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Investigating Effects of Sex Differences and Prior Concussions on Symptom Reporting and Cognition Among Adolescent Soccer Players

Brian L. Brooks,[*†‡§] PhD, Noah Silverberg,[||¶] PhD, Bruce Maxwell,[#] PhD, Rebekah Mannix,[**] MD, MPH, Ross Zafonte,[††] DO, Paul D. Berkner,[‡‡] DO, and Grant L. Iverson,[§§] PhD
Investigation performed at Colby College, Waterville, Maine, USA

Background: There has been increasing concern regarding the possible effect of multiple concussions on the developing brain, especially for adolescent females.

Hypothesis/Purpose: The objectives were to determine if there are differences in cognitive functioning, symptom reporting, and/or sex effects from prior concussions. In a very large sample of youth soccer players, it was hypothesized that (1) there would be no differences in cognitive test performance between those with and without prior concussions, (2) baseline preseason symptoms would be better predicted by noninjury factors than concussion history, and (3) males and females with prior concussions would not have differences in cognition or symptoms.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: Participants included 9314 youth soccer players (mean = 14.8 years, SD = 1.2) who completed preseason baseline cognitive testing, symptom reporting, and a health/injury history questionnaire from the ImPACT battery (Immediate Post-concussion Assessment and Cognitive Testing). On the basis of injury history, athletes were grouped by number of prior concussions: 0 (boys, n = 4012; girls, n = 3963), 1 (boys, n = 527; girls, n = 457), 2 (boys, n = 130; girls, n = 97), or $\geq$3 (boys, n = 73; girls, n = 55). The primary measures were the 4 primary cognitive scores and the total symptom ratings from ImPACT. Primary outcomes were assessed across injury groups, controlling for age, sex, learning disability, attention-deficit/hyperactivity disorder (ADHD), treatment for headaches/migraines, substance abuse, and mental health problems.

Results: Cognitive test performance was not associated with concussion history but was associated with sex, age, learning disability, ADHD, and prior mental health problems. Greater symptom reporting was more strongly associated with psychiatric problems, older age, learning disability, substance abuse, headaches, being female, and ADHD than with a history of multiple concussions. Boys and girls did not differ on cognitive scores or symptom reporting based on a history of concussion.

Conclusion: In this very large sample of youth soccer players with prior concussion, there was no evidence of negative effects on cognition, very weak evidence of negative effects on symptom reporting, and no evidence of sex × concussion differences in cognition or symptom reporting.

Keywords: child; adolescent; traumatic brain injury; sports; postconcussion syndrome; cumulative

Soccer is the most widely played sport in the world. FIFA (Fédération Internationale de Football Association) reported in 2006 that there were >265 million people playing soccer.[21] Over half the registered soccer players were <18 years old, with the United States having the highest rates of youth soccer participation for boys and girls.

Soccer carries a risk of concussive injury for youth. Although the highest rates of injury involve lower body musculoskeletal injuries (~75%), an estimated 10% of soccer injuries in youth are concussions,[60] with head-to-head contact being the most common mechanism of concussive injury.[15] Meta-analysis indicated that there are 0.23 (95% CI = 0.21-0.28) concussions per 1000 athlete exposures for youth soccer players,[48] which is higher than other sports with a potential for unintentional collisions, such as basketball (0.13, 95% CI = 0.12-0.15) and field hockey (0.10, 95% CI = 0.08-0.12), but remains lower than other high-speed sports that involve deliberate and intense physical contact—for example, rugby (4.18, 95% CI = 2.50-5.86),

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ice hockey (1.20, 95% CI = 1.00-1.31), and American football (0.53, 95% CI = 0.40-0.67).[48]

The data regarding the effects of concussions on cognition and symptoms in athletes remain mixed,[‖‖] and for soccer players, studies have ranged from reporting no effects of concussions on cognition[23,25,61] to worse acute[14,49] and long-term[20] cognitive abilities among those who sustain a concussion. Differences in these studies may in part be due to the heterogeneity of the populations studied, including level of play, age, and sex.

