Premorbid Diagnosis of Attention Deficit Hyperactivity Disorder and the Association of Concussion Risk and Prolonged Recovery

An Evidence-Based Report

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ABSTRACT

Attention deficit hyperactivity disorder (ADHD) has been identified as a risk factor for concussion or delayed recovery. However, these recommendations are often based on anecdotal or limited evidence. This critically appraised topic aimed to address the clinical question of whether a premorbid diagnosis of ADHD increases the risk for a concussion and prolonged symptoms. A search strategy using PICO terminology related to the clinical question was conducted in several electronic databases. Seven studies were identified and five met the inclusion criteria. The clinical bottom line suggests there is moderate evidence to support the relationship between patients who are diagnosed as having ADHD and the incident rate of concussion, as well as a prolonged recovery time. The findings of this critically appraised topic suggest strength of recommendation of grade B to support that ADHD is a risk factor for concussion and a predictor of prolonged recovery.

A concussion is defined as “a complex pathophysiological process that affects the brain as a result of biomechanical forces” landing on the spectrum of a traumatic brain injury. Concussion is considered to be a mild traumatic brain injury resulting from axonal shearing. As the most common traumatic brain injury within the United States, approximately 70.5% of concussions occur in patients aged 10 to 19 years, with 13.5% resulting from high school athletics. The rise of public interest in concussion over the past decade has led to more funding for research. A popular area of research is investigating modifying factors that influence an individual’s risk of concussion and the duration of recovery.

Attention deficit hyperactivity disorder (ADHD) is a neurobehavioral disorder caused by impaired axonal integrity. Three subtypes of ADHD have been identified as primarily inattentive, primarily hyperactive, and combined inattentive and hyperactive. Although the subtypes vary in presentation, they all exhibit deficits in executive function that lead to academic, social, and emotional deficits. ADHD has become more prevalent in recent years, affecting 10% of children and 4.4% of adults in the United States.

Some behavioral effects of ADHD, such as decreased self-awareness, may place the individual in a vulnerable position to sustain a mechanism that may result in a concussion. Recent research has addressed the relationship between ADHD and concussion, but due to the primarily retrospective and inconsistent nature of these investigations, the evidence is limited. As such, a consensus has yet to determine whether ADHD is a risk factor of concussion or delayed recovery. Therefore, the clinical question guiding this critically appraised topic was “Does a premorbid diagnosis of ADHD increase the risk for a concussion and prolonged symptoms of concussion?”

METHODS

Search Strategy

The search strategy was developed from the clinical question using the PICO format that allowed specific search terms to be standardized among databases. The search terms used were “attention deficit...”
hyperactivity disorder AND concussion risk.” The search was conducted in January 2016 on several databases, including the Cochrane Library, Dynamed Plus, PEDro, PubMed, MEDLINE, and CINAHL. Publication dates were limited to 2006 through 2016. A hand search of reference lists for relevant literature was also conducted.

**Inclusion and Exclusion Criteria**

Studies were included in the appraisal if they were of level 3 evidence or higher on the Oxford classification, investigated ADHD as a risk factor for concussion or prolonged recovery after concussion, were published in English, and were published in the past 10 years (2006 to 2016).

Studies that did not address the relationship between ADHD and incidence of concussion or prolonged recovery were excluded from the appraisal.

**RESULTS**

The literature searches returned 34 articles. PubMed retrieved 11 articles, 7 of which were excluded. CINAHL retrieved 10 articles, 8 of which were excluded. MEDLINE retrieved 13 articles, 13 of which were excluded. The most common exclusion criteria were failure to address ADHD as a risk factor of concussion, being review articles or position statements, and repeated articles. The Cochrane Library, Dynamed Plus, and PEDro retrieved 0 articles.

The literature search returned 7 possible studies (1 retrospective cohort, 1 cross-sectional study, 3 retrospective case-control studies) related to the clinical question; 5 studies1-4,7 met the inclusion criteria and were included (Table 1). These studies were selected because they were considered level 3 evidence or higher and investigated the relationship of ADHD and mild traumatic brain injury. The 2 excluded studies failed to meet the inclusion criteria of providing level 3 evidence or higher. Included studies are summarized in Table 2.

