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## Attention-deficit/hyperactivity disorder is associated with baseline child sport concussion assessment tool third edition scores in child hockey players

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### ABSTRACT

**Objectives:** The objectives of this study were to report baseline, preseason data for the Child-SCAT3, stratified by attention deficit hyperactivity disorder (ADHD) status, and examine group differences in Child-SCAT3 performance between children with and without ADHD.

**Design:** Cross-sectional study.

**Methods:** Young male hockey players ( $n = 304$ ), aged 8–12 years, were administered the Child-SCAT3 during pre-season. Child-SCAT3 measures included a 20-item symptom scale, a Standardised Assessment of Concussion Child Version (SAC-C), a modified Balance Error Scoring System (m-BESS), a tandem gait task, and a coordination test.

**Results:** Children with ADHD ( $n = 20$ ) endorsed significantly more symptoms ( $d = 0.95$ ) and greater symptom severity ( $d = 1.13$ ) compared to children without ADHD. No statistically significant differences were found between groups on Child-SCAT3 measures of cognitive or physical functioning (e.g. balance and coordination).

**Conclusions:** ADHD should be considered when interpreting Child-SCAT3 scores, especially symptom reporting, in the context of concussion assessment. Better understanding of symptom reporting in uninjured child athletes with ADHD can inform the clinical interpretation of symptoms at baseline and following an actual or suspected concussion. Normative data for the Child-SCAT3 that is not stratified by or otherwise accounts for ADHD status should be used with caution when appraising performance of children with ADHD.

### KEYWORDS

Brain; concussion; Child-SCAT3; traumatic brain injury; cognition

## Introduction

Concussion in ice hockey participants occurs at a rate of 2.9 for every 10,000 participants, and is comparable to the yearly rate of concussion in both soccer and football (1). Given the frequency of sport-related concussion and heightened public awareness regarding the injury, several assessment tools have been developed to facilitate rapid, sideline clinical assessment following injury or suspected injury. The Child Sports Concussion Assessment Tool (Child-SCAT3) is a sideline concussion assessment for children ages 5–12 (2). A professional consensus statement recommends the Child-SCAT3 as a screening instrument for sport concussion in children (3). However, to date, only two published studies have examined the Child-SCAT3. The first study reported pre-season baseline normative data from 227 male hockey players, aged 7–12 years, did not find consistent age-differences across Child-SCAT3 scores, and noted that parents reported significantly lower symptom severity ratings compared to child self-report (4). A second study compared pre- and post-season Child-SCAT3 results from 57 boys, aged 8–12 years, participating in either

contact (American football) or non-contact (baseball) sports (5). Participation in a season of contact sport, without suffering a diagnosed concussion, did not influence Child-SCAT3 performance (5).

Attention deficit hyperactivity disorder (ADHD) is a common neurodevelopmental disorder occurring in approximately 8% of children and adolescents (6). Adolescent and collegiate athletes with ADHD are more likely to report a history of prior concussion compared to those without ADHD (7–9). Further, some evidence suggests that ADHD is associated with greater post-injury neuropsychological dysfunction in children following concussion (10). Moreover, ADHD can confound concussion assessment given symptom overlap. Namely, both ADHD and concussion can present with neurocognitive deficits in attention, concentration, processing speed, learning and memory, and executive functioning (11–15). Thus, it may be difficult to differentiate pre-existing ADHD symptoms from concussion-related symptoms (16).

In recent years, studies have explored associations between ADHD and baseline neurocognitive performance and

symptom reporting on preseason concussion assessment. Studies consistently suggest that ADHD is associated with measurable differences in neurocognitive performance and increased symptom endorsement (8,13,17,18). However, there are no published studies on the potential influence of ADHD on Child-SCAT3 performance. Therefore, this study examined Child-SCAT3 performance stratified by parent-reported diagnoses of ADHD in child athletes, ages 8–12.

