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Concussion-Recovery Trajectories Among Tactical Athletes: Results From the CARE Consortium

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Context: Assessments of the duration of concussion recovery have primarily been limited to sport-related concussions and male contact sports. Furthermore, whereas durations of symptoms and return-to-activity (RTA) protocols encompass total recovery, the trajectory of each duration has not been examined separately.

Objective: To identify individual (eg, demographics, medical history), initial concussion injury (eg, symptoms), and external (eg, site) factors associated with symptom duration and RTA-protocol duration after concussion.

Design: Cohort study.

Setting: Three US military service academies.

Patients or Other Participants: A total of 10 604 cadets at participating US military service academies enrolled in the study and completed a baseline evaluation and up to 5 postinjury evaluations. A total of 726 cadets (451 men, 275 women) sustained concussions during the study period.

Main Outcome Measure(s): Number of days from injury (1) until the participant became asymptomatic and (2) to complete the RTA protocol.

Results: Varsity athlete cadets took less time than nonvarsity cadets to become asymptomatic (hazard ratio [HR] = 1.75, 95% confidence interval = 1.38, 2.23). Cadets who reported less symptom severity on the Sport Concussion Assessment Tool, third edition (SCAT3), within 48 hours of concussion had 1.45 to 3.77 times shorter symptom-recovery durations than those with more symptom severity. Similar to symptom duration, varsity status was associated with a shorter RTA-protocol duration (HR = 1.74, 95% confidence interval = 1.34, 2.25), and less symptom severity on the SCAT3 was associated with a shorter RTA-protocol duration (HR range = 1.31 to 1.47). The academy that the cadet attended was associated with the RTA-protocol duration ($P < .05$).

Conclusions: The initial total number of symptoms reported and varsity athlete status were strongly associated with symptom and RTA-protocol durations. These findings suggested that external (varsity status and academy) and injury (symptom burden) factors influenced the time until RTA.

Key Words: mild traumatic brain injury, return to activity, athletes

Key Points

- Varsity status and acute symptom severity were the most consistent and robust predictors of asymptomatic and return-to-activity protocol durations among US military service academy cadets.
- Whereas the study site was associated with the duration of the return-to-activity protocol, it is unclear whether this reflects differences in clinical management or another unmeasured construct.
- The time-dependent effects of varsity status and symptom severity may indicate that different factors are associated with typical versus atypical recovery durations.

Despite a steady increase in concussion-related research, investigators have not fully elucidated clinical recovery, which has 2 subcomponents. The first subcomponent is the number of days from injury until symptom resolution,[1] which is either determined using clinical judgment[2] or occurs when a person returns to preinjury symptom norms.[3] The second subcomponent, which follows symptom resolution, is the return-to-activity (RTA) protocol. The RTA protocol progressively increases physical exertion over time as long as symptoms do not reemerge. If symptoms reemerge, the clinician reduces the athlete's physical exertion, and the protocol extends until the athlete can complete the prescribed physical activity without symptoms.[1] To date, most researchers[4–7] have investigated factors related to total time loss without assessing the 2 recovery subcomponents individually. Moreover, to our knowledge, no authors have examined factors associated with the duration of the RTA protocol. In addition, individual (eg, sex, concussion history), external (eg, school), and concussive-injury (eg, initial number of symptoms) factors associated with the subcomponents of recovery have not been systematically evaluated.

Recently, the International Conference on Concussion in Sport[1] identified multiple individual and injury characteristics associated with total recovery time. In a systematic review, Iverson et al[8] determined that preinjury individual characteristics, such as age, sex, race, genetics, concussion history, attention-deficit disorder, learning disability, psychiatric history, migraine, and headache history were associated with total recovery time. Injury characteristics, including loss of consciousness (LOC), posttraumatic amnesia (PTA), retrograde amnesia (RGA), delayed removal from play, more initial symptoms, and specific symptoms (eg, headache, dizziness, balance) were also factors associated with recovery duration.[8] Factors that displayed the most frequent associations with recovery duration were sex, concussion history, headache history, LOC, PTA, RGA, delayed removal from participation, more initial symptoms, and postconcussion headache.[8] However, none of these factors consistently demonstrated associations with recovery duration.

