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Concussion History and Postconcussion Neurocognitive Performance and Symptoms in Collegiate Athletes

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Context: Athletes are at an inherent risk for sustaining concussions. Research examining the long-term consequences of sport-related concussion has been inconsistent in demonstrating lingering neurocognitive decrements that may be associated with a previous history of concussion.

Objective: To determine the relationship between concussion history and postconcussion neurocognitive performance and symptoms in collegiate athletes.

Design: Repeated-measures design.

Setting: Multi-center analysis of collegiate athletes.

Patients or Other Participants: Fifty-seven concussed collegiate athletes (36 without concussion history, 21 with a history of 2 or more concussions).

Intervention(s): All subjects were administered an Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) neurocognitive test battery, which measures verbal memory, visual memory, reaction time, and visual processing speed and 22 concussion symptoms.

Main Outcome Measure(s): Subjects who sustained a concussion were administered 2 follow-up tests at days 1 and 5 postinjury. Independent variables were history of concussion (no history of concussion, 2 or more concussions) and time (baseline, day 1 postconcussion, or day 5 postconcussion).

Results: A within-subjects effect (time) on ImPACT performance ($P < .001$), a between-subjects multivariate effect of group ($P < .001$), and a group-by-time interaction ($P = .034$) were noted. Athletes with a concussion history performed significantly worse on verbal memory ($P = .01$) and reaction time ($P = .023$) at day 5 postconcussion compared with athletes who did not report a previous concussion. No significant group differences were seen at day 5 postinjury on visual memory ($P = .167$), processing speed ($P = .179$), or total concussion symptoms ($P = .87$).

Conclusions: Concussed collegiate athletes with a history of 2 or more concussions took longer to recover verbal memory and reaction time than athletes without a history of concussion.

Key Words: mild traumatic brain injury, ImPACT, memory, reaction time

Key Points

- Compared with collegiate athletes having no history of concussion, those with a history of concussion took longer to recover after concussion on neurocognitive measures of verbal memory and reaction time.
- After concussion, collegiate athletes with a history of concussion were impaired in verbal memory and reaction time, demonstrating at least 1 reliable decline in each measure, at day 5 compared with baseline.

Sport-related concussion continues to warrant attention from sports medicine professionals. Approximately 300 000 sport-related concussions are reported in the United States each year.[1] An athlete who has suffered 1 concussion is at 3 to 6 times greater risk for suffering a second concussion.[2–5] Long-term neurocognitive impairments are rarely associated with a single concussion; however, multiple concussions have had detrimental effects on athletes participating in boxing,[6] men's ice hockey,[7] and men's soccer.[8] With respect to significant lingering effects after injury, findings on the cumulative effect of multiple concussions are equivocal. Furthermore, most research on multiple concussions has been retrospective, using only posttest designs.

Several researchers[5,9–13] have suggested that the cumulative effects of repeated concussions can have long-term consequences. Specifically, Guskiewicz et al[9] found that dementia-related symptoms may be a result of repetitive concussions in professional football players. Guskiewicz et al[5] also noted that collegiate football players with a history of 3 or more concussions were at 3 times greater risk for suffering another concussion compared with athletes without a history of concussion. Lingering or lasting effects from concussion have also been found in high school populations. Iverson et al[13] reported that high school athletes with a history of 3 or more concussions presented more symptoms and poorer memory performance on neurocognitive testing at baseline than athletes with no history of concussion. In addition, Moser et al[12] found that high school athletes with a history of 2 or more concussions demonstrated similar cognitive performance as high school athletes who had sustained a concussion in the past week. These results suggest that a history of concussion may be associated with a prolonged recovery after subsequent concussions. Furthermore, these findings are consistent with previous research suggesting that athletes with a history of 3 or more concussions showed decreased memory performance,[2] a greater number of postconcussion symptoms during baseline testing,[14] and 3 or 4 on-field markers.[15]

Several investigators[5,12,13] have examined the possible lingering effects of multiple concussions on participants of different ages (high school and college) with 1, 2, or 3 previous concussions. Wall et al[16] compared the cognitive performance of jockeys with or without a history of concussion. After a 3-month recovery period, jockeys with a history of concussions performed worse on neurocognitive testing than their counterparts with no history of concussion. In addition, younger jockeys with a history of concussion exhibited poorer neurocognitive performance than older jockeys with a history of concussion. These findings suggest that a history of concussion may place an athlete at risk for developing long-term sequelae associated with postconcussion syndrome and that younger athletes may be more vulnerable to long-term effects than older athletes.

