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Symptom Severity Predicts Prolonged Recovery after Sport-Related Concussion: Age and Amnesia Do Not

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Abstract

Objective—To identify predictors of prolonged symptoms for athletes who sustain concussions.

Study design—We conducted a multi-center, prospective, cohort study of patients in 2 sport concussion clinics. Possible predictors of prolonged symptoms from concussion were compared between two groups: those whose symptoms resolved within 28 days and those whose symptoms persisted beyond 28 days. Candidate predictor variables were entered into a logistic regression model that was used to generate adjusted odds ratios.

Results—During the study period, 182 patients met inclusion criteria. The mean age was 15.2 years (SD 3.04 years). Over a third (N=65) of patients underwent computerized neurocognitive testing on their initial visit. In univariate analyses, Post Concussion Symptom Scale (PCSS) score and all composite scores on computerized neurocognitive testing appeared to be associated with prolonged symptom duration. Sex, age, loss of consciousness at time of injury and amnesia at time of injury were not associated with prolonged symptom duration. After adjusting for potential confounding, however, only total score on the PCSS score was associated with the odds of suffering prolonged symptoms.

Conclusions—After adjusting for other potential confounding variables, only total score on the PCSS was associated with the odds of suffering prolonged symptoms from sport-related concussions; age and amnesia were not. Further efforts to develop clinical tools for predicting which athletes will suffer prolonged recoveries after concussion should focus on initial symptom score.

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Keywords

mild traumatic brain injury (mTBI); concussion; post-concussion syndrome; sports

Most athletes who suffer sport-related concussions recover within a few days or weeks.¹⁻⁶ A small percentage, however, suffer symptoms that persist beyond a month^{5, 6} and in some cases longer.⁷ The ability to predict which patients will have prolonged symptoms would help clinicians and patients by allowing for proper anticipatory guidance, determining the need for academic or occupational accommodations, allowing athletic team members and coaches to plan for the prolonged absence of a player, and allowing patients and their co-workers prepare for prolonged absences from work. Furthermore, clinicians could better predict which patients are likely to need medication for prolonged symptoms.

Recent studies have investigated factors that may predict recovery outcomes in concussed athletes. On field dizziness, visual memory, processing speed, and migraine and cognitive symptom clusters have been associated with longer recovery from sport-related concussions.^{8, 9} Many other factors have been postulated as potentially predictive of a longer recovery, including number of prior concussions,^{1, 10} amnesia at the time of injury,^{1, 11, 12} computerized neurocognitive test scores,^{8, 13} and age at the time of injury.¹⁴⁻¹⁶

We sought to assess the independent association of potential risk factors on recovery time after adjustment for potential confounders. Because previous studies have shown that the majority of athletes will recover within 4 weeks of injury,^{5, 6} we sought to identify risk factors that predispose patients to suffering symptoms that last longer than 4 weeks.

Methods

We conducted a multi-centered, prospective, cohort study of patients seen in 2 sport concussion clinics, Boston Children's Hospital and University of Pittsburgh medical Center, Bethel Park Location. Both hospitals are located in urban setting and receive referrals from a variety of sources including, emergency departments, primary care physicians, and directly from athletic trainers and team physicians. Most patients live in an urban or suburban setting, although each hospital cares for a minority of patients living in a more rural setting. All patients were seen. This study was approved by the institutional review board of Boston Children's Hospital.

Any patient seen in one of the clinics between October 1, 2009 and September 30, 2010 who presented within 3 weeks of injury, had completed all intake and follow-up forms, and had fully recovered from their injury by the end of the study period was considered for enrollment. We included all sport-related concussions. In addition, patients with injury mechanisms and forces similar to those observed in sports, such as falling from a standing position or fist-fighting, were also included. We excluded patients with more severe injury mechanisms and forces, such as motor vehicle accidents and falls from above ground level. Standardized intake and follow-up visit forms were used at each location. Patients entered demographic information (eg, date of birth, sex), and clinical data (eg, day of injury, sport played at time of injury, score on the post-concussion symptom scale) at each visit. At the end of each visit, physicians entered clinical data relevant to the management plan (eg, whether or not the patient was cleared to return to play, whether computerized neurocognitive test scores were obtained). For patients that underwent computerized neurocognitive testing at their initial visit, a ll raw composite scores, raw reaction time, and total score on the symptom inventory were collected. All computerized neurocognitive

assessments were performed using ImPACT™. We used the definition of concussion proposed by the international consensus on concussion in sport⁴ when diagnosing concussion. Thus, athletes experiencing a traumatic acceleration of the brain followed by the onset of symptoms of concussion, signs of concussion, or decreases in neurocognitive function were diagnosed as a concussion.

