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High School Athletes With ADHD and Learning Difficulties Have a Greater Lifetime Concussion History

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Abstract

Objective: Examine lifetime history of concussions in adolescents who have developmental problems in comparison with those with no developmental problems. **Method:** Thirty-two thousand four hundred eighty-seven adolescent athletes completed baseline/pre-season evaluations. Based on self-reported histories, athletes were divided into four groups: ADHD only, ADHD and learning difficulties (LD), LD only, and controls. **Results:** Athletes with ADHD, LD, or ADHD plus LD reported a greater prevalence of prior concussions than athletes without these developmental conditions (*p*s < .05). When adjusting for sex differences in concussion prevalence rates (boys are greater than girls), there was an increase in prevalence of prior injuries in those with ADHD, and ADHD plus learning difficulties compared with those with LD only. This pattern was found for both girls and boys. There was no additive effect of having both conditions. **Conclusion:** Developmental conditions in adolescent athletes, such as ADHD and learning difficulties, are associated with a greater prevalence rate of prior concussion. *(J. of Att. Dis. 2020; 24(8) 1095-1101)*

Keywords

adolescent ADHD, concussion, learning disabilities, athletes

Introduction

ADHD is a neurodevelopmental disorder with a strong genetic component (Franke, Neale, & Faraone, 2009; Gizer, Ficks, & Waldman, 2009). The relationship between ADHD and traumatic brain injury (TBI) is complex, bidirectional, and not well understood. Children who sustain a *moderate or severe* TBI are at increased risk for having pre-injury ADHD (Gerring et al., 2000) and being diagnosed with new-onset ADHD in the first 2 years following injury (Bloom et al., 2001; Max et al., 2005a, 2005b). In children who have genetic and/or environmental risk factors for ADHD, the extent to which a moderate or severe TBI triggers a latent condition, exacerbates a manifest condition, or is unrelated to the nature and course of ADHD is unknown.

ADHD is characterized, in part, by both inattention and impulsivity, which could place children, adolescents, and adults at increased risk for accidental injury. In fact, there is evidence that individuals with ADHD have higher bodily injury rates than the general population (Kaya et al., 2008; Lam, 2002; Merrill, Lyon, Baker, & Gren, 2009; Pastor & Reuben, 2006; Sabuncuoglu, Taser, & Berkem, 2005; Shilon, Pollak, Aran, Shaked, & Gross-Tsur, 2012; Swensen et al., 2004). Therefore, it is reasonable to assume that children and adolescents with ADHD would be at increased risk for head trauma and mild traumatic brain injury (MTBI). The relation between ADHD and MTBI is not well understood (Adeyemo et al., 2014), and the literature on MTBI injury rates in those with ADHD is mixed. Fann and colleagues (2002) conducted a case control study using a large health maintenance organization database. They examined the rate of psychiatric diagnoses in the year prior to sustaining a TBI (89.8% identified as MTBI), compared with control participants who did not sustain a TBI. Of the 1,440 who sustained a TBI, 14 (1%) had a chart diagnosis of pre-existing ADHD compared with

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48/4,320 (1.1%) of control participants. Fann and colleagues (2004) also conducted a prospective cohort study using a large health maintenance organization database. The rate of pre-injury ADHD diagnoses in those with MTBI was 0.4% compared with 0.5% in the control group. These two studies did not reveal a significant association between ADHD and risk for an MTBI. Similarly, in two large chart review studies of child psychiatry inpatient (Max, Sharma, & Qurashi, 1997) and outpatient (Max & Dunisch, 1997) samples, those with a history of MTBI were not more likely to have ADHD. Two longitudinal cohort studies revealed mixed results. Bijur, Haslum, and Golding (1990) examined a longitudinal cohort of children and reported that hyperactivity at age 5 was not significantly associated with future risk for head injury. In contrast, McKinlay, Grace, Horwood, Fergusson, and MacFarlane (2009) examined a longitudinal birth cohort and reported that adolescents diagnosed with ADHD were more likely to have sustained an MTBI before the age of 5 than adolescents who did not have ADHD.