Although their review was informative, Iverson et al[8] focused on sport-related concussion, limiting generalizations to nonsport injuries. For example, the concussions of people presenting to the emergency department represented sport- and non–sport-related injuries, with most concussions resulting from motor vehicle accidents.[9] Those seeking care at the emergency department for a concussion reported nausea[10] and experienced LOC[9,10] more commonly than those with sport-related concussions.[8] Differences between sport- and non–sport-related concussions make it difficult to identify factors consistently associated with recovery.

In addition to the limited number of studies on non–sport-related concussion recovery, our understanding of whether any factors influence RTA-protocol duration is limited. Environmental factors, such as reduced access to athletic trainers, have been shown to decrease the likelihood that an RTA protocol will be completed.[11] Moreover, clinicians have varying preferences for the types of exercise to use in the graded exertional protocol.[12] Elements associated with the RTA protocol may influence RTA-protocol duration and, thus, total recovery time. Therefore, the purpose of our study was to identify and describe individual, initial injury, and external characteristics associated with symptom recovery and RTA-protocol durations after concussion. First, we hypothesized that men would have shorter symptom durations but that we would find no sex effect on RTA-protocol duration. Second, we hypothesized that a greater initial number of reported symptoms would be associated with longer symptom and RTA-protocol durations. Third, we hypothesized that external factors, including athletic status (ie, varsity or nonvarsity athlete) and study site, would influence symptom and RTA-protocol durations, with shorter recovery durations associated with varsity athlete cadets. By better understanding which factors are associated with the 2 clinical subcomponents of total recovery, researchers can develop novel clinical interventions that can be more effective and lessen total recovery time.

METHODS

Study Design

This study was part of a larger joint effort by the US Department of Defense and the National Collegiate Athletic Association. This partnership funded the Concussion, Assessment, Research and Education (CARE) Consortium, a multisite investigation on the natural history of concussion. A detailed description of the CARE Consortium has been published.[13] For this study, data collection began in 2014 and ended in 2017.

Participants

All cadets at participating US military service academies were eligible for the CARE study, and 10 604 cadets (8183 men, 2421 women) enrolled. Each participating cadet provided written informed consent, and the study was approved by the site-level institutional review board and US Department of Defense Human Research Protections Office.[13]

Procedures

Before each academic year, enrolled cadets at all sites completed the same baseline assessment protocol per the CARE Consortium study methods.[13] *Incident concussions* were defined using evidence-based guidelines.[14] Clinicians, including predominantly athletic trainers or physicians, diagnosed each concussion using the definition set forth by Carney et al.[14] The definition stipulates that a concussion (1) is a change in brain function, (2) follows a force to the head, (3) may result in a temporary LOC, (4) is identified in people who are awake, and (5) includes measures of neurologic and cognitive function.[14] After a diagnosed concussion, research staff recorded the injury characteristics, including the date and time of injury; injury activity; and presence of LOC, RGA, PTA, and symptoms. All sites used the same concussion definition for diagnosis and recorded the same postinjury information.[13]

Injury activities were categorized into sport (varsity, club, intramural), academy training (physical education, military training), and free-time–related concussions. *Academy training* consisted of a variety of training activities, including boxing, combatives, land navigation, air assault and airborne schools, and physical fitness examinations. *Free-time–related concussions* were defined as those not occurring during any structured service academy activity. Cadets were at risk for a concussion during any of the 3 injury activities because they were exposed to all 3 settings. For example, a varsity athlete cadet could sustain a concussion during boxing. This concussion would be classified as an *academy-training concussion*, but the cadet's individual characteristics would include his or her varsity status.

The Sport Concussion Assessment Tool, third edition (SCAT3), was used to evaluate symptoms.[15] Cadets completed postconcussion assessments within 18 hours postconcussion when possible or within 24 to 48 hours after injury. Cadets also completed the SCAT3 symptom scales daily until a clinician deemed them asymptomatic or they began the RTA protocol. If symptoms persisted for more than 2 weeks, assessments were administered weekly. Per institutional protocol, all cadets, regardless of varsity status, completed an RTA protocol before final clearance.

