Neurocognitive Deficits Associated With ADHD in Athletes: A Systematic Review

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Context: Attention deficit hyperactivity disorder (ADHD) is a common childhood disorder and is frequently diagnosed in young adults. Emerging studies suggest a relationship between ADHD and concussion.

Objective: To determine whether athletes with ADHD are at increased risk for neurocognitive deficits related to concussion risk, symptom reporting, and recovery.

Data Sources: A comprehensive search of PubMed, CINAHL, PsychInfo, and Cochrane Library databases was performed. Studies conducted between 2006 and 2017 were reviewed, although only those between 2013 and 2017 met inclusion criteria.

Study Selection: Studies that examined neurocognitive deficits in adolescent and young adult athletes aged 15 to 19 years who had ADHD and reported using notable neuropsychological evaluation tools were included.

Study Design: Systematic review.

Level of Evidence: Level 2.

Results: A total of 17 studies met the inclusion criteria. The prevalence of ADHD in athletes varied between 4.2% and 8.1%. Overall, athletes with ADHD demonstrated lower scores on neurocognitive testing such as the ImPACT (Immediate Post-Concussion Assessment and Cognitive Test), increased risk for concussion, and increased symptom reporting. There was no evidence that treatment with stimulant medication changed these risks.

Conclusion: ADHD is associated with increased neurocognitive deficits in athletes, although pathophysiology remains unclear. Evidence for stimulant treatment in athletes with ADHD continues to be sparse.

Keywords: ADHD; attention deficit hyperactivity disorder; ADD; athletes; sports

Attention deficit hyperactivity disorder (ADHD) is classically defined as a childhood disorder characterized by symptoms of inattention, hyperactivity, and impulsivity.[3] ADHD is a common diagnosis, with an estimated international prevalence of 7.2% in children younger than 18 years,[42] although rates in the United States have been reported closer to 11%.[44] Between 2003 and 2011, the prevalence of ADHD increased by approximately 42%.[44] A recent survey by the Sports & Fitness Industry Association identified ADHD in 21.47 million children who regularly participate in sports,[26] suggesting that it is similarly common in young athletes. Estimates of ADHD prevalence in adults are considerably lower at 4.4% in the United States and 3.4% internationally.[16,27]

The diagnosis of ADHD is made clinically and is based on DSM-5 (*Diagnostic and Statistical Manual of Mental Disorders*, 5th edition) criteria[3] that apply to both adults and children, including at least 6 months of inattention, hyperactivity, or impulsivity that interferes with function or development, with symptoms presenting prior to the age of 12 years. Until recently, the focus of ADHD in sports has been on the ethics of stimulant use in ADHD treatment, given the risks for potential abuse[45] and performance enhancement.[36] Approximately 5% to 31% of athletes report illicit use of performance-enhancing substances, including stimulants and amphetamines, which are used to treat ADHD.[32]

Emerging studies now demonstrate relationships between ADHD and neurocognitive conditions such as concussion in addition to its known association with other psychiatric disorders. The American Medical Society for Sports Medicine consensus statement on concussion classifies attention deficit disorder as a "concussion modifier" as it is associated with

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The authors report no potential conflicts of interest in the development and publication of this article.

DOI: 10.1177/1941738117751387

increased cognitive dysfunction and prolonged recovery.[20] The National Survey of Children's Health found that compared with those without ADHD, children with ADHD had 16% more anxiety, 13% more depression, and 25% more episodes of conduct disorder.[44] In adults, those with ADHD have more concomitant mood (odds ratio [OR], 2.7-7.5), anxiety (OR, 1.5-5.5), and substance use disorders (OR, 3.0).[1]

We conducted a review of the existing literature to (1) assess for the prevalence of ADHD in athletes compared with the general population, (2) identify specific concussion-related morbidities in athletes diagnosed with ADHD, and (3) determine the effects of stimulants in modifying the risk for concussion.