Segalowitz and Lawson (1995) conducted a survey study of high school students (5.4% with ADHD), vocational students with learning problems (19.9% with ADHD), and university students (3.4% with ADHD). The rate of "head injury" was greater in those with ADHD. Iverson, Atkins, Zafonte, and Berkner (2016) examined lifetime history of concussion in a sample of more than 6,500 young athletes and found that those with ADHD were significantly more likely to report a history of one (26.1%), two or more (9.8%), and three or more (5.1%) prior concussions compared with those without ADHD (17.1%, 5.5%, and 1.8%, respectively). Boys with and without ADHD had a greater lifetime history of concussions than girls. In a study of National Collegiate Athletic Association (NCAA) Division 1 athletes, 50.4 % of athletes with ADHD reported a history of at least one prior concussion compared with 14.4% of athletes without ADHD (Alosco, Fedor, & Gunstad, 2014). Nelson and colleagues found that having ADHD or a learning disorder in high school and collegiate athletes was associated with 2.93 and 2.08 times the prevalence, respectively, of having three or more prior concussions. These developmental problems were considered separately, and not in combination, in that study (Nelson et al., 2016).

The purpose of this study was to examine lifetime history of concussions in high school students who have developmental problems, such as ADHD, learning difficulties, or both, in comparison with students with no developmental problems. Based on prior research, we hypothesized the following:

Hypothesis 1: High school athletes with ADHD would report a greater history of concussion than those without ADHD.

Hypothesis 2: Boys would report a greater history of concussion than girls, and that those with ADHD would report a greater history of concussion than those without ADHD.

Hypothesis 3: Students with learning difficulties would have a greater history of concussion than those without LD.

Method

Between 2009 and 2013, 33,732 student athletes from Maine completed baseline, preseason testing with ImPACT®. ImPACT® is a computerized program that includes measures of symptom ratings and cognitive functioning intended for concussion management (i.e., athletes' post-injury test scores are compared with their pre-injury scores). As part of the program, students completed a health survey and are asked to self-report: problems with ADHD, diagnosis of a learning disability, repeating one or more years in school, and whether they attended special education classes. Information about the number of diagnosed concussions was also collected. Students who had missing data regarding their concussion history and/or endorsed a history of treatment for epilepsy, meningitis, and/or history of brain surgery were excluded from analyses (N = 1,245, 3.7%). Students completed baseline testing prior to participating in their first sport for that season.

Students were divided into four groups: (a) ADHD (self-reported diagnosis of ADHD, with no other reported learning difficulties), (b) ADHD and learning difficulties (self-reported diagnosis of ADHD and self-reported diagnosis of learning disorder, having repeated one or more years in school, and/or having attended special education classes), (c) learning difficulties (self-reported diagnosis of learning disorder, having repeated one or more years in school, and/or having attended special education classes, with no ADHD), and (d) controls (no reported ADHD or learning difficulties).

Frequency of athletes in each group who reported a past history of one or more, two or more, three or more, and four or more past concussions were computed and analyzed using chi-square tests. Alpha was set a priori at $p < .05$.

Results

The final sample included 32,487 adolescent student athletes between the ages of 13 and 18 years (M = 15.5 years, SD = 1.3 years), including more than 6,500 students reported in a prior study (Iverson et al., 2016). There were 17,582 (54.1%) boys and 14,905 girls (45.9%). For boys, the breakdown of sports played at the time of assessment was as follows: football = 29.6%, soccer = 23.6%, basketball = 11.1%, hockey = 7.4%, lacrosse = 4.8%, track and field and cross-country = 6.2%, wrestling = 3.2%, baseball = 3.9%, and other = 10.2%. For girls, the breakdown of sports played at the time of assessment was as follows: soccer = 27.9%, field

hockey = 17.2%, cheerleading = 13.5%, basketball = 10.8%, track and field and cross-country = 6.6%, lacrosse = 4.7%, softball = 4.1%, volleyball = 3.3%, swimming = 2.2%, ice hockey = 2.1%, and other = 7.6%.

In the total sample, 17.0% reported a history of one or more past concussions, 5.0% reported two or more concussions, 1.8% reported three or more concussions, and 0.7% reported four or more concussions. Stratified by gender, 19.6% of boys and 13.9% of girls reported one or more past concussions, 6.3% of boys and 3.5% of girls reported two or more concussions, 2.3% of boys and 1.2% of girls reported three or more concussions, and 0.9% of boys and 0.4% of girls reported four or more concussions.

See Table 1 for frequency of concussions in student athletes with ADHD, ADHD and learning difficulties, and learning difficulties without ADHD. Compared with control participants, student athletes were more likely to report having one or more prior concussions if they had self-reported ADHD, 24.5%, $\chi^2(1) = 64.72$, $p < .0001$, odds ratio [OR] = 1.69, 95% confidence interval [CI] = [1.48, 1.93]; self-reported ADHD and learning difficulties, 25.8%, $\chi^2(1) = 49.49$, $p < .0001$, OR = 1.81, 95% CI = [1.52, 2.14]; or self-reported learning difficulty but with no diagnosis of ADHD, 19.7%, $\chi^2(1) = 22.32$, $p < .0001$, OR = 1.27, 95% CI = [1.15, 1.41]. Similar results were found with two or more and three or more prior concussions, where those with ADHD, ADHD and learning difficulties, and learning difficulties without ADHD had significantly greater prevalence rates compared with the control group (all ps < .05). Consistent with our first hypothesis, more boys reported having a history of concussion than girls, $\chi^2(1) = 188.29$, $p < .001$, OR = 1.51, 95% CI = [1.43, 1.61]. Further analyses were stratified by sex to consider these differences between boys and girls. Results are presented visually in Figure 1.