All studies found that a premorbid diagnosis of ADHD is associated with a prolonged recovery following concussion.1-4,7 Findings of two studies demonstrated increased incidence of concussion in patients with ADHD compared to those without ADHD.2,3 Similarly, patients with ADHD experienced a greater incidence of concussion symptoms and greater symptom severity compared to patients without ADHD.2 However, the evidence does not support a relationship between history of previous concussion and prolonged recovery for a subsequent injury in patients with ADHD.4 Literature suggests that patients who sustain a concussion are not likely to be diagnosed as having ADHD as a sequelae of the concussion.2 Finally, the results of this critically appraised topic found that patients with ADHD require more intensive resources following concussion compared to patients without ADHD.7

There is moderate evidence to support the relationship between patients who are diagnosed as having ADHD and the incident rate of concussion, as well as prolonged recovery time. The research shows that those who were previously diagnosed as having ADHD have reported greater incidence of concussion than their counterparts without ADHD. The association also exists between premorbid diagnosis of ADHD and prolonged recovery of disablement. Symptom severity was also associated with ADHD and concussion, stating that those with ADHD suffered from a higher severity of symptoms than those who were not diagnosed as having ADHD. In addition to experiencing more severe symptoms, patients with ADHD reported more symptoms during their recovery.

In accordance with the Oxford Centre for Evidence-Based Medicine (CEBM),9 the findings of this critically appraised topic indicate a grade B strength of recommendation supporting ADHD as a risk factor for concussion and a predictor of prolonged recovery. This

<table>
<thead>
<tr>
<th>LEVEL OF EVIDENCE</th>
<th>STUDY DESIGN</th>
<th>NUMBER LOCATED</th>
<th>AUTHOR (YEAR)</th>
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<tbody>
<tr>
<td>2</td>
<td>Cross-sectional</td>
<td>1</td>
<td>Alosco et al. (2014)</td>
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<tr>
<td>2</td>
<td>Retrospective cohort</td>
<td>1</td>
<td>Biederman et al. (2015)</td>
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<tr>
<td>2</td>
<td>Retrospective case-control</td>
<td>3</td>
<td>Bonfield et al. (2013); Miller et al. (2015); Mautner et al. (2015)</td>
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</tbody>
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**TABLE 1**

