medicine's RUSK Rehabilitation, Steven Flanagan, MD, as well as RUSK Rehabilitation's Director of Brain Injury Medicine, Brian S. Im, MD, for their continued leadership and support of RUSK Rehabilitation's inter-professional approach to vision rehabilitation.

REFERENCES

1. Carney N, Ghajar J, Jagoda A, Bedrick S, Davis-O'Reilly C, du Coudray H, et al. Concussion guidelines step 1: systematic review of prevalent indicators. Neurosurgery. 2014;75 Suppl 1:S3-15. Epub 2014/07/10. doi: 10.1227/neu.0000000000000433. PubMed PMID: 25006974. https://goo.gl/u3CohU
2. McCrory P, Meeuwisse W, Aubry M, Cantu B, Dvorak J, Echemendia R, et al. Consensus statement on Concussion in Sport--the 4th International Conference on Concussion in Sport held in Zurich, November 2012. J Sci Med Sport. 2013;16(3):178-89. Epub 2013/04/02. doi: 10.1016/j.jsams.2013.02.009. PubMed PMID: 23541595. https://goo.gl/h1m67Y
3. Broglio SP, Cantu RC, Gioia GA, Guskiewicz KM, Kutcher J, Palm M, et al. National Athletic Trainers' Association position statement: management of sport concussion. J Athl Train. 2014;49(2):245-65. Epub 2014/03/08. doi: 10.4085/1062-6050-49.1.07. PubMed PMID: 24601910; PubMed Central PMCID: PMCPMC3975780. https://goo.gl/7GR1YQ
4. Giza CC, Hovda DA. The new neurometabolic cascade of concussion. Neurosurgery. 2014;75 Suppl 4:S24-33. Epub 2014/09/19. doi: 10.1227/neu.0000000000000505. PubMed PMID: 25232881; PubMed Central PMCID: PMCPMC4479139. https://goo.gl/6yYFsd
5. Vagnozzi R, Signoretti S, Cristofori L, Alessandrini F, Floris R, Isgro E, et al. Assessment of metabolic brain damage and recovery following mild traumatic brain injury: a multicentre, proton magnetic resonance spectroscopic study in concussed patients. Brain. 2010;133(11):3232-42. Epub 2010/08/26. doi: 10.1093/brain/awq200. PubMed PMID: 20736189. https://goo.gl/RPjPge
6. Johnson VE, Stewart W, Smith DH. Axonal pathology in traumatic brain injury. Exp Neurol. 2013;246:35-43. Epub 2012/01/31. doi: 10.1016/j.expneurol.2012.01.013. PubMed PMID: 22285252; PubMed Central PMCID: PMCPMC3979341. https://goo.gl/nkcbxb
7. Pettus EH, Povlishock JT. Characterization of a distinct set of intra-axonal ultrastructural changes associated with traumatically induced alteration in axolemmal permeability. Brain Res. 1996;722(1-2):1-11. Epub 1996/05/25. PubMed PMID: 8813344. https://goo.gl/LMq3Qv
8. Tang-Schomer MD, Johnson VE, Baas PW, Stewart W, Smith DH. Partial interruption of axonal transport due to microtubule breakage accounts for the formation of periodic varicosities after traumatic axonal injury. Exp Neurol. 2012;233(1):364-72. Epub 2011/11/15. doi: 10.1016/j.expneurol.2011.10.030. PubMed PMID: 22079153; PubMed Central PMCID: PMCPMC3979336. https://goo.gl/PLZUxL

9. Langlois JA, Rutland-Brown W, Wald MM. The epidemiology and impact of traumatic brain injury: a brief overview. J Head Trauma Rehabil. 2006;21(5):375-8. Epub 2006/09/20. PubMed PMID: 16983222. https://goo.gl/7GirbF

10. Gessel LM, Fields SK, Collins CL, Dick RW, Comstock RD. Concussions among United States high school and collegiate athletes. J Athl Train. 2007;42(4):495-503. Epub 2008/01/05. PubMed PMID: 18174937; PubMed Central PMCID: PMCPMC2140075. https://goo.gl/GfUH6h

11. Torres DM, Galetta KM, Phillips HW, Dziemianowicz EM, Wilson JA, Dorman ES, et al. Sports-related concussion: Anonymous survey of a collegiate cohort. Neurology Clinical Practice. 2013;3(4):279-87. doi: 10.1212/CPJ.0b013e3182a1ba22. PubMed PMID: 24195017; PubMed Central PMCID: PMC3787116. https://goo.gl/quwa98