Statistical Analysis

We assessed participant characteristics using χ^2 tests for categorical variables. Independent-samples *t* tests were used to examine participant characteristics for continuous measures between groups. The α level was set a priori at .05. *Symptom duration* was defined as the number of days between the concussion date and the date the cadet was determined to be asymptomatic. The asymptomatic date was determined by the cadet's clinician, based on clinical judgment. *Long asymptomatic duration* was determined based on the results of the survival analysis of asymptomatic duration. The median asymptomatic duration was 11 days. Therefore, *long asymptomatic duration* was defined as any asymptomatic duration >11 days. The *RTA-protocol duration* was defined as the number of days between the asymptomatic date and final clearance (ie, the date the clinician provided final clearance minus the date the cadet was declared asymptomatic). Therefore, total recovery time was represented by symptom duration plus RTA-protocol duration:

$$\text{Total recovery time} = (\text{Symptom Duration}) + (\text{RTA Protocol Duration}).$$

We did not evaluate total recovery time in this analysis as our primary objective was to understand the 2 clinical subcomponents that compose total recovery time. Examining total recovery time rather than the subcomponents may wash out the effects of individual or injury factors that may be present in only 1 subcomponent of recovery time.

Initial symptom severity was defined as the SCAT3 symptom severity sum collected at the 6-hour or 24- to 48-hour time point based on previous work.[16] The total SCAT3 symptom severity scores were divided into quartiles for analysis because a categorical variable can generate Kaplan-Meier plots for easier interpretation. However, Supplemental Tables 1 and 2 (available online at http://dx.doi.org/10.4085/1062-6050-54.12.19.S1) present total SCAT3 symptom severity scores as both continuous and categorical variables. Quartile 1 contained total SCAT3 symptom severity scores from 0 to 12; quartile 2, from 13 to 23; quartile 3, from 24 to 40; and quartile 4, >40. The Tukey correction was used to adjust for multiple comparisons between SCAT3 symptom severity score quartiles.

Baseline psychological symptoms, measured using the Brief Symptom Inventory 18 (BSI 18),[17] were categorized as high or low. Rather than a median split, we identified the upper quartile for the Somatization, Depression, and Anxiety scale scores as categorizing a high level of psychological symptoms. Given that the median scores for each domain on the BSI 18 were well below the clinical cutoff score,[17] the upper quartile was used to identify cadets with clinically meaningful psychological symptom burdens. Although scores lower than the clinical cutoff were described in the BSI 18 manual, the upper quartile scores in our cadet sample were similar to scores that indicated clinically meaningful psychological distress in another study.[18]

Recovery trajectories were evaluated using univariate and multivariate survival methods. First, we conducted univariate tests using Kaplan-Meier survival estimates to measure the effect of individual characteristics (sex, medical history, baseline psychological symptoms), initial injury characteristics (SCAT3 total symptom severity score, LOC, RGA, PTA), and external factors (site, varsity status) on symptom and RTA-protocol durations. The proportional hazard assumption for each test was checked by inspecting the log[–log(survival)] plots. When the proportional hazard assumption was violated, the generalized Wilcoxon test was used rather than the log-rank test. Supplemental Tables 1 and 2 indicate the test used for each variable. Means, 95% confidence intervals (CIs), medians, and quartiles are reported for each variable in Supplemental Tables 1 and 2. Cadets who were missing the RTA completion date but had the asymptomatic date (n = 55) were censored using the cadet's graduation date or end-of-study date. Censored events were truncated at 180 days for asymptomatic and RTA-protocol durations. We selected the cutoff of 180 days because a 6-month postinjury follow-up was included in the CARE study protocol and 180 days was longer than the maximum observed asymptomatic (maximum = 122 days) or RTA-protocol (maximum = 130 days) durations. Data from cadets who were missing the asymptomatic duration date but had an RTA-protocol completion date (n = 91) and cadets who were missing both the asymptomatic and RTA durations (n = 36) were excluded from the survival analyses.

Results from the univariate tests were used to select potential variables for the multivariate models. Sex was identified a priori as a potential effect-modifying variable and was included in each of the multivariate analyses. Other predictors were included if they had a *P* value $\leq$.15. We used Cox proportional hazard models with stepwise selection-generated final models to estimate symptom and RTA-protocol durations for all concussions related to sport, academy training, and free time.