Although most research findings have demonstrated detrimental outcomes in athletes who have a history of concussion, other authors have shown the opposite. Iverson et al[17] observed that high school athletes with a history of 2 or more concussions and recently concussed athletes (within 1 week of injury) displayed similar performance on tests of processing speed and attention. No effects were noted for either group in verbal memory, visual memory, reaction time, processing speed, and postconcussion symptom totals. Broglio et al[18] examined baseline computerized neurocognitive performance of collegiate athletes with a history of 0, 1, 2, or 3 previous concussions. In contrast with previous research,[5,9–13,19] there were no between-group differences to suggest lingering cognitive deficits from previous concussion. However, they did not assess the influence of concussion history on neurocognitive performance immediately after a concussion.

Considerable debate exists among sports medicine professionals regarding diagnosis of, and safe return-to-play guidelines after, a concussion. To support on-field diagnoses, computerized neurocognitive testing has become a widely used objective method for determining subtle cognitive changes in postconcussion athletes.[20,21] Although normative data exist for neurocognitive testing without a baseline, baseline testing is strongly recommended so athletes can serve as their own controls.[20]

Most researchers examining the effect of history on concussion have limited their scope to football players,[2,3] high school athletes,[2,13] or both. Furthermore, few authors have examined neurocognitive deficits in athletes with a history of 2 or more concussions or collegiate athletes in a variety of sports. Therefore, our purpose was to investigate whether concussed collegiate athletes with a history of 2 or more concussions demonstrated neurocognitive impairments when compared with concussed athletes with no history of concussion.

METHODS

We used a repeated-measures design to compare baseline and postconcussion neurocognitive scores and symptoms. The independent variables were history of concussion (no history of concussion, 2 or more concussions) and time (baseline, day 1 postconcussion, or day 5 postconcussion). The dependent variables were verbal memory, visual memory, reaction time, visual processing speed, and individual and total concussion-related symptoms.

Table 1. Sport and Sex by History of Concussion (n = 57)

Sport	No Previous Concussion	2 or More Previous Concussions
Women's basketball	4	2
Men's basketball	2	2
Women's soccer	4	2
Men's soccer	3	3
Women's lacrosse	2	0
Men's lacrosse	3	2
Men's baseball	1	1
Men's football	5	4
Men's wrestling	3	2
Women's gymnastics	3	2
Women's softball	2	0
Women's volleyball	1	1
Women's cheerleading	3	0

Participants

Participants were collegiate athletes from 5 northeastern universities active in men's and women's basketball, soccer, and lacrosse; men's baseball, football, and wrestling; and women's gymnastics, softball, volleyball, and cheerleading. The athletes selected for this study were practicing and competing during the 2002–2003 and 2003–2004 academic seasons. A total of 57 athletes sustained concussions during the 2-year study (Table 1) for a cohort of 36 controls (age = 20.55 ± 1.54 years, height = 167.41 ± 7.49 cm, mass = 76.8 ± 16.17 kg) and 21 subjects with a history of 2 or more concussions (age = 21.10 ± 1.69 years, height = 169.19 ± 8.10 cm, mass = 75.43 ± 11.02 kg). Athletes with a history of 1 concussion were excluded from this study because the small sample size provided inadequate data.

Instrumentation

The Quality Standards Subcommittee of the American Academy of Neurology[22] described a cerebral concussion as an altered mental state that may or may not include loss of consciousness. In our study, the American Academy of Neurology grading scale criteria were used by physicians and certified athletic trainers to assess athletes who suffered a concussion.

The Immediate Post-Concussion Assessment Cognitive Testing (ImPACT) (version 2.0; NeuroHealth System, LLC, Pittsburgh, PA) computer software program was used to assess neurocognitive function and concussion symptoms. The program consists of 6 neurocognitive tests that evaluate attention, verbal recognition memory, visual working memory, visual processing speed, reaction time, numerical sequencing ability, and learning. These 6 neurocognitive tests yield 4 composite scores in verbal memory, visual memory, reaction time, and visual processing speed. Using reliable change indices, we found that repeated administrations over a 2-week period produced no practice effects.[23] Iverson et al[24] reported 1-week test-retest reliability coefficients of 0.70 for verbal memory, 0.67 for visual memory, 0.79 for reaction time, and 0.86 for processing speed. Within-subjects comparisons revealed test-retest differences only for processing speed composite scores. Schatz et al[25] documented a combined sensitivity of 81.9% for ImPACT indices and total symptom score and specificity of 89.4%; positive likelihood ratio was approximately 8:1 and negative likelihood ratio was 2:1.