We defined recovery as: (1) symptom-free both at rest and with exertion after discontinuing any medication prescribed for post-concussion symptoms; (2) computerized neurocognitive test scores at or above baseline values when available, or, when baseline data were unavailable, within the age-adjusted published norms and consistent with estimates of pre-morbid levels of functioning; and (3) balance error symptom scores at baseline values, when available.

Balance error scores and computerized neurocognitive assessments are not performed daily, but rather, only at clinic visits. The time between actual recovery and the next clinic visit varied between athletes. Indeed, we have no way of knowing when actual recovery, as defined by the criteria above, occurred. We only know whether athletes had met all of the recovery criteria at the time of their next clinic visit. Thus, we used duration of post-concussion symptoms as our primary outcome, as opposed to time to recovery. The duration of post-concussion symptoms was defined as the time interval between the date of injury and the date the athlete last had symptoms.

The PCSS developed by the international consensus on concussion in sports was completed at each visit. The PCSS is a symptom inventory containing a total of 22 symptoms that athletes rank on a scale from 0, when an athlete is not experiencing a given symptom, to 6, when an athlete describes the symptom as “severe.” The PCSS is part of the Sport Concussion Assessment Tool 2 (SCAT 2), which was proposed by the 3rd international consensus on concussion in sport. The total score on the PCSS is the sum of the athlete’s severity score (0–6) for each of the 22 symptoms. Thus, the maximum possible score on the PCSS is 132 (6 × 22).

As we were only interested in the symptoms caused by the injury, athletes were instructed to rate only those symptoms that started at the time of their concussion and that they were still experiencing within the 24 hours prior to their clinic visit. Symptom-free was defined as a post-concussion symptom score of 0. Athletes recorded the date they last had symptoms on the same page as the PCSS.

All computerized neurocognitive assessments were performed using ImPACT™. ImPACT is a well-studied, validated tool for assessing the neurocognitive function of athletes at risk for sport-related concussions.^{8, 9, 17–20} The assessment typically takes between 20 and 30 minutes. Athletes enter historical and demographic information followed by a concussion symptom inventory before completing 6 neurocognitive modules, each designed to evaluate different aspects of attention, memory, processing speed, and reaction time. Upon completion of the modules, 4 composite scores are generated: verbal memory, visual memory, processing speed, and reaction time. We did not interfere with clinicians’ current practice with regards to computerized testing. Not all athletes were tested at their initial visit. Many times, athletes are highly symptomatic at their initial visit. Therefore, clinicians may not expose them to testing, as it often exacerbates symptoms. This is especially true if the diagnosis is clear and the clinician is planning on providing the athlete with academic accommodations regardless of test performance.

Statistical analyses

Because previous studies have shown that the majority of athletes will recover within 4 weeks of injury,^{5, 6} we sought to identify risk factors for having symptoms that last longer than 4 weeks. Participants were therefore separated into two groups: those who were symptom-free within 28 days of injury and those who had symptoms for longer than 28 days. We first compared possible predictors of a prolonged recovery between the two groups in univariate analyses. Possible predictor variables included, age, total score on symptom inventory (PCSS and inventory from computerized neurocognitive assessment), number of prior concussions, composite scores on the computerized neurocognitive tests at the time of initial visit, prior treatment for headaches, history of migraines, family history of concussions, loss of consciousness at time of injury, and amnesia at the time of injury.^{1, 8, 10–14, 21}

Continuous variables were assessed by a Student t-test when comparing mean values between the two groups; categorical variables were assessed by a chi-square test when comparing proportions between the two groups. Any independent variable that differed between the two groups with a statistical probability of $p < 0.2$ was identified as a potential predictor and placed into a logistic regression model.

Because previous studies have examined the effect of individual symptoms on recovery,^{8, 9, 22} we did not assess individual symptoms in this study. Furthermore, there are 22 symptom options included in the PCSS. As the number of variables entered into a logistic regression model increases, the stability of the model decreases. Therefore, the inclusion of individual symptoms, in addition to the other variables, would have compromised the stability of our model.