## Methods

Participants were players from a regional minor hockey association in British Columbia who completed a baseline Child-SCAT3 evaluation in a registered athletic therapy clinic before beginning the 2014 and/or 2015 seasons. If the participants had assessments in both seasons, the first valid Child-SCAT3 was used to control for prior exposure and practise effects. Due to the small number of girls in the league, only data from boys were analysed. The full sample included 314 boys, of which 221 (70%) overlapped with a previous study (4). For the current study, one participant was excluded due to missing health history data and another nine were excluded due to a reported history of a learning disorder (LD) or epilepsy, resulting in a final sample of 304 boys, with a mean age of 10.2 years ( $SD = 1.2$ , range 8–12). A total of 20 children (6.6%) had ADHD per parent report during either the 2014 visit ( $n = 12$ ) or the 2015 visit ( $n = 8$ ). No subject reported having ADHD in 2014, but not having it in 2015, but three subjects reported having it in 2015 and not in 2014.

The Child-SCAT3 has several subsections, including a symptom rating scale, physical assessment, and cognitive assessment. Each participant, along with his parent, reported demographics (e.g. age, gender, dominant hand) and health history information (i.e. number of prior concussions, history of headaches or migraine diagnosis, and history of depression or anxiety diagnosis). Of primary interest to the current study, the Child-SCAT3 includes a question asking if the child has a history of ADHD, learning disability, dyslexia, and/or a seizure disorder. ADHD status was further clarified by a parent-report questionnaire developed for the research study. Following the health history questionnaire, players and parents (responding in reference to their child's symptomatology) completed a symptom rating scale, indicating the current presence and severity of 20 symptoms (e.g. headache, confusion, dizziness, and cognitive difficulties). Each symptom is rated from 0 to 3 based on the way the participant is feeling on the day of their examination, and includes the headings never (0), rarely (1), sometimes (2), and often (3). The parent is asked to complete the symptom scale based on how the child has been over the previous 24 hours. Of the 20 symptoms, 11 are cognitive symptoms, 7 are physical symptoms, and two are sleep symptoms. We evaluated both the total number of symptoms endorsed and the total symptom severity, which is the sum of the 0–3 score on each of the 20 symptoms (0–60). Next, children completed the Standardised Assessment of Concussion Child Version (SAC-C), a brief neurocognitive screener comprised of four subtests: Orientation, Immediate Memory, Concentration, and Delayed Recall. The Orientation subtest consists of four questions to assess the participant's awareness of the month, date, day, and year

(maximum of 4-points). In the Immediate Memory task, the participant is read a list of five words and is asked to recite them over three trials (maximum 15-points). For the Digits Backwards subtest, participants repeat a string of numbers in reverse order. Similarly, for Days in Reverse Order, participants recite the days of the week backwards. Taken together, these two tasks comprise the Concentration score (maximum 6-points). The total SAC-C score is calculated as the sum of Orientation, Immediate Memory, Concentration, and Delayed Recall (described below) scores, with a maximum possible score of 30. Next, the modified Balance Error Scoring System (m-BESS) is conducted and includes double-leg stance and tandem stance with eyes closed on a firm surface. Error points are given if participants deviate from the predetermined stance, with a maximum of ten errors. This is followed by a tandem gait task, where participants walk heel-to-toe along a 3-meter length of tape. The fastest (i.e. best) time out of four trials is retained. The final physical assessment is a finger-to-nose coordination test. At the end of the Child-SCAT3, the participant is asked to recall the list of five words read to them during the Immediate Memory subtest (Delayed Recall score: maximum of 5-points). There was a minimum of 5 minutes between the Immediate Memory and the Delayed Recall subtests.

The minor hockey association's concussion protocol requires preseason Child-SCAT3 testing for all registered players. Parents provided written consent and players provided assent prior to the evaluation. Evaluations took place at a registered athletic therapy clinic in British Columbia, in private rooms, and were conducted by certified athletic therapists, physiotherapists or trained graduate students. Administrators received standardised training in testing procedures prior to data collection. Participants were evaluated at various times throughout the week, depending on individual availability. All health history information included in this study is retrospective and based on parent/self-report. This study was approved by the University of British Columbia's Clinical Research Ethics Board.

