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Oculomotor examination and treatment for concussion

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Abstract

Background: Individuals who have sustained concussion frequently develop impairments in oculomotor function. Some providers have attempted to improve these impairments and aid the overall recovery from concussion by prescribing vision therapy.

Objective: To review and assess the validity of common clinical oculomotor findings and subsequent vision therapy for concussion.

Methods: A literature review was conducted via OVID MEDLINE and ePub databases. Three hundred and sixty-three records were obtained. Results were pared down to include only those with adequate power and relevance to the study questions. Eleven studies on examination and 2 studies on treatments met inclusion criteria.

Results: There is reasonable evidence to support the use of near-point convergence, pursuits, and saccades (when computerized) aiding the diagnosis of concussion. Adequately powered randomized controlled trials do not exist to support of the use of vision therapy for the treatment of concussion.

Conclusions: Oculomotor examination findings are useful in clinical practice to aid the diagnosis of concussion, but further research using adequately powered randomized controlled trials are required to clarify the efficacy of vision therapy in the treatment of concussion.

Introduction

Concussion is a common sports and occupational health problem [1] with numerous clinical trajectories [2]. The visual trajectory is associated with prolonged recovery [3] and academic difficulties in adolescents [4]. Brain structures involved in visual function appear to have a vulnerability to shear stress and are thus commonly impacted [5-7], with oculomotor symptoms in over 60% of concussed children and adolescents [8] and over 90% of concussed adults [9].

Examination techniques assessing oculomotor function are based on eye movements [10], including vergence, saccades, and pursuits [11], and are not commonly assessed in primary care.

Vergence movements align the fovea with targets at different distances from the eye. They involve disconjugate adjustments (convergence and divergence) as opposed to conjugate adjustments (e.g., eyes moving the same direction to track a moving object) and are part of the near reflex triad which includes accommodation and pupillary constriction. Near point convergence is tested by having the patient focus on the examiner's finger from a distance and gradually bringing the finger closer to the patient (Figure 1). The point at which the image of the finger becomes double is measured from the eye.

Saccades are rapid, ballistic movements of the eyes, that abruptly change the focal point. This includes smaller movements made while reading and larger movements scanning a crowd. They are tested by the examiner holding fingers at far ends of the visual fields while the patient looks back and forth between fingers (Figure 2). With abnormal saccades, the patient is unable to correctly fix on the object after ballistic movements.

Smooth pursuit eye movements are slow, voluntary tracking movements designed to keep a moving object on the fovea. They are examined by having the patient fix their gaze on the examiner's finger while it is slowly moved in the horizontal and vertical planes (Figure 3). An abnormal finding is difficulty with performing this task.

This review attempts to clarify the utility of (1) oculomotor examination findings as they relate to the diagnosis of concussion and (2) proposed oculomotor treatments for concussion.

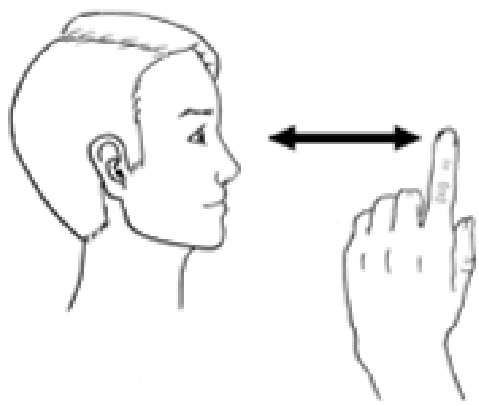

Figure 1. Examination of near point convergence

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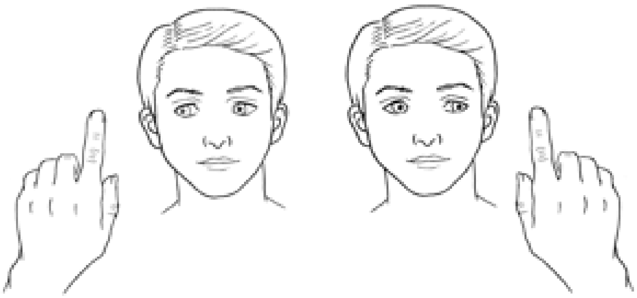

Figure 2. Examination of saccadic eye movements

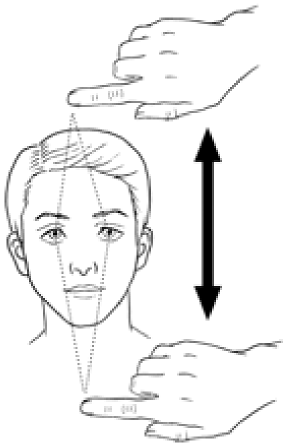

Figure 3. Examination of (vertical) smooth pursuit eye movements

Table 1. Articles on oculomotor examination findings that met inclusion criteria.