METHODS

CINAHL, Medline/PubMed, Cochrane Library, and PsychInfo databases were searched for the terms *attention deficit hyperactivity disorder, ADHD, attention deficit disorder, athletes*, and *sports*. Expanded subsearches using the terms *sports concussion, sports-related concussion*, and *TBI* were also performed. We reviewed all studies from January 2006 through March 2017 that evaluated subjects with ADHD who were engaged in any organized sports activity and that included results from studies meeting the 3 objectives as specified above. Studies that did not include athletes, those that did not address the diagnosis of ADHD, and those that did not look at neurocognitive effects of ADHD were excluded. Interpretive or review articles that provided nonspecific recommendations regarding management of ADHD in athletes and without presenting new data addressing our clinical question were not included in this review. Given the emerging nature of this topic, inclusion criteria were purposely kept broad to ensure that we captured relevant data. Published studies were grouped by study type and assessed for relevant key findings, including the prevalence of ADHD in athletes. Extracted data were synthesized qualitatively in both a graphical and narrative format, including the study type, study size, and effect sizes for important results. We were unable to perform quantitative analysis on assimilated data because of the variability in data reporting in the included studies.

RESULTS

A total of 328 articles were identified; 17 studies met our inclusion criteria, addressing the relationship between ADHD, concussions, and neurocognitive performance in athletes (Tables 1 and 2). Three studies published from Medline-indexed presentations were also included. One study, initially published as a presentation,[41] was later published as a full article and was included.[30]

Mean reported age of participants was 15 years (range, 15-19 years).[27] All studies reported a greater percentage of male (52%-89%) versus female participants. Overall, the prevalence of ADHD in athletes varied between 4.2% and 8.1%. Based on our review, we found that ADHD is associated with (1) lower baseline neurocognitive testing, (2) increased symptomatology, (3) increased risk for concussion, and (4) increased recovery time.

Neurocognitive Testing

Eight studies addressed the effects of a prior ADHD diagnosis on baseline and postconcussive neurocognitive testing.[13,14,17,19,30,33,39,46] Of these, 7 studies[13,14,17,19,30,39,46] used scores from the Immediate Post-Concussion Assessment and Cognitive Test (ImPACT), as summarized in Table 3, and 1 study[33] used other neuropsychiatric tests, such as the Hopkins Verbal Learning Test (results not included in Table 3).

These studies consistently demonstrated lower ImPACT composite scores among athletes with ADHD compared with those without. Largely, the differences in scores were statistically significant, with some of the differences persisting after concussion.

Only 1 study[33] assessed the effects of ADHD using other neuropsychiatric tests. Nelson et al[33] found that high school and collegiate athletes with ADHD (n = 144) performed significantly poorer on the Hopkins Verbal Learning Test, Controlled Oral Word Association Test, Trails test, Stroop test, and symbol digit test.

Increased Symptomatology

Six studies[6,9,13,23,33,35] analyzed the effects of ADHD on concussion symptom scoring. Among athletes with mild traumatic brain injury (mTBI), Biederman et al[5] found that, compared with controls (n = 18), those with ADHD (n = 11) reported more fatigue (3.4 vs 1.9, $P = 0.02$), worse concentration (4 vs 1.9, $P = 0.008$), and were more likely to score ≥5 items as severe (100 vs 38.5, $P = 0.01$) on the British Columbia Postconcussion Symptom Inventory, with scores representing intensity (0 = not at all to 5 = very severe problem). At baseline, Nelson et al[33] found that those with ADHD only had higher scores on the Graded Symptom Checklist (GSC), with more difficulty concentrating ($P < 0.001$), fatigue ($P = 0.007$), trouble sleeping ($P < 0.001$), difficulty remembering ($P < 0.001$), balance problems ($P = 0.004$), and feeling "in a fog" ($P = 0.034$). This study also found that athletes with ADHD (n = 144), had overall lower Standardized Assessment of Concussion (SAC) scores (26 vs 27, $P < 0.01$) at baseline compared with those without (n = 3719).