Testing Procedures

Approval for the study and use of human subjects was granted from each participating university's institutional review board. Similarly, permission was obtained from all team physicians, athletic directors, certified athletic trainers, and athletes at each participating institution. All test procedures were explained to each athlete, who then completed the ImPACT neurocognitive test battery in a computer laboratory at his or her university during the preseason for baseline and at day 1 and day 5 postconcussion.

Data Analysis

The ImPACT yielded composite scores for verbal memory, visual memory, reaction time, and visual processing speed. A high score indicated better performance for all measures except reaction time. Verbal and visual memory scores were presented as percentages of 100. The ImPACT also yielded individual scores for concussion symptoms. Athletes indicated if they were experiencing any of the 22 concussion symptoms during postconcussion testing. Concussion symptoms were rated on a 6-point Likert scale, with zero indicating *not experiencing* and 5 indicating *severe*. Scores were summed to reflect a total symptom score.

A χ^2 using the Fisher exact test was performed on concussion severity by history of concussion. A 3 × 2 mixed-factors design multiple analysis of variance was conducted with time (baseline, day 1 postconcussion, day 5 postconcussion) and group (no history of concussion, 2 or more concussions) as the factors and the ImPACT indices as the dependent variables. A multiple analysis of variance was conducted on all concussion symptoms across days and groups. The statistical significance level was set at .05. We conducted all analyses using SPSS software (version 15.1; SPSS Inc, Chicago, IL).

RESULTS

A total of 57 athletes sustained a concussion during the 2-year study. On average, athletes were posttested 1.2 and 5.1 days after sustaining a concussion. Of the 36 concussed athletes who reported no concussion history, 29 had grade I, 4 had grade II, and 3 had grade III concussions. The group of previously concussed athletes consisted of 15 athletes with grade I, 1 athlete with grade II, and 5 athletes with grade III concussions. A χ^2 using the Fisher exact test revealed that athletes with a history of concussion did not have a greater likelihood of sustaining a more severe concussion (grade II or III concussion) compared with a grade I concussion (χ^2_2 = 5.02, $P = .10$). In terms of on-field markers, 5 athletes with a history of 2 or more concussions (23.8%) and 3 athletes with no history of concussion (8.3%) suffered loss of consciousness. Six athletes with a history of 2 or more concussions (28.6%) and 4 athletes with no history of concussion (11.1%) reported both retrograde and anterograde amnesia after injury.

The assumption of covariance matrix homogeneity in the data was not violated (M = 96.47, $F_{78,5675.08}$ = .911, P = .698). Wilks Λ revealed a multivariate within-subjects effect (time) on ImPACT performance (Λ = .559, $F_{2,54}$ = 4.73, $P <$ .001), a between-subjects multivariate effect of group (Λ = .709, $F_{1,55}$ = 5.35, $P < .001$), and a group-by-time interaction (Λ = .720, $F_{2,54}$ = 2.33, P = .034).

Table 2. ImPACT Index at Baseline and 1 and 5 Days Postconcussion by History of Concussion (Mean ± SD) (n = 57)

ImPACT Index	No Previous Concussion	2 or More Previous Concussions	*P*
Verbal memory			
Baseline	0.87 ± 0.10	0.89 ± 0.10	
Day 1	0.80 ± 0.11	0.81 ± 0.09	
Day 5	0.88 ± 0.08	0.81 ± 0.09	.01[a]
Reaction time			
Baseline	0.53 ± 0.06	0.53 ± 0.07	
Day 1	0.60 ± 0.05	0.63 ± 0.08	
Day 5	0.52 ± 0.06	0.60 ± 0.07	.023[a]
Visual memory			
Baseline	0.78 ± 0.12	0.74 ± 0.13	
Day 1	0.64 ± 0.11	0.71 ± 0.12	
Day 5	0.74 ± 0.13	0.72 ± 0.11	.167
Processing speed			
Baseline	39.86 ± 5.82	39.50 ± 6.97	
Day 1	32.37 ± 7.96	33.29 ± 6.32	
Day 5	37.64 ± 7.03	37.26 ± 7.00	.179

[a] Significant at the .05 level between groups at 5 days postconcussion.