The supremum test was conducted to check the proportional hazards assumption. If a variable violated the proportional hazards assumption, a time-dependent variable was created by multiplying it by time (symptom duration or RTA-protocol duration) and included in the model. In addition, to facilitate interpretation, survival analyses were stratified by times with varying proportional hazards. By using residual plots, we could observe periods with different proportional hazards. Using this visual inspection,

Table. Participant Characteristics (N = 726)

Variable	Value Mean ± SD
Age, y	19.14 ± 1.41
Height, m	1.75 ± 0.10
Mass, kg	74.57 ± 13.92
No. of previous concussions	0.43 ± 0.75
	No. (%)[a]
Sex	
Men	451 (62.12)
Women	275 (37.88)
Race	
White	486 (66.94)
African American	64 (8.82)
Other	150 (20.67)
Missing	26 (3.58)
Previous concussion	
Yes	215 (29.61)
No	475 (65.43)
Missing	36 (4.96)
Site	
1	280 (38.57)
2	421 (57.99)
3	25 (3.44)
Varsity status	
Varsity	268 (36.91)
Nonvarsity	433 (59.64)
Missing	25 (3.44)
	5 (3.44)

[a] Percentages were rounded, so the sums may not equal 100.

duration until asymptomatic was divided into 3 periods: 0 to 7 days, 8 to 21 days, and >21 days. We divided the RTA-protocol duration into 2 periods: 0 to 7 days and ≥8 days. Both time-dependent and stratified methods controlled for time-dependent effects (supremum test: all *P* values > .05 after adjustment).

Hazard ratios (HRs) and 95% CIs are reported. Given that the models estimated the survival function, an HR >1.0 was interpreted as *less time to event* (eg, symptom recovery or RTA-protocol completion), whereas an HR <1.0 represented a *slower time to event*. A mediation analysis was conducted to evaluate the mediating role of symptom resolution on RTA duration.[16] All univariate and multivariate statistical analyses were completed using SAS (version 9.4; SAS Institute Inc, Cary, NC). Time-split analysis and plots of predictors were generated using R (version 3.6.1 and packages "survival," "survminer," and "simPH"; The R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Sample Characteristics

Among the 10 604 cadets enrolled in the CARE study at the service academies, 738 sustained 800 concussion injuries. Of these cadets, 56 had 2 concussions, and 3 had 3 concussions. We only evaluated recovery after the first concussion. No repeat concussions occurred during the recovery period from the incident concussion.

Cadets with missing data for sex or varsity status were removed from the data set, leaving 726 (451 men, 275 women) individual cadets with incident injuries for analysis. Sample characteristics are presented in the Table. Of the 726 incident concussions, 42.56% (n = 309) occurred during sport, 32.37% (n = 235) occurred during academy training, 15.15% (n = 110) occurred during free time, and 9.92% (n = 72) were missing an injury-activity category.

A total of 638 (400 men 238 women) of the 726 cadets with concussions had symptom-duration data and 601 (382 men, 219 women) had RTA-protocol data. The median symptom duration for any concussion was 11 days (interquartile range [IQR] = 6–20 days). Of the 638 cadets, 33.39% (n = 213) were declared asymptomatic by day 7, 62.38% (n = 398) after 2 weeks, 77.27% (n = 493) at 3 weeks, and 84.01% (n = 536) by day 28. The median RTA-protocol duration was 8 days (IQR = 6–20 days). Overall, cadets did not return to full activity or duty until a median of 22 days (IQR = 13–25 days). Cadet characteristics by sex, concussion history, and varsity status are provided in Supplemental Tables 3 through 5.

