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Characteristics and Outcomes of Athletes With Slow Recovery From Sports-Related Concussion

A CARE Consortium Study

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Abstract

Background and Objectives

Some athletes experience a slow recovery after sport-related concussion (SRC). There is little agreement on what constitutes slow recovery, however, and minimal data on the prevalence, predictors, or prognosis for this group. The objectives of this study were to apply an operationalized definition of slow recovery and characterize predictors and long-term prognosis of these individuals.

Methods

This is a prospective multisite observational study of collegiate athletes. Participants underwent multimodal assessments preseason and 5 additional time points after SRC. Time from injury to initiation of return to play progression (asymptomatic timepoint) and from injury to return to play (RTP) were the primary markers of recovery.

Results

One thousand seven hundred fifty-one concussed male and female collegiate athletes were studied. Eighty percent of participants reached the asymptomatic and/or RTP time points by days 14 and 24, respectively. Slow recovery was thus defined as exceeding 1 or both of those intervals (n = 399). This group was statistically more likely to be female (41.1% vs 35.6%, $p = 0.05$), have higher initial postinjury SCAT symptom severity scores (mean [SD]: 36.6 [23.4] vs 25.4 [19.9], $p < 0.001$), lower postinjury Standardized Assessment of Concussion scores (mean [SD]:25.74 [2.98] vs 26.26 [2.85], $p = 0.004$), perform worse on the postinjury Balance Error Scoring System (mean [SD]: 17.8 [8.9] vs 15.9 [8.5], $p < 0.01$), have fewer assessments in the first 14 days after injury (mean [SD]: 48.8 [29.7] vs 67.9 [24.6], $p < 0.01$), and be injured in practice (70.7% vs 65.1%, $p = 0.04$). 77.6% of the slow recovery group returned to play within 60 days of injury, and 83.4% (n = 349) returned to play within 90 days of injury. Only 10.6% had not returned to play 6 months postinjury.

Discussion

This study suggests an overall favorable prognosis for slowly recovering athletes and provides data for athletes and medical teams to consider in calibrating RTP expectations and making decisions about medical disqualification vs ongoing engagement in their sport.

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Glossary

BSI = Brief Symptom Index; **CARE** = Concussion Assessment, Research, and Education; **RTP** = return to play; **SAC** = Standardized Assessment of Concussion; **SCAT-3** = Sport Concussion Assessment Tool–3rd Edition; **SRC** = sport-related concussion; **TBI** = traumatic brain injury.

Historically, sport-related concussion (SRC) has been considered an injury with a favorable prognosis.[1] However, it has long been acknowledged that a small percentage of individuals experience a longer recovery trajectory and in some cases, remain symptomatic for months or even years after injury.[2-6] This issue is complicated by varying conceptualizations of "recovered" (e.g., symptom-free vs minimally symptomatic vs return to preinjury baseline),[7-9] different outcome metrics (e.g., cognitive testing only vs multimodal assessments), and relatively small sample sizes. Furthermore, even when a concussed athlete is asymptomatic, measures of brain structure and function may differ from nonconcussed athletes, suggesting that resolution of symptoms may not be the final recovery endpoint.[10,11]

Data on the percentage of athletes with SRC who experience slow recovery are scarce and come primarily from American football. McCrea et al.[2] found that while most of a cohort of concussed high school and collegiate football players returned to baseline performance on clinical measures within 7–10 days, approximately 10% of the cohort had not returned to preinjury baseline several weeks after injury. The etiology of persisting symptoms has been a subject of debate with some arguing that they reflect ongoing neural dysfunction and others arguing they are tied to psychological health factors or an interaction of preinjury and postinjury factors.[5,12-14] More recently, concerns have been raised that concussion may trigger a cascade of neurobiological events that degrade cognitive and neurobehavioral function and increase the risk for neurodegenerative disease.[15-17]

There has been little study of the natural history and determinants of outcome of athletes who recover slowly. Such data would be useful to inform medical management, to calibrate the expectations of athletes and coaches for return to play (RTP), and to advance our knowledge of concussion recovery. The objectives of this study were to apply an operationalized definition of slow recovery and characterize the long-term prognosis for these athletes.