**Summary of Study Designs of Articles Retrieved**
### TABLE 2
Characteristics of Included Studies

<table>
<thead>
<tr>
<th>STUDY</th>
<th>PARTICIPANTS</th>
<th>OUTCOME MEASURES</th>
<th>MAIN FINDINGS</th>
<th>CONCLUSIONS</th>
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<tr>
<td>Alosco et al. (2014)</td>
<td>Cross-sectional study. 139 patients (67 female, 72 male; 72 football players) who were Kent State University, Division 1 athletes. No inclusion or exclusion criteria were given. All patients performed a baseline ImPACT test and self-reported number of prior concussions and diagnostic history of ADHD and other learning disabilities. All patients performed a Spot The Word Test to assess pre-morbid intelligence. One patient was missing data for history of dyslexia and was excluded from the ANCOVA analysis.</td>
<td>(1) Positive or negative diagnostic history of ADHD.</td>
<td>ADHD was common among sample of Division 1 NCAA athletes presenting in 10.1% of patients. At least one previous concussion was reported by 50.4% of patients with ADHD compared to 14.4% of patients without ADHD. This was shown to be a significant difference. One prior concussion was reported by 18% of patients, whereas two or more prior concussions were reported by 12.3% of patients.</td>
<td>Athletes with history of ADHD report a greater history of prior concussions than those without ADHD.</td>
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<td>Blederman et al. (2015)</td>
<td>Retrospective cohort study. The group of interest included student athletes who sustained an mTBI in the past 10 years (n = 29). Participants with post-concussive neurological sequelae, history of psychiatric disorders requiring hospitalization, previous neurosurgery, chronic medical disease, chronic neurological disease, or history of drug and alcohol abuse were excluded from the comparison group. Two comparison participants were randomly selected and matched for age and sex for each patient. Patients completed the BREF self and parent report and the BREF-Adult self and informant report (for participants ≥ 18 years).</td>
<td>(1) BC-PSI was used to determine status of post-concussive symptoms; severity rated 0 to 5 on a Likert scale. (2) ImPACT battery was used to provide composite scores for verbal memory, visual memory, reaction time, and processing speed.</td>
<td>On the BC-PSI scale fatigue (3.4 vs 1.9, P = .029) and poor concentration (4.0 vs 1.9, P = .008) were significantly more severe in mTBI+ADHD compared with mTBI–ADHD patients. mTBI+ADHD had a larger percentage of patients with ≥ 5 items scored as severe (severe score ≤ 3) than mTBI–ADHD patients (100 vs 38.5, P = .015). Compared with mTBI–ADHD participants, those with mTBI+ADHD were significantly more impaired on individual BREF subscale scores for Inhibit (5.1 vs 4.5, P = .015), Working Memory (5.7 vs 4.6, P = .001), and Planning/Organization (55.9 vs 44.3, P = .009). Compared with mTBI–ADHD participants, those with mTBI+ADHD were significantly more impaired on BREF composite scores: Metacognition Index (57.3 vs 45.7, P = .006), Behavioral Regulation Index (46.8 vs 42.4, P = .044), and Global Executive Composite (53.7 vs 43.7, P = .006).</td>
<td>ADHD is an antecedent risk factor for mTBI. ADHD is not a complication of mTBI. A greater incidence and severity of mTBI symptoms occurs in mTBI patients with ADHD when compared with mTBI patients without ADHD.</td>
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<td>Bonfield et al. (2013)</td>
<td>Retrospective case-control study. Patients consisted of those diagnosed as having a mCHI and admitted to Children’s Hospital of Pittsburgh between January 2003 and May 2010. The case group was required to have a premorbid diagnosis of ADHD and an initial GCS score of 13 to 15. The control group was a randomly selected sample of age-matched controls admitted with an initial GCS score of 13 to 15 without presence of ADHD. Patient demographic data, MOI, hospital course, initial nonpharmacologically influenced GCS score, and KOSCHI score at the latest clinical outpatient follow-up were recorded.</td>
<td>(1) GCS was used to measure injury severity. (2) KOSCHI was used to measure outcomes following CHI.</td>
<td>Mean follow-up time after mTBI was 24-9 weeks (range: 2 to 208 weeks) for the ADHD group and 7.2 weeks (range: 3 to 60 weeks) for the control group (P = .01). For mild CHI patients with ADHD, 25% were moderately disabled at follow-up (KOSCHI 4b) compared with 2% of mild CHI patients without ADHD. For mild CHI patients with ADHD, only 56% had a complete recovery without sequelae (KOSCHI 5b), compared with 84% in the control group (P &lt; .01). The associations between mTBI and KOSCHI score adjusted for patient and demographic factors are statistically significantly impacted by age (β = 0.047, CI: 0.048 to 0.066); length of follow-up (β = -0.01, CI: -0.014 to 0.006); a diagnosis of ADHD (β = -0.33, CI: -0.55 to -0.01); an MOI of MVC (β = 0.45, CI: 0.26 to 0.882), or a sports accident (β = 0.65, CI: 0.21 to 1.09).</td>
<td>Patients with pre-morbid ADHD were more likely to be moderately disabled following mild CHIs than those without ADHD. Compared to children without ADHD, children with ADHD have a lower KOSCHI score at follow-up by a factor of 0.3.</td>
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**TABLE 2 (cont’d)**