Sex differences, in particular, are an ongoing concern in concussion management,[41] although most research to date has focused solely on male athletes. Girls have a higher rate of concussive injuries in soccer (0.27 per 1000 athlete exposures, 95% CI = 0.24-0.30) than boys (0.19, 95% CI = 0.16-0.21).[48] Girls and young women may have worse cognitive functioning and greater symptoms than boys, acutely[49] and subacutely,[14,17] after a concussion in soccer, but the sex effect may not always be present.[3,61] Time loss after concussion among soccer players has been reported as being greater for females than males based on a collegiate sample.[18] More research is clearly needed on the cumulative effects and sex-based differences of prior concussions in sport, with the present study helping to fill these gaps in knowledge.

The aims of this study were as follows:

Aim 1: Determine if adolescent soccer players with a history of concussions perform more poorly on neurocognitive testing or report more symptoms than athletes with no history of concussion

Aim 2: Determine if noninjury factors predict cognitive performance and symptom ratings among adolescent soccer players with a history of concussions

Aim 3: Determine if the effect of multiple past concussions on cognition or symptom reporting is different in boys versus girls

Based on previous work with youth who have a history of concussions,[5,6,37,47,61] the following was hypothesized: (1) there would be no differences in cognitive test performance between those with and without prior concussions, but those with prior concussions would report more baseline preseason symptoms, and (2) factors other than prior concussions would predict cognition and symptoms. Based on prior work comparing cognition and symptoms between boys and girls with prior concussions,[7,61] the following was hypothesized: (3) girls with prior concussions would not have worse cognitive functioning and would not report more symptoms than boys with prior concussions when accounting for sex differences on tests and symptom questionnaires among noninjured youth.

METHODS

Participants

Participants in this cross-sectional descriptive cohort study included 10,494 adolescent soccer players between 13 and 18 years of age from Maine. All completed baseline preseason testing with ImPACT (Immediate Post-concussion Assessment and Cognitive Testing) between 2009 and 2014. As part of the ImPACT program, there is an embedded self-report demographics and history questionnaire that provides

‖‖References 4-7, 10, 11, 14, 24, 30, 32, 37, 46, 50, 55-57.

*Address correspondence to Brian L. Brooks, PhD, Alberta Children's Hospital, Neurosciences Program, 2888 Shaganappi Trail NW, Calgary, AB T3B 6A8, Canada (email: brian.brooks@ahs.ca).

†Neurosciences Program, Alberta Children's Hospital, Calgary, Alberta, Canada.

‡Departments of Pediatrics, Clinical Neurosciences, and Psychology, University of Calgary, Calgary, Alberta, Canada.

§Alberta Children's Hospital Research Institute, University of Calgary, Calgary, Alberta, Canada.

‖Division of Physical Medicine and Rehabilitation, University of British Columbia; Vancouver Coastal Health Research Institute Rehabilitation Research Program, Vancouver, British Columbia, Canada.

¶Department of Physical Medicine and Rehabilitation, Harvard Medical School, Boston, Massachusetts, USA.

#Department of Computer Science, Colby College, Waterville, Maine, USA.

**Division of Emergency Medicine, Brain Injury Center, Boston Children's Hospital, Boston, Massachusetts, USA.

††Department of Physical Medicine and Rehabilitation, Spaulding Rehabilitation Hospital, Massachusetts General Hospital, Brigham and Women's Hospital, Harvard Medical School, and Home Base, A Red Sox Foundation and Massachusetts General Hospital Program, Boston, Massachusetts, USA.

‡‡Health Services and the Department of Biology, Colby College, Waterville, Maine, USA.

§§Department of Physical Medicine and Rehabilitation, Harvard Medical School, Spaulding Rehabilitation Hospital, Home Base, A Red Sox Foundation and Massachusetts General Hospital Program, MassGeneral Hospital for Children Sport Concussion Program, Boston, Massachusetts, USA.

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limited information about developmental, academic, and medical history.[42] All data collected and used in this study were obtained through the ImPACT program. Youth with a history of academic, learning, or attention problems, as well as those who received prior treatment for headaches, migraines, psychiatric conditions, or substance/alcohol use, were included in this study, with these variables being considered as covariates in our analyses. Exclusion criteria were as follows: (1) missing data on number of prior concussions (n = 185); (2) concussion identified as occurring within 6 months before baseline testing (n = 237); (3) self-reported history of meningitis, epilepsy, or brain surgery (n = 150; ie, 10% of the total sample had missing responses, which were treated as a negative response to these questions); (4) testing completed in a language other than English (n = 67); and (5) baseline testing deemed to be possibly questionable (n = 541; determined by the program to be "invalid" and labeled "baseline++"[28]). After application of exclusion criteria, the final sample was 9314 soccer players (4742 boys and 4572 girls). Institutional review board approval for this de-identified database was obtained.