Group differences between children with and without parent-reported ADHD on baseline Child-SCAT3 scores were examined. For continuous variables, Mann-Whitney U tests were conducted due to non-normally distributed data and unequal cell sizes. To aid interpretation of findings, Cohen's  $d$  effect sizes were also computed and characterised according to conventional guidelines, that is  $d = 0.2$ , small;  $d = 0.5$ , medium;  $d = 0.8$ , large (19). For categorical variables, chi-square tests were conducted and relative risks (RRs) were computed. Data were analysed using SPSS version 23.0, except for RRs and their 95% confidence intervals (CIs), which were calculated using an online 2-way contingency table calculator (<http://statpages.info/ctab2x2.html>), and Cohen's  $d$  values, which were calculated using an online effect size calculator (20).

## Results

The majority of participants did not endorse a history of concussion ( $n = 266$ , 87.8%). The rate of prior concussion in the total sample was 12.2% ( $n = 37$ , range 1–2), with the majority of these children ( $n = 31$ ) reporting one previous concussion. History of health problems was rare. Only 3.0%

( $n = 9$ ) of children had prior diagnosis of headache or migraine and only 2.6% ( $n = 8$ ) had previous diagnosis of depression, anxiety, or other psychiatric disorder, per parent report. Table 1 reports comparisons between children with and without ADHD on health history variables. Compared to children without ADHD, children with ADHD were more likely to have sustained at least one previous concussion. Although the difference was not statistically significant ( $p = 0.07$ ), the relative risk suggests this difference is nonetheless noteworthy ( $RR = 2.21$ ). They were also more likely to have prior psychiatric diagnosis and diagnosis of headaches/migraines, and these differences were statistically significant.

The mean number of symptoms reported by participants was 8.33 ( $SD = 5.16$ ) and the mean symptom severity score was 12.06 ( $SD = 8.52$ ). Participants differed significantly on both symptom count and severity ratings based on ADHD

status (see Table 1). Specifically, boys with ADHD reported more individual symptoms than boys without ADHD (Cohen's  $d = 0.95$ , large effect), and had more severe symptoms ( $d = 1.13$ , large effect). Median severity ratings and the percentages of participants endorsing individual symptoms as either occurring at least 'rarely' or greater as well as at least 'sometimes' or greater are presented in Table 2. For most the symptoms ( $n = 19$ ), the risk of boys with ADHD endorsing the symptoms was higher compared to boys without ADHD (i.e. 95% CI for the RR did not include 1). Several symptoms that ADHD children endorsed at a greater rate are expected vulnerabilities in ADHD, such as difficulty paying attention and concentrating. However, several symptoms not commonly attributed to ADHD were also endorsed at a much higher rate, such as headache, dizziness, and feeling faint. Further, it is interesting to note that at baseline,