Among athletes with sports-related concussion (SRC), Oliver et al[35] found that those with ADHD had higher scores on the Post-Concussion Symptom Scale (7 vs 5, $P = 0.05$). Athletes with ADHD reported feeling more "dazed" (66% vs 46%, $P = 0.03$), confused (60% vs 36%, $P = 0.0009$), and slowed down (75% vs 55%, $P = 0.03$); they also reported poorer concentration (75% vs 57%, $P = 0.04$). Using the same sample, Blueitt et al[6] found increased symptom provocation during visual ocular motor testing, specifically smooth pursuit (57% vs 36%, $P = 0.02$), horizontal saccade (69% vs 48%, $P = 0.02$), and horizontal vestibular ocular reflex (64% vs 41%, $P = 0.01$), among athletes with ADHD.

In a study of more than 30,000 athletes, Iverson et al[23] found that nonconcussed athletes with ADHD experience more

Table 1. Summary of included cross-sectional studies

Study	Population	ADHD Prevalence, %	Key Points
Iverson et al (2016)[21]	N = 6529 Mean age = 15.9 ± 1.3 y 57.2% male	6.3	Athletes with ADHD have increased risk of concussion. ADHD medication does not affect rate of concussion.
Iverson et al (2015)[23]	N = 31,958 Mean age = 15.5 ± 1.3 y 54.2% male	6.4	ADHD is a strong predictor of concussion-like symptoms in nonconcussed athletes.
Iverson et al (2016)[24]	N = 32,487 Mean age = 15.5 ± 1.3 y 54.1% male	4.0	Athletes with ADHD have increased risk of concussion. ADHD medication increases risk of concussion.
Alosco et al (2016)[2]	N = 139 Mean age not reported 51.7% male	10.1	Athletes with ADHD have increased rates of prior concussion.
Blueitt et al (2016)[6]	N = 223 Mean age = 15 ± 2 y 64.1% male	14.3	Athletes with ADHD have increased symptom provocation postconcussion.
Oliver et al (2016)[35]			Athletes with ADHD have increased symptom reporting postconcussion.
Chin et al (2016)[9]	N = 2018 Mean age = 17.8 ± 1.9 y 76.9% male	7.7	Athletes with ADHD have more symptom reporting and lower SAC scores.
Cook et al (2016)[11]	N = 37,510 Age not reported Sex not reported	6.4	There is no difference in athletes with ADHD who are taking and not taking stimulants on the postconcussion scale.
Hall et al (2017)[19]	N = 486 Mean age = 19.0 ± 1.3 y 63.8% male	8.1	No difference in baseline ImPACT scores between athletes with and without ADHD.
Nelson et al (2016)[33]	N = 8056 Mean age = 18.00 ± 2.07 y 96% male	ADHD only, 3.0 ADHD + LD, 1.0	Athletes with ADHD had increased risk of concussion, lower baseline scores, and increased symptom reporting.

ADHD, attention deficit hyperactivity disorder; ImPACT, Immediate Post-Concussion Assessment and Cognitive Test; LD, learning disability; SAC, Standardized Assessment of Concussion.