Predictors of Symptom Duration

The univariate results, using Kaplan-Meier estimators, revealed that concussion activity was associated with symptom duration ($\chi^2_1 = 20.05$, $P < .001$). Specifically, sport-related concussions had shorter symptom durations than free-time–related concussions ($P < .001$) and tended to have shorter symptom durations than academy-training–related concussions ($P = .07$). We observed no difference between academy-training–related concussions and free-time–related concussions (Supplemental Table 1). Among all concussions, male sex, varsity status, immediate reporting, immediate removal from play or activity, lower SCAT3 initial symptom severity score, and no PTA were associated with a shorter symptom duration (all *P* values < .05; Supplemental Table 1). The Tukey correction was used to adjust for multiple comparisons between SCAT3 symptom severity score quartiles. Specifically, using the Tukey correction, we observed differences in all SCAT3 symptom severity score quartiles (all *P* values < .001) except for quartile 2 versus quartile 3 ($P = .17$) and quartile 3 versus quartile 4 ($P = .10$).

Across all concussions, Cox proportional hazards regression models revealed that SCAT3 symptom severity score and varsity status were associated with symptom duration (both *P* values < .05; Figure 1). The average effects of varsity status and SCAT3 quartiles are presented in Figure 1. Varsity cadets had, on average, 75% faster recovery rates (HR = 1.75, 95% CI = 1.38, 2.23; Figure 1A). However, varsity status was time dependent, such that the effect of varsity status decreased over time. Varsity status was associated with faster recovery only until day 21. Within 7 days of concussion, varsity cadets had a 97% faster recovery than nonvarsity cadets (Figure 2A). Varsity cadets recovered 39% faster within 8 to 21 days postconcussion (Figure 2B).

Greater elevations in SCAT3 symptom severity score were associated with longer durations until cadets were asymptomatic (Figure 1B). On average, quartile 1 recovered 122% faster than quartile 2 (HR = 2.22, 95% CI = 1.61, 3.06), 160% faster than quartile 3 (HR = 2.60, 95% CI = 1.89, 3.58), and 277% faster than quartile 4 (HR = 3.77,

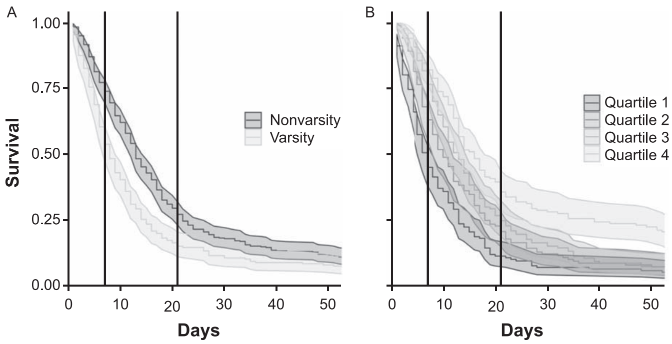

Figure 1. Kaplan-Meier plots of symptom-recovery duration among all concussions. A, Varsity status. B, Sport Concussion Assessment Tool, third edition, severity score quartile. Survival curve with 95% confidence interval.

95% CI = 2.70, 5.26). Quartile 2 recovered 70% faster than quartile 4 (HR = 1.70, 95% CI = 1.34, 2.16), and quartile 3 recovered 45% faster than quartile 4 (HR = 1.45, 95% CI = 1.15, 1.83). On average, no difference existed between quartiles 2 and 3. However, SCAT3 symptom severity score was time dependent, whereby the effect of SCAT3 symptom severity decreased with time. Specifically, SCAT3 symptom severity score was associated with a slower recovery only until day 21 (Figure 2C and D). After day 21, no effect of SCAT3 symptom severity score was present. Within 7 days of concussion, a greater SCAT3 symptom severity score was associated with a slower recovery (Figure 2C). At 8 to 21 days postconcussion, only cadets with the highest SCAT3 symptom severity scores had slower recoveries compared with cadets with the lowest SCAT3 symptom severity scores (Figure 2D).