**Table 1.** Comparisons between boys with ADHD ( $n = 20$ ) and without ADHD ( $n = 284$ ).

Variables	ADHD			No ADHD			d	Significance Test
	Mean	SD	Range	Mean	SD	Range		
Child SCAT3								
Number of Symptoms	12.50	4.36	3–19	8.02	5.09	0–20	0.95	U = 1471.0, p < 0.001
Total Symptom Severity	20.80	8.35	5–37	11.42	8.21	0–35	1.13	U = 1206.5, p < 0.001
m-BESS	1.30	1.66	0–5	1.69	2.01	0–10	–0.21	U = 2475.5, p = 0.35
Gait (seconds)	19.51	9.20	7–38	17.87	9.32	4.8–57	0.18	U = 2030.0, p = 0.35
Coordination	1.00	0.00	–	0.94	0.24	0–1	^	U = 2610.0, p = 0.26
SAC-C Total	23.15	4.76	11–29	24.49	3.21	12–30	–0.33	U = 2478.5, p = 0.34
SAC-C Orientation	3.60	0.50	3–4	3.72	0.48	2–4	–0.24	U = 2480.0, p = 0.22
SAC-C Immediate Memory	12.25	3.06	3–15	13.12	2.07	5–15	–0.33	U = 2385.5, p = 0.22
SAC-C Concentration	3.30	1.17	1–6	3.70	1.09	1–6	–0.35	U = 2230.5, p = 0.10
SAC-C Delayed Recall	4.00	1.30	1–5	3.94	1.19	0–5	0.05	U = 2664.0, p = 0.63
Health History								
	n	%		n	%		RR	Significance Test
History of Concussion	5	25.0		32	11.3		2.21	χ2 (1, N = 303) = 3.27, p = 0.07
History of Headache/Migraine	3	15.0		6	2.1		7.1	χ2 (1, N = 304) = 10.80, p = 0.001
History of Depression/Anxiety	2	10.0		6	2.1		4.73	χ2 (1, N = 304) = 4.54, p = 0.03

Note. ADHD = Attention Deficit Hyperactivity Disorder; Child-SCAT3 = Sport Concussion Assessment Tool for children ages 5–12 years; m-BESS = modified Balance Error Scoring System; SAC-C = Standardized Assessment of Concussion – Child Version; RR = Relative risk.

^No effect size was calculated, as there was no variation in Coordination amongst the ADHD group.

**Table 2.** Symptom reporting between participants with and without ADHD.

Symptoms	ADHD ( $n = 20$ )			No ADHD ( $n = 284$ )			RR <sub>Rarely</sub>	RR <sub>Sometimes</sub>
	Median Severity	'Rarely' or greater (%)	'Sometimes' or greater	Median Severity	'Rarely' or greater (%)	'Sometimes' or greater		
Trouble paying attention <sup>C</sup>	2.00	85.0	70.0	1.00	58.1	29.9	1.46*	2.34*
Distracted easily <sup>C</sup>	2.00	100.0	90.0	1.00	66.2	31.7	1.51*	2.84*
Hard time concentrating <sup>C</sup>	2.00	85.0	60.0	0.00	49.3	18.0	1.72*	3.34*
Problems remembering what people tell me <sup>C</sup>	1.00	75.0	40.0	1.00	56.3	25.4	1.33	1.58
Problems following directions <sup>C</sup>	1.00	80.0	45.0	0.00	45.4	15.8	1.76*	2.84*
Daydream too much <sup>C</sup>	0.00	45.0	20.0	0.00	28.2	14.1	1.60	1.42
Get confused <sup>C</sup>	1.00	90.0	45.0	1.00	59.5	21.5	1.51*	2.10*
Forget things <sup>C</sup>	2.00	90.0	60.0	1.00	68.0	36.3	1.32	1.65
Problems finishing things <sup>C</sup>	1.00	65.0	30.0	0.00	44.0	16.2	1.48	1.85
Trouble figuring things out <sup>C</sup>	1.00	90.0	40.0	1.00	54.2	18.3	1.66*	2.19*
Hard to learn new things <sup>C</sup>	1.00	65.0	35.0	0.00	46.5	17.3	1.40	2.03
Headaches <sup>P</sup>	1.00	65.0	35.0	0.00	48.9	14.8	1.33	2.37*
Dizzy <sup>P</sup>	1.00	60.0	25.0	0.00	26.4	4.9	2.27*	5.07*
Room is spinning <sup>P</sup>	0.00	30.0	10.0	0.00	8.5	1.1	3.55*	9.47*
Faint <sup>P</sup>	0.00	15.0	5.0	0.00	6.3	1.1	2.37	4.73
Blurred vision <sup>P</sup>	0.00	30.0	10.0	0.00	12.0	4.2	2.51*	2.37
See double <sup>P</sup>	0.00	5.0	0.0	0.00	11.3	2.1	0.44	0.0
Nausea <sup>P</sup>	0.50	50.0	15.0	0.00	26.8	7.4	1.87*	2.03
Tired a lot <sup>S</sup>	1.00	75.0	45.0	1.00	50.4	16.5	1.49*	2.72*
Tired easily <sup>S</sup>	0.50	50.0	25.0	0.00	35.6	10.6	1.41	2.37

Symptoms are rated as 0 = 'never', 1 = 'rarely', 2 = 'sometimes', and 3 = 'often'.

