Sport concussion and attention deficit hyperactivity disorder in student athletes

A cohort study

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Abstract

Background

Attention deficit hyperactivity disorder (ADHD) is associated with impulsive behavior and inattention, making it a potential risk factor for sport-related concussion (SRC). The objectives of this study were to determine whether ADHD is an antecedent risk factor for SRC and whether ADHD complicates recovery from SRC in youth athletes.

Methods

Student athletes with a history of SRC were evaluated for the presence of ADHD using diagnostic interview and to determine whether ADHD symptoms began before or after SRC. Concussion-specific measures of concussive symptoms and cognitive function were compared in SRC + ADHD and SRC + No ADHD groups to assess SRC recovery between groups.

Results

ADHD was overrepresented in youth with SRC compared with population rates. ADHD was found to be an antecedent risk factor for SRC, with age at ADHD onset earlier than the date of SRC. Student athletes with SRC and ADHD reported more concussive symptoms compared with athletes without ADHD and were more likely to have a history of greater than one concussion.

Conclusions

The results of this study support our hypothesis that ADHD is an antecedent risk factor for SRC and may contribute to a more complicated course of recovery from SRC. Future research should focus on determining whether screening, diagnosis, and treating ADHD in youth athletes may prevent SRC. Providers that care for youth athletes with ADHD should be aware of the vulnerabilities of this population toward SRC and its complications.

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Page 377

A sport-related concussion (SRC) is as a transient disturbance in brain function after a blow to the head or body during sport and lacks evidence of brain trauma on standard neuroimaging.[1] Over 69% of girls and 75% of boys in the United States participate in sports,[2] with 2–3 SRCs occurring per 10,000 player exposures.[3] Although most recover quickly, some athletes

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Previous Presentation: An interim analysis using 29 mTBI individuals was published in November 2015 in the Journal of Nervous and Mental Disease. Data from the current manuscript were presented during a poster session at the American Professional Society of ADHD and Related Disorders 2018 Annual Meeting.

In this study, we evaluated whether ADHD is an antecedent risk factor for SRC and whether ADHD complicates its course.

experience persistent symptoms. One potential risk factor for SRC is attention deficit hyperactivity disorder (ADHD), a neurobiological disorder associated with an increased risk of injuries in adolescents, including traumatic brain injury (TBI).[4,5] This risk is likely related to the core deficits of ADHD, including poor impulse control, inattention, and distractibility.

We conducted a pilot study of student athletes and found that student athletes with SRC were more likely to have ADHD, the presentation of ADHD was before SRC, and ADHD was associated with a complicated recovery from SRC.[6] However, expansion upon these preliminary data is needed to strengthen our understanding of the association.

In this study, we evaluated whether ADHD is an antecedent risk factor for SRC and whether ADHD complicates its course. To this end, we evaluated student athletes with SRC for ADHD, assessing whether ADHD developed before or after SRC and whether ADHD complicates recovery from SRC by assessing postconcussion symptoms. We hypothesize that ADHD is strongly associated with SRC, that ADHD is an antecedent risk factor for SRC, and that ADHD complicates the course of recovery.

Methods

Participants

Participants were male and female student athletes aged 12–24 years who had sustained SRC in the last 10 years (N = 79). An SRC was defined as a traumatically induced physiologic disruption of brain function as manifested by at least one of the following: any period of loss of consciousness less than 30 minutes; any loss of memory for events immediately before or after the accident with posttraumatic amnesia not exceeding 24 hours; any alteration in the mental state at the time of the accident; and focal neurologic deficits that may or may not be transient.[7]

To limit confounding symptomatology, we excluded patients with neurologic sequelae (e.g., seizure), previous psychiatric disorder requiring hospitalization, a diagnosis of autism, psychosis, or bipolar disorder, a lifetime diagnosis of epilepsy, history of neurosurgery, serious chronic medical disease or major neurologic disease, or a history of alcohol or drug abuse.

Patients with SRC were recruited through a hospital-wide e-mail for clinical studies and a mailer to patients in a sport concussion clinic. The advertisement did not mention ADHD, to avoid bias toward recruiting patients with ADHD. Eligible and consenting patients with SRC completed a 2-hour assessment battery to collect information regarding their medical and psychiatric history, including details about their head injuries and ADHD symptoms. Participants <18 years of age were accompanied by a parent/guardian. When possible, parents of participants 18–24 years of age were contacted for an indirect report.

