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Sports-Related Concussion: The "Eyes" Have It

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Editorial

Concussion is a form of mild traumatic brain injury (TBI) owing to structural, metabolic and functional changes involving white mater tracts of the central nervous system in the absence of macroscopic findings [1-4]. Sports-related concussion is a rapidly evolving condition stimulating interest among lay and scientific communities [3]. Recent studies have shown a high rate of underreporting of concussion signs and symptoms by athletes and sideline personnel [5,6]. Accordingly, reliable and validated testing strategies are necessary to insure timely detection and removal from play for individuals suspected of concussion. Vision and visual motor problems are commonly reported among athletes following concussion [7-15]. This is to be expected as it is estimated that approximately 50% of the brain is devoted to vision and visual motor processing [16]. As such, testing of vision and ocular motility function are critical to the evaluation of a concussed individual. While disorders of vision and ocular motility have been well-reported with TBI, most of these studies have focused on visual motor problems in the setting of combat-related TBI resulting from blast injuries [8]. There are limited studies related to vision and visual motor abnormalities from sport-related concussion.

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Common vision and visual motor problems in the setting of concussion include photophobia, convergence insufficiency, disorders of accommodation and disorders of saccades and pursuit eye movements (versional dysfunction). A comprehensive ocular examination with attention to these areas of vision and visual motor function is essential to the evaluation of a concussed individual.

Photophobia

Photophobia and phonophobia are commonly reported in the setting of concussion [18-21]. It is speculated that the mechanism may be related to disturbance of the cortico-thalamic pathways with meningeal irritation in a manner similar to that reported with migraine [18]. Light-filtering lenses have shown benefit in reducing light intolerance and reading performance in patients with trauma-induced photophobia [22]. Lynch et al. have recently reported on the therapeutic value of computer gaming lenses in the mitigation of photosensitivity and headache following concussion [23].

Vergence and accommodative disorders

Military models of traumatic brain injury show a high prevalence of vergence and accommodative deficits in these populations. In a study of 40 soldiers with combat-related mild traumatic brain injury (mTBI), Capo-Aponte and colleagues reported on the proportion of near point-related visual-motor abnormalities as compared to age-matched controls [17]. Specific oculomotor abnormalities included high exophoria, decreased fusion ranges, receded near point of convergence, defective pursuit and saccadic eye movements, decreased amplitude of accommodation and decreased monocular accommodative facility. These clinical findings were associated with reduced reading speed and comprehension and an increased convergence insufficiency symptom survey score [17].

Convergence insufficiency is a binocular vision disorder characterized by a receded near point of convergence with associated symptoms while performing near point tasks [24]. Convergence insufficiency has been reported in 23% to 46% of individuals with traumatic brain injury [25-27,8]. By comparison, convergence insufficiency is found in 1% to 8% of individuals without a history of traumatic brain injury [28-31]. Recession in near point of convergence in TBI populations has largely been reported among military and auto injury patients with sustained visual symptoms. In a recent study of soccer players, Tierney and colleagues reported on recession in near point of convergence following repetitive headers in test subjects who were exposed to ten consecutive headers from a JUGS machine [32]. In a prospective study of sports-related head trauma, Figler and colleagues have noted an improvement (shortening) in near point of convergence as a function of overall improvement in concussion-related symptoms [33].

Accommodative dysfunction is reported in 21% to 47% of non-presbyopic TBI populations [25,34,11,35]. As is true with convergence insufficiency, the majority of research studies devoted to accommodative disorders with TBI represent analysis of motor vehicle and military populations. Given that these populations encompass, on average, more severe and sustained forms of TBI, it is difficult to draw similar conclusions with sport-related injuries.

Impaired saccade and pursuit eye movements

Ocular motility dysfunction is reported in approximately 90% of individuals with concussion [14]. Anatomical correlates for impaired eye movements are linked to the lesions of the anterior corona radiata (ACR), dorsolateral prefrontal cortex (DLPFC) and genu of the corpus callosum [36,37]. These areas of "frontal vulnerability" also represent the most commonly affected substrates for trauma-induced axonal injury as determined through meta-analyses of functional magnetic resonance imaging (fMRI) and diffusion tensor imaging (DTI) abnormalities in individuals with mTBI [38]. In addition to the initiation and control of eye movements, frontal regions of neuronal injury also correlate with depressed working memory and neurocognitive dysfunction [38,39].

In 2009, Heitger and colleagues reported on impaired eye movements among individuals with post-concussion syndrome (PCS) following mild closed head injury (mCHI) [12]. This study compared 36 PCS subjects with 36 individually matched controls (mCHI patients with similar severity of injury but with resolution of signs and symptoms) as a function of reflexive, anti- and self-paced saccades, memory-guided sequences and smooth pursuits [12]. They found worse performance on anti-saccades, self-paced saccades, memory-guided sequences and smooth pursuits [12]. Furthermore, compared with neuropsychological tests, eye movement abnormalities were more likely to be related to PCS cases with high symptom load [12].

The King Devick (KD) Test has recently been studied as rapid sideline screening test for the detection of concussion [40]. KD is a test of rapid number naming that assesses saccades, accommodation, convergence, immediate recall and verbalization of response [41]. Post incident responses are recorded and compared to pre incident baseline responses with an increase in test time being suggestive of concussion [41]. In a study of boxers and mixed martial arts fighters, Galetta and colleagues showed reduced KD performance (longer test time) in the setting of concussion [41]. Similar studies have shown impaired rapid number naming with sports-related concussion in collegiate and youth sports [42,43,10] and club rugby players [44]. Meta-analysis of pooled data from 15 studies has shown an 86% sensitivity and 90% specificity for the detection of concussion using the KD rapid number naming protocol [45]. Marindes and colleagues have reported on a comparative analysis of cognitive performance (Standardized Assessment of Concussion {SAC}), balance (Balance Error Scoring System {BESS}) and rapid number naming (KD) among college athletes in the sideline evaluation of concussion [43]. Their analysis showed increase (worsening) of KD time scores in 79% of concussed athletes as compared to a 52% worsening with SAC. Combining KD and SAC correctly identified 89% of concussions. The addition of BESS to KD and SAC resulted in a 100% capture of all concussions.

Conclusion

With increasing attention to sport-related concussion, there is a need to develop validated and efficient testing protocols for sideline concussion evaluation so as to facilitate immediate removal from play. Vision and visual motor abnormalities are common in the setting of concussion and are shown to be highly sensitive and specific for concussion detection as compared to cognitive and balance assessments. Optometrists are strategically positioned for the development of research initiatives and testing paradigms for individuals with suspected concussion. While no one test is definitive for the sideline diagnosis of concussion, composite test batteries that include vision, balance and cognitive function are emerging as required guidelines for concussion detection and removal from play.

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