Measures

Baseline preseason assessment for all soccer players included the ImPACT battery. ImPACT is a brief computerized screen of cognitive abilities that has been used in several studies investigating neurocognitive functioning after concussive injuries.[6,7,30,31,37,38,54] ImPACT includes 6 tests/modules (ie, word memory, design memory, x's and o's, symbol match, color match, and 3 letters) that yield 4 primary composite/domain scores (ie, verbal memory, visual memory, visual motor speed, and reaction time). ImPACT was administered in a group setting in high school computer laboratories by the local athletic training staff. ImPACT also contains a postconcussion symptom scale that consists of 22 commonly reported symptoms (eg, headache, dizziness, fogginess) rated from 0 (none) to 6 (severe). The primary dependent measure is the total raw score (range = 0-132) derived from this 22-item scale.

Analyses

All analyses were completed with SPSS (v 19.0; IBM).[27] Student t tests and odds ratios were used for describing the sample characteristics. Generalized linear modeling was used for prediction of each cognitive domain score and the total symptom score. Predictor variables were entered hierarchically in the following 3 steps to address the 3 aims. First, a categorical variable for the number of prior concussions (0, 1, 2, or $\geq$3) was entered as the sole predictor to address aim 1. Next, other predictors—sex, age, history of learning disability, history of attention-deficit/hyperactivity disorder (ADHD), history of treatment for headaches, history of migraines, history of substance use, and history of psychiatric problems—were added to the model to address aim 2. Finally, an interaction term, sex $\times$ concussion history, was added to address aim 3. We initially fit generalized linear models for each cognitive domain score based on a normal (gaussian) distribution and identity link function but then considered models with alternative distributions and link functions and selected the model with the lowest Akaike information criterion value (ie, best fit). Reaction time scores were positively skewed; an inverse gaussian distribution with power link function best fit these data. For the symptom score, which has a high zero count and extreme positive skewing, a negative binomial distribution with a log link achieved the lowest Akaike information criterion value. As noted, participants with questionable validity identified by the ImPACT program were excluded from the modeling of cognitive domain scores but not symptom reporting.

RESULTS

Demographic, educational (attention disorders, learning disorders), medical, and injury history information for the sample is presented in Table 1. A small proportion of soccer players reported a history of ADHD, learning disability, or treatment for headaches, migraines, substance abuse, or a psychiatric condition. Boys were significantly older than girls and more likely than girls to have ADHD, learning disabilities, and prior treatment for substance abuse. Girls were more likely than boys to have prior treatment for a psychiatric condition. Boys were more likely than girls to have a history of concussion, although the absolute difference in concussion rates was very small.

Aim 1: Determine if adolescent soccer players with a history of concussions perform more poorly on neurocognitive testing or report more symptoms than athletes with no history of concussion.

The cognitive test performances of boys and girls, as stratified by their concussion history, are presented in Table 2. The results of the generalized linear modeling for each ImPACT score are presented in Table 3. In the base model with concussion history as the sole predictor, there was not a consistent relationship between the number of prior concussions and current cognitive performance in any domain. Concussion history did, however, show a frequency-response association with symptom reporting (ie, more concussions associated with greater/worse symptoms).

Aim 2: Determine if noninjury factors predict cognitive performance and symptom ratings among adolescent soccer players with a history of concussions.