Prior to performing regression analyses, we assessed for collinearity. We decided *a priori* that a condition index of greater than 30 would require individual assessments for collinearity. We performed individual assessments by calculating variable inflation factors. When variables were collinear, defined as a variable inflation factors > 2.5 , only 1 was included in a given logistic regression model.²³ Binary logistic regression models were used to generate adjusted odds ratios. A significant, independent association was defined as any adjusted odds ratio with a 95% confidence interval that did not contain 1. All analyses for the study were done with PASW Statistics 18.0 (SPSS Inc., Chicago, IL) and Stata 10.1 (StataCorp, College Station, TX).

Results

Although 266 participants had sustained a sport-related concussion, completed all forms, and were recovered by the end of the study period, 84 were not seen in clinic until more than 3 weeks since the time of injury and were thus excluded, leaving 182 patients included in analyses. Most (172) sustained their injury during organized sports, and 9 had similar injury mechanisms and forces similar to those that occur in sports but were not participating in organized athletics at the time of their injury. Participants were predominantly male (64%) and ranged in age from 7.6 – 26.7 years with a mean of 15.2 years (SD 3.04 years). Twenty-two percent suffered a loss of consciousness at the time of their injury, 34% suffered amnesia. Over a third of participants (N=65) had computerized neurocognitive testing performed at the time of their initial visit. Most participants sustained their concussions while playing a collision or contact sports (Table I). The mean time between injury and first unit to clinic was similar between the 2 groups (11 days for those with symptoms for greater than 28 days, and 13 days for those whose symptoms resolved within 28 days). There were

no significant differences in the mean values or proportions of the potential risk factors between the 2 sites (Boston and Pittsburgh).

Of the continuous variables, the total score on the PCSS at initial visit, total score on the computerized symptom inventory, and each of the composite scores on computerized neurocognitive assessments met criteria for inclusion in the regression model (Table II). None of the dichotomous variables met criteria for inclusion in the model (Table III).

Significant collinearity was noted between the total score on the PCSS and the total score on the computerized neurocognitive symptom inventory. Thus, a logistic regression model could not be performed reliably using both symptom inventories. Therefore, we performed two separate regression analyses: one using the PCSS and another using the symptom inventory from the computerized neurocognitive assessment.

Adjusted odds ratios were calculated for each potential predictor. As many clinicians may not have access to computerized neurocognitive assessments, we first used the PCSS score at patients' initial visits in the regression model (Table IV). Only total score on PCSS was independently associated with symptoms lasting greater than 28 days. When we performed the regression model using the symptom inventory from the computerized neurocognitive assessment, no variables were independently associated with a prolonged recovery (data not shown). Neither amnesia nor age was independently associated with a prolonged recovery in the regression models.

Discussion

Our study shows that after adjusting for potential confounding variables, only total score on the PCSS is independently associated with prolonged symptoms after concussion. For each point higher an athlete scored on the PCSS, the odds of suffering prolonged symptom duration increased. No other possible predictor variables included in our investigation were independently associated with suffering symptoms for greater than 28 days.

Although crucial for patients who suffer prolonged symptoms, medical interventions, academic accommodations, and occupational accommodations are often unnecessary for those who recover within a few days of injury. Thus, clinicians may wait to implement these therapies until symptoms have persisted. The ability to distinguish between those patients who will likely suffer prolonged symptoms and those who will likely recover more quickly would help patients and clinicians better prepare for prolonged recoveries. Although prior speculation, anecdotal evidence, and previous clinical investigations have suggested many factors as potential predictors of a prolonged recovery from concussion, 2 in particular have received substantial attention: age and amnesia.

Studies conducted on younger athletes have revealed longer mean times to recovery than studies conducted on older athletes,^{14, 24, 25} leading to speculation that perhaps, it takes longer for younger athletes to recover from concussions than older athletes.^{15, 16} It is difficult, however, to compare studies conducted on distinct populations, as differences in results might be due to other inherent differences between the populations besides age. Furthermore, methods and definitions vary between studies, making direct comparisons unreliable. These studies may, in part, reflect a tendency by providers to treat younger patients more conservatively. Our data show that age is not independently associated with the odds of suffering concussion symptoms for more than 28 days. In addition, the presence of amnesia has tended to correlate with increased duration of symptoms in prior studies.^{1, 11} In our study, however, amnesia was not associated with prolonged symptom duration.

