

## Outcomes of Sport-Related Concussion Among College Athletes

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*The author collected and analyzed data for all student-athletes diagnosed with concussion between 1998 and 2011. Outcome measurements were post-concussion symptom duration, time interval until return-to-play, and clinical outcomes self-reported by athletes and by athlete's parent/guardian 1 year post-injury. A total of 98 concussions occurred in 95 student athletes among a cohort averaging 350 athletes competing yearly. Athletes were managed according to expert-consensus guidelines. Forty-one (43%) of the athletes had experienced a previously-diagnosed concussion (range: 1–3). Eight athletes (10.4%), retired from their sport for concussion-related issues. Six athletes (6.3%) with completed follow-up experienced memory and/or concentration impairment(s) lasting more than 1 year.*

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Management of sport-related head injury is a challenge to sports medicine practitioners. Although diagnostic criteria have been defined,<sup>1,2</sup> return-to-play (RTP) issues remain controversial.<sup>3–5</sup> Utilizing current consensus guidelines based on symptom resolution, athletes typically return to practice and play within 7–10 days. In a study of high school football players, Collins et al. reported an RTP interval from 10.9 to 13 days.<sup>6</sup> In contrast, Pellman et al. reported that 15% of concussed National Football League athletes return to play “immediately;” 34% return during the same game after a “rest;” and 92% return to play within 7 days after injury.<sup>7</sup> Late consequences involving memory impairment associated with this treatment paradigm were reported by Guskiewicz et al.<sup>8</sup> They administered a questionnaire to 758 retired professional football players and found that multi-concussed athletes “had a threefold prevalence of reported significant memory problems compared with retirees without a history of concussion.”

Ellemborg et al. administered neuropsychological tests to concussed collegiate female soccer athletes, finding persisting impairment in decision-making and planning 6–8 months post-injury.<sup>9</sup> Collins et al. detected subtle neurocognitive deficits among multi-concussed college football players.<sup>10</sup> However, several studies<sup>11–14</sup> utilizing both computerized and traditional neuropsychological assessments have reported normal results in previously-concussed athletes. No studies were found that assessed long-term *clinical outcomes* among a consecutive cohort of uniformly managed collegiate athletes, specifically longer-term memory and concentration

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TABLE 1. Concussion Incidence by Sport Over 12 Years

| Sport          | Concussions, N        | % of Total Concussions |
|----------------|-----------------------|------------------------|
| Football*      | 51                    | 53                     |
| Basketball**   | 10 (5 female, 5 male) | 10                     |
| Soccer#        | 9                     | 9                      |
| Lacrosse*      | 7                     | 7                      |
| Softball#      | 4                     | 4                      |
| Cheerleading#  | 4                     | 4                      |
| Baseball*      | 5                     | 5                      |
| Volleyball#    | 2                     | 2                      |
| Equestrian#    | 4                     | 4                      |
| Snowboarding   | 1 (female)            | 1                      |
| Swimming       | 1 (male)              | 1                      |
| Miscellaneous§ | 1 (male)              | 1                      |

\*male sport.

#female sport.

§athlete injured playing intramural sport.

issues. The purpose of this observational study is to report clinical outcomes (self-reported disabilities 1 year post-injury) occurring after sport-related concussions among a consecutive cohort of collegiate athletes at a single university between 1998 and 2009.

## METHODS

An ambi-directional, observational cohort design was utilized to study concussed college athletes. The student-athletes (N=95), with a mean age (SD) of 19.8 (2.1) years, had participated in their sport(s) for a mean (SD) of 10.6 (3.6) years. Nearly half of them had experienced diagnosed concussions before entering college (Table 1). Therefore, a major portion of their sports exposure and consequent head trauma occurred during childhood and adolescence. None of these athletes, however, reported concussion-related symptoms on their initial collegiate medical history questionnaire.

Concussion is most recently defined as "a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces."<sup>2</sup> Diagnosis for athletes included in this study required the appearance of several of the following symptoms<sup>15</sup> and signs after a "head incident:" confusion, amnesia, headache, nausea/vomiting, sleep disturbance, visual disturbance, disequilibrium, dizziness, difficulty concentrating, and feeling "spacey."

Certified athletic trainers (ATCs) attended all competitions and practices involving athletes in contact sports. They and/or hospital emergency room physicians

provided initial evaluations for student-athletes with suspected concussion if the team physician was not present at the competition or practice site. Hospital records were obtained from the respective institutions, and athletes' clinical data were recorded and maintained on an electronic medical record. Although lack of recognition and under-reporting of symptoms by athletes is an issue affecting the incidence of diagnosed concussions,<sup>16,17</sup> we believe that most episodes were identified by the trained personnel attending the contact-sport practices and competitions at our school.