Standard protocol approvals, registrations, and patient consents

The Partners Human Research Committee approved this protocol, and patients provided written or verbal consent for participation. For minors, consent was signed by the parent or guardian and assent was obtained from the participating youth.

Assessments

Procedures for the assessment of ADHD consisted of completing the ADHD module from the Kiddie Schedule for Affective Disorders and Schizophrenia Epidemiologic version[8,9] with the participants and independent interviews with the parent or guardian for minors. Whenever possible, indirect interviews were obtained from older patients. When both direct and indirect interviews were obtained, data were combined by considering a diagnostic criterion positive if it was endorsed in either interview, consistent with our methods in previous studies.[10] We considered a full diagnosis of ADHD to be present if *Diagnostic and Statistical Manual of Mental Disorders: Fourth Edition* diagnostic criteria were met.[11] We considered a subthreshold diagnosis of ADHD present if patients met at least one of the following criteria[1]: age at ADHD symptom onset was ≥12 years[2] and having 4 or 5 symptoms of ADHD on at least one of the modules (Inattention or Hyperactivity). All structured interviews were administered by trained interviewers who were supervised by board-certified child and adolescent psychiatrists.

Parents of patients aged <18 years completed the Behavior Rating Inventory of Executive Function (BRIEF)[12] Parent Report; patients aged ≥18 years completed the BRIEF-Adult Self-Report.[13] These are standardized instruments with psychometric properties that assess behaviors associated with executive function deficits.

Estimates of IQ were based on the Vocabulary and Matrices subtests of the Wechsler[14] Abbreviated Scale of Intelligence (WASI). The WASI was not administered to patients who completed the study remotely. Socioeconomic status was measured using the 5-point Hollingshead scale.[15]

TBI-specific assessment measures

Questions from the British Columbia postconcussion symptom inventory (BC-PSI) scale were adapted for this study to assess postconcussive symptoms and their duration.[16] Specific questions included mechanism of injury, details of the injury, and duration and severity of postconcussive symptoms. Severity of each symptom was rated from 0 (did not have this symptom at all) to 5 (very severe problem). Patients reported details of up to 3 concussions. We used the BC-PSI from the most severe concussion if a patient reported more than one.

The immediate postconcussion assessment and cognitive testing (ImPACT) was used to assess postconcussive symptoms and cognitive function. This is a 20-minute computerized neuropsychological battery[17] comprising 6 modules measuring attention, memory, reaction time, and processing speed. Each module contributes to 4 composite scores: Verbal Memory, Visual Memory, Reaction Time, and Processing Speed. The ImPACT was not administered to patients who completed the study remotely.

Statistical analysis

This analysis compared SRC patients with ADHD (SRC + ADHD) and SRC patients without ADHD (SRC + No ADHD). Given that children with subthreshold ADHD have similar patterns of impairment as children with full ADHD,[18,19] SRC patients with subthreshold ADHD were included in the SRC + ADHD group. We performed weighted analyses, giving SRC patients with full ADHD and SRC patients without ADHD a weight of 2 and SRC patients with subthreshold ADHD a weight of 1. This weighting gave data from full ADHD patients more influence than data from the subthreshold ADHD patients within the SRC + ADHD group but equal influence in analysis when compared with controls. We reported weighted means and test statistics for continuous outcomes (with the exception of demographics and ADHD onset vs TBI onset) and unweighted percentages and weighted test statistics for binary outcomes.

We compared demographics between the SRC + ADHD and SRC + No ADHD groups using the Student *t* test for continuous measures, Kruskal-Wallis test for ordinal measures, and Pearson χ^2 test or the Fisher exact test (when expected cell counts were <5) for binary outcomes. Within patient-comparisons were made using paired *t* tests. All other outcomes were analyzed using linear, logistic, ordered logistic, or negative binomial regression, as appropriate. We reported effect sizes for outcomes, calculating the standardized mean difference (SMD), using Cohen d, and 95% confidence intervals (CIs) for continuous outcomes and odds ratios (ORs) and 95% CIs for binary outcomes. All analyses were 2-tailed and performed at the 0.05 alpha level using Stata (version 15.1).