Adjusting the cognitive findings across the groups based on the noninjury covariates maintained the findings of no consistent effect of concussion history on cognitive performance. The effect of concussion history on symptom reporting was reduced considerably after other noninjury predictors were included in the model. Of note, greater/worse symptoms were predicted by all covariates, not only concussion history. In descending order of effect size—see Table 3 for the exponentiated coefficients, Exp(B)—the strongest predictors of current symptom reporting were as follows: prior treatment for a psychiatric problem, being an older adolescent (16, 17, or 18 years vs 13 years), a history of learning disability, prior treatment

TABLE 1
Demographics and Concussion Histories for Adolescent Soccer Players

	Sample, No. (%) or Mean ± SD		
	Total	Boys	Girls
Players	9314	4742 (50.9)	4572 (49.1)
Age, y	14.8 ± 1.2	14.9 ± 1.3	14.7 ± 1.1[a]
13	648 (7.0)	280 (5.9)	368 (8.0)
14	4631 (49.7)	2234 (47.1)	2397 (52.4)
15	1596 (17.1)	833 (17.6)	763 (16.7)
16	1325 (14.2)	715 (15.1)	610 (13.3)
17	923 (9.9)	527 (11.1)	396 (8.7)
18	191 (2.1)	153 (3.2)	38 (0.8)
History			
Attention-deficit/hyperactivity disorder	463 (5.0)	324 (6.8)	139 (3.0)[a]
Learning disability	219 (2.4)	133 (2.8)	86 (1.9)[a]
Treatment for headaches	796 (9.4)	386 (9.1)	410 (9.7)
Treatment for migraines	540 (6.4)	259 (6.1)	281 (6.7)
Treatment for substance/alcohol problem	50 (0.4)	35 (0.8)	15 (0.4)[a]
Treatment for psychiatric problem	480 (5.7)	193 (4.6)	287 (6.8)[a]
No. of prior concussions	0.20 ± 0.6	0.22 ± 0.6	0.18 ± 0.6[a]
0	7975 (85.6)	4012 (84.6)	3963 (86.7)[a]
1	984 (10.6)	527 (11.1)	457 (10.0)
2	227 (2.4)	130 (2.7)	97 (2.1)[a]
≥3	128 (1.4)	73 (1.5)	55 (1.2)
History of ≥1 concussions by age, y			
13	68 (10.5)	36 (12.9)	32 (8.7)[a]
14	575 (12.4)	301 (13.5)	274 (11.4)
15	227 (14.2)	123 (14.8)	104 (13.6)
16	236 (17.8)	128 (17.9)	108 (17.7)
17	192 (20.8)	110 (20.9)	82 (20.7)
18	41 (21.5)	32 (20.9)	9 (23.7)

[a]$P < .05$, boys vs girls.

for a substance/alcohol use, being 15 years old (vs 13 years old), prior treatment for headaches, being a girl, having ADHD, having multiple prior concussions, being 14 years old (vs 13 years old), having treatment for migraines, and then having a single prior concussion.

Aim 3: Determine if the effect of multiple past concussions on cognition or symptom reporting is different in boys versus girls.

There were sex differences on cognitive test performance and symptom ratings when controlling for covariates in the full model. Regardless of injury history, girls performed better on the verbal memory composite and the visual motor speed composite and slightly faster on the reaction time composite. Girls also endorsed more symptoms than boys: the top 3 symptoms endorsed at any level for girls were dizziness (26.0%), sadness (23.7%), and headaches (23.0%); the top 3 for boys were dizziness (19.3%), trouble falling asleep (17.7%), and balance problems (16.7%). Regardless of injury history, boys performed better on the visual memory composite. To explore whether there were sex differences in the context of concussion history and ImPACT performances, an interaction (number of concussions × sex) was added to the full model. The interaction between concussion history and sex did not significantly predict ImPACT cognitive scores (all 95% CIs included 1.0) or total symptom ratings (all 95% CIs included 1.0), suggesting no differences between boys and girls as a result of their history of concussion.

DISCUSSION

There is trepidation that repeated concussions in sport will result in long-term problems for children and adolescents. In the largest youth soccer sample to date, this study investigated whether adolescent soccer players with a history of concussions perform more poorly on cognitive testing and/or report more symptoms than athletes with no history of concussion. In addition, we examined whether there are sex differences in cognition and symptoms among those with a history of concussion—an area of concussion research that is grossly understudied for children and adolescents. Investigating potential interactions of sex differences by concussion history in a very large sample of male and female adolescent athletes is a unique contribution of this study to the broader concussion literature.