Injured athletes underwent repeated (usually every 2–3 days) physical and neurological examinations, including mental function measures (orientation, serial 7's or months-backward tasks, immediate and delayed recall (5 elements), and repetition of numbers forward (maximum: 8) and backward (maximum: 7). We found the tandem-walking and the repetition of numbers backward tasks to be the most sensitive tests of impairment.

Computerized neurocognitive tests were not performed because of the lack of logistical and financial resources.

Consensus guidelines pertaining to management and RTP were utilized to advise athletes. Complete physical and, when practical, cognitive rest was prescribed until symptoms resolved; this was followed by a graded resumption of activity. RTP was only approved when this process was completed without symptom recurrence. Athletes were allowed to attend classes if disability related to headache, nausea, vision, and concentration/attention impairments permitted. During this interval, they were advised to avoid the use of aspirin and/or nonsteroidal anti-inflammatory medications and alcohol. Data concerning symptom duration, time to RTP, and history of previous concussions are presented in Results to provide a clearer context of our study cohort and to demonstrate that our management of head injury conformed to recommended practice.

One year after each athlete's concussion, they and their responsible parent or guardian were contacted in person or by telephone to ascertain their current status (symptoms, school or job performance, and estimate concerning possible concussion effects on their well-being). This study was approved as "exempt" by the Pace University Institutional Review Board.

## RESULTS

### Concussion Incidence

A total of 98 concussions occurred among 95 athletes (three sustained two concussions during their competitive careers at the university). Their ages (mean (SD): 19.8 (2.1)) ranged from 18 to 22 years, with one athlete 24 and the other 30. Sixty-six (69%) were male and 29 (31%) female. The concussion-associated sports are shown in Table 1.

### Imaging Studies

A group of 17 athletes underwent imaging studies, mostly performed when injury occurred during "away" games, and initial evaluation occurred in hospital emergency rooms. In a few instances, MRI scans were obtained for athletes with prolonged symptoms; 14 head CT scans and 4 brain MRI scans (one athlete had both) were normal. These results conform with the current consensus that conventional imaging contributes little to the evaluation of athletic concussion in the absence of clear indications from a neurological examination.<sup>2</sup>

### Return-to-Play (RTP)

Analysis of days-with-symptoms and time-to-RTP by gender was performed, excluding athletes with symptoms exceeding 30 days and those who retired or could not return before the end of a sport's season. The mean number of days (SD) with symptoms was 6.9 (4.7); (N=81), and mean number of days (SD) until RTP was 14.6 (5.7); (N=70), as some injuries occurred near the end of the sports season). On separate analysis, we observed no significant gender effects on symptom duration or RTP times among our athletes.

### Previous Head Injury

In all, 41 of our 95 concussed athletes (43%) had experienced a previous diagnosed concussion (range: 1–3). Also, many among the remainder commented that they had experienced similar incidents that were unreported or undiagnosed during Youth League or high school sports participation. Therefore, many of our athletes were "multi-concussed." This confirms observations from several recent studies cited by Meehan and Bachur.<sup>17</sup>

### Late Symptomatic Outcome

In the group, 8 athletes (6 football, 1 lacrosse, 1 cheerleader), comprising 10.6% of the cohort for whom 1-year follow-up information was available, elected to

retire from competition as the result of 1) having experienced multiple concussions (range: 2–4), with increasing severity and duration of symptoms; and/or 2) persistent post-concussion symptoms (headache, impairment of short-term memory, and/or difficulty concentrating). One-year follow-up was not available from 21 athletes whose injury occurred less than 1 year before this report and from 2 athletes who could not be located.

Among the athletes suffering persistent short-term memory impairment, only one recovered after 8 months. The others (4 football, 1 soccer, 1 cheerleader) were still impaired after 1 year. Their clinical details are shown in Table 2. Only the soccer athlete, cheerleader, and one football player were able to continue in college. Three football players were unable to continue their education. Their outcomes are summarized in Table 2.

## DISCUSSION

During the study period, the university's athletic program enrolled approximately 350 athletes per year. Allowing for numbers of sports exposures, participating athletes, and reported rates of concussion occurring among collegiate athletes,<sup>18</sup> our concussion incidences, by sport, are typical.

A major concern confronting sports-medicine practitioners when advising concussed athletes involves the timing of RTP. Our overall RTP interval was slightly longer than the 10.9–13.0 days reported by Collins et al. among a cohort of high school football players.<sup>6</sup> Since no active therapy for sport-related head injury exists, physical and cognitive rest of the injured brain and protection from further trauma is required until healing has occurred. Expert consensus guidelines suggest that, before RTP, all concussion symptoms must have resolved, and graded return to activity does not cause them to recur.<sup>2</sup> Although conforming to current guidelines based on symptom resolution and normalization of neurocognitive tests (if available) generally results in RTP within 1–2 weeks, several different methods of assessing cerebral dysfunction suggest that pathophysiological manifestations persist for as long as 4 weeks or beyond. Therefore, longer recovery intervals may be required.<sup>19</sup> This issue remains unsettled. If our experience that nearly 50% of concussed collegiate athletes are experiencing their second (or more) concussion(s) is typical, then studies demonstrating prolonged periods