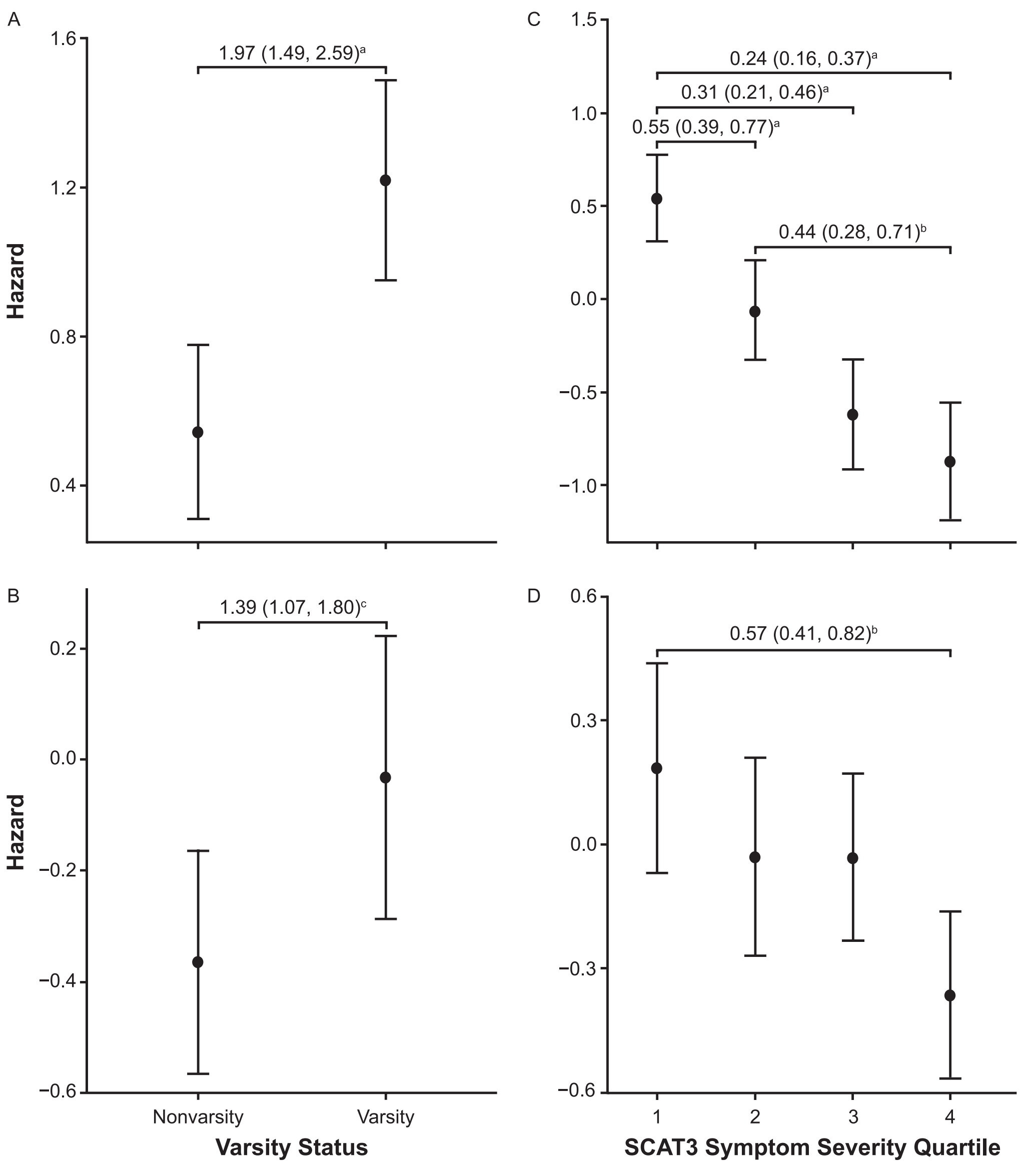

Figure 2. Time-dependent hazards for days until asymptomatic after concussion. The hazards that occurred within, A, the first 7 days and, B, days 8 to 21 of the asymptomatic period by varsity status. The hazards that occurred within, C, the first 7 days and, B, days 8 to 21 of the asymptomatic period by SCAT3 symptom severity score quartile. All comparisons were adjusted for multiple comparisons using the Tukey correction. Abbreviation: SCAT3, Sport Concussion Assessment Tool, third edition. [a] Hazard ratio was different ($P < .001$). [b] Hazard ratio was different ($P < .01$). [c] Hazard ratio was different ($P < .05$).