Having a history of 1, 2, or ≥3 concussions was not associated with consistent adverse effects on cognitive functioning (aim 1)—both in a univariate model and in a multivariate model that adjusted for known covariates. The few small but statistically significant group differences among participants with varying concussion histories

TABLE 2
Cognitive Performances and Symptom Ratings Among Adolescent Soccer Players[a]

	No. of Prior Concussions, Mean ± SD							
	Boys				Girls			
ImPACT Score	0	1	2	≥3	0	1	2	≥3
Players, No.	4012	527	130	73	3963	457	97	55
Verbal memory	82.4 ± 9.8	82.9 ± 10.0	81.9 ± 8.7	82.8 ± 9.9	84.8 ± 9.8	84.5 ± 10.1	84.7 ± 10.4	82.5 ± 10.0
Visual memory	74.2 ± 13.2	73.7 ± 13.5	71.9 ± 14.4[b]	72.7 ± 14.8	72.6 ± 13.1	73.0 ± 13.5	71.0 ± 14.4	69.2 ± 14.9
Visual motor speed	34.2 ± 7.1	34.5 ± 7.5	34.0 ± 7.2	33.1 ± 8.4	34.8 ± 6.6	35.0 ± 6.5	36.0 ± 7.2	34.8 ± 7.6
Reaction time	0.63 ± 0.11	0.63 ± 0.11	0.63 ± 0.12	0.65 ± 0.15	0.62 ± 0.10	0.62 ± 0.10	0.62 ± 0.08	0.63 ± 0.14
Total symptom score	3.5 ± 6.6	3.8 ± 6.4	6.1 ± 7.3[b]	7.0 ± 9.7[b]	5.3 ± 8.7	7.5 ± 11.4[b]	7.9 ± 9.9[b]	11.3 ± 12.8[b]

[a]Values represent raw scores. With the exception of reaction time scores, higher scores represent better or stronger cognitive abilities. Reaction time scores are presented with 2 decimal places. Greater symptom scores represent worse symptom ratings. ImPACT, Immediate Post-concussion Assessment and Cognitive Testing.
[b]$P < .05$, vs same-sex group with zero concussions at a univariate level.

are likely of minimal clinical significance and may possibly even represent type 1 error (false positive). In the context of mixed outcome findings from several previous studies of individual sports and multiple sports,[¶¶] our results add weight to the conclusion that a history of concussion (self-reported), even multiple prior concussions, does not have durable effects on cognition as measured by ImPACT. Findings from prior studies with soccer players ranged from no effects of concussions on cognition[23,25,61] to worse acute[14,49] and long-term[20] cognitive abilities among those who sustain a concussion. However, differences may be due to heterogeneity in level of play, age, and sex. It is possible that the cognitive test measures used in our study were not sufficiently sensitive to identify adverse effects associated with prior concussions; however, the tests were sensitive to differences associated with other factors measured, such as age, sex, and developmental conditions (learning disability and ADHD).

Although no consistent association was found in the present study between cognition and concussion history, there was an association between symptom reporting and concussion history in univariate and multivariable models. With each additional prior concussion noted in their history, youth athletes reported more symptoms during baseline preseason testing. This association was considerably attenuated but remained significant after controlling for other factors that more likely contributed to current postconcussion-like symptom reporting, including demographics (being an older adolescent, being female), developmental history (ADHD, learning disabilities), and psychological history (aim 2). In fact, prior mental health treatment was the strongest predictor for greater symptom reporting among these youth soccer players and is consistent with the findings from mixed-sport youth samples[33,37] and a large youth football sample[5] recruited from this same statewide cohort.

The third aim was to examine sex differences among those with a history of concussion (eg, sex × concussion interactions). Consistent with existing literature on noninjured males and females,[1,7-9,19,29,43] there were indeed sex differences in both cognitive test performance and symptom reporting among youth without a history of concussion. These sex differences, considered normal/expected in the absence of injury, should be accounted for by researchers when considering functioning after an injury, as others have done when including baseline performances[61] or when accounting for sex differences among those with a history of injury.[7]

This study does not support the hypothesis that boy and girl adolescent soccer players with a history of multiple concussions have differential symptom reporting or cognitive impairment. The absence of sex differences among those with a concussion history contrasts with prior studies of mixed-age soccer players (youth and young adult)[14,17] but is consistent with other studies of youth soccer players,[61] collegiate soccer players,[25] mixed-sport varsity athletes,[3] and elite youth hockey players[7] that did not support sex differences after concussion. In addition, not all literature on sex differences from past concussion supports that girls fare worse than boys. Covassin and colleagues[16] reported the baseline ImPACT performances of 188 collegiate-level soccer players with histories of multiple concussions and found that girls outperformed boys cognitively on verbal memory, visual memory, visual motor speed, and reaction time.

