



Vision and Concussion: Symptoms, Signs, Evaluation, and Treatment

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Visual symptoms are common after concussion in children and adolescents, making it essential for clinicians to understand how to screen, identify, and initiate clinical management of visual symptoms in pediatric patients after this common childhood injury. Although most children and adolescents with visual symptoms after concussion will recover on their own by 4 weeks, for a subset who do not have spontaneous recovery, referral to a specialist with experience in comprehensive concussion management (eg, sports medicine, neurology, neuropsychology, physiatry, ophthalmology, otorhinolaryngology) for additional assessment and treatment may be necessary. A vision-specific history and a thorough visual system examination are warranted, including an assessment of visual acuity, ocular alignment in all positions of gaze, smooth pursuit (visual tracking of a moving object), saccades (visual fixation shifting between stationary targets), vestibulo-ocular reflex (maintaining image focus during movement), near point of convergence (focusing with both eyes at near and accommodation (focusing with one eye at near because any of these functions may be disturbed after concussion. These deficits may contribute to difficulty with returning to both play and the learning setting at school, making the identification of these problems early after injury important for the clinician to provide relevant learning accommodations, such as larger font, preprinted notes, and temporary use of audio books. Early identification and appropriate management of visual symptoms, such as convergence insufficiency or accommodative insufficiency, may mitigate the negative effects of concussion on children and adolescents and their quality of life.

abstract

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BACKGROUND

Concussion is a common injury in childhood, affecting an estimated 1.4 million children and adolescents annually in the United States¹ and occurring most often in sports and recreational settings.² Pediatricians will encounter concussions in their clinical practice, and their offices represent an important and frequent point of entry into the health care system for children and adolescents with concussion.³ As such, pediatricians play an important role in the initial diagnosis and management of concussion. The Clinical Report on Sport-related Concussion in Children and Adolescents by the American Academy of Pediatrics (AAP) and the Centers for Disease Control and Prevention Guideline on the Diagnosis and Management of Mild Traumatic Brain Injury Among Children comprehensively summarize the general approach to pediatric concussion.^{4,5} Neurologic pathways associated with the visual system, including oculomotor and vestibular function, are widely distributed throughout the brain and appear to be sensitive to even subconcussive head impacts. It is, therefore, not surprising that the diffuse shear injury associated with concussion often produces broad dysfunction throughout the afferent and efferent visual systems.⁵⁻¹⁰ Although concussion symptoms generally spontaneously resolve over the course of 4 weeks after injury in children and adolescents, up to one-third may have prolonged symptoms.^{11,12} Vision disorders are prevalent in children and adolescents with prolonged symptoms after concussion, with one study from a tertiary referral center reporting that 69% of children and adolescents with a concussion had at least one associated vision disorder⁷ and another study finding that 62.5% of those with persisting symptoms had

vestibulo-ocular dysfunction.¹³ These disorders include accommodative insufficiency (AI), convergence insufficiency (CI), dysfunction of saccadic and pursuit eye movements, or a combination of these diagnoses.^{7,10,13,14} Symptoms associated with these vision disorders include difficulty reading, blurred vision, difficulty focusing, and eye fatigue. It is not clear whether these observed deficits result from direct injury to the efferent visual system or are more broadly related to the global dysfunction that patients with concussion experience. Nonetheless, the presence of visual symptoms predicts delayed recovery from concussion in children and adolescents¹⁰ and may also be associated with a delay in a child's return to school and recreational activities, as well as return to driving for adolescents.¹⁵⁻¹⁸ Clinicians can learn how to recognize associated vision disorders in patients with concussion and understand how to screen, recommend appropriate school-based accommodations immediately after the injury and throughout recovery, and refer for additional management when necessary. This policy statement will aid clinicians in their approach to the screening and diagnosis of visual conditions after concussion and improve their understanding of the impact that vision disorders often have on a child's functioning and quality of life after a concussion.

DIAGNOSIS

Vision-Related Concussion History

Visual complaints are among the myriad symptoms that patients report after concussion.^{8,19} Blurred vision, light sensitivity, and double vision have been reported to occur in up to 40% of children and adolescents immediately after concussion.^{10,11} Additional

symptoms may include complaints of losing one's place or ocular fatigue while reading. Another consideration is that children are frequently unable to recognize or articulate specific visual complaints; thus, clinicians may need to have an appropriately elevated index of suspicion to identify vision-specific issues.