Table 2. Summary of included case-control studies

Study	Case[a]	Control[a]	ADHD Prevalence, %	Key Points
Covassin et al (2013)[13]	Concussion (+) ADHD N = 122 Age = 17.6 ± 2.8 y	Concussion (–) ADHD N = 61 Age = 17.6 ± 2.6 y	—	No difference between baseline and postconcussive ImPACT scores between athletes with and without ADHD.
Elbin et al (2013)[14]	ADHD N = 582 Age = 15.32 ± 1.42 y 73% male	No ADHD N = 938 Age = 15.35 ± 1.43 y 54% male	—	Athletes with ADHD performed worse on baseline ImPACT.
Zuckerman et al (2013)[46]	ADHD N = 262 Age = 15.8 ± 1.7 y 77% male	No ADHD N = 407 Age = 15.9 ± 1.7 y 75% male	ADHD only, 4.0 ADHD + LD, 0.8	Athletes with ADHD performed worse on baseline ImPACT.
Mautner et al (2015)[30]	SRC (+) ADHD N = 70 Age = 15.5 y 77.9% male	SRC (–) ADHD N = 70 Age = 15.7 y 74.0% male	11.3	Athletes with ADHD performed worse on baseline ImPACT.
Biederman et al (2015)[5]	Mild TBI 11 with vs 18 without ADHD Age = 17.1 ± 2.9 y 51.7% male	No TBI 22 with vs 58 without ADHD Age = 17 ± 2.7 y 51.7% male	—	Athletes with mild TBI were more likely to have ADHD than athletes without mild TBI. Those with both mild TBI and ADHD reported more symptoms.
Salinas et al (2016)[39]	ADHD N = 256 Age = 15.50 y 73.4% male	No ADHD N = 256 Age = 15.66 y 73.4% male	4.2	Athletes with ADHD performed worse on baseline ImPACT.
Gardner et al (2017)[17]	ADHD N = 277 Age = 15.8 ± 1.93 y 87% male	No ADHD N = 4036 Sex/age matched	—	Athletes with ADHD performed worse on ImPACT at baseline and postconcussion.

ADHD, attention deficit hyperactivity disorder; ImPACT, Immediate Post-Concussion Assessment and Cognitive Test; LD, learning disability; SRC, sports-related concussions; TBI, traumatic brain injury.
[a]Age reported as mean.

Table 3. ImPACT scores comparing neurocognitive testing in athletes with ADHD versus controls[a]

		Verbal Memory	Visual Memory	Visual Motor	Reaction Time	Total Symptom
Elbin et al (2013)[14]	ADHD (n = 582)	83.40 (±9.73)	69.45 (13.24)	35.92 (7.31)	0.60 (0.09)	4.5 (4.83)
	Control (n = 938)	84.46 (9.87)	71.90 (12.96)	37.05 (7.36)	0.59 (0.08)	3.07 (4.05)
	P value	<0.01	<0.01	<0.01	<0.01	<0.01
Zuckerman et al (2013)[46]	ADHD (n = 407)	79.2 (12.8)	69.1 (14.8)	32.3 (6.7)	0.64 (0.09)	7.9 (13)
	Control (n = 262)	84.2 (11.5)	74.6 (12.6)	37.3 (7.5)	0.6 (0.09)	9.4 (13.9)
	P value	<0.001	<0.001	0.001	0.001	<0.001
Mautner et al (2015)[30] post-concussion	ADHD (n = 70)	81.8 (11)	70.2 (17.7)	31.6 (12.5)	0.63 (0.08)	—
	Control (n = 70)	86.4 (10.2)	73.7 (16)	33.4 (12.7)	0.61 (0.09)	—
	P value	0.01	0.2	0.37	0.11	—
Salinas et al (2016)[39]	ADHD (n = 256)	81.18 (11.78)	70.64 (14.53)	35.59 (7.11)	0.61 (0.08)	—
	Control (n = 265)	84.04 (9.50)	72.91 (12.71)	36.86 (6.25)	0.59 (0.08)	—
	P value	0.003	0.61	0.35	0.057	—
Gardner et al (2017)[17] baseline	ADHD (n = 277)	82.0 (10.9)	71.1 (13.0)	34.70 (7.38)	0.63 (0.09)	5.66 (8.41)
	Control (n = 831)	84.6 (9.9)	76.1 (12.6)	37.10 (7.02)	0.61 (0.09)	33.31 (6.23)
	P value	0.001	<0.001	<0.001	0.001	<0.001
Gardner et al (2017)[17] post-concussion	ADHD	82.8 (12.8)	73.0 (14.1)	36.00 (7.28)	0.63 (0.10)	7.91 (14.5)
	Control	86.9 (10.7)	77.8 (12.8)	38.5 (7.1)	0.60 (0.10)	5.60 (10.58)
	P value	<0.001	<0.001	<0.001	<0.001	0.05
Covassin et al (2013)[13] baseline	ADHD (n = 61)	83.3 (10.8)	70.3 (13.7)	34.9 (6.2)	0.586 (0.10)	—
	Control (n = 61)	85.0 (8.4)	72.1 (11.9)	36.5 (6.8)	0.608 (0.08)	—
	P value	<0.06	<0.22	<0.19	<0.48	—
Covassin et al (2013)[13] 2 days out[b]	ADHD	68.5 (16.4)	59.0 (15.4)	31.7 (10.0)	0.716 (0.20)	—
	Control	75.5 (13.6)	63.8 (13.9)	34.6 (7.9)	0.66 (0.16)	—
	P value	<0.23	<0.59	<0.45	<0.22	—
Covassin et al (2013)[13] 7 days out[b]	ADHD	78.3 (14.9)	66.5 (14.7)	37.3 (8.7)	0.595 (0.08)	—
	Control	81.6 (12.1)	68.5 (14.3)	38.4 (8.7)	0.584 (0.09)	—
Hall et al (2017)[19] (n = 486)[c]	ADHD (n = 29)	82.5 (11.4)	70.8 (13.6)	37.4 (5.7)	0.60 (0.06)	9.5 (16.0)
	No ADHD (n = 327)	85.9 (9.7)	76.9 (13.2)	40.4 (5.8)	0.59 (0.08)	4.0 (7.6)
	P value	≥0.05	<0.05	<0.01	≥0.05	<0.001