Univariate post hoc analyses were conducted for days 1 and 5 postconcussion to determine between-groups differences in neurocognitive function. No differences were seen between the groups 1 day after incurring a concussion (P = .34). However, differences were noted at day 5 postconcussion. Athletes with a history of 2 or more concussions demonstrated a lower verbal memory score (P = .01) and slower reaction time (P = .023) than athletes without a history of concussion (Table 2). No group differences were found on day 5 postinjury for visual memory (P = .167) or visual processing speed (P = .179).

Within-groups comparisons for athletes with a history of 2 or more concussions revealed worse verbal memory (P = .002), visual memory ($P < .001$), visual processing speed (P = .001), and reaction time ($P < .001$) 1 day postinjury compared with baseline scores. Similarly, within-groups comparisons for athletes who did not report a history of concussion revealed lower scores for verbal memory (P = .01), visual memory ($P < .001$), visual processing speed ($P < .001$), and reaction time ($P < .001$) at day 1 postconcussion compared with baseline scores. All athletes with a history of concussion improved by day 5 postinjury compared with day 1 postinjury on verbal memory (P = .001), visual memory ($P < .001$), visual processing speed ($P < .001$), and reaction time ($P < .001$). All athletes without a concussion history improved by day 5 postinjury compared with day 1 postinjury for verbal memory (P = .002), visual memory ($P < .001$), visual processing speed ($P < .001$), and reaction time ($P < .001$). In addition, all athletes in both groups made progress toward regaining their baseline scores by day 5 postconcussion for all ImPACT measures and total concussion symptoms.

Ratings for 22 concussion symptoms are shown at baseline and day 1 and day 5 postconcussion (Table 3). Multivariate assessment of symptoms across days and groups revealed no differences between groups (Λ = .636,

Table 3. All Concussion Symptoms by History of Concussion at Baseline and Day 1 and Day 5 Postconcussion (Mean ± SD) (n = 57)

Symptom	History of Concussion	Baseline	Day 1	Day 5
Headache	No	0.67 ± 1.06	1.86 ± 1.6	1.25 ± 0.72
	≥2	0.62 ± 0.87	2.56 ± 1.4	1.73 ± 1.01
Nausea	No	0.31 ± 0.82	0.71 ± 0.85	0.03 ± 0.67
	≥2	0.00 ± 0.00	1.11 ± 1.2	0.05 ± 0.78
Vomiting	No	0.00 ± 0.00	0.05 ± 0.21	0.25 ± 0.84
	≥2	0.00 ± 0.00	0.28 ± 0.66	0.83 ± 1.04
Balance problems	No	0.00 ± 0.00	0.85 ± 1.25	0.25 ± 0.55
	≥2	0.11 ± 0.40	1.28 ± 1.5	0.10 ± 0.43
Dizziness	No	0.14 ± 0.35	1.19 ± 1.40	0.29 ± 0.72
	≥2	0.25 ± 0.64	1.75 ± 1.46	0.39 ± 0.80
Fatigue	No	1.14 ± 1.5	1.75 ± 1.79	0.65 ± 0.90
	≥2	0.81 ± 1.25	2.19 ± 1.78	0.95 ± 0.71
Trouble falling asleep	No	0.72 ± 1.1	0.97 ± 1.6	0.15 ± 0.62
	≥2	0.43 ± 1.03	0.57 ± 1.3	0.56 ± 0.74
Sleeping more than usual	No	0.28 ± 0.74	0.91 ± 1.6	0.61 ± 0.59
	≥2	0.38 ± 0.86	0.57 ± 1.03	0.47 ± 0.32
Sleeping less than usual	No	0.05 ± 0.21	0.81 ± 1.6	0.10 ± 0.41
	≥2	0.56 ± 0.97	0.57 ± 1.39	0.16 ± 0.32
Drowsiness	No	0.69 ± 1.14	1.94 ± 1.7	0.63 ± 0.81
	≥2	0.71 ± 1.10	2.19 ± 2.1	0.93 ± 0.67
Sensitive to light	No	0.44 ± 0.87	0.67 ± 0.85	0.25 ± 0.54
	≥2	0.33 ± 0.97	1.78 ± 1.8	0.10 ± 0.42
Sensitive to noise	No	0.19 ± 0.75	0.86 ± 1.4	0.52 ± 0.76
	≥2	0.10 ± 0.31	1.31 ± 1.83	0.78 ± 0.65
Irritability	No	0.44 ± 0.88	1.08 ± 1.66	0.68 ± 0.64
	≥2	0.71 ± 1.3	1.05 ± 1.68	0.85 ± 0.50
Sadness	No	0.14 ± 1.02	0.50 ± 0.87	0.15 ± 0.60
	≥2	0.39 ± 1.05	0.43 ± 1.16	0.33 ± 0.69
Nervousness	No	0.14 ± 0.35	0.75 ± 1.2	0.09 ± 0.91
	≥2	0.72 ± 1.34	0.33 ± 0.79	0.12 ± 1.04
Feeling more emotional	No	0.53 ± 0.97	0.56 ± 1.13	0.51 ± 0.84
	≥2	0.19 ± 0.60	0.52 ± 1.12	0.72 ± 0.75
Numbness	No	0.25 ± 0.94	0.44 ± 1.05	0.05 ± 0.15
	≥2	0.00 ± 0.00	0.10 ± 0.30	0.07 ± 0.21
Feeling slowed down	No	0.53 ± 0.88	2.03 ± 1.89	0.41 ± 0.34
	≥2	0.38 ± 0.97	1.95 ± 1.94	0.45 ± 0.41
Feeling mentally foggy	No	0.56 ± 0.97	2.06 ± 1.85	0.39 ± 0.80
	≥2	0.29 ± 0.90	1.95 ± 1.66	0.29 ± 0.72
Difficulty concentrating	No	0.24 ± 0.70	1.67 ± 1.56	0.44 ± 0.82
	≥2	0.83 ± 1.2	1.97 ± 1.89	0.51 ± 1.03
Difficulty remembering	No	0.50 ± 1.02	1.29 ± 1.48	0.35 ± 0.59
	≥2	0.24 ± 0.77	1.08 ± 1.42	0.48 ± 0.66
Visual problems	No	0.25 ± 0.65	1.11 ± 1.58	0.09 ± 0.26
	≥2	0.00 ± 0.00	0.67 ± 0.97	0.18 ± 0.35
Total symptoms	No	10.38 ± 9.49	22.08 ± 17.8	6.40 ± 6.8
	≥2	5.9 ± 7.67	25.91 ± 21.05	5.30 ± 7.0