12. Cantu RC. Recurrent athletic head injury: risks and when to retire. Clinics in Sports Medicine. 2003;22(3):593-603, x. Epub 2003/07/11. PubMed PMID: 12852688. https://goo.gl/tZ9p6s

13. Barkhoudarian G, Hovda DA, Giza CC. The molecular pathophysiology of concussive brain injury. Clinics in Sports Medicine. 2011;30(1):33-48, vii-iii. Epub 2010/11/16. doi: 10.1016/j.csm.2010.09.001. PubMed PMID: 21074080. https://goo.gl/Cexv9J

14. Galetta KM, Brandes LE, Maki K, Dziemianowicz MS, Laudano E, Allen M, et al. The King-Devick test and sports-related concussion: study of a rapid visual screening tool in a collegiate cohort. J Neurol Sci. 2011;309(1-2):34-9. Epub 2011/08/19. doi: 10.1016/j.jns.2011.07.039. PubMed PMID: 21849171. https://goo.gl/6Jajx3

15. Galetta MS, Galetta KM, McCrossin J, Wilson JA, Moster S, Galetta SL, et al. Saccades and memory: baseline associations of the King-Devick and SCAT2 SAC tests in professional ice hockey players. J Neurol Sci. 2013;328(1-2):28-31. Epub 2013/03/19. doi: 10.1016/j.jns.2013.02.008. PubMed PMID: 23499425. https://goo.gl/AgSrTD

16. Galetta KM, Morganroth J, Moehringer N, Mueller B, Hasanaj L, Webb N, et al. Adding Vision to Concussion Testing: A Prospective Study of Sideline Testing in Youth and Collegiate Athletes. J Neuroophthalmol. 2015. Epub 2015/03/06. doi: 10.1097/WNO.0000000000000226. PubMed PMID: 25742059. https://goo.gl/F6qXQP

17. Galetta KM, Liu M, Leong DF, Ventura RE, Galetta SL, Balcer LJ. The King-Devick test of rapid number naming for concussion detection: meta- analysis and systematic review of the literature. Concussion. 2015;15(8):1-15.

18. Novak Z, Aglipay M, Barrowman N, Yeates KO, Beauchamp MH, Gravel J, et al. Association of Persistent Postconcussion Symptoms With Pediatric Quality of Life. JAMA Pediatrics. 2016;170(12):e162900. Epub 2016/10/25. doi: 10.1001/jamapediatrics.2016.2900. PubMed PMID: 27775762. https://goo.gl/4UCsBt

19. Sawyer Q, Vesci B, McLeod TC. Physical Activity and Intermittent Postconcussion Symptoms After a Period of Symptom-Limited Physical and Cognitive Rest. J Athl Train. 2016;51(9):739-42. Epub 2016/11/05. doi: 10.4085/1062-6050-51.12.01. PubMed PMID: 27813685; PubMed Central PMCID: PMCPMC5139792. https://goo.gl/h9BGij

20. Schneider KJ, Leddy JJ, Guskiewicz KM, Seifert T, McCrea M, Silverberg ND, et al. Rest and treatment/rehabilitation following sport-related concussion: a systematic review. Br J Sports Med. 2017. Epub 2017/03/28. doi: 10.1136/bjsports-2016-097475. PubMed PMID: 28341726. https://goo.gl/QtcdsW

21. Roberts PS, Rizzo JR, Hreha K, Wertheimer J, Kaldenberg J, Hironaka D, et al. A conceptual model for vision rehabilitation. J Rehabil Res Dev. 2016;53(6):693-704. Epub 2016/12/21. doi: 10.1682/jrrd.2015.06.0113. PubMed PMID: 27997671; PubMed Central PMCID: PMCPMC5444332. https://goo.gl/CdsKtR

22. Ripley DL, Politzer T, Berryman A, Rasavage K, Weintraub A. The vision clinic: an interdisciplinary method for assessment and treatment of visual problems after traumatic brain injury. NeuroRehabilitation. 2010;27(3):231-5. Epub 2010/11/26. doi: 10.3233/nre-2010-0602. PubMed PMID: 21098991. https://goo.gl/1jqA8u

23. Announcing the Third Edition of the Occupational Therapy Practice Framework: Domain and Process. American Journal of Occupational Therapy. 2014;68(2):139-. doi: 10.5014/ajot.2014.682005.