ADHD, attention deficit hyperactivity disorder.
[a]Cases = ADHD; controls = no ADHD. Shaded cells indicate statistical significance ($P < 0.05$). Data presented as mean score (SD).
[b]Days after concussion.
[c]Prospective study.

concussion-like symptoms at baseline. A logistic regression model showed that one of strongest predictors of postconcussion syndrome (PCS) in both boys and girls is ADHD, although other factors such as treatment for substance abuse and treatment of psychiatric condition ranked higher on the scale.

Incidentally, Chin et al,[9] in their assessment of the reliability and validity of the Sports Concussion Assessment Tool–3 (SCAT3), found that athletes with ADHD had higher symptom rating (d = 0.25-0.32), lower baseline SAC scores (d = 0.28-0.68), and poorer Balance Error Scoring System performance (d = 0.14-0.26), although effect size was small to moderate.

Sex-Based Effects

A total of 4 studies, 3 by the Iverson group[21,23,24] and 1 by Cook et al,[11] performed additional analysis of athletes with ADHD stratified by sex. In the Iverson group, male athletes had greater rates of ADHD diagnosis (7%-8% compared with 4% among female athletes), although statistical significance was not calculated. Iverson et al[23] found that at baseline, male athletes with ADHD are 42% (OR, 1.42; 95% CI, 1.22-1.66) more likely to report mild PCS compared with those without ADHD, whereas female athletes with ADHD are 102% (OR, 2.02; 95% CI, 1.64-2.49) more likely to report mild PCS. Cook et al[11] found that regardless of medication status, girls with ADHD had greater total symptom score compared with boys with ADHD, although statistical significance was not specified.

Increased Risk of Concussion and Prolonged Recovery

Eight studies[2,5,17,21,24,30,33,39] assessed the effects of prior ADHD diagnosis on the risk of concussion (Table 4). In a retrospective study of 139 collegiate athletes, Alosco et al[2] found that 50% of those with ADHD reported at least 1 prior concussion, compared with 14% of those without ADHD (P = 0.04). Similarly, Salinas et al[39] found an increased concussion prevalence of 28% (P = 0.02) in those with ADHD compared with those without. Conversely, Biederman et al[5] found a 22% (P < 0.01) greater prevalence of ADHD in athletes with mTBI compared with controls.

In a study of 6529 high school athletes, Iverson et al[21] found that those with ADHD are 71% more likely to sustain at least 1 concussion (P < 0.01), 87% more likely to sustain at least 2 concussions (P < 0.01), and 1.9 times more likely to sustain at least 3 concussions (P < 0.01) than those without ADHD. From that population (n = 32,487), Iverson et al[24] found that athletes with both ADHD and learning disabilities were 81% more likely to have had at least 1 concussion compared with athletes without either condition. The stepwise increase in prevalence with multiple concussions found by Iverson et al[21] was also observed by Nelson et al,[33] who demonstrated that the rate of concussion increased 1.9 times in athletes with ADHD who had 0 versus 3 or more concussive episodes.