Methods

CARE Consortium and Protocol

The NCAA-DoD Concussion Assessment, Research and Education (CARE) Consortium is a 30-site study of the natural history and neurobiology of concussion previously described.[18] In brief, participants completed a preseason baseline evaluation consisting of demographics, medical history, concussion-like symptoms, postural control, and neurocognitive functioning. All CARE sites used a common definition of concussion[19] with diagnosis made by a local team physician. Concussed participants were reassessed at 5 additional postinjury time points: within 6 hours and again 24–48 hours after injury, at clearance to initiate return to play progression (defined herein as the asymptomatic time point), at clearance for unrestricted return to play (RTP), and 6 months postinjury. Concussed participants reported symptoms to the medical staff daily, up to 14 days after injury and then weekly if they had not yet returned to unrestricted play. Symptoms were captured using the Sport Concussion Assessment Tool–3rd Edition (SCAT-3) symptom list, a 22-item inventory with severity ranked on a 0–6 scale. Percent completion of the daily symptom reports was used as a metric of clinical care assessment frequency. The presiding clinician's examination served as the gold standard for determining an athlete's readiness to initiate the return to progression protocol[20,21] and for unrestricted RTP.

Standard Protocol Approvals, Registrations, and Patient Consents

Before participation, all participants gave written informed consent. The research protocol and consent form were approved by the Institutional Review Board of each participating site and the US Army Human Research Protection Office. This study was conducted in accordance with the Declaration of Helsinki.

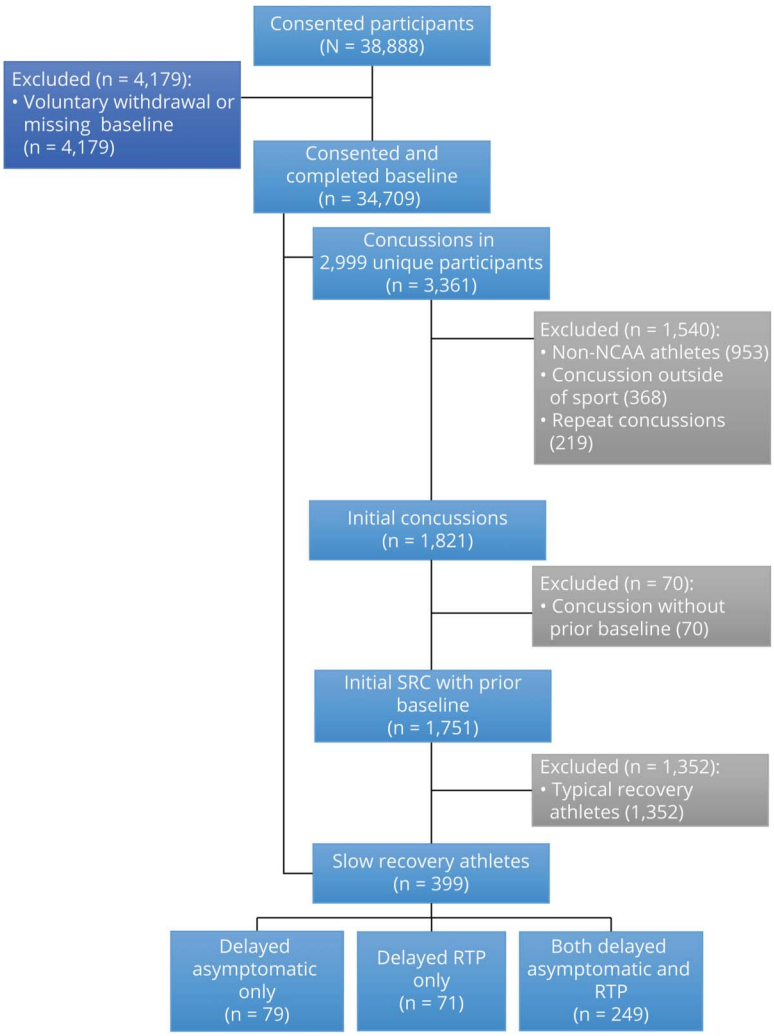
Participants

All varsity athletes at 26 civilian universities and all varsity athletes and cadets from 4 military service academies within the United States were eligible to participate. Between Fall 2014 and Spring 2018, a total of 34,709 athletes and cadets were enrolled in the CARE Consortium and completed a minimum of 1 baseline evaluation. After enrollment and intake, 3,361 concussions were recorded. A previous report[22] used this same cohort to characterize the natural history of concussion recovery including the median time from injury to initiation of graded exercise and to clearance for RTP.