Data availability

Any data not published within the article is available and will be shared upon request from any qualified investigator.

Results

ADHD in student athletes with SRC

Twenty-three (29%) of the 79 patients with SRC had full ADHD. Broken down by age group, 50% (11/22) of SRC patients aged ≤17 years and 21% (12/57) of SRC patients aged >17 years had full ADHD (figure 1A). These rates are almost 5 times the US population rate of ADHD, estimated as 11% in children 4–17 years of age and 4.4% in adults 18–44 years.[20,21]

In addition, 24 (30%) of the 79 patients with SRC had subthreshold ADHD, according to the criteria described above. Of those with a subthreshold ADHD (N = 24), 38% had an onset ≥12 years of age (mean age at onset: 5.5 ± 2.5 years vs 8.7 ± 4.7 years for full and subthreshold, respectively; t_{43} = −2.84, p = 0.007) and 79% had insufficient symptoms (<6 of 9 symptoms on each of the ADHD modules, Inattention and Hyperactivity, and ≥4 but <6 of 9 symptoms on at least one of the modules) (mean number of symptoms: 12.2 ± 3.5 symptoms vs 6.2 ± 1.8 symptoms for full and subthreshold, respectively; t_{43} = 7.36, p < 0.001).

Demographic Characteristics

Comparisons were made between SRC patients with full or subthreshold ADHD (SRC + ADHD; N = 47) and SRC patients without ADHD (SRC + No ADHD; N = 32). As shown in table 1, the SRC + No ADHD group had a higher representation of females compared with the SRC + ADHD group (table 1). There were no other meaningful sociodemographic differences between the groups (table 1). Given the differences in sex, we controlled for it in all subsequent analyses.

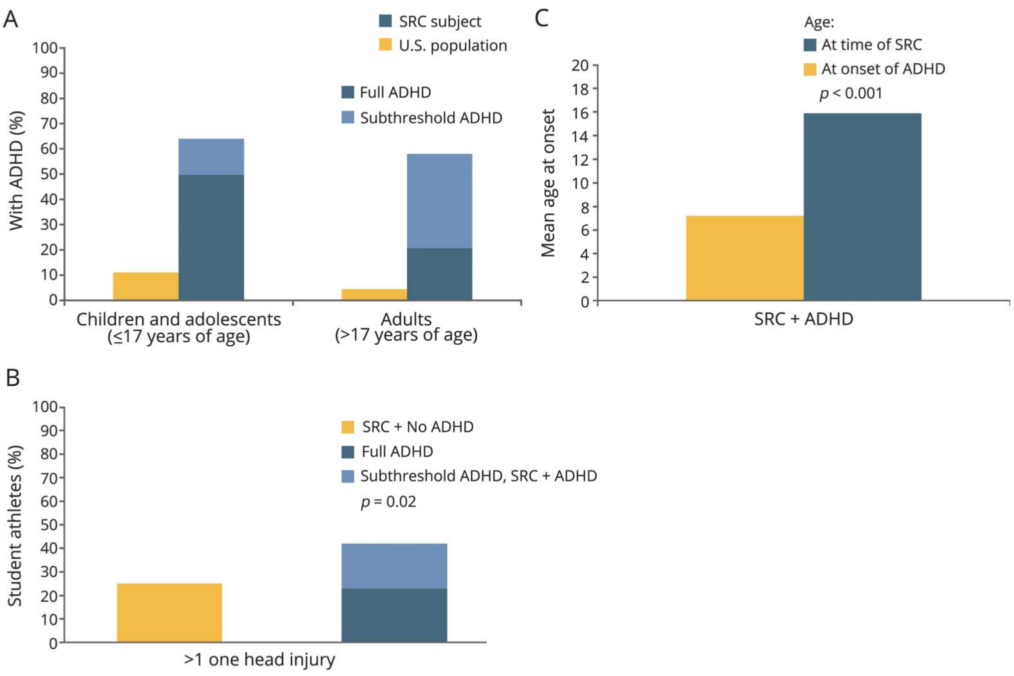
Clinical correlates of SRC in student athletes with and without ADHD