Two studies[17,30] reported no effect of ADHD on the risk of concussion. Mautner et al[30] found no statistical difference in the number of prior concussions between athletes with ADHD and matched controls (P = 0.63). Similarly, Gardner et al[17] also saw no difference in the number of prior concussions in athletes with ADHD (n = 277) versus controls (n = 831) (0.42 vs 0.34, P = 0.4).

The study by Mautner et al[30] was the only one that addressed the effect of ADHD on recovery time. Although not statistically significant (P = 0.12), athletes with ADHD took on average 3 days longer to return to baseline neurocognitive testing compared with controls without ADHD.

Effects of Stimulant Treatment

Four studies[13,17,21,24] looked at how treatment with stimulants affected neurocognitive performance in athletes with ADHD. Gardner et al[17] analyzed baseline and postconcussive ImPACT scores from athletes who were treated with stimulants and compared them versus those with untreated ADHD and controls. Compared with controls (n = 270), athletes who were treated with stimulants did worse on verbal (82 vs 84, P =0.047) and visual memory (72 vs 76, P = 0.013) and reported greater total symptoms (7 vs 3, P < 0.01), with the difference persisting postconcussively. However, those treated with stimulants did no worse than controls in visual motor (37 vs 37, P = 0.49) and reaction time (0.62 vs 0.61, P = 0.71), whereas those with untreated ADHD did poorer than controls across all modules. Comparing athletes with treated and untreated ADHD, those who were treated not only had better visual motor scores (37 vs 7, P = 0.025) but also reported greater total symptoms (7 vs 5, P = 0.037). Postconcussively, there was no difference in ImPACT scores between the treated and untreated groups.

Iverson et al[24] found that those who reported taking ADHD medication were 67% (P < 0.001) more likely to report a history of 1 or more concussion compared with those who did not report taking medication. Contrary to that study, Iverson et al[21] saw similar rates of concussion in those who were taking medication (26.8%, 10.6%, and 4.9% reporting they had 1 or more, 2 or more, or 3 or more concussions, respectively) and those who did not report taking medication (25.7%, 9.3%, and 5.2%, respectively). Cook et al[11] analyzed baseline scores from the Post-Concussion Scale completed by 37,510 high school athletes. Although pairwise comparison showed no difference between the medication and no-medication groups, both groups differed significantly from controls.

DISCUSSION

The prevalence of ADHD in young athletes is between 4% and 14.3%, which appears consistent with the 5% to 15% reported among the general population from the National Survey of Children's Health.[44] Although the rate of ADHD is not greater in athletes compared with the general population, the diagnosis is associated with increased neurocognitive deficits relative to appropriate comparison groups.

Basis of Neurocognitive Testing

Neuropsychological tests evaluating brain-behavior relationships, such as ImPACT, claim to offer more sensitive

Table 4. Increased risk of concussion

		1+ concussions	2+ concussions	3+ concussions
Nelson et al (2016)[33]	ADHD	3.8%	5.9%	10.6%
	PR (95% CI)	1.05 (0.83-1.34)	1.63 (1.1-2.42)	2.93 (2.05-4.19)
Iverson et al (2016)[21]	ADHD	26.1%	9.8%	5.1%
	No ADHD	17.1%	5.5%	1.8%
	OR (95% CI)	1.71 (1.35-2.15)	1.87 (1.33-2.64)	2.90 (1.80-4.67)
Iverson et al (2016)[24]	ADHD	24.5%	9.4%	4.5%
	No ADHD	16.1%	4.6%	1.5%
	P	OR, 1.69 (95% CI: 1.48-1.93)	<0.05	<0.05
Alosco et al (2014)[2]	ADHD	50.4%	—	—
	No ADHD	14.4%	—	—
	χ^2 (*P*)	15.54 (<0.01)	—	—
		0 concussions	**1 prior concussion**	**2+ prior concussions**
Mautner et al (2015)[30]	ADHD	62.3%	31.2%	6.5%
	Controls[a]	76.6%	16.9%	6.5%
	P	0.11	—	—
		0 concussions	**1+ prior concussion**	
Salinas et al (2016)[39]	ADHD	85.9%	14.1%	
	Controls[a]	92.2%	7.8%	
	χ^2 (*P*)	—	5.133 (0.02)	
		Prior concussions, mean		
Gardner et al (2017)[17]	ADHD	0.42 ± 0.85		
	Controls[a]	0.34 ± 0.62		
	P	0.477		