Slow Recovery Definition

Our previous work[22] found that across all sports, the median time to asymptomatic was 6.4 days (interquartile range 3.7–11.8), with 80% achieving asymptomatic status by day 14. The median time to RTP was 12.8 (interquartile range 8.7–20.1) days, with 76% returning to play by day 21 and 84% by day 28 postinjury. We therefore included athletes in the slow recovery group if they took ≥14 days to reach the asymptomatic timepoint and/or ≥24 days to reach the RTP timepoint, thresholds that signified that they were taking longer than 80% of their peers to achieve 1 or both of the stated recovery mileposts.

Figure 1 Cohort Consort Diagram



Data Analysis

Descriptive statistics, mean values, and SDs for continuous variables and percentages for categorical variables were calculated for baseline demographic and examination measures, injury characteristics, and postinjury (within 48 hours) measures. Analyses for time to *asymptomatic* and total time to RTP was limited to the first concussion for each athlete (N = 1,751). Athletes who had not reached the *asymptomatic* or RTP timepoint when the season ended and for whom follow-up was not readily available (e.g., practices were no longer scheduled and/or athletes left campus) were right censored for analysis. Thus, an exact time for RTP or RTP protocol initiation could not be determined. There were 161 athletes with the date of RTP protocol initiation available but not RTP. Similarly, there were 131 athletes with an RTP date but no protocol initiation date. For these 292 athletes, the missing time was imputed using the other available time and the mean duration of the RTP protocol. Using time-to-event (survival) analysis techniques, censored observations (73 where *asymptomatic* and full RTP were not captured) were included in the analysis up until the censoring time.

Initial analyses compared the typical and slow recovery cohorts. Statistical comparisons for continuous characteristics between slow and typical recovery were performed using the Wilcoxon rank-sum test. Chi-square tests were used for the comparisons of categorical variables. Subsequent analyses focused on the recovery trajectory of the slow recovery cohort. The survival trajectory for time to RTP was estimated using a Kaplan-Meier curve. Bivariate associations between time to RTP and athlete and injury characteristics were assessed using the Cox proportional hazards model. The best multivariable model among possible predictors, based on the Akaike Information Criterion, was identified using the characteristics that met the screening criteria of $p \leq 0.2$ from the bivariate proportional hazards models. A p value of ≤0.20 was selected to reduce the number of candidate predictors but allow those that may be important in multivariable models to remain. The condition index method was used to check for multicollinearity (indices >30 indicates strong multicollinearity). Additional analyses compared individuals at the far end of the recovery trajectory, defined as having an RTP time greater than 74 days (n = 63), with those with

Table 1 Comparison of Assessment Measures—Typical vs Slow Recovery Athletes

Variables	Slow recovery, n = 399		Typical recovery, n = 1,352		*p* Value
	n	%	n	%	
Sex					
Male	235	58.90	871	64.42	0.05
Female	164	41.10	481	35.58	
Division					
I	323	80.95	1,076	79.59	0.28
II	33	8.27	147	10.87	
III	43	10.78	129	9.54	
Sport category					
Contact sport	305	76.44	1,082	80.03	0.12
Limited contact sport	71	17.79	221	16.35	
Noncontact sport	23	5.76	49	3.62	
ADHD diagnosis at baseline					
Yes	27	7.01	128	9.70	0.13
No	358	92.99	1,192	90.30	
Migraine diagnosis at baseline					
Yes	36	9.30	114	8.62	0.75
No	351	90.70	1,209	91.38	
Injury situation					
Competition	117	29.32	472	34.91	0.04
Practice	282	70.68	880	65.09	
Loss of consciousness					
Yes	18	4.57	63	4.70	1.00
No	376	95.43	1,277	95.30	
Post-traumatic amnesia					
Yes	49	12.47	129	9.63	0.13
No	344	87.53	1,210	90.37	
	Mean	**SD**	**Mean**	**SD**	
History of prior concussions[a]	0.72	0.99	0.59	0.83	0.03
SCAT symptom severity at baseline	5.75	9.59	4.82	8.53	0.06
BSI somatic raw score at baseline	0.91	2.04	0.84	1.83	0.44
SCAT symptom severity score postinjury (first score within 48 h)	36.62	23.42	25.41	19.85	<0.001
SAC total score postinjury (first score within 48 h)	25.74	2.98	26.26	2.85	0.004
BESS total score postinjury (first score within 48 h)	17.81	8.91	15.91	8.50	0.002
BESS firm score postinjury (first score within 48 h)	5.74	4.62	4.92	4.34	0.003
Bess foam score postinjury (first score within 48 h)	12.19	5.41	11.10	5.26	0.004
Percent compliance with daily checks up to 14 d after injury	48.84	29.70	67.93	24.64	<0.001
BSI somatic raw score postinjury	3.94	3.54	2.00	2.62	<0.001