Our findings must be interpreted in light of several limitations. Only 65 patients had computerized neurocognitive testing at their initial visit. Thus, we may have been underpowered to fully assess the prognostic value of computerized neurocognitive testing. Indeed, in our univariate analyses, verbal memory, visual memory and reaction time on computerized neurocognitive assessments were all associated with prolonged symptom duration. In addition, the list potential predictors of prolonged recovery is extensive, even limitless; it precludes the development of an exhaustive regression model. Similarly, the role of individual symptoms, such as anxiety, which has previously been associated with recovery, could not be properly analyzed in conjunction with all of the other factors we assessed. However, previous studies have attempted to address the role of individual symptoms in concussion recovery.^{8, 9, 22} Although the findings of our study reveal an independent association between PCSS score and a prolonged recovery, they do not allow for precise calculations of the probability that an individual athlete will suffer a prolonged concussion. Thus, our findings are more useful for developing such a clinically relevant prediction model than for direct clinical management. Finally, we examined patients seen in specialty clinics. There are likely fundamental differences between the populations seen in such clinics and those seen in more general out-patient settings.

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Abbreviations

PCSS	Post Concussion Symptom Scale
SCAT 2	Sport Concussion Assessment Tool 2

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Table 1Sport played by participants at the time of concussion^{*}

Sport	Patients with symptoms for 28 days	Patients with symptoms for > 28 days
Football	26	11
Ice hockey	22	14
Soccer	18	7
Basketball	18	4
Lacrosse	11	4
Skiing	4	1
Equestrian	2	0
Wrestling	3	0
Baseball	2	1
Softball	2	0
Swimming	1	1
Dancing	2	0

^{*} One participant sustained a concussion in each of the following sports: track and field, cycling, field hockey, volleyball. Fifteen listed their sport as “other.”

Table 2

Mean values of continuous variables

	Patients with symptoms for > 28 days	Patients with symptoms for 28 days	p- value
Age (N=182)	14.7 years	15.4 years	0.17
PCSS* score at initial visit (N=182)	33.3	16.6	< 0.01
Number of prior sport concussions (N=182)	0.58	0.63	0.81
Number of prior non-sport concussions (N=182)	1.33	1.26	0.84
Neurocognitive Composite scores (N=65)			
Verbal memory	74.9	85.3	< 0.01
Visual memory	60.2	74.4	< 0.01
Visual motor speed	31.9	35.8	0.14
Reaction time	0.70 seconds	0.61 seconds	0.04
Symptom score [†]	20.3	11.4	0.05

* PCSS = Post-Concussion Symptom Scale from the international consensus on concussion in sports (total score at initial visit)

[†] Symptom score from computerized symptom inventory

Table 3

Proportion of patients with each of the dichotomous variables.*

	Patients with symptoms for > 28 days n/N (%)	Patients with symptoms for 28 days n/N (%)	p- value
Male	32/48 (66.7)	84/134 (62.7)	0.76
Loss of consciousness	12/46 (26.1)	25/123 (20.3)	0.42
Amnesia	7/48 (14.6)	11/134 (8.2)	0.20
Prior treatment for headache	5/48 (10.4)	18/131 (13.7)	0.56
History of migraine headaches	5/48 (10.4)	14/133 (10.5)	0.98
Family history of concussion	18/47 (38.3)	39/129 (30.2)	0.31

* The denominator (N) varies slightly as not all patients responded to each question.

Table 4

Adjusted odds ratios (AOR) for variables included in logistic regression model using post-concussion symptom scale score

Potential predictor variable	Adjusted odds ratio [†]	95% CIs
Age	0.776	0.519, 1.159
Composite scores		
Verbal memory	0.961	0.902, 1.025
Visual memory	0.969	0.916, 1.024
Visual motor speed	1.057	0.942, 1.187
Reaction time	4.990	0.170, 1440
PCSS [‡]	1.039	1.006, 1.072 [*]

^{*} 95% CI do not include 1.

[†] Adjusted odds ratios represent the difference in odds per point of the given variable

[‡] PCSS = Post-Concussion Symptom Scale from the international consensus on concussion in sports (total score at initial visit)