ADHD = Attention-Deficit/Hyperactivity Disorder; <sup>C</sup> = cognitive symptom; <sup>P</sup> = physical symptom; <sup>S</sup> = sleep symptom.

RR<sub>Rarely</sub> = Relative risk comparing the percentage of each group endorsing a symptom as 'Rarely' or greater.

RR<sub>Sometimes</sub> = Relative risk comparing the percentage of each group endorsing a symptom as 'Sometimes' or greater.

\*95% CI for RR does not include 1, suggesting greater risk of endorsing the symptom among ADHD boys.

even children without ADHD endorsed many concussion-like symptoms.

The mean overall error rate on the m-BESS was 1.66 out of a maximum possible error score of 20. Nearly all participants (98.7%) completed the double-leg stance with no errors, while only about one-third (36.0%) completed the tandem-leg stance with no errors. The mean gait time for all participants was 17.95 seconds ( $SD = 9.30$ ). About half of the participants (54.1%) completed the task within 16 seconds and it was uncommon (10.4% of participants) to take more than 30 seconds to complete. Thirteen participants (4.3%) attempted, but were unable to complete the gait task. Nearly all participants (94.3%) successfully completed the coordination test. Diagnosis of ADHD was not associated with m-BESS, gait times, or coordination scores.

The mean score for total SAC-C was 24.40 ( $SD = 3.34$ ). Overall, 90.8% of participants attained at least 20 points and slightly less than half (44.9%) scored above 25. It was uncommon to achieve a score of 30 (i.e. only 2 participants, or 0.7% of the sample). The majority of participants (72.5%) earned a perfect score on Orientation and it was rare to score 2 or lower (only 1.3%). On Immediate Recall, nearly one-third (31.5%) of participants were able to recall all items on each trial (i.e. earn a perfect score of 15). Few participants (8.9%) earned a score of nine or lower on Immediate Recall. The average total Concentration score was 3.68 ( $SD = 1.10$ ). On the tasks that comprise the Concentration score, 88.5% of participants were able to recite at least two digits backwards, but only 5.2% could recite all five digits backwards. Almost all participants (92.5%) were able to recite all days of the week in reverse order. For Delayed Recall, it was uncommon (4.6% of participants) for children to recall fewer than two words. The majority (70.1%) of participants were able to recall at least four words, and a sizeable group (41.6%) was able to recall all five.

Overall, children with ADHD scored lower than children without ADHD on the SAC-C total and subscale scores (Table 1). However, group differences were not statistically significant for any of the SAC-C measures and effect sizes were generally negligible to small ( $d$  from 0.05 to 0.35).

Given that children with and without ADHD exhibited significantly different rates of prior concussion, diagnosis of headache/migraine, and diagnosis of depression/anxiety, we examined differences in Child-SCAT3 performance based on these potential mediators. No statistically significant differences on Child-SCAT3 scores were noted for children with and without a history of at least one prior concussion. In contrast, differences in symptom reporting were noted between children with and without a history of headache or migraine diagnosis and history of depression/anxiety diagnosis. Specifically, children with a history of headache/migraine diagnosis endorsed significantly more symptoms (Mann-Whitney  $U = 768.5$ ,  $p = 0.03$ ,  $d = 0.79$ ) and greater symptom severity ( $U = 668.5$ ,  $p = 0.01$ ,  $d = 0.90$ ). Children with a history of depression/anxiety diagnosis also endorsed significantly more symptoms (Mann-Whitney  $U = 513.5$ ,  $p = .006$ ,  $d = 1.11$ ) and greater symptom severity ( $U = 594.5$ ,  $p = 0.02$ ,  $d = 0.94$ ). There were no significant differences on other Child-SCAT3 scores (i.e. SAC-C, balance, coordination)

between children with and without diagnosis of headache/migraine or depression/anxiety.