24. Vargo MM, Vargo KG, Gunzler D, Fox KW. Interdisciplinary Rehabilitation Referrals in a Concussion Clinic Cohort: An Exploratory Analysis. Pm R. 2016;8(3):241-8. Epub 2015/08/01. doi: 10.1016/j.pmrj.2015.07.006. PubMed PMID: 26226207. https://goo.gl/Hhw57D

25. Garzia RP, Richman JE, Nicholson SB, Gaines CS. A new visual-verbal saccade test: the development eye movement test (DEM). J Am Optom Assoc. 1990;61(2):124-35. Epub 1990/02/01. PubMed PMID: 2313029. https://goo.gl/mTXUio

26. King AT, Devick S. The proposed King-Devick Test and its relation to the Pierce Saccade Test and reading levels. Chicago, Illinois Illinois College 1976.

27. Gallaway M, Scheiman M, and Mitchell GL. Vision therapy for post-concussion vision disorders. Optom Vis Sci 2017; 94(1): 68-73. doi: 10.1097/OPX.0000000000000935. PMID: 27505624. https://goo.gl/V7eyrP

28. Finn C, Waskiewicz M. The role of occupational therapy in managing post-concussion syndrome. Physical Disabilities Special Interest Section Quarterly. 2015, March;38(1):1-4.

29. Kraus MF, Little DM, Donnell AJ, Reilly JL, Simonian N, Sweeney JA. Oculomotor function in chronic traumatic brain injury. Cogn Behav Neurol. 2007;20(3):170-8. Epub 2007/09/12. doi: 10.1097/WNN.0b013e318142badb. PubMed PMID: 17846516. https://goo.gl/TjkymH

30. Heitger MH, Jones RD, Macleod AD, Snell DL, Frampton CM, Anderson TJ. Impaired eye movements in post-concussion syndrome indicate suboptimal brain function beyond the influence of depression, malingering or intellectual ability. Brain. 2009;132(Pt 10):2850-70. Epub 2009/07/21. doi: 10.1093/brain/awp181. PubMed PMID: 19617197. https://goo.gl/kovyna

31. Schneider KJ, Iverson GL, Emery CA, McCrory P, Herring SA, Meeuwisse WH. The effects of rest and treatment following sport-related concussion: a systematic review of the literature. Br J Sports Med. 2013;47(5):304-7. Epub 2013/03/13. doi: 10.1136/bjsports-2013-092190. PubMed PMID: 23479489. https://goo.gl/1Xvrkq

32. Grabowski P, Wilson J, Walker A, Enz D, Wang S. Multimodal impairment-based physical therapy for the treatment of patients with post-concussion syndrome: A retrospective analysis on safety and feasibility. Physical Therapy in Sport: official journal of the Association of Chartered Physiotherapists in Sports Medicine. 2017;23:22-30. Epub 2016/09/26. doi: 10.1016/j.ptsp.2016.06.001. PubMed PMID: 27665247. https://goo.gl/niSt1V

33. Hugentobler JA, Vegh M, Janiszewski B, Quatman-Yates C. Physical Therapy Intervention Strategies for Patients with prolonged Mild Traumatic Brain Injury Symptoms: A Case Series. International Journal of Sports Physical Therapy. 2015;10(5):676-89. Epub 2015/10/23. PubMed PMID: 26491618; PubMed Central PMCID: PMCPMC4595921. https://goo.gl/EsyAor

34. Murray DA, Meldrum D, Lennon O. Can vestibular rehabilitation exercises help patients with concussion? A systematic review of efficacy, prescription and progression patterns. Br J Sports Med. 2017;51(5):442-51. Epub 2016/09/23. doi: 10.1136/bjsports-2016-096081. PubMed PMID: 27655831. https://goo.gl/X138V2

35. Smith-Forbes EV, Quick CD, Brown KM. Roles of Occupational Therapists in Theater, Past and Present. US Army Medical Department Journal. 2016(2-16):66-70. Epub 2016/05/25. PubMed PMID: 27215870. https://goo.gl/Jo9nhQ

CORRESPONDING AUTHOR BIOGRAPHY: John-Ross Rizzo, MD, MSCI

Dr. Rizzo is a physician-scientist at NYU Langone Medical Center's Rusk Rehabilitation, where he is an Assistant Professor of Physical Medicine and Rehabilitation with a cross-appointment in the Department of Neurology and the Department of Mechanical and Aerospace Engineering (NYU-Tandon School of Engineering). He leads the Visuomotor Integration Laboratory (VMIL), where his team focuses on eye-hand coordination, as it relates to acquired brain injury (ABI), and the Technology Translation in Medicine Laboratory (TTML), where his team focuses on assistive technology for the visually impaired and benefits from his own personal experiences with vision loss.