Among the SRC + ADHD patients, the age at onset of ADHD was younger than the age at the time of SRC (t_{41} = −11.45, p < 0.001) (figure 1B). In all but one case, the age at onset of ADHD preceded the age at the time of SRC. The one exclusionary case received a diagnosis of subthreshold ADHD at the same age as sustaining an SRC. A higher percentage of patients with SRC + ADHD sustained more than one head injury (χ^2 = 5.14, p = 0.02) (figure 1C). In addition, there were substantial differences between the groups in the time elapsed since their oldest head injury (SRC + ADHD: 3.0 ± 2.0 years vs SRC + No ADHD: 4.3 ± 3.5 years; t_{115} = −2.46, p = 0.02) and the time since their most recent head injury (SRC + ADHD: 2.7 ± 2.8 years vs SRC + No ADHD: 4.2 ± 4.0 years; t_{115} = −2.33, p = 0.02).

Concussion symptoms and severity in SRC student athletes with and without ADHD

Patients with SRC + ADHD reported more severe headaches (SMD = −0.44; 95% CI: −0.89 to 0.0008), balance problems (SMD = −0.43; 95% CI: −0.87 to 0.02), sleeping more than usual (SMD = −0.47; 95% CI: −0.92 to −0.03), drowsiness (SMD = −0.64; 95% CI: −1.08 to −0.18), sensitivity to noise (SMD = −0.68; 95% CI: −1.13 to −0.23), irritability (SMD = −0.66; 95% CI: −1.11 to −0.21), nervousness (SMD = −0.61; 95% CI: −1.05 to −0.15), feeling slowed down (SMD = −0.47; 95% CI: −0.91 to −0.02), and difficulty concentrating (SMD = −0.85; 95% CI:

Figure 1 Clinical correlates of SRC in student athletes with and without ADHD



(A) Rates of ADHD in the US population and the SRC patients from this study. (B) Mean age at onset of ADHD and SRC for student athletes with SRC + ADHD. (C) Percent of student athletes in the SRC + No ADHD and SRC + ADHD groups who have sustained more than one head injury. ADHD = attention deficit hyperactivity disorder; SRC = sport-related concussion.

−1.30 to −0.39) compared with patients with SRC + No ADHD on the ImPACT symptom scores (table 2).

The ImPACT Total Symptom composite score was also higher in the SRC + ADHD group than in the SRC + No ADHD group (SMD = −0.71, 95% CI: −1.16 to −0.26; $z = 3.37$, $p < 0.001$) (figure 2A) and remained so when we compared the percent of patients in each group with Total Symptom composite scores above the median split of 5 (OR = 5.02, 95% CI: 1.44 to 17.54; $\chi^2 = 6.39$, $p = 0.01$) (figure 2B). In contrast, there were no differences between the 2 groups in any of the other composite scores on ImPACT (table 3).

Table 1 Demographic characteristics of student athletes with SRC without ADHD and student athletes with SRC with ADHD

	SRC + No ADHD, N = 32[a]	SRC + ADHD, N = 47[a]		
	Mean ± SD	Mean ± SD	Test statistic	*p* Value
Age	19.6 ± 3.4	19.4 ± 3.3	$t_{77} = 0.32$	0.75
Socioeconomic status	1.5 ± 0.7	1.5 ± 0.6	$\chi^2 = 0.003$	0.96
Full IQ	116.7 ± 13.4	110.7 ± 11.8	$t_{47} = -1.62$	0.11
	SRC + No ADHD, N = 32[a]	**SRC + ADHD, N = 47[a]**		
	N (%)	N (%)	Test statistic	*p* Value
Sex (% male)	7 (22)	24 (51)	$\chi^2 = 6.80$	0.009
Intact (% intact)	25 (89)	33 (75)	$\chi^2 = 2.23$	0.14
Race (% white)	30 (94)	40 (85)	Exact	0.30

Abbreviations: ADHD = attention deficit hyperactivity disorder; SRC = sport-related concussion.
[a] Socioeconomic status: SRC + No ADHD: N = 1 missing; SRC + ADHD: N = 6 missing; Full IQ: SRC + No ADHD: N = 13 missing; SRC + ADHD: N = 17 missing; Intact: SRC + No ADHD: N = 4 missing; SRC + ADHD: N = 3 missing.