Next, we examined whether observed differences in symptom reporting between children with and without ADHD were unique from the effects of diagnosis of either headache/migraine or depression/anxiety. For these supplemental analyses, we excluded 17 children with history of headache/migraine diagnosis ( $n = 9$ ) and depression/anxiety diagnosis ( $n = 8$ ) and re-examined for group differences in total symptoms and symptom severity ratings between children with and without ADHD. Results were consistent with analyses from the full sample. Specifically, children with ADHD endorsed significantly more symptoms ( $U = 940.5$ ,  $p < 0.001$ ,  $d = 1.05$ ) and greater symptom severity ( $U = 828.5$ ,  $p < 0.001$ ,  $d = 1.08$ ) than children without ADHD. Further, the effect sizes were essentially identical to those from the full sample. Thus, the group differences based on ADHD status held, suggesting that diagnosis of headache/migraine and/or depression/anxiety did not account for the ADHD effect. Of note, after controlling for headache/migraine and depression/anxiety history, children with ADHD performed worse on the Concentration subtest ( $U = 1397.5$ ,  $p = 0.03$ ,  $d = -0.35$ ). However, as noted above, the effect size or magnitude of this difference was identical to results from the full sample (see Table 1).

## Discussion

The present study adds to a developing body of literature regarding the influence of ADHD on pediatric concussion assessment. To our knowledge, this is the first study to examine differences on baseline Child-SCAT3 results based on ADHD status. Several notable findings emerged. First, boys with ADHD have a greater concussion history than boys without ADHD. Specifically, one-quarter (25.0%) of boys with ADHD reported at least one prior concussion, compared to 11.3% of boys without ADHD. Second, boys with ADHD have a greater history of both mental health difficulties (10.0%) and headaches/migraine diagnosis (15.0%), compared to boys without ADHD (2.1% for both conditions). Boys with ADHD endorsed more individual symptoms and reported markedly greater symptom severity compared to boys without ADHD. Further, boys with ADHD endorsed a range of symptoms that would not typically be attributed to ADHD. Lastly, no statistically significant differences were found on balance and coordination, overall cognition (i.e. SAC-C Total), or orientation, concentration, and immediate or delayed recall tasks.

Our results are consistent with prior studies suggesting that children with attention problems report more baseline concussion-like symptoms, on average, compared to those without attention problems (13,17,18). Of note, these prior studies have included samples of adolescents and young adults, whereas the present sample included children (i.e. 8–12 year olds). Moreover, prior studies examining baseline concussion-like symptom reporting and cognition among young athletes with ADHD have examined ImPACT®, whereas we studied the Child-SCAT3. Thus, our findings offer preliminary cross-instrument support regarding the baseline, preinjury symptom reporting differences among student athletes with and



without ADHD and extend these findings to a younger age group.

While we expected to find differences in cognitive symptom reporting (e.g. hard time paying attention, difficulty concentrating), it is interesting that there were significant differences between ADHD and non-ADHD participants on physical symptom reporting as well. As hypothesised by Elbin and colleagues (13), perhaps increased baseline symptom reporting is reflective of a heightened awareness of 'state-like' feelings associated with an ADHD diagnoses. An alternate explanation may have a more neurobiological basis. Literature from both the animal models of ADHD and psychopharmacology studies implicate dysregulated dopamine and norepinephrine in ADHD, which influence impulsivity and attention (21–23). While the link between cognitive symptoms and these neurotransmitters is strongly reported, a potential connection between dizziness/nausea symptoms and dopamine has also been suggested in studies of opioid treatment (24). This may provide insight as to why children with ADHD experience symptoms of nausea and dizziness, although further research is required to clarify this hypothesis. Regarding visual symptoms, previous studies have shown that children with ADHD report and experience more visual symptoms than age-matched controls without ADHD, and are overrepresented in patients with convergence insufficiency (25,26). Finally, children with ADHD are often reported to experience more sleep problems as compared to their neurotypical peers (27,28), which may explain the difference in sleep-arousal symptoms (e.g. 'tired a lot') between ADHD and non-ADHD children in our study.