TABLE 2. Athletes With Persisting Post-Concussive Symptoms at 1 Year

| Gender | Age, years | Sport | Concussions, N | Disability 1 Year Post-Injury                                 |
|--------|------------|-------|----------------|---------------------------------------------------------------|
| Male   | 18         | FB    | 1              | Headaches, memory impairment <sup>a</sup>                     |
| Male   | 18         | FB    | 4              | Memory impairment <sup>a</sup>                                |
| Male   | 18         | FB    | 2              | Memory/concentration impairment; "slow thinking" <sup>a</sup> |
| Male   | 21         | FB    | 2              | None: memory impairment that resolved after 8 months          |
| Male   | 20         | FB    | 3              | Memory impairment, sleep disorder                             |
| Female | 19         | CH    | 1              | Headaches, concentration difficulty <sup>b</sup>              |
| Female | 18         | SC    | 1              | Headaches, concentration difficulty                           |

FB: football; CH: cheerleading; SC: soccer.

<sup>a</sup>unable to continue college education.

<sup>b</sup>unable to attend school for one semester.

of brain dysfunction in multi-concussed athletes<sup>8,20</sup> raise concern for their future well-being.

The question of how many concussions are "enough" remains of great concern to all responsible practitioners, athletes, parents, and administrators. Among our cohort, eight athletes (8.6%) retired from their sport consequent to recurrent injury and/or persistent residual effects. In several instances, the athlete acted after recognizing increased susceptibility to injury and/or increasing severity and duration of symptoms after injury; that is, short-term memory loss. In some cases, retirement was recommended to the athlete, with the opportunity to consult about the issue with recognized authorities at university expense.

At 1-year follow-up, 63 of our concussed athletes (68%) reported no self-recognized consequences or functional impairment; 22 (24%) had incurred their injury less than 1 year previously; and 2 (2%) were not located. The mean (SD) number of diagnosed concussions experienced by the athletes with prolonged post-concussion symptoms was 2.62 (1.1), whereas, in the athletes without sequelae, it was 1.59 (0.9);  $p=0.03$ . This finding agrees with the studies cited above reporting greater degrees of cerebral dysfunction in multi-concussed athletes. If our experience is confirmed, then the current concussion-management paradigm (starting with pre-high school through college-level competition) does not appear to prevent consequent disability in a significant percentage of head-injured athletes, especially among football players.

#### Limitations of the Current Study

One may question the memory and concentration impairments reported by our athletes, since neuropsychological testing was not performed, and their post-college medical management was provided by

their family physicians. However, several groups have assessed previously-concussed (and multi-concussed) former collegiate and professional football players by use of computerized tests and found them to be normal.<sup>12–14</sup> These cohorts necessarily were convenience samples consisting of subjects who volunteered to be studied. It is possible that individuals believing that they were impaired did not choose to be tested or were unavailable for testing. Our athlete cohort was continuously cared for by one medical provider during their college careers, resulting in virtually complete follow-up (98%). Also, the policy of involving the athletes' parents during the initial stages of concussive episodes resulted in their participation and confirmation of the results of our follow-up assessments of their children.

The reported results are from a single cohort from a single institution. However, our concussed athletes were managed in accordance with consensus guidelines, or perhaps, more conservatively, as reflected by our RTP mean intervals, and our annual concussion incidence (mean: 7.5 episodes/year) is similar to that reported by ATCs responding to a national survey in 2005.<sup>21</sup>

Self-reported symptoms were utilized for RTP decisions, with all of the attendant uncertainties involved. A standardized concussion symptom assessment questionnaire was employed, however.

We had no information concerning the clinical severity and appropriateness of management of our athletes' previously-experienced concussions. Nevertheless, our athletes did not report disability related to these injuries on their collegiate pre-participation medical questionnaires.

No baseline studies were available to determine pre-existing learning, memory, or attention disabilities that may have affected our athletes' outcomes.

We cannot exclude the possibility that our findings are idiosyncratic. However, Shuttleworth-Edwards and Radloff<sup>22</sup> have reported that a “series of neuropsychological studies on American football, Australian rules football, and soccer have documented persistent mild neurocognitive deficit” in participants, and they found “lower performance for rugby players versus non-contact sport controls...on a series of visuomotor processing tasks known to be particularly sensitive to the effects of mild traumatic brain injury.” These and the previously-cited studies confirm persistent cognitive dysfunction among many athletes whose common experience is sports-related brain injury.

## CONCLUSION

In conclusion, these outcomes suggest that prolonged memory impairment occurs after sports-related concussions among a significant number of collegiate athletes. A computerized literature search located no reports of the prevalence of long-term post-concussion memory loss among this group. Further studies are indicated to quantify the incidence of post-concussion disability among larger cohorts of injured junior high, high school, and collegiate athletes.

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