Vision-Related Physical Examination

A detailed vision history and thorough evaluation of the visual system is important in the assessment of concussion. Although patients with vision deficits may ultimately require referral to a specialist familiar with the diagnosis and management of concussion, it is important for the primary care provider to identify these vision deficits through a detailed vision history and office assessment. Certain visual and vestibular deficits are associated with concussion and may be detected with targeted screening, with attention to smooth pursuit, saccades, vestibulo-ocular reflex (VOR), near point of convergence, and accommodation (Table 1). The AAP clinical report on sport-related concussion provides a review of approaches to evaluate balance and the vestibular system.⁴ A complete assessment of the visual system after concussion includes visual acuity, pupillary function, confrontation visual fields, and testing of ocular alignment, eye movements, accommodation, and binocular vision. The visual system may be evaluated by using examination techniques that assess smooth pursuit, saccades, VOR, near point of convergence, and accommodation, making sure that appropriate accommodative targets are used for testing.^{7-10,13,14} The accompanying clinical report²⁰ provides a detailed description of the evaluation of the visual system after suspected concussion. Specific components of this extended vision assessment have demonstrated

TABLE 1 Visio-vestibular Examination After a Suspected Concussion

Test	Description
Pursuit eye movements	Pursuit is examined by holding a near visual stimulus at 1–2 feet from the patient. Move the stimulus back and forth in a slow and steady fashion, horizontally about 160 degrees (from patient's ear to ear) and vertically about 120 degrees (from patient's forehead to chin). Both eyes should follow the stimulus symmetrically and smoothly.
Saccadic eye movements	Saccades are tested with 2 near stimuli as above, 1 in each hand. Hold them about 2 feet apart, 1–2 feet in front of the patient, horizontally then vertically. Ask the patient to refixate between the 2 stimuli on your command several times horizontally then vertically. The eyes should move quickly and symmetrically and end accurately on the stimulus.
VOR	VOR is examined while holding the stimulus at 1–2 feet directly in front of the nose. The patient rotates his or her head horizontally for about 160 degrees (shaking head from side to side) and then vertically for about 120 degrees (nodding head up and down). The eyes should remain on the near stimulus throughout the head movement.
Near point of convergence	Convergence testing is accomplished by holding a visual stimulus about 2 feet in front of the patient and bringing the stimulus toward the face until the eyes stop converging. The eyes should continue to converge on the stimulus until about 6 cm (~2 in.) from the forehead.
Accommodative amplitude	Accommodation testing is performed monocularly using a standard reading card. After patching one eye, ask the patient to fixate on the smallest readable letter at about 2 feet away, move the card toward the eye until the patient reports blurring of that same letter; then measure that distance in centimeters. Most children will be able to see the letter clearly until 10 cm (~4 in.) from the eye.
Strabismus	While the patient fixates on a distant target, the monocular cover-uncover test is performed by covering and uncovering each eye (right eye, then left eye), with the examiner watching carefully for any movement in the opposite, noncovered eye; such movement indicates the possible presence of strabismus.

Refer to Master et al²⁰ for a more in-depth discussion.

feasibility in the general pediatric primary care and emergency department settings and may be used in a screening examination,^{21,22} which is described in more depth in Table 1 and the accompanying video (<https://youtu.be/Uy8V5MGX8Ag>). This screening examination may be performed by general pediatricians, representing an extended evaluation for concussion that may also occur over multiple follow-up visits, thus necessitating commensurate adjustment in payment. In the organized sports setting, a sideline evaluation after suspected concussion may include the King-Devick test, a rapid number-naming test in which the total time needed to read 3 test cards and the number of errors committed while reading the cards are recorded. Preinjury testing to obtain an individual's baseline test time and error rate is recommended for comparison with postinjury testing.²³ Another promising tool for use after concussion, particularly in children, is the Mobile Universal Lexicon Evaluation System (MULES), a rapid picture-naming test that comprises a series of 54 color

photographs.²⁴ It is likely that these tests assess global dysfunction and may not necessarily be specific to the visual system alone.

CONCUSSION-RELATED VISION DISORDERS

Multiple vision disorders may occur after concussion,^{7,10,13,14,25–29} including injury to the binocular vergence system. Convergence is the inward turning of both eyes to maintain fusion on a near target. Convergence insufficiency (CI) is the reduced ability to converge and is one of the most common visual dysfunctions seen acutely after concussion, often persisting in patients with prolonged symptoms.^{7,14,25–27} CI may produce problems with reading, such as diplopia and asthenopia (eye strain), skipping words or losing one's place, and becoming more easily fatigued while reading or having disinterest in reading.