$F_{1,55}$ = .886, P = .622), within-subjects effect (time) (Λ = .157, $F_{2,54}$ = 1.63, P = .171), or group-by-time interaction (Λ = .224, $F_{2,54}$ = 1.046, P = .493).

Reliable change indices were calculated to determine clinically significant decreases at days 1 and 5. The use of reliable change indices is well documented; a discussion of their application and implementation using ImPACT was recently published by Iverson et al.[23] At day 1 postinjury, 81% of subjects with a concussion history demonstrated at least 1 reliable decline for reaction time (n = 17), 57% for visual processing speed (n = 12), 52% for verbal memory (n = 11), and 48% for visual memory (n = 10). At day 1 postinjury in athletes without a concussion history, at least 1 reliable decline was seen in 56% of subjects for visual processing speed (n = 20), 50% for reaction time (n = 18), 44% for visual memory (n = 16), and 39% for verbal memory (n = 14).

At day 5 postinjury, 57% of athletes with a concussion history demonstrated at least 1 reliable decline for both reaction time and verbal memory (n = 12), 48% for visual processing speed (n = 10), and 29% for visual memory (n = 6). At day 5 postinjury in athletes with no history of concussion, at least 1 reliable decline was found in 31% of subjects for processing speed (n = 11), 22% for visual memory (n = 8), 14% for reaction time (n = 5), and 11% for verbal memory (n = 4).

DISCUSSION

While researchers continue to examine how a history of concussion relates to lasting neurocognitive effects, the current study suggests areas of concern regarding recovery and neurocognitive performance. Our purpose was to examine the effects of a concussion history on recovery in concussed collegiate athletes. We found that concussed collegiate athletes reporting a history of concussion may take longer to recover on neurocognitive measures of verbal memory and reaction time than athletes without a concussion history. Specifically, athletes with a concussion history were impaired in verbal memory and reaction time at day 5 postconcussion when compared with baseline. In addition, reliable change indices were calculated to determine the clinical interpretation of change in neurocognitive performance. A larger percentage of previously concussed athletes was found to have at least 1 reliable decline in reaction time and verbal memory than athletes without a concussion history at day 5 postinjury.