ADHD, attention deficit hyperactivity disorder; OR, odds ratio; PR, prevalence ratio (compared with athletes without ADHD).
[a]Controls are athletes without ADHD, but matched.

detection of subtle cognitive impairments compared with clinical examination[20] and could conceivably play a role in assessing and managing concussed athletes with neurocognitive comorbidities such as ADHD. Even with their documented use, the Consensus Statement on Concussion in Sports[31] does not recommend mandatory neuropsychological testing since it is not a prerequisite in the clinical assessment of concussion. The data presented here suggest an adjunct role for neurocognitive testing to track neurocognitive deficits in certain athlete populations, in this case, athletes with ADHD.

Based on our review, 6 studies[14,17,19,30,39,46] found that athletes with ADHD did poorer pre- or postinjury in at least 1 of 4 composite scores. However, there were definite inconsistencies between studies, with some[14,17,46] showing statistical significance in all categories, while others did not. In fact, 2 studies by Hall et al[19] and Covassin et al[13] found no statistical difference

($P \geq 0.05$) in ImPACT scores either at baseline or postconcussively. These results are partly consistent with Gardner et al,[17] who found that athletes with ADHD did not differ postconcussively in total symptoms, despite lower composite scores on ImPACT pre- and postinjury.

Furthermore, the difference in test scores between athletes with and without ADHD, although statistically significant, were small, ranging in the order of 0.01 to 6 points (Table 3), and may not translate into measurable clinical significance. In fact, these scores, although lower than controls, are considered "average" and in the normative range for adolescents aged 13 to 15 years.[22]

Only 4 studies[13,17,30,46] compared athletes with ADHD to matched controls, and only 3 studies[13,17,46] accounted for education, body mass index, and history of prior concussion. Inconsistent accounting for potential confounders, such as age and level of education, could diminish the differences observed between athletes with and without ADHD and may account for some of the observed discrepancies.

Neurocognitive testing is at best an imperfect science that continues to evolve. Measures of attention, memory, and impulse, which are used to detect subtle effects of concussion, are in fact the very symptoms that help define ADHD.[3] Nelson et al[34] showed that validity indicators for neurocognitive testing may not be appropriate or equally meaningful for athletes with ADHD since they could not rule out lack of effort or motivation as causes of invalid scores. In fact, the structure of ImPACT itself continues to be debated, as new data suggest that a 2- versus 4-factor composite score may be more reliable in acute concussion and athletes with learning disabilities.[18]

These limitations highlight the importance of baseline testing in athletes with comorbid ADHD and other psychiatric disorders and the precautions necessary in evaluating test results in isolation, outside of the clinical context.

Symptom Reporting and the Effects of Sex

Athletes with ADHD also differed in degree of symptom reporting, with increased symptom severity and duration.[5,30,35,46] Of those recently diagnosed with mTBI, Biederman et al[5] saw that athletes with ADHD reported more fatigue and reduced concentration, consistent with preliminary findings by Oliver et al[35] who found that athletes with ADHD felt more "confused," "dazed," and "slowed down" after an injury. Even at baseline, 3 studies[9,23,33] demonstrated increased reporting of concussion-like symptoms in nonconcussed athletes with ADHD compared with those without ADHD.