Boys

As seen in Figure 1, compared with boys without these developmental problems, boys with self-reported ADHD ($\chi^2(1) = 32.29$, $p < .001$, OR = 1.56, 95% CI = [1.33, 1.82]), self-reported ADHD and learning difficulties ($\chi^2(1) = 20.56$, $p < .001$, OR = 1.56, 95% CI = [1.28, 1.90]), or self-reported learning difficulty but with no diagnosis of ADHD, $\chi^2(1) = 9.22$, $p = .002$, OR = 1.21, 95% CI = [1.07, 1.36], were more likely to report having a history of concussion. Across all three groups with developmental problems, the prevalence of two or more and three or more prior concussions was greater compared with boys in the control group (all ps < .05; see Table 1).

The effects of each developmental condition (ADHD only, ADHD and learning difficulties, and learning difficulties only) on concussion history were considered in the boys. There was a significant effect of developmental group (i.e., ADHD only, ADHD and learning difficulties, and learning difficulties only) in boys regarding prior concussion history, $\chi^2(2) = 54.79$, $p < .001$. There was no difference between those with only ADHD and those with both ADHD and learning difficulties in concussion history, $\chi^2(1) = 0.0$, $p = .98$. However, those with ADHD, $\chi^2(1) = 7.21$, $p < .01$, OR = 1.29, 95% CI = [1.07, 1.56], and those with ADHD plus learning difficulties, $\chi^2(1) = 5.25$, $p = .02$, OR = 1.29, 95% CI = [1.03, 1.62], had significantly higher prevalence rates of prior concussions compared with those boys who reported only learning difficulty but no ADHD. These analyses within the boys who have developmental conditions suggest a higher prevalence of prior concussions in those with either ADHD or learning difficulties, but having both ADHD and learning difficulties does not appear to result in an additive effect on concussion rates.

Girls

Girls reported more prior concussions if they had self-reported ADHD, $\chi^2(1, 13{,}755) = 17.99$, $p < .0001$, OR = 1.68, 95% CI = [1.31, 2.16]; self-reported ADHD and learning difficulties, $\chi^2(1) = 18.83$, $p < .0001$, OR = 2.05, 95% CI = [1.45, 2.90]; or self-reported learning difficulty but no diagnosis of ADHD, $\chi^2(1, 14{,}293) = 4.85$, $p = .03$, OR = 1.22, 95% CI = [1.02, 1.47], when compared with the control sample of girls. Girls with any history of ADHD (only ADHD or ADHD plus learning difficulties) also endorsed having significantly greater rates of multiple past concussions (two or more and three or more) compared with the control group of girls (all ps < .05). Significantly more girls with only learning difficulties (but no ADHD) reported having three or more prior concussions compared with the girls with no developmental problems (p = .02), however, there were no differences in the endorsement rates for two or more prior concussions ($p > .05$).

The effects of each developmental condition (ADHD only, ADHD and learning difficulties, and learning difficulties only) on concussion history were considered in the girls. There were significantly different prevalence rates of having one or more prior concussions across the three developmental groups in girls, $\chi^2(2) = 38.86$, $p < .001$. There were no differences in the rates of one or more concussions between those with only ADHD and those with both ADHD and learning difficulties, $\chi^2(1) = 0.95$, $p = .33$. However, girls with ADHD only, $\chi^2(1) = 4.49$, $p = .03$, OR = 1.37, 95% CI = [1.01, 1.86], and those with ADHD plus learning difficulties, $\chi^2(1) = 7.58$, $p = .006$, OR = 1.68, 95% CI = [1.14, 2.47], had significantly greater prevalence rates of prior concussions compared with those who report only learning difficulty but no ADHD. Similar to the analyses with the boys, the results with the girls suggest that those who have developmental conditions have a greater prevalence of prior concussions, and that having ADHD and learning difficulties does not appear to have an additive effect on number of past concussions.

Table 1. Frequency of Concussion in Student Athletes With ADHD, ADHD and Learning Difficulties, and Learning Difficulties.