Authors	Topic	Study design	Key findings
Near point convergence dysfunction			
Thiagarajan et al. [12]	Vergence dysfunction in concussion	Review	Mild traumatic brain injury is associated with a range of vergence dysfunctions in adults with increased distance of break and recovery in cases vs controls studies reviewed
Szymanowicz et al. [14]	Vergence dysfunction in concussion	Case-control (N= 31)	Significant difference (increased distance) of NPC break and recovery between case and control groups
DuPrey et al. [15]	Vergence dysfunction in concussed athletes	Retrospective cohort (N=270)	Concussed athletes with NPC had significantly longer recovery periods (51.6 days) than those without convergence insufficiency (14.7 days)
Kawata et al. [16]	Vergence dysfunction with sub-concussive head injury	Prospective cohort study (N= 29)	Higher impact sub-concussive head trauma in university football players is associated with prolongation of NPC from baseline with return to baseline after 3 weeks.
Saccadic Dysfunction			
Hunfalvay et al. (2019) [24]	Saccades in concussion	Case-control (N=287)	Horizontal saccadic dysfunction has sensitivity of 0.77 and specificity of 0.78 in predicting concussion.
Smooth Pursuit Eye Movement Dysfunction			
Murray et al. [26]	SPEM after concussion	Case-control (N=36)	Abnormalities in SPEM amplitude and velocity were associated with concussion vs control groups.
Wetzel et al. [27]	SPEM after concussion	Case-control (N=146)	Patients with post-concussion syndrome had abnormalities in tracking movements used in SPEM vs controls.
Multiple Abnormalities			
Snegireva et al. [21]	Eye tracking technology in concussion	Systematic review and meta-analysis	Saccadic and pursuit dysfunction is seen (by computerized assessment) in the context of concussion and remains affected in the acute (<30 days) phase.
Capo-Aponte et al. [13]	Visual dysfunction after blast-induced concussion	Case-control (N=40)	Significant difference (increased distance) of NPC after blast-induced concussion vs controls. Significant differences in errors in smooth pursuit and saccadic eye movements.
Hunt et al. [17]	Oculomotor abnormalities in concussion	Systematic review	Exploratory studies find that concussion appears to be associated with saccadic abnormalities (greater amplitudes smaller peak accelerations slower velocities and less accurate target prediction) as well as abnormalities of smooth pursuit eye movements.
Cifu et al. [23]	Oculomotor abnormalities post-concussion	Case-control (N=86)	Military veterans with concussion had significantly poorer smooth pursuit tracking ability as well as altered saccadic amplitudes accelerations and velocities.

Table 2. Articles on effects of oculomotor treatments for concussion meeting inclusion criteria.

Authors	Topic	Study design	Key findings
Peters et al. [36]	Vision therapy in concussion	Cohort study (N=137)	Concussed hockey players who participated in therapy had symptom resolution in 5.8 weeks versus 12.3 weeks in those who did not.
Gallaway et al. [34]	Vision therapy in concussion	Retrospective case series (no control group) (N=218)	85% of patients who completed vision therapy protocol had improvements in NPC base-out demand and/or concussion symptoms.

Methods

An OVID MEDLINE and ePub database search was conducted for articles published in the last 10 years in English with keywords relating to the above-noted oculomotor tests and treatments for concussion. A total of 363 records were obtained. A total of 11 studies of oculomotor examination findings and 2 studies of oculomotor treatments met our inclusion criteria. Only articles relevant to the study purpose were used. Sports-related, incidental, and blast-related were all considered if the patient met the definition of concussion. Case reports, studies with small sample size (approximately 20 participants or fewer), and uncontrolled studies were given less or no consideration. Random automatized naming tools (King-Devick and others) and vestibulo-oculomotor tests were excluded as they incorporate multiple oculomotor systems at once. Treatment with optic devices (lenses, etc.) was not reviewed.

Results

Oculomotor examination findings for concussion

Results are summarized in Table 1.

Abnormalities of near point convergence

In adults, abnormalities of near point convergence after concussion have been reported in numerous studies [12-14]. The normal finding in adults is a break in unified visual image at 5 cm from the eye and recovery at 7 cm. Convergence abnormalities appear to be a reliable marker for prolonged concussion recovery; those with this abnormality have taken more than 50 days (as opposed to approximately 15 days) to recover from concussion [15].

Sub-concussive head injury in athletes (as measured by accelerometers) has also been associated with mildly impaired NPC [16], which may confound the assessment of the acutely or previously injured patient.