Concussion symptoms are subjective and may be influenced by psychiatric comorbidities. A study by Balasundaram et al[4] found that symptoms of concussion measured on the Sports Concussion Assessment Tool–2 (SCAT2) may present in nonconcussed individuals depending on time of day, fatigue level, and location. In athletes, Iverson et al[23] found that prior treatment for a psychiatric condition is the strongest independent predictor for symptom reporting, in addition to factors like ADHD, migraine, and substance abuse. This finding is consistent with studies of the general population, in which concurrent psychiatric comorbidities were associated with persistence of postconcussive symptoms in patients with mTBI both 1 week and 3 months postinjury.[38]

This is important since up to half of children and adolescents with ADHD have 1 or more coexisting behavioral-emotional condition.[25,43] Similarly adults with ADHD have increased risk of both mood disorder (OR, 2.7-7.5; 95% CI, 3.0-8.2) and anxiety disorder (OR, 1.5-5.5; 95% CI, 2.4-5.5).[27] Understanding the increased symptom burden among athletes with ADHD helps us better tailor our management of these athletes postconcussively and highlights the importance of addressing their unique psychosocial burden as primary care providers, including appropriate referral to psychiatry and support services.

In female athletes with ADHD, stratified analysis shows increased symptom reporting, although specific analyses comparing male versus female athletes were not performed. These findings are consistent with prior studies documenting that female athletes have greater postconcussive symptom reporting and prolonged recovery time.[10,12]

Concussion Risk

Six studies[2,5,21,24,33,39] demonstrated increased risk of concussion in athletes with ADHD, which raises the question of causality. Do behaviors associated with ADHD, such as impulsivity, increase risk for concussion, or does the physiology of the ADHD brain make it more prone to traumatic injury? Studies looking at the pediatric population have shown an association between ADHD and childhood injuries, including increased risk of fracture,[15,28] traumatic dental injuries,[38] and accidental trauma,[7,29] although causality has yet to be affirmed. Likewise, brain imaging studies of adult and children with ADHD have, at best, given us a limited understanding on the pathophysiology of ADHD.[8,40]

Conversely, does the diagnosis of ADHD increase concussion reporting, for example, because of more interaction with health care providers or increased symptom burden? These questions require answers that are not yet forthcoming and serve as fertile ground for future research.

Effects of Stimulants

Four studies[11,17,21,24] that evaluated the effect of stimulants on athletes with ADHD showed only marginal improvements in baseline testing without overall improvement in total reported symptoms. Iverson et al[24] saw an increased risk of concussion in those who were treated with stimulants. A survey of children with ADHD in Germany showed that medication status did not influence the occurrence of accidents overall.[29]

Still, limited data on this subject hinder definitive conclusions regarding the benefits or harm of stimulant treatment in athletes. The subject continues to remain controversial given the risk of diversion and abuse compared with the potential benefit to reduced risk of depression, anxiety, and academic failure in youth with ADHD. More studies in both adolescent and collegiate athletes are needed to determine the effects of stimulants in athletes with ADHD.

Limitations

There are several limitations to the data included in this review. Diagnosis of ADHD was based on either self-reporting or review of medical charts without confirmation through clinical evaluation. The diagnosis of ADHD itself can be difficult, requiring multiple clinical encounters. Determination of stimulant status was also performed through self-reporting, which does not address the type of stimulant, dose, formulation, compliance with, or duration of actual therapy.

Only 2 studies used prospective methodology,[12,24] limiting the quality and assuredness of findings. Importantly, our findings are based on reviews of published research without access to the original data, which limits our own interpretation and analysis of these findings. Finally, our results were primarily focused on adolescents and young adults with insufficient data to allow any generalizability to the adult population. This largely inhibits any insight into the issue of stimulant use in adult athletes, including higher-stakes competition, where stimulant use is more controversial.

CONCLUSION

This systemic review suggests some relationships between ADHD and increased neurocognitive deficits in athletes, although the details of how and why still need explanation. As team physicians, it is imperative to take into context both clinical findings and individual psychosocial needs of athletes with ADHD to best optimize their care.

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