These findings suggest neurocognitive deficits in athletes who report a history of concussion.[13] In collegiate football players, Guskiewicz et al[5] indicated that a history of 3 of more concussions may place an athlete at a higher risk of incurring a concussion in the same season. Furthermore, Guskiewicz et al[5] proposed that athletes with multiple concussions may take longer to recover from subsequent concussions. Iverson et al[13] found that athletes with a history of concussion exhibited a decrease in memory and were more likely to demonstrate a major drop in memory performance than athletes with no previous concussion 2 days after injury. However, at 5 days postinjury, Iverson et al[13] noted no differences in neurocognitive function between the groups. These findings differ from our results that indicated differences in verbal memory and reaction time at day 5 postconcussion between athletes with and without a concussion history.

Recently, investigators have identified an emerging pattern of neurocognitive decrements commonly occurring in the days after a concussion. These impairments include visual-motor reaction time, memory, and attention.[26–28] Our findings of verbal memory and reaction time impairments in athletes with a history of concussion at day 5 postinjury add to this emerging pattern. A possible explanation for these verbal memory and reaction time impairments in athletes with a history of concussion may be increased glycolysis, which leads to increased lactate production after a subsequent head injury.[29] This increase in lactate production after brain injury may lead to secondary ischemic injury, which may predispose the brain to repeat injury.[30] Furthermore, animal studies have shown decreased cerebral blood flow up to 10 days after a concussion.[31] Although only shown in animal models, this decreased cerebral blood flow after a concussion may be a mechanism that predisposes athletes with a history of concussion to take longer to recover or to sustain further injury. However, these results have not yet been tested in human models and need further investigation.

In contrast to our findings, Macciocchi et al[27] noted no cumulative effects in athletes who sustained 2 grade I concussions more than 2 weeks apart. However, a small sample size (n = 24) may have limited their ability to identify statistical significance. Collie et al[32] examined baseline neurocognitive performance in professional athletes with a history of concussion. No differences were found in cognitive function on measures of memory, motor function, decision making, attention, and learning. Broglio et al[18] also reported no difference in baseline neurocognitive function in athletes with a history of concussion. However, these authors did not examine neurocognitive performance in athletes recovering from concussion.

Sports medicine professionals often rely on symptom reporting of the concussed athlete. Gaetz et al[14] reported that junior ice hockey players who had a history of 3 or more concussions demonstrated a greater number of postconcussion symptoms than those without a history of concussion. However, in our study, concussed athletes did not demonstrate differences between groups on concussion symptoms, even though they were still exhibiting neurocognitive impairments in reaction time and verbal memory. Van Kampen et al[33] found that 19% of athletes who did not report concussion symptoms demonstrated impairments. A possible explanation may be athletes trying to minimize their symptoms, so they can continue to participate in practice or competition. Another explanation may be that athletes are not fully aware of their concussion symptoms and, thus, do not report them to the certified athletic trainer or team physician. Therefore, it is important that a concussed athlete not be returned to practice or competition until he or she is symptom free and neurocognitive test scores return to baseline. Furthermore, these findings concur with those of Van Kampen et al,[33] who suggested that neurocognitive testing is a valuable tool to use in conjunction with reported symptoms, increasing the accuracy in making safe return-to-play decisions.

Researchers who have examined the history of concussion and its influence on concussion outcomes have largely focused on football, soccer, and ice hockey. We examined male and female athletes who incurred multiple concussions across a variety of collegiate sports. Most of the sports played by both males and females had a fairly equal distribution of concussions between the sexes. Unfortunately, we could not conduct a statistical analysis due to insufficient sample size. Sex differences and concussion history may warrant future attention, as females have demonstrated more severe declines in measures of reaction time and more total symptoms after concussion than males.[34] Therefore, future authors should compare neurocognitive effects of multiple concussions among sports and between sexes. Further investigation is also needed as to time of year of previous concussion and how sports medicine professionals manage concussions in relation to the time the athlete suffered a concussion.

Certain limitations of the current study should be addressed. First, concussion history data were self-reported. It was impossible to verify medical records to establish if a concussion was diagnosed by a physician. Second, many concussions go unreported and unrecognized by certified athletic trainers and physicians. Third, athletes self-reported their concussion symptoms and may have been motivated to minimize or underreport their symptoms to continue sport participation. Therefore, sports medicine professionals should continue with follow-up testing, and closely monitor neurocognitive recovery (back to baseline) before returning athletes to the playing field.[35]

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