Saccadic dysfunction

Dysfunctional saccadic eye movements can be measured by computer and are those with greater amplitude, smaller peak acceleration, slower velocity, and lower accuracy with target prediction [17]. Several systematic reviews have demonstrated that saccadic eye movements are affected by concussion. Previously, only class 3-4 level evidence indicated significant reduction in saccade velocity *vs*. controls [17-23]; however, newer, adequately powered case-controlled research suggests a sensitivity of 0.77 and specificity of 0.78 for predicting concussion [24].

Smooth pursuit eye movements (SPEM)

Impairments in SPEM in concussion has been previously studied [25] and discussed in a 2016 systematic review [17]. More recently, two case-control studies (one with a study population of 146 and the other of 36) have supported the finding of abnormalities of smooth pursuit eye movements in concussion [26,27].

Treatment for oculomotor manifestations of concussion

A number of therapies have been proposed for the treatment of visual/oculomotor dysfunctions associated with concussion [28-31]. These include laboratory-based versional, vergence, and accommodative eye movement training, simulated reading exercises, balance training and visual awareness exercises, driving simulators [32], light filtering and photochromic lenses, and use of glasses with various tints and prism combinations [33]. These treatments have been utilized in non-concussed patients [34]; however, they have only recently been applied to concussion.

This review presents the best available information with regards to proposed treatments, summarized in Table 2.

Vision therapy

There is no single consensus method of vision therapy; however, many propose to improve concussion symptoms through various oculomotor exercises targeting components of the oculomotor system. An example of a proposed therapy is the Computer Oculomotor Rehabilitation (COR) Program for concussion [35], which includes exercises in gaze fixation (central, horizontal, vertical) for set periods of time, predictable saccades and non-predictable saccades (horizontal and vertical), smooth pursuits (horizontal and vertical), vestibulo-ocular reflex in different positions of gaze (central, horizontal, vertical, oblique), and simulated reading. One can modify the base-in, -out, -up, or -down of spectacle prisms to alter horizontal or vertical vergence on demand. The program allows variation in parameters for each eye movement trained, including speed of movement, amplitude of movement, and other modifications to alter the degree of difficulty. Large, controlled trials have not yet assessed these programs.

A retrospective chart review of concussed professional hockey players (N=137) compared those who received a form of vision therapy and those who did not [36]. Vision therapy consisted of a review of their visual prescription, anti-glare and 40% blue tint glasses for those with photophobia, avoiding prism spectacles, challenge the oculomotor system by playing catch with a bean bag while adding difficulty by talking to the patient, and playing catch with glasses with base-in and -out prisms (15 prism diopters), then wearing yoked prisms (yoked right then left), and using a balance board while wearing the above noted glasses. Those who participated had symptom resolution in 5.8 weeks versus 12.3 weeks in those who did not.

An uncontrolled retrospective case series [34] assessed a vision therapy program that consisted of once or twice weekly 45-minute office sessions and home-based sessions using therapy described in the Convergence Insufficiency Treatment Trials (CITT) [37] (a trial assessing the interventions of pencil push-ups vs office-based vision therapy in non-concussed individuals), with the addition of exercises for saccadic and pursuits using Hart Charts, thumb rotations, an use of the Sanet Vision Integrator software. Specific protocols were not further described. Eighty-five percent of participants who completed vision therapy had significant improvements in NPC, base-out demand, and/or symptoms.

Many of the studies reviewed were not considered due to low sample size or other methodological limitations [30,38-46].

Discussion

Abnormalities in vergence appear to be the most reliably affected by concussion. However, history of sub-concussive impacts may affect interpretation. Saccadic and pursuit abnormalities do appear to be associated with concussion but are less easily detected without computerized detection methods and are thus of less utility in a primary care clinical setting.

There is insufficient evidence at this time to establish the medical requirement of most oculomotor treatments for concussion patients. The literature surrounding therapies for concussion is unfortunately limited by small sample size, lack of control groups, and other methodological limitations. Only one controlled cohort study met our inclusion criteria, and demonstrated possible benefit from vision therapy, though it was limited by lack of randomization (participants chose whether to opt-in or out for therapy). At this time, it is therefore not possible to draw definitive conclusions regarding the efficacy of these interventions. Large, randomized controlled trials or Bayesian-style meta-analysis of the existing smaller studies would better establish any potential benefit of vision therapies for oculomotor impairments in concussion.

Conclusion

There appears to be validity to the oculomotor examination findings in relation to concussion, with vergence chief among them in the primary care setting. At the time of this review, further research is required to be able to clarify the potential efficacy of vision therapy for concussion-related oculomotor disorders.

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