Table 2 Immediate postconcussion assessment and cognitive testing symptom severity in student athletes with SRC + No ADHD and SRC + ADHD (0 = not experiencing to 6 = very severe)

	SRC + No ADHD, N = 19	SRC + ADHD, N = 26		
	Mean ± SD	Mean ± SD	Test statistic	*p* Value
Headaches	0.32 ± 0.81	0.81 ± 1.31	z = 2.91	0.004
Nausea	0	0.17 ± 0.54	NA	NA
Vomiting	0	0	NA	NA
Balance problems	0.11 ± 0.45	0.52 ± 1.25	z = 2.51	0.01
Dizziness	0.11 ± 0.31	0.33 ± 1.12	z = 1.25	0.21
Fatigue	0.95 ± 1.33	1.02 ± 1.54	z = 0.35	0.72
Trouble falling asleep	0.26 ± 0.64	1.07 ± 1.79	z = 1.79	0.07
Sleeping more than usual	0.32 ± 0.66	0.79 ± 1.22	z = 2.69	0.007
Sleeping less than usual	0.21 ± 0.62	1.05 ± 1.62	z = 1.63	0.10
Drowsiness	0.42 ± 0.89	1.19 ± 1.44	z = 2.43	0.02
Sensitivity to light	0.42 ± 0.89	0.64 ± 1.14	z = 1.97	0.05
Sensitivity to noise	0.05 ± 0.23	0.43 ± 0.74	z = 3.04	0.002
Irritability	0.11 ± 0.45	0.81 ± 1.40	z = 2.99	0.003
Sadness	0.21 ± 0.53	0.76 ± 1.39	z = 0.76	0.45
Nervousness	0.11 ± 0.45	0.79 ± 1.49	z = 3.15	0.002
Feeling more emotional	0.37 ± 0.67	0.88 ± 1.56	z = 1.50	0.13
Numbness or tingling	0.05 ± 0.23	0.19 ± 0.71	z = 0.46	0.65
Feeling slowed down	0.26 ± 0.79	0.83 ± 1.50	z = 3.03	0.002
Feeling mentally foggy	0.68 ± 1.09	0.93 ± 1.63	z = 1.09	0.28
Difficulty concentrating	0.32 ± 0.81	1.36 ± 1.51	z = 3.87	<0.001
Difficulty remembering	0.32 ± 0.66	0.90 ± 1.39	z = 1.61	0.11
Visual problems	0.11 ± 0.45	0.19 ± 0.55	z = 1.65	0.10

Abbreviations: ADHD = attention deficit hyperactivity disorder; NA = not applicable; SRC = sport-related concussion.

Findings from an adapted version of the BC-PSI showed a higher percentage of SRC + ADHD patients with more than 5 severe symptoms (severity > 2), as determined by the median split, compared with SRC + No ADHD patients (OR = 3.73, 95% CI: 1.50 to 9.32; z = 2.83, p = 0.005) (figure 2C). Patients in the SRC + ADHD group had more symptoms with severity rated above zero compared with SRC + No ADHD (SRC + ADHD: 8.8 ± 3.8 vs SRC + No ADHD: 6.7 ± 4.0; SMD = −0.54, 95% CI: −0.93 to −0.14; z = 3.27, p = 0.001). In contrast, there were no meaningful differences in the adapted version of the BC-PSI between the SRC + ADHD and the SRC + No ADHD patients in average symptom severity (SRC + ADHD: 1.8 ± 1.0 vs SRC + No ADHD: 1.5 ± 1.0; t = 0.97, p = 0.33) or percent of patients with more than half of the symptoms registered (severity > 0) (SRC + ADHD: 58% vs SRC + No ADHD: 60%; z = 0.39, p = 0.70).

Executive functioning in SRC student athletes with and without ADHD

Patients with SRC + ADHD had more impaired BRIEF scores compared with those with SRC + No ADHD on all but one of the BRIEF subscales (p < 0.05 for all subscales except Emotional Control; SMDs ranged from −1.17 to −0.77 for each subscale except for Shifting, which had SMD = −0.43) (figure 3).