Importantly, our participants who did not have ADHD also reported a substantial number of symptoms (mean 8.02) at baseline. This is consistent with both pediatric (29,30) and adolescent (16) studies illustrating that the symptoms often attributed to concussion are non-specific and are endorsed at high rates in uninjured athletes. Anxiety and stress powerfully influence symptom reporting (31) implying that many factors unrelated to sport, such as family and school environment, likely influenced the base rates in this sample.

Limitations of the current study include the small number of ADHD participants. Thus, we may have been underpowered to detect smaller effects. Still, our study provides preliminary data regarding baseline Child-SCAT3 performance among boys with ADHD, which is not currently available in the clinical research literature. Additionally, given the nature of our sample, this study only included boys. Prior research with other concussion assessment measures reported differential associations between boys and girls with ADHD (17). Ideally, we would have stratified our results by sex. Additional research is needed to provide normative data and examine for potential difference in baseline Child-SCAT3 performance based on preexisting health conditions among female youth. Further, parents reported attention and learning problems during baseline testing and we were not able to confirm that children had formal diagnoses. However, self- or parent reported health history information is often the only source available for baseline and rapid screening assessments in applied clinical situations. Additionally, multiple evaluators

administered the Child-SCAT3 and we do not have interrater reliability data regarding the consistency between evaluators. However, evaluators were certified professional clinicians (i.e. athletic therapists or physiotherapists) or trained and closely supervised graduate students. Additionally, we were not able to account for or examine medication usage. Medication usage may have attenuated the effects of ADHD on Child-SCAT3 results, perhaps especially on the cognitive portion. Recent studies have suggested that baseline concussion assessment results among individuals with attention problems who report taking ADHD medication are comparable to healthy controls (32,33). A final limitation concerns the applicability of our findings to acute athletic concussion evaluations, which usually occur on the sidelines during competition. Studies such as Gorman et al. (34) and Patel et al. (35) suggest that, as a result of dehydration and other factors, even un-injured athletes' symptom reporting (eg. dizziness, headache, fatigue) is altered proximal to intense athletic activity. Whether our findings generalise to the on-field condition (ie. whether uninjured children with ADHD also report more symptoms during competition) requires further study.

## Conclusion

Better understanding of symptom reporting in uninjured child athletes with ADHD can aid the clinical interpretation of symptoms during baseline assessment as well as following a concussion or suspected concussion. The variability in Child-SCAT-3 scores, even in healthy children, implies that normative data should be applied cautiously irrespective of health history. More research is needed to determine the value and clinical usefulness of baseline testing, versus the use of normative reference values, for interpreting post-injury performance and appraising change at the individual level. Finally, clinicians should also note that having ADHD is associated with a greater reporting of baseline concussion-like symptoms in children, adolescents, and young adults. Levels of pre-injury symptom reporting among healthy, uninjured athletes should be considered when interpreting pre-season or post-concussive assessment results with the Child-SCAT3.

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## Declaration of interest

GLI has been reimbursed by the government, professional scientific bodies, and commercial organizations for discussing or presenting research relating to MTBI and sport-related concussion at meetings, scientific conferences, and symposiums. He has a clinical practise in forensic neuropsychology involving individuals who have sustained mild TBIs. He has received honorariums for serving on the research panels that provide scientific peer review of programmes. He is a co-investigator, collaborator, or consultant on grants relating to mild TBI

funded by several organizations. WJP has a private practise in forensic Neuropsychiatry. All other authors declare no conflicts or interests.

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