		Number of prior self-reported concussions					
		1+		2+		3+	
	N	*f*	%	*f*	%	*f*	%
Total athletes with no ADHD or learning difficulties	27,705	4,472	16.1	1,266	4.6	425	1.5
Boys	14,367	2,686	18.7	828	5.8	295	2.1
Girls	13,338	1,786	13.4	438	3.3	130	1.0
ADHD	1,324	325	24.5	124	9.4	59	4.5
ADHD with meds	437	136	31.1	59	13.5	25	5.7
ADHD with no meds	887	189	21.3	65	7.3	34	3.8
Boys with ADHD	907	239	26.4	95	10.5	41	4.5
Girls with ADHD	417	86	20.6	29	7.0	18	4.3
ADHD and learning difficulties	748	193	25.8	80	10.7	39	5.2
ADHD and learning difficulties with meds	229	70	30.6	24	10.4	12	5.2
ADHD and learning difficulties no meds	519	123	23.7	56	10.8	27	5.2
Boys with ADHD and learning difficulties	553	146	26.4	59	10.7	29	5.2
Girls with ADHD and learning difficulties	195	47	24.1	21	10.8	10	5.1
Learning difficulties	2,710	533	19.7	159	5.9	61	2.3
Boys with learning difficulties	1,755	381	21.7	126	7.2	44	2.4
Girls with learning difficulties	955	152	15.9	33	3.5	17	1.8

Note. *f* = frequency; % = percentage; meds = self-reported ADHD medications; no meds = the student left this question blank indicating either a failure to record current medications or that they are not taking medications; learning difficulties = any reported learning difficulty, including diagnosed learning disorder, repeat one or more years in school, and/or attended special education classes.

Information regarding ADHD medication use was available for 32.1% (666/2,072) of individuals with self-reported ADHD and ADHD plus learning difficulties (see Table 1). The remainder of individuals either did not record information regarding ADHD medications during the survey or were not taking medications. Within the group of students with self-reported ADHD only, those who reported taking ADHD medications reported a history of one or more, $\chi^2(1) = 15.22$, $p < .001$, OR = 1.67, 95% CI = [1.28, 2.18], past concussions more frequently than those with ADHD who did not record their ADHD medications or were not taking medications. Students with self-reported ADHD and learning difficulties who were also taking ADHD medications reported a history of one or more past concussions more frequently than those with ADHD and learning difficulties but who did not record their ADHD medications or were not taking medications, $\chi^2(1, 748) = 3.92$, $p = .05$, OR = 1.42, 95% CI = [0.99, 2.03].

Discussion

This is the largest study to date examining lifetime concussion history in high school athletes, including those student athletes with a history of ADHD, learning difficulties, or both. Because of this large sample size, we were also able to examine the relationships between these developmental conditions and history of concussion separately in boys and girls. Boys are more likely to have a prior history of concussion than girls, and students with ADHD, learning difficulties, or both have a greater lifetime history of concussion than students who do not have these developmental problems. For example, 16% of control participants had a history of one or more prior concussions compared with approximately 24% to 26% of students with ADHD and 19.7% of those with learning difficulties (but no ADHD). Overall, the literature on the relation between ADHD and MTBI is mixed. Some researchers have reported an association (Iverson et al., 2016; Massagli et al., 2004; McKinlay et al., 2009; Segalowitz & Lawson, 1995) and some have not (Fann et al., 2004; Keenan, Hall, & Marshall, 2008; Max & Dunisch, 1997, 2004; Max & Dunisch, 1997). The present results are similar to prior survey studies of high school and university students from Canada (1995), and high school students from Maine (Iverson et al., 2016), who have reported an association between ADHD and lifetime history of concussion. It is possible that the characteristic features of ADHD, such as impulsivity and executive dysfunction, are associated with increased risk of physical injuries in general, including injuries to the head resulting in concussion.

In both boys and girls, having a learning difficulty (but no ADHD) was associated with a significantly higher rate of concussions. To date, few studies have examined learning difficulties and concussion history. One recent study found that collegiate athletes with a learning disorder (LD) had 2.08 times the prevalence of three or more past concussions than those without LD (Nelson et al., 2016). It remains