Discussion

We set out to clarify the relationship between ADHD and SRC by conducting a study of student athletes with a history of SRC. Findings revealed that: (1) ADHD was over-represented in student athletes with SRC, (2) the age at onset of ADHD was earlier than the date of the SRC, (3) ADHD

Our results suggest that athletes with subthreshold ADHD represent a clinically important at-risk group with similar vulnerabilities as those with full ADHD.

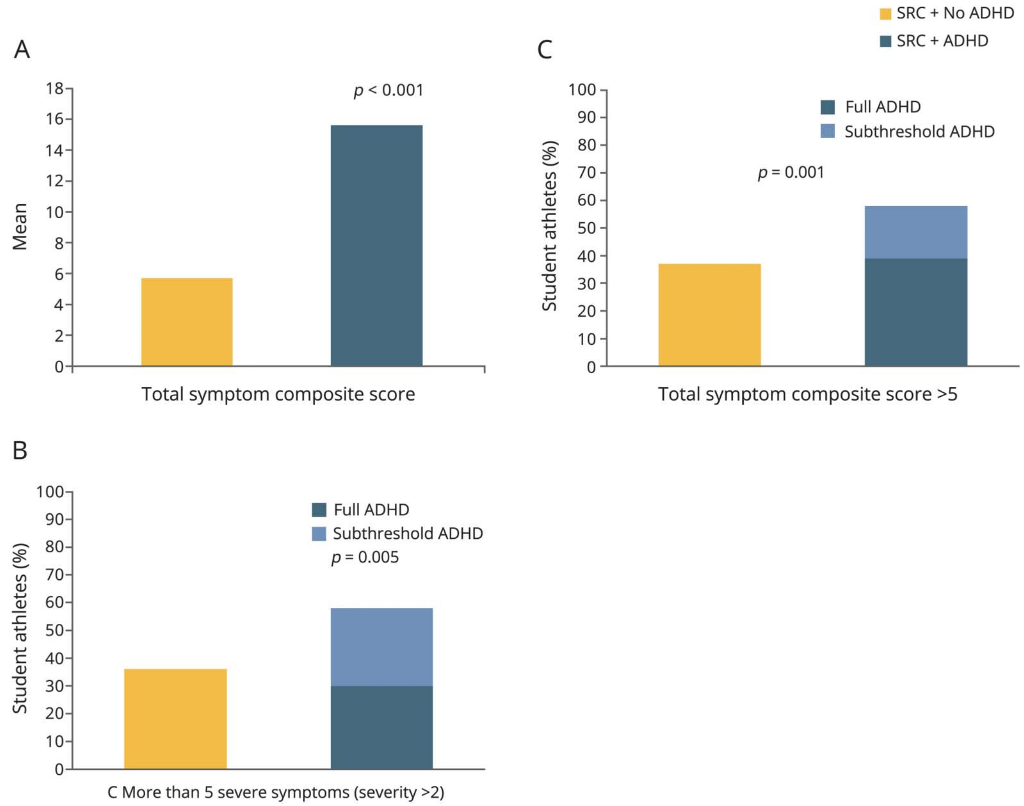
increased the risk of sustaining more than one SRC, and (4) athletes with ADHD reported more severe concussion symptoms than athletes without ADHD. Together, these findings support the study hypothesis and suggest that ADHD is an antecedent risk factor for SRC, is a risk factor for sustaining multiple head injuries, and contributes to complicate recovery from SRC.

In all but 1 case, ADHD preceded the first concussive event, strongly supporting the hypothesis that ADHD is an antecedent risk factor for SRC and not a secondary consequence of SRC. Although this conclusion agrees with the finding of our previous study,[6] the literature on the directionality of effect between ADHD and TBI is mixed.[22–24] For example, Max et al.[24] found that children with TBI developed ADHD; however, this finding was dependent on TBI severity with secondary ADHD correlating with more severe TBI. Conversely, in a murine model, mTBI is associated with the development of inattention, impulsivity, hyperactivity, and ADHD-like symptoms.[25] More work is needed to elucidate the directionality of effect between ADHD and SRC and to determine which ADHD symptoms are commonly associated with SRC.