Accommodation is the ability of the eye to change focus from a distant to a near target and contributes to binocular visual function. Accommodative insufficiency (AI)

may also develop after concussion, producing blur with near tasks, as well as headaches, fatigue, and a loss of interest in reading. The rate of accommodative insufficiency after concussion is reported to be as high as 50% in a subspecialty referral concussion population.⁷ Accommodation, convergence, and pupillary miosis are intrinsically linked within brainstem reflexes, forming the near triad that consists of accommodation, convergence, and miosis. It is, therefore, not surprising that AI may be seen in conjunction with CI.³⁰ These deficits in accommodation and convergence, which often resolve with time, are milder forms of similar abnormalities associated with other types of brain injury, suggesting a common mechanism in controlling the near triad.^{31,32} Eye movement dysfunction involving saccades and smooth pursuit may also be observed after concussion.^{7,14,22,23} Saccades represent rapid refixation eye movements from one target to another. Both vertical and horizontal saccades are important in most visual tasks, including reading and

TABLE 2 Strategies to Address Concussion-Related Vision Disorders

Strategies	
Initial symptom management with task modification after concussion	Reduce time spent on visual work and reading, use of reprinted notes, audiobooks, temporary use of reading glasses, guided reading strips, limiting time on electronic screens, visual pacing (taking breaks as needed from visual work to manage symptoms), enlarged font or double spacing or blocking out sections, adjusting brightness on electronic devices, gradual return to full visual workload over course of recovery
Comprehensive multidisciplinary management of concussion	Referral to appropriate specialist (eg, sports medicine, physiatry, neurology, neuropsychology, ophthalmology, otorhinolaryngology) with expertise in comprehensive management of concussion, including active management

athletics. Generated from the frontal eye fields, saccades are found to be abnormal after concussion in as many as 25% to 33% of children and adolescents.^{7,14,28,29} Smooth pursuit eye movements are neurally complex and represent conjugate, steady, symmetric eye movements when following a target, requiring attention, anticipation, and working memory. In studies in children and adolescents with concussion, 33% to 66% had symptom provocation with smooth pursuit.^{10,14} The precise mechanism by which these disturbances occur is unknown but is likely a complex interaction between brainstem vestibulo-oculomotor pathways and cortical neurocognitive pathways that control both attention and the oculomotor system.

STRATEGIES TO ADDRESS CONCUSSION-RELATED VISION DISORDERS

Reintegration of children and adolescents into the academic setting requires addressing their vision deficits and potential impact on school activities.³³⁻³⁵ In general, treatment of the visual complications of concussion can be divided into 2 categories: symptom management with task modification and referral to specialists for targeted treatment of the observed oculomotor abnormalities.^{36,37} A summary of strategies to manage concussion-

related vision disorders is provided in Table 2. In the management of concussion, school accommodations that account for visual disturbances may be provided during the recovery period and can be incorporated into return-to-learn plans as described in the AAP clinical report on returning to learning after concussion.¹⁵

Decreasing external environmental stressors, such as bright lights or use of electronic screens, and length of visual tasks plays an important role in managing vision symptoms after concussion.^{15-17,33-35} For primary care providers, it is important to recommend these accommodations early during school re-entry after a concussion. Previous studies have documented that vision deficits like CI and AI are common in children and adolescents with visual symptoms and may play a part in return-to-school planning.³³⁻³⁵ The AAP and the Centers for Disease Control and Prevention advise returning to school with some task modifications based on symptoms to decrease visual demands.^{4,5} These modifications may be accomplished by reducing the time spent performing visual work as well as making changes to the student's physical environment. CI and AI may be associated with poor attention to task because of diffuse cortical dysfunction and will often resolve with time but, nevertheless, can be addressed and treated.

Patients who have blurred vision when reading, especially when associated with accommodative and convergence insufficiencies, can be treated with prescription base-in prism glasses to correct the strabismus and refractive correction to provide accommodation. Visual tasks in the classroom include reading, adjusting visual focus at near and then at a distance to copy notes from a board or screen, and using electronic screens. Modifications include rearranging presented material, such as double spacing or blocking out sections, to decrease overall visual demands. If reading remains difficult despite these accommodations, audiobooks or text-to-speech software programs may be necessary short-term options.³³⁻³⁵ For students who have difficulty taking notes, possible solutions include obtaining preprinted teacher's notes before class, photocopying a classmate's notes after class, or recording lectures.³³⁻³⁵