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<td>Miller et al. (2015)</td>
<td>Retrospective case-control study. A total of 562 patients presented to CCCOA between August 2011 and January 2013. Inclusion criteria required patients to present within 4 weeks of their date of concussion and a follow-up appointment after 28 days from their date of concussion. Of these, 256 patients who sustained a concussion from a motor vehicle accident, presented more than 4 weeks after their date of concussion, or were 18 years or older were excluded from this study. The 294 patients remaining were split into a control group of 189 patients and a case group of 105 patients. The control group consisted of patients whose symptoms resolved within 28 days. The case group consisted of patients whose symptoms did not resolve within 28 days.</td>
<td>(1) Presence or absence of an initial SCAT2 score. (2) Early or delayed recovery status.</td>
<td>Case and control groups did not statistically significantly differ in available SCAT2 scores ($P = .08$). For patients who underwent a SCAT2 assessment, delayed recovery was statistically significantly associated with female sex ($P = .001$), a history of previous concussion(s) ($P = .006$), a SCAT2 score &lt; 80 ($P &lt; .0001$), LOC at the time of injury ($P = .04$), a lower initial total SCAT2 score ($P &lt; .0001$), and incurring the concussion in a non-helmet sport ($P = .01$). For patients without SCAT2 assessments, only female sex was significantly associated with delayed recovery ($P = .001$), and the association of delayed recovery with participation in a non-helmet sport was borderline statistically significant ($P = .05$).</td>
<td>In this case-control study, a history of previous concussion(s), a presenting SCAT2 score of less than 80, a history of ADHD female sex, and playing non-helmet sport were all associated with a higher risk for prolonged recovery (&gt; 28 days) after a concussion.</td>
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<td>Mautner et al. (2015)$^3$</td>
<td>Retrospective case-control study. Patients were selected from 10 different high schools in greater Atlanta, Georgia between July 2008 and June 2013. The case group consisted of student athletes who self-reported diagnoses of ADHD on their baseline ImPACT test and subsequently sustained a concussion resulting in a functional decline in at least 1 test module before recovering to baseline. The control group consisted of student athletes without ADHD who sustained a concussion resulting in a functional decline in at least 1 test module before recovering to baseline. Patients were excluded if they failed to return to baseline in any of the 4 neurocognitive modules, if their baseline ImPACT was not available, the date of the concussion was not documented, or the ImPACT score was invalid or taken over 2 years prior to the date of concussion.</td>
<td>(1) ImPACT battery was used to provide composite scores for verbal memory, visual memory, reaction time, and processing speed. (2) Length of concussion.</td>
<td>There was no significant difference in the number of previous concussions between the ADHD and control group. The ADHD patients recovered in 16.5 vs 13.5 days, although not statistically significantly ($P = .12$). Although all 4 test modules tested on the ImPACT tended to be less in the ADHD group, the verbal memory composite score showed the only significant difference ($P = .01$) compared with the control group.</td>
<td>Number of previous concussion is not associated with a delay in concussion recovery in youth athletes with and without ADHD. Although not statistically significant, the finding that youth athletes with ADHD take on average 3 days longer to recover from a concussion when compared to athletes without ADHD is clinically relevant.</td>
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ImPACT = Immediate Post-Concussion Assessment and Cognitive Testing; ADHD = attention deficit hyperactivity disorder; ANCOVA = analysis of covariance; NCAA = National Collegiate Athletic Association; mTBI = mild traumatic brain injury; BRIEF = Behavior Rating Inventory of Executive Function; BC-PSI = The British Columbia Post-Concussion Symptom Inventory; mTBI-ADHD = mTBI patients with ADHD (N = 11); mTBI−ADHD = mTBI patients without ADHD (N = 18); ADHD comparators (ADHD; n = 22), and control comparators (Controls; n = 58); CH = closed head injury; GCS = Glasgow Coma Scale; KOSCHI = King’s Outcome Scale for Childhood Head Injury; MOI = mechanism of injury; MVC = motor vehicle crash; CCCOA = Concussion Clinic at Children’s Hospital of Alabama; SCAT2 = Sport Concussion Assessment Tool 2; LOC = loss of consciousness.
grade B strength of recommendation results from consistent findings of level 2 and level 3 evidence.