Our finding that student athletes with ADHD were more likely to sustain multiple (>1) head injuries than athletes without ADHD is consistent with the literature. Data from high school athletes (24.5% with >1 concussion)[26] and collegiate athletes (OR 2.93 for ≥3 concussions) showed that those with ADHD had a greater history of SRC.[27]

Also, consistent with the literature is our finding showing that student athletes with ADHD and history of SRC have higher scores (more symptomatic) on the postconcussive symptom

Figure 2 Concussion symptoms and severity in SRC student athletes with and without ADHD



(A) Immediate postconcussion assessment and cognitive testing (ImPACT) and adapted British Columbia postconcussion symptom inventory (BC-PSI) results for student athletes with SRC + No ADHD and SRC + ADHD. Total symptom composite score on the ImPACT. (B) ImPACT and adapted BC-PSI results for student athletes with SRC + No ADHD and SRC + ADHD. Percent of patients with a total symptom composite score >5 on the ImPACT as determined by the median split. (C) ImPACT and adapted BC-PSI results for student athletes with SRC + No ADHD and SRC + ADHD. Percent of patients with >5 severe symptoms (severity >2) on the adapted version of the BC-PSI as determined by the median split. ADHD = attention deficit hyperactivity disorder; SRC = sport-related concussion.

Table 3 Immediate postconcussion assessment and cognitive testing composite scores for student athletes with SRC + No ADHD and SRC + ADHD

	SRC + No ADHD, N = 19	SRC + ADHD, N = 26		
	Mean ± SD	Mean ± SD	Test statistic	*p* Value
Visual memory composite (percentile)	73.2 ± 24.3	64.3 ± 29.3	$t_{76} = -0.76$	0.45
Visual motor speed composite (percentile)	57.4 ± 27.0	52.2 ± 25.5	$t_{76} = -1.21$	0.23
Reaction time composite (percentile)	48.7 ± 29.0	46.5 ± 27.4	$t_{76} = -1.15$	0.25
Impulse control composite	5.5 ± 3.6	6.8 ± 4.4	$z = 0.68$	0.50
Cognitive efficiency index	0.39 ± 0.16	0.37 ± 0.13	$t_{77} = -0.21$	0.83

Abbreviations: ADHD = attention deficit hyperactivity disorder; SRC = sport-related concussion.

inventory on ImPACT than those without ADHD. This finding suggests that patients with ADHD may have more severe injury presentation and more complicated course of recovery.

Although we did not observe meaningful differences on the cognitive function portion of the ImPACT between patients with and without ADHD, there were deficits in executive function in those with ADHD. Athletes with SRC and ADHD performed markedly worse in almost every subscale of the BRIEF compared with athletes without ADHD. This finding is consistent with the literature that shows that patients with mTBI and ADHD performed poorly on measures of executive functions, such as problem solving, verbal learning, memory,[28,29] and processing speed.[30] In contrast, the literature is not clear as to the effect of ADHD on baseline ImPACT composite scores or validity measures.[31–33] In our study, postinjury ImPACT composite scores and cognitive efficiency index were not different between groups. More work is needed to further clarify the effect of ADHD on cognition after SRC.

Our findings of high representation of females in the SRC group is consistent with the literature showing that females are more likely to report SRC, and they are more likely to have a complicated course of recovery.[34,35] Although the reasons for the overrepresentation of females remains unclear and is likely multifactorial, it is possible that females may be more vulnerable to SRC or that females are more likely to share their experience of concussion.

Figure 3 Executive functioning in SRC student athletes with and without ADHD

Behavior rating inventory of executive functioning (BRIEF) subscale scores of student athletes with SRC + No ADHD and SRC + ADHD. Standardized mean difference (95% confidence interval) for each significant subscale: inhibit: −1.17 (−1.55 to −0.78); shift: −0.43 (−0.79 to −0.07); self-monitoring: −0.77 (−1.14 to −0.40); initiate: −0.77 (−1.14 to −0.04); working memory: −1.18 (−1.57 to −0.80); plan/organize: −0.94 (−1.32 to −0.57); organize materials: −0.88 (−1.25 to −0.50); MI: −1.05 (−1.43 to −0.67); BRI: −0.78 (−1.15 to −0.41); GEC: −1.07 (−1.45 to −0.69). ADHD = attention deficit hyperactivity disorder; BRI = Behavioral Regulation Index; GEC = Global Executive Composite; MI = Metacognition Index; SRC = sport related concussion.