There are some limitations to consider. First, we could not define the injury severity characteristics of prior concussions or when the prior concussions occurred, as with most past studies.[##] Second, baseline testing was performed only on athletes who had never been concussed or who were cleared to return to play after concussion, which could have led to the exclusion of soccer players who recovered incompletely from a past concussion and thus to an underestimation of the long-term effects of multiple concussions. Third, prior concussion was based solely on self-report, which can result in slightly different information compared with other forms of documentation, such as

[¶¶]References 2, 5, 6, 14, 20, 23, 25, 30, 31, 37, 39, 40, 44, 45, 47, 61.

[##]References 4-7, 11, 13, 30, 32, 37, 39, 40, 46, 53, 58.

TABLE 3
Parameter Estimates for Predictors of ImPACT Domain Scores and Symptom Ratings[a]

	ImPACT Variables									
	Verbal Memory		Visual Memory		Visual Motor		Reaction Time		Total Symptoms	
	Exp(*B*)	95% CI	Exp(*B*)	95% CI	Exp(*B*)	95% CI	Exp(*B*)	95% CI	Exp(*B*)	95% CI
					Concussion history only					
Overall model	χ^2 = 5.94, *P* = .115		χ^2 = 7.97, *P* = .047		χ^2 = 2.86, *P* = .414		χ^2 = 3.36, *P* = .339		χ^2 = 141.35, *P* < .001	
No. of concussions										
≥3	0.25	0.04-1.39	0.11	0.01-1.10	0.50	0.15-1.66	0.90	0.79-1.03	2.02[b]	1.68-2.43
2	0.37	0.10-1.37	0.15[c]	0.03-0.85	1.49	0.60-3.70	1.02	0.92-1.12	1.57[b]	1.36-1.81
1	0.65	0.34-1.25	0.95	0.39-2.28	1.23	0.78-1.64	1.02	0.97-1.07	1.27[b]	1.18-1.37
0	1	—	1	—	1	—	1	—	1	—
					Concussion history and covariates					
Overall model	χ^2 = 134.18, *P* < .001		χ^2 = 118.61, *P* < .001		χ^2 = 497.79, *P* < .001		χ^2 = 331.76, *P* < .001		χ^2 = 1,488.42, *P* < .001	
No. of concussions										
≥3	0.52	0.09-3.08	0.21	0.02-2.32	0.32	0.09-1.07	0.85[c]	0.75-0.97	1.29[b]	1.06-1.57
2	0.41	0.11-1.56	0.12[c]	0.02-0.69	0.83	0.33-2.08	0.96	0.87-7.06	1.35[b]	1.17-1.57
1	0.74	0.38-1.44	0.96	0.39-2.37	0.92	0.58-1.46	1.00	0.95-1.05	1.15[b]	1.07-1.24
0	1	—	1	—	1	—	1	—	1	—
Sex										
Girls	3.66[b]	2.40-5.61	0.16[b]	0.09-0.29	2.23[b]	1.67-2.98	1.06[d]	1.02-1.09	1.54[b]	1.46-1.62
Boys	1	—	1	—	1	—	1	—	1	—
Age, y										
18	1.55	0.30-7.97	0.12	0.01-1.08	40.22[b]	13.13-123.20	1.34[b]	1.19-1.52	1.75[b]	1.42-2.11
17	1.69	0.59-4.79	0.16[d]	0.04-0.63	86.75[b]	42.74-177.20	1.65[b]	1.52-1.79	1.77[b]	1.57-1.99
16	1.85	0.70-4.88	0.29	0.08-1.08	30.07[b]	15.45-58.52	1.45[b]	1.35-1.56	1.67[b]	1.49-1.87
15	0.94	0.37-2.41	0.17[d]	0.05-0.60	3.62[b]	1.90-6.90	1.23[b]	1.14-1.32	1.58[b]	1.41-1.76
14	0.84	0.36-1.96	0.26[c]	0.08-0.80	1.49	0.84-2.67	1.10[d]	1.03-1.17	1.22[b]	1.10-1.34
13	1	—	1	—	1	—	1	—	1	—
History of learning disability										
Yes	0.01[b]	0.01-0.06	0.01[b]	0.01-0.07	0.01[b]	0.01-0.03	0.79[b]	0.72-0.88	1.64[b]	1.40-1.91
No	1	—	1	—	1	—	1	—	1	—
ADHD										
Yes	0.33[c]	0.12-0.94	0.34	0.09-1.38	0.49[c]	0.24-0.99	0.94	0.87-1.02	1.51[b]	1.35-1.69
No	1	—	1	—	1	—	1	—	1	—
Treatment for headaches										
Yes	0.51	0.20-1.28	0.85	0.25-2.95	0.98	0.52-1.84	0.94	0.88-1.01	1.57[b]	1.42-1.73
No	1	—	1	—	1	—	1	—	1	—
Treatment for migraines										
Yes	0.67	0.22-2.02	0.25	0.06-1.11	1.40	0.66-2.98	1.07	0.99-1.17	1.22[d]	1.08-1.37
No	1	—	1	—	1	—	1	—	1	—
Treatment for substance or alcohol problem										
Yes	0.04[c]	0.01-0.82	0.35	0.01-17.68	0.78	0.11-5.71	0.91	0.73-1.14	1.59[d]	1.17-2.16
No	1	—	1	—	1	—	1	—	1	—
Treatment for psychiatric condition										
Yes	0.40	0.15-1.06	0.07[b]	0.02-0.28	1.58	0.80-3.11	1.01	0.93-1.09	2.24[b]	2.01-2.48
No	1	—	1	—	1	—	1	—	1	—