Continued

Table 1 Comparison of Assessment Measures—Typical vs Slow Recovery Athletes *(continued)*

	Mean	SD	Mean	SD	
BSI anxiety score postinjury	2.41	3.56	1.15	2.24	<0.001
BSI depression score postinjury	2.20	3.05	1.16	2.29	<0.001
BSI global severity index score postinjury	8.55	8.70	4.31	6.12	<0.001

Abbreviations: ADHD = Attention Deficit Hyperactivity Disorder; BESS = Balance Error Scoring System; BSI = Brief Symptom Index; SCAT-3 = Sport Concussion Assessment Tool–3rd Edition.
[a] Refers to athlete self-report of number of concussions sustained before study entry.

RTP between 24 and 74 days, using the χ^2 and Wilcoxon rank-sum tests.

Data Availability

Qualified investigators may obtain access to the data used in this investigation through the Federal Interagency Traumatic Brain Injury Research Informatics System (fitbir.nih.gov/).

Results

Concussed Participants

The characteristics of the overall cohort of concussed athletes have been described elsewhere.[22] In brief, 1,751 athletes with SRC sustained during the CARE study were included in the analysis. For those with repeat concussions during the CARE study, only the initial concussion was included (see consort diagram Figure 1).

Concussed participants averaged 19.2 (±1.3) years of age; 63% were male and 37% female. Most of the participants (n = 1,387; 79%) participated in contact sports such as football or ice hockey. The remainder participated in limited contact sports (n = 292; 17%) such as baseball/softball and noncontact sports (n = 72, 4%) such as golf or track. Concussed female athletes most commonly participated in soccer (23.4%), volleyball (14.0%), basketball (12.9%), and lacrosse (8.4%). Concussed male athletes primarily participated in football (54.7%), soccer (10.7%), basketball (6.8%), and wrestling (6.4%).

Slow Recovery Participants

Of the 1,751 concussed individuals, 399 (22.8%) had a slow recovery defined by a delayed asymptomatic timepoint only (n = 79), a delayed RTP timepoint only (n = 71), or both (n = 249). There were no statistically significant differences in demographic variables between the 3 slow recovery groups (delayed asymptomatic only; delayed RTP only; delayed both); thus, subsequent analyses combined these individuals into a single slow recovery group. Compared with those with typical recovery, the slow recovery group was more likely to be female ($p = 0.05$), be injured in practice ($p = 0.04$), have higher

Figure 2 Kaplan-Meier Curve for the Probability of Return to Play for the Slow Recovery Group