About half of athletes in the SRC and ADHD cohort had subthreshold ADHD. Although subthreshold ADHD is increasingly recognized as a serious clinical problem,[18] studies of SRC do not commonly assess subthreshold ADHD. Clinical relevance of subthreshold ADHD has been recently evaluated in a systematic literature review and meta-analysis[36] and in a data study from our group.[37] These studies clearly emphasize that patients with subthreshold ADHD have a similar level of morbidity and dysfunction as those with the full ADHD and subthreshold ADHD is a predictor of developing full ADHD. Thus, our results suggest that athletes with subthreshold ADHD represent a clinically important at-risk group with similar vulnerabilities as those with full ADHD. Although more work is needed to further evaluate this issue, our finding raises the possibility that student athletes with subthreshold ADHD may be subject to similar difficulties in recovery from SRC as those observed in athletes with full ADHD.

If replicated, the results of this study may have important clinical and public health importance in the care of youth with ADHD that participate in sport. If, as our data suggest, ADHD is an antecedent risk factor for SRC, more efforts are needed to screen student athletes for ADHD and determine whether such athletes may require clinical evaluation and treatment for ADHD. Treatment of ADHD may be a useful strategy for prevention of SRC and mitigation of complications in recovery from SRC. Although prospective data are lacking, this hypothesis is supported by a retrospective analysis of children with treated vs untreated ADHD showing a lower risk of head injury in children treated with stimulants.[5] At this time, there are no specific recommendations for the use of stimulants in student athletes with ADHD. However, stimulants have been shown to improve participation and performance in school and sports in youth with ADHD and have been proposed as a treatment of mild neurotrauma.[38–40] More work is needed to evaluate whether treatment of ADHD may be a useful preventive strategy or help with recovery from SRC.

Our findings need to be viewed considering some methodological limitations. The sample size was relatively small, limiting our statistical power to detect small effects. The study population consisted of mostly white patients, limiting the generalizability of our findings to other ethnic groups. The diagnosis of ADHD was based on completing a structured diagnostic interview systematically assessing for symptoms of ADHD. Although retrospective assessment could be subject to recall bias, all evaluations of ADHD are based on similarly conducted retrospective evaluations assessing signs and symptoms. Although we included patients with subthreshold ADHD, we weighted these patients differently than those with full ADHD. Finally, the effect of ADHD on performance on ImPACT may be a potential confounder; however, normative data for those with ADHD are lacking.

Although our findings suggest that patients with SRC and a concomitant diagnosis of ADHD may have a more complicated course of concussion recovery, the causal nature of the effect could not be fully determined. Ultimately, a prospective longitudinal study of student athletes with ADHD is needed to determine a causal relationship between ADHD and SRC. However, if replicated, these findings would support further efforts aimed at screening for ADHD in student athletes and examining whether diagnosing and treating ADHD in student athletes may mitigate the risk of SRC and its complications.

Author contributions

M.A. Iaccarino: study concept/design, analysis/interpretation of data, drafting/revising the manuscript. M. Fitzgerald, A. Pulli, and K.Y. Woodworth: analysis/interpretation of data, drafting/revising the manuscript. T.J. Spencer, R. Zafonte, and J. Biederman: study concept/design, analysis/interpretation of data, drafting/revising the manuscript.

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Disclosure

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TAKE-HOME POINTS

- → ADHD is overrepresented in student athletes compared with the general population.
- → Student athletes with a diagnosis of ADHD report multiple SRCs.
- → ADHD may contribute to a protracted recovery from SRC.
- → More efforts are needed to screen for ADHD in student athletes engaged in contact sports.
- → More work is needed to evaluate whether diagnosis and treatment of ADHD will have preventive effects on SRC or facilitate recovery.

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