DISCUSSION
ADHD has been associated with increased incidence of concussion\(^2\)\(^6\)\(^7\) and a prolonged duration of recovery\(^2\)\(^4\)\(^7\) and is an issue of concern for sports medicine clinicians.\(^8\) This association should alter expectations for recovery in patients with ADHD and is clinically important when health care providers are discussing prognosis and recovery with the patient and family.\(^1\)\(^4\)\(^7\) Identification of “difficult” patients with concussion is currently based on the duration of recovery.\(^1\)\(^5\) Clinical practice may benefit from considering concussion patients with diagnosed ADHD to be “difficult” patients with concussion automatically.

Several symptoms of concussion correspond to known symptoms of ADHD and can cause a misinterpretation of a patients’ response to a graded symptom scale. Patients with ADHD may also exhibit limited self-awareness,\(^4\) which further complicates distinguishing pre-morbid and post-concussive symptoms.\(^2\) Under-reporting concussive symptoms is common among athletes,\(^1\)\(^1\) and this behavior may be amplified in athletes with ADHD who have diminished self-awareness.\(^3\) Athletic trainers must consider these implications when assessing symptoms. In these cases, baseline symptom scales may be useful and better symptom reports identified when administered via a patient interview, rather than having the patient self-complete a symptom scale.

A unique relationship exists between concussion and ADHD that is further exaggerated within the athletic population. It has been identified that patients with ADHD may also exhibit balance deficits, poor coordination, and inhibited motor skills,\(^5\) which are also signs clinicians often monitor following concussion. Sport-related concussions make up the second most common mechanism of concussion within the United States.\(^7\) Some of the signs associated with ADHD may predispose the athlete to concussion.\(^2\)\(^7\) Furthermore, evidence shows ADHD to be more prevalent in student athletes when compared to the student population as a whole.\(^2\)\(^3\) Such prevalence requires that coaches be knowledgeable of the implications ADHD has on sport-related concussion and emphasizes the need for athletic trainers to follow current practice guidelines for management of athletes with ADHD.\(^3\)

IMPLICATIONS FOR CLINICAL PRACTICE
Student athletes with ADHD have been shown to achieve lower composite scores across all assessments included in the ImPACT battery.\(^4\) The theory of “cognitive reserve”\(^4\) may be applied to these findings. Normally, the brain is able to compensate for mild traumatic injuries by using redundant pathways.\(^1\)\(^2\) However, the comprised synaptic function seen in ADHD inhibits effective use of this redundant system.\(^1\)\(^2\) Therefore, patients with ADHD may achieve lower scores on neurocognitive baseline tests and are more vulnerable to functional deficit following concussion. Evidence shows patients with ADHD experience more severe concussion symptoms and present higher symptom severity for a longer duration.\(^2\) This may be caused by the common pathophysiology seen in ADHD and concussion, both of which impair axonal function.\(^3\) Consequently, instances of comorbidity lead to worse outcomes and amplified vulnerability of long-term disability.\(^7\) As a result, athletic trainers may need to specialize their concussion management for patients with ADHD.\(^3\) A multidimensional approach uses more intensive resources such as cognitive therapy and has been suggested to provide the greatest chance of full recovery.\(^2\)\(^7\)

Future research should include further studies investigating ADHD as a risk factor for concussion using more objective measures for patient history of ADHD and concussion. These studies should isolate ADHD from existing comorbidities to single out ADHD as a risk factor.\(^3\)\(^4\) Further investigation of effective interventions for patients with ADHD is indicated.\(^4\) Studies should also investigate the influence stimulant medication has on the increased risk associated with ADHD.\(^2\)\(^4\) The findings from these articles need to be replicated in prospective studies with larger sample sizes to better inform clinical practice.\(^2\)\(^4\)\(^7\)

This critically appraised topic should be reviewed in 2 years or when additional best evidence becomes available to determine whether additional findings may change the clinical bottom line for the research question posed in this review.

REFERENCES