[a]Exp(*B*) = exponentiated coefficient (not raw coefficient), which can be interpreted similar to an odds ratio. Items with an exponentiated coefficient of 1 are set as the reference value. ADHD, attention-deficit/hyperactivity disorder; ImPACT, Immediate Post-concussion Assessment and Cognitive Testing.
[b]*P* < .001.
[c]*P* < .05.
[d]*P* < .01.

prospective injury surveillance medical record review, or parental interviews.[42] Fourth, this study used a cross-sectional methodology, similar to other studies examining athletes during baseline preseason testing.[a] Longitudinal research designs are needed to more definitely confirm or rule out persistent cognitive effects of prior concussions in youth soccer players. Fifth, the data collection did not include pubertal stage, luteal stage, or body mass index, which can be potential moderators of cognition, symptoms, and recovery trajectories.[22,35,59] Sixth, this study did not examine or consider number of years of exposure to sport, ball heading, or subconcussive impacts to the head. Seventh, these data are derived from adolescent athletes in the state of Maine, and we did not have access to ethnicity

[a]References 4, 11, 12, 24, 26, 30, 32, 34, 36, 46, 51, 52, 58.

or socioeconomic status, so the results may not represent youth soccer players from other states or other countries. Eighth, the sample was >6 months after injury, but we did not know the exact time since concussion. Therefore, we cannot comment on whether there are long-term effects from prior concussions that exceed the period studied in this sample. Finally, the primary outcome measure is a brief computerized test of cognitive abilities and does not represent a comprehensive neuropsychological evaluation. Although prior studies with traditional neuropsychological testing have also suggested no long-term cognitive differences among those with prior concussion for a meta-analysis (see Belanger et al[2]), it is possible that a different test battery used in this population would reveal different results (a direction for future research).

Many clinicians, researchers, sport organizations, and policy makers are concerned that concussions among youth will cause deleterious and lingering effects on brain development. There is additional concern that possible effects are more pronounced in girls than in boys. The present study did not find evidence to support these concerns in this sample, suggesting that this information can be used clinically to guide concerns about the effects of concussion among youth soccer players. Cognitive performance was not lower for youth soccer players with a history of concussions. Girls differed from boys on verbal memory (better), visual memory (worse), and visual motor speed (better), but these were sex differences, not injury-related differences. Symptom ratings were highly elevated for youth with prior concussions, and those who reported more prior concussions reported greater symptoms. However, mental health history, developmental history, sex, and age contributed more strongly to symptom scores than concussion history. Girls reported more symptoms than boys, but similar to the cognitive test results, this was a sex difference and not an injury difference.

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