In general, emerging evidence indicates that early referral after injury to sports medicine specialty care improves outcomes, possibly because of more active management, including exercise, rather than simply passive supportive care. In a recent study, children and adolescents referred for sports medicine specialty care within 7 days recovered more quickly than those who were seen later than 7 days after injury; the challenge remains in identifying which pediatric patients with concussion warrant early referral.³⁸ Another study found that girls had higher rates of vestibular and visual dysfunction after concussion with longer recovery times, but if referred early for sports medicine specialty care within 7 days of injury, they had similar recovery times as boys, indicating that early referral to sports medicine specialty care, a modifiable extrinsic factor, improves outcomes for girls.³⁹ Up to one-third of children

and adolescents with concussion¹² may have persisting visual symptoms for several weeks or months,^{7-10,13,14} and these may contribute to prolonged academic difficulties and should be accounted for in the clinical management of pediatric concussion.^{11-17,33-35} For these patients with persistent issues, timely referral to multispecialty concussion care can be helpful but may be limited depending on geographic location and availability of relevant subspecialists. In the future, the further development of telemedicine may enable pediatrician support in regions lacking specialty expertise in pediatric concussion. There is emerging evidence from 2 randomized controlled trials that active rehabilitation for balance and vestibulo-oculomotor issues, as well as exercise intolerance associated with concussion, are beneficial for symptomatic patients, but additional studies are needed to determine optimal timing and best practice.^{36,37,40} Similarly, although vision therapy has been widely promoted for the treatment of concussion, a thorough assessment of this practice does not provide sufficient evidence for the efficacy of such therapy.⁴¹ Additional research in all these areas of concussion treatment is warranted.

CHILDREN AND YOUTH WITH SPECIAL HEALTH CARE NEEDS

Children and youth with special health care needs may have specific pre-existing conditions that should be taken into account when diagnosing and managing concussion. Doing so can mitigate potential negative consequences of the interaction between concussion and special health care needs. Consideration should be given to whether the underlying condition may make the diagnosis of

concussion more challenging or require adaptations to properly assess the visual system. In addition, accommodations for school and activity should also take into account any additional diagnoses that interact with concussion. Academic adjustments will need to be incorporated into any existing 504 plan or individualized education program (IEP) already in place for the student with special health care needs. Recovery goals should be similar, however, in that children with special health care needs should be able to return to their full pre-injury level of function despite having co-existing medical diagnoses that require consideration.

HEALTH EQUITY IMPLICATIONS

As there have been well-documented disparities in both vision care and concussion awareness, knowledge, and care, it is essential that clinicians who care for children with concussion account for the many factors that may drive disparities.⁴²⁻⁴⁵ Timely recognition, diagnosis, and access to care have been identified as factors that improve outcomes for children with concussion.^{38,39} Efforts aimed at raising awareness and recognition of the signs and symptoms of concussion, in particular the specific visual signs and symptoms associated with concussion, may improve recognition of concussion-related vision problems and time to specialty care. Addressing any access barriers to specialized care for concussion-related vision complaints should be a priority to optimize outcomes.

CONCLUSIONS

Visual symptoms are important to recognize after pediatric concussion and can be managed to minimize their negative impact on function in

school, sports, and activities of daily living for children and adolescents. For most patients who have only mild and temporary injury, these symptoms are likely indicative of diffuse brain dysfunction associated with decreased attention and visual symptoms. Patients with prolonged visual symptoms may have difficulty with convergence and accommodation attributable to dysfunction of the brainstem's near triad. For the minority of patients who continue to have ongoing visual symptoms, referral to appropriate specialty care (ie, sports medicine, physiatry, neurology, neuropsychology, ophthalmology, otorhinolaryngology) may be beneficial, and additional study is needed to establish best practices. There remains a lack of high-quality evidence to support isolated treatment of visual symptoms, such as double vision or blurred vision, after concussion with vision therapy; additional study is needed. Obtaining a vision-specific history and performing a targeted visual system examination will aid the clinician in identifying these issues; an assessment of visual acuity alone is insufficient in the setting of concussion. If deficits are identified, clinicians can provide timely supportive care and suggest academic accommodations during the school re-entry process. Temporary base-in prism combined with refractive correction for near vision can improve symptoms of blurred vision and diplopia associated with accommodative and convergence dysfunction. Therefore, children and adolescents who have persistent visual symptoms may benefit from referral to appropriate specialists, as described earlier, with expertise in the comprehensive multidisciplinary management of concussion for additional evaluation and treatment to optimize visual function and quality of life.

RECOMMENDATIONS

1. Clinicians should consider screening for vision problems after concussion in children and adolescents to determine potential academic and activity modifications after injury.
2. Beyond visual acuity, a screening examination that assesses the patient's smooth pursuit, saccades, VOR, convergence, and accommodation may be helpful to the clinician in identifying these problems after concussion.
3. Academic accommodations for school that account for possible vision problems after concussion may be helpful to children during recovery from concussion.
4. Some children with persistent visual issues after concussion may benefit from appropriate specialist referral for treatment.

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ABBREVIATIONS

AAP: American Academy of
Pediatrics
AI: accommodative insufficiency
CI: convergence insufficiency
VOR: vestibulo-ocular reflex

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