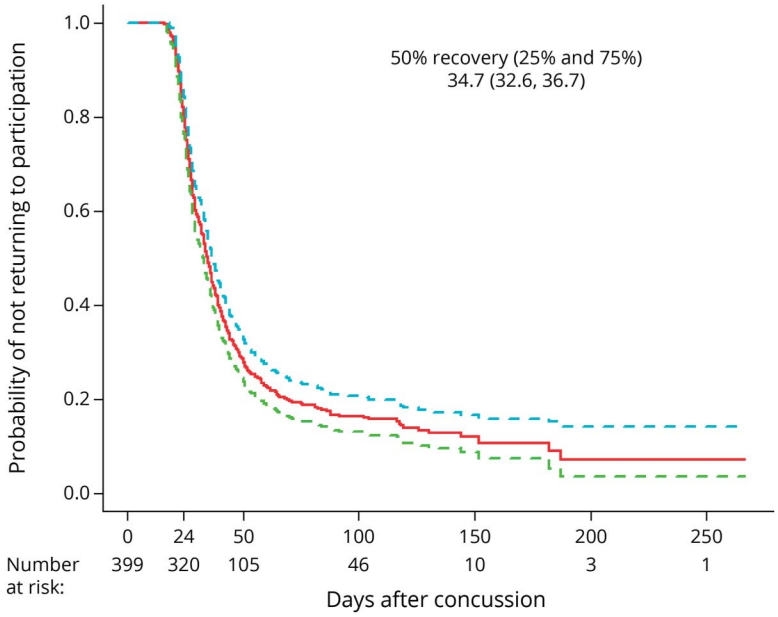


Figure 2 shows the Kaplan-Meier curve (red line) for the probability of return to play for the slow recovery group (n = 399). The blue and green lines represent the 95% point-wise confidence intervals for the Kaplan-Meier curve.

Table 2 Cumulative Percentage of Athletes Who Return to Play in the Slow Recovery Group (n = 399)

Days since injury	% RTP
≤15	0.00
≤18	1.5[a]
≤25	23.0
≤32	44.6
≤39	59.3
≤46	68.7
≤53	74.6
≤60	77.6
≤67	79.6
≤74	80.8
≤81	81.8
≤88	83.4
<180	89.4

Abbreviation: RTP = return to play.
[a] These individuals had a delayed time to asymptomatic (hence meeting the definition of delayed recovery trajectory); however, they progressed rapidly enough through the graded exercise protocol to be returned to play before 24 days postinjury.

initial postinjury SCAT symptom severity scores ($p < 0.001$) and lower postinjury Standardized Assessment of Concussion (SAC) scores ($p = 0.004$), perform worse on the initial postinjury Balance Error Scoring System (BESS; total score, firm only score, and foam only score; $p < 0.01$), have less frequent assessments in the first 14 days after injury ($p < 0.01$), and have higher initial postinjury Brief Symptom Index (BSI) somatic, anxiety, depression, and global severity score ($p < 0.001$ for all four) (Table 1). A large number of postinjury BSI values were missing (n = 183, 46% missing) in the slow recovery group; thus, the BSI findings should be viewed with caution.

RTP Within the Slow Recovery Group

Figure 2 shows the Kaplan-Meier curve for the probability of RTP for the slow recovery group. The median time for RTP was 34.7 days (Q_{25}–Q_{75}: 32.6–36.7) after injury in the slow recovery group, compared with 12.8 (Q_{25}–Q_{75}: 8.7–20.1) days in the overall concussed group (see Broglio et al. 2021[22]). Based on the Kaplan-Meier cumulative percentage estimates of days to RTP since date of concussion in the slow recovery group, 77.6% were able to RTP within 60 days of concussion, and 83.4% were able to RTP within approximately 3 months (88 days) of concussion (Table 2). Figure 2 shows that the trajectory for the proportion of those able to RTP begins to flatten substantially approximately 60 days after concussion. Of those unable to RTP at approximately 3 months (90 days, n = 50) after injury, the median RTP was 187.1 days. Overall, an estimated 10.6% (Table 2) in the slow recovery group did not RTP 180 days after concussion; this represents 2.4% of our overall cohort of 1,751 concussed athletes.

Predictors of Recovery Within the Slow Recovery Group

As noted earlier, the slow recovery group was more likely to be female and have indicators of a more severe concussion within 48 hours of injury compared with the typical recovery group. However, other than the history of self-reported concussion ($p = 0.05$), these characteristics were not strong predictors of RTP within the slow recovery group (e.g., female slow recovery athletes did not differ from male slow recovery athletes regarding eventual RTP). Five variables met the screening criteria for entry into the multivariable model selection (Table 3—postinjury SCAT severity score, postinjury SAC total score, postinjury BESS firm score, concussion history, and postinjury BSI somatic score). All condition indices were <30. Owing to the high rate of missing BSI data, we did not include it in the best multivariable model selection process. The final best model included only the postinjury SCAT severity score. However, the hazard ratio was not significantly different from 1 (Table 3).