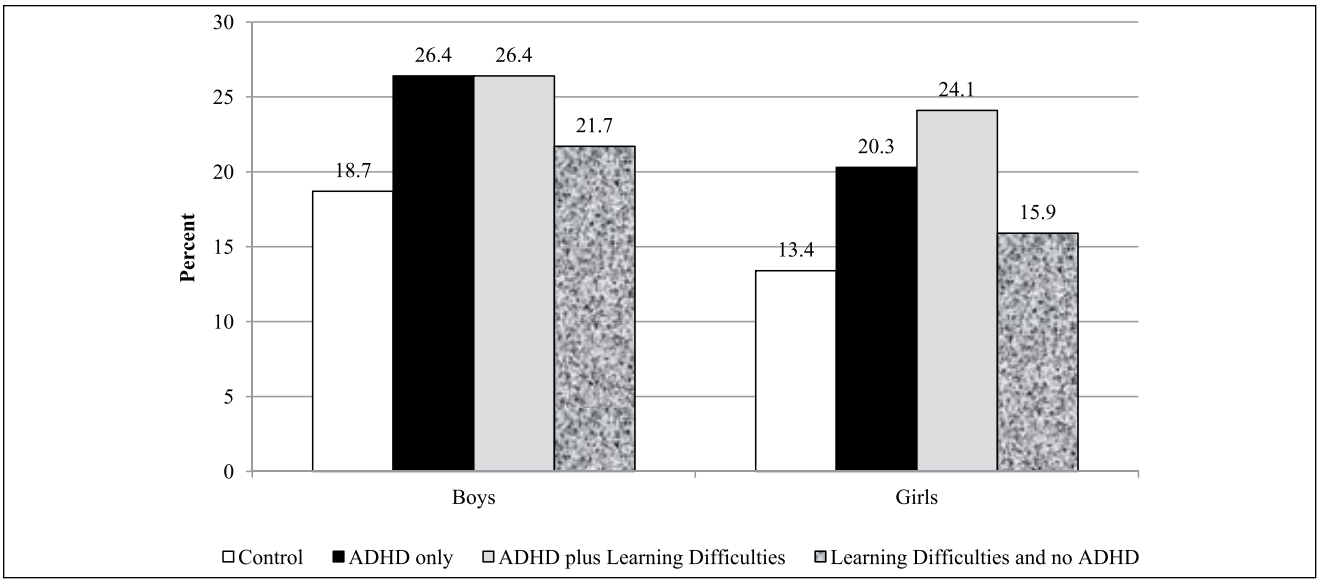

Figure 1. History of having one or more prior concussions for boys and girls, stratified by the presence of attention problems and/or learning difficulties.

unclear why athletes with learning difficulties would have a greater lifetime history of concussion. Evidence of poorer information processing speed and reaction time on computerized cognitive baseline measures has been observed in those with learning difficulties (Elbin et al., 2013). Therefore, one potential hypothesis is that slower processing speed and reaction time may contribute to a higher risk of injury in this population. However, the difference in concussion histories in those with learning difficulties was small—only about 3%—so it is possible that this could be attributed to reporting differences between groups. It is possible that athletes who took the time to endorse having learning difficulties on the history questionnaire might be slightly more likely to carefully review and answer the other questions on the survey (whereas some student athletes might more quickly or carelessly respond with "no" to questions on the health survey).

There is no way of knowing in the present study when the students were diagnosed with ADHD and when they sustained their concussions, so directional inferences cannot be made from this cross-sectional retrospective cohort. Presumably, however, the students with ADHD, by definition, had the condition since early childhood so most of them likely sustained their concussions after they were diagnosed with ADHD. Researchers have reported that some children who sustain a moderate or severe TBI develop new-onset ADHD (termed *secondary ADHD*), but this has not been established in children who have sustained MTBIs (Max et al., 2004).

This study has several methodological limitations. Because this was a cross-sectional, retrospective, survey study, we could not determine (a) when the prior concussions occurred, (b) the mechanisms of injury (e.g., sports vs. daily life), (c) when the diagnosis of ADHD was made, or (d) whether their self-reported histories of concussion or ADHD were accurate. It is reasonable to assume that high school students who reported that they had ADHD and typed in that they were taking a specific medication for ADHD were, in fact, medically diagnosed with the condition. These students had the highest lifetime rate of concussion, adding confidence to the overall conclusion that there is an association between ADHD and risk for concussion.

This study provides strong evidence that high school students with ADHD have a greater lifetime history of concussion than students without ADHD. It is not known, however, whether students with ADHD are more likely to sustain a sport-related concussion. This will need to be determined with future studies. In the present study, students with learning difficulties but no reported ADHD had a modestly greater lifetime history of concussion compared with students with no developmental problems. We do not have an explanation for this finding. Additional research is needed to examine short-, medium-, or long-term outcomes from sport-related concussion in athletes with ADHD, learning difficulties, or both, and to determine the best medical management strategies for returning to school and to sports.

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