A further analysis compared those who took >74 days to RTP (n = 63; the timepoint at which 80% of the slow recovery group had returned to play) with those whose RTP was between 24 and 74 days after concussion (n = 336). There were no statistically significant differences regarding baseline measures (SCAT; BSI); initial postinjury severity measures (SCAT, SAC, BESS, BSI, the presence of loss of consciousness, or PTA); sex; or the number of self-reported previous concussions (data not shown).

Discussion

We studied the characteristics and outcome of a diverse cohort of 399 concussed male and female collegiate athletes from a wide range of NCAA-sanctioned varsity sports who demonstrated a slow recovery. Those with a slow recovery were more likely to be female, be injured in noncontact or limited contact sport activities during practice/training sessions, have a higher symptom burden immediately after injury, and have completed fewer postinjury assessment time points. However, once these individuals exceeded the threshold we used to define a slow recovery, these characteristics were not predictors of eventual RTP. This raises the possibility that while neurobiological factors related to sex and injury severity are primary drivers of recovery trajectory within the first 4 weeks after injury, additional factors may assume a greater role further out in time from the injury. The possibility of a complex interaction between initial neurobiological factors and psychosocial factors was difficult to evaluate definitively in our study, partly due to the missing BSI data, but warrants further investigation. Indeed, Nelson et al.[5] evaluated factors associated with outcome after mild traumatic brain injury (TBI) and noted a similar pattern in which markers of initial injury severity were predictive of acute outcomes, whereas prolonged recovery was more clearly associated with psychosocial and psychological health variables. This does not mean there is a causal relationship between these measures and outcome. It is equally plausible that certain individuals are more likely to become discouraged by a prolonged and complicated recovery

Table 3 Predictors of RTP in the Slow Recovery Group

	N	Hazard ratio (CI)	*p* Value	C-statistic[a]
Sex				
Male (ref)	235	—	0.96	0.52
Female	164	1.00 (0.80–1.24)		
Division				
I	323	—	0.56	0.51
II	33	0.90 (0.60–1.36)		
III	43	0.84 (0.59–1.19)		
Sport category				
Contact (ref)	305	—	0.70	0.52
Limited contact	71	0.92 (0.70–1.22)		
Noncontact	23	0.85 (0.53–1.36)		
ADHD diagnosis at baseline				
No (ref)	358	—	0.76	0.50
Yes	27	0.94 (0.61–1.43)		
Migraine diagnosis at baseline				
No (ref)	351	—	0.36	0.51
Yes	36	0.83 (0.56–1.24)		
Injury situation				
Competition (ref)	117	—	0.89	0.49
Practice	282	1.02 (0.80–1.29)		
Loss of consciousness				
No (ref)	376	—	0.21	0.51
Yes	18	0.70 (0.40–1.22)		
Post-traumatic amnesia				
No (ref)	344	—	0.65	0.51
Yes	49	1.08 (0.78–1.49)		
SCAT symptom severity at baseline	391	1.00 (0.99–1.01)	0.98	0.49
BSI somatic raw score at baseline	388	1.00 (0.94–1.06)	0.94	0.50
Daily postinjury symptom assessment frequency	270	1.00 (0.99–1.00)	0.56	0.53
SCAT symptom severity score postinjury	**293**	**1.01 (0.99–1.01)**	**0.06**	**0.53**
SAC total score postinjury	**287**	**0.97 (0.93–1.01)**	**0.10**	**0.52**
BESS firm score postinjury	**265**	**1.02 (0.99–1.05)**	**0.16**	**0.53**
BSI somatic score at post	**216**	**1.03 (0.99–1.07)**	**0.13**	**0.52**
BSI anxiety score at post	216	0.97 (0.93–1.02)	0.21	0.51
BSI depression score at post	216	0.98 (0.94–1.03)	0.46	0.49
BSI GSI score at post	216	1.00 (0.98–1.02)	0.83	0.50
History of previous concussion[2]	**389**	**0.90 (0.80–1.00)**	**0.05**	**0.51**

Abbreviations: GSI = Global Symptom Index; RTP = return to play.
Bolded variables met the criteria for inclusion in the multivariable model selection process. Owing to the high rate of missing BSI data, it was not included it in the selection process.
[a] C-statistic represents predictive validity. Values <0.70 suggest low predictive ability. A value of 1 represents perfect prediction, while values near 0.50 represent chance (no predictive ability).
[b] Refers to athlete self-report of number of concussions sustained before study entry.

after injury and thus score higher than their peers on some of these measures. The role that frequency of symptom evaluation within the first 14 days after injury plays is not entirely clear. Possibly, more frequent evaluations are associated with an earlier determination of readiness to initiate graded exercise protocols and thus shortened RTP intervals. In addition, concussions occurring near holiday breaks, at the end of semester, or in postseason tournament play may have resulted in student athletes not being seen daily and a longer interval between determination of the asymptomatic or RTP time points.

These results add important nuance to the evolving narrative about recovery from SRC. The perception of the "typical" recovery from concussion has been changing over the last 15 years, evolving from a belief that such injuries typically have a short-term (7–10 days) period of signs and symptoms[1] with a highly favorable prognosis for full recovery, to concerns that a single concussion may put an individual at risk for long-term consequences including the possibility of chronic traumatic encephalopathy.[16,23] While not directly contradicting this view, the largely favorable outcomes in the slow to recover athletes is reassuring. While these athletes took longer than 24 days to RTP, it is encouraging that more than three-fourths (77.6%) were able to RTP within 60 days of injury and four-fifths (83.4%) were able to RTP within 88 days of injury. This is an important message to share with slow to recover athletes, who may be worried that they will never RTP.

However, our data does suggest that a slow recovery trajectory does have implications for the athlete and their medical providers. As has been noted for some time, a minority of concussed athletes and individuals with other types of mild TBI can develop a more chronic symptom pattern and struggle to fully recover. As noted in Figure 2, the rate of RTP diminishes around 60 days postinjury and of those unable to RTP at approximately 3 months (90 days, n = 50) after injury, the median RTP was 187.1 days. Taken together, these findings suggest that while the overall prognosis in the slow recovery group is quite good, the longer the recovery period takes, the probability curve for successful RTP flattens and the prognosis becomes less favorable.

There are important limitations to consider in interpreting the results of this study. While this is a large and diverse cohort of athletes with slow recovery, the participants were all collegiate varsity athletes and may not be representative of other age groups or levels of sport nor are we able to generalize the findings to other types of mild brain injury (e.g., military or civilian trauma). As noted in the methods, both asymptomatic and return to play data were not available on all of our participants, and 73 of our 1,751 injuries were censored either by the last contact with study personnel or by the end of the season in which they were injured, which ever was earlier; thus, their data may not accurately depict their final recovery trajectories. However, survival analysis methods use all the available data to best estimate the overall recovery trajectory. It is also important to point out that resolution of symptoms at rest (*asymptomatic* timepoint interval) and RTP interval are not the sole indicators of concussion recovery. It could be considered a limitation that the delayed asymptomatic-only group was included in the RTP analysis; however, they were included because the focus of this study was on any delayed recovery, and it is important to note that this group was no different from the other 2 delayed groups regarding demographic characteristics. It is also noteworthy that additional measures such as a directed physical examination, with more detailed assessment of autonomic nervous system function, oculomotor and vestibular function, and potential neck injury were not part of the CARE protocol for all participants and if carefully assessed in future studies might contribute significantly to our understanding of factors driving slow recovery.

The results of this study provide useful data for athletes and medical teams to consider in calibrating RTP expectations and in making difficult decisions about medical disqualification and the value of ongoing engagement in their sport.[24] We found that three-fourths of our slow recovery cohort were able to return to play if given an additional month beyond what is considered the typical recovery interval. Overall, only 10.6% of our 399 delayed recovery athletes did not RTP by the end of the 6-month follow-up. On balance, this is reassuring and may provide additional information to guide discussions on the risk-benefit ratio of ongoing participation in collegiate-level varsity athletics. Although an athlete may experience a slow or delayed recovery, there is reason to believe recovery is achievable with additional time and injury management. Overall, this is an encouraging message that may help to mitigate some of the dysphoria and discouragement that can be associated with prolonged resolution of symptoms and return to full sport activities.

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Appendix 2 Coinvestigators

Coinvestigators are listed at http://links.lww.com/WNL/C596.

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