Predictors of RTA-Protocol Duration

All univariate predictors of RTA-protocol duration are presented in Supplemental Table 2. Site influenced the RTA-protocol duration ($\chi^2_2 = 62.68$, $P < .001$). Varsity cadets spent fewer days in an RTA protocol than nonvarsity cadets ($\chi^2_1 = 20.40$, $P < .001$). Varsity status was associated with a shorter RTA-protocol duration after any concussion or sport-related concussion. Finally, the SCAT3 symptom severity score was associated with more RTA-protocol days ($\chi^2_3 = 25.23$, $P < .001$). Specifically, quartile 1 had a shorter RTA-protocol duration than quartile 3 ($P = .02$) or quartile 4 ($P < .001$). We observed that quartile 2 also had a shorter RTA-protocol duration than quartile 4 ($P < .001$). Elevated BSI Somatization scale scores at baseline were associated with longer RTA-protocol durations ($\chi^2_1 = 4.09$, $P = .04$). Finally, cadets who had an asymptomatic duration >11 days tended to also have longer RTA-protocol durations ($\chi^2_1 = 12.75$, $P < .001$).

Using multivariate Cox proportional hazard models, we noted that site, varsity status, and SCAT3 symptom severity were associated with RTA-protocol duration. On average, varsity cadets had RTA-protocol durations that were 74% shorter than those of nonvarsity cadets (HR = 1.74, 95% CI = 1.34, 2.25). However, varsity status was time dependent ($P = .004$), with the effect of varsity status decreasing over time. Specifically, we found the effect of varsity status only within the first 7 days of the RTA-protocol duration (HR = 1.73, 95% CI = 1.35, 2.21). Higher SCAT3 symptom severity scores were associated with longer RTA-protocol durations. Specifically, quartile 1 had a 31% shorter RTA-protocol duration than quartile 3 (HR = 1.31, 95% CI = 1.03, 1.65) and a 47% shorter duration than quartile 4 (HR = 1.47, 95% CI = 1.16, 1.88). Similarly, quartile 2 had a 30% shorter RTA-protocol duration than quartile 3 (HR = 1.30, 95% CI = 1.01, 1.65) and a 46% shorter duration than quartile 4 (HR = 1.46, 95% CI = 1.14, 1.87). We observed no differences between quartiles 1 and 2 or quartiles 3 and 4.

DISCUSSION

Our investigation revealed that concussion symptoms extended beyond the assumed 14-day duration[1] and that different intrinsic and acute injury characteristics contributed to symptom and RTA-protocol durations. A large proportion of cadets who sustained concussions had symptoms that persisted beyond 14 days. The typical recovery window for adults put forth by the most recent International Conference on Concussion in Sport[1] was primarily based on data from male intercollegiate athletes. Our study expanded on the current concussion research by including multiple levels of athletic participation and non–sport-related injuries. Therefore, caution should be used when defining a typical recovery period.

When examining injury factors associated with concussion recovery, we determined that the elevated SCAT3 symptom severity score within 48 hours of a concussion was the most robust and consistent estimator of longer symptom and RTA-protocol durations. This finding was consistent with a previous examination[8] of concussion recovery. Although, in their review of recovery, Iverson et al[8] found that increased initial symptoms after concussion influenced recovery, few authors of original studies have systematically evaluated both symptom and RTA-protocol durations as subcomponents of the entire concussion-recovery trajectory.

By separating the recovery period into symptom and RTA-protocol durations, we identified different factors associated with each subcomponent of concussion recovery. Conceptually, symptom duration was a more physiologically driven component of recovery, and RTA-protocol duration represented physiological recovery and possibly clinical management because the clinician oversees the stepped progression of the RTA protocol. The symptom-duration portion of recovery was more heavily influenced by individual and injury factors, whereas RTA duration was also influenced by the external factor of site. Although our research was not designed to identify the drivers of the external factor of site on RTA-protocol duration, site may reflect differences in clinical management or RTA protocols.

Other important factors were also associated with recovery, and their effects over time were characterized. Many researchers have examined total time loss,[4–7,19–22] yet distinct but related processes contribute to concussion recovery. Authors[4–7,19–22] assessing total time loss have evaluated the effects of predictors on symptom and RTA-protocol durations. This method of analysis may wash out the effects that are present in only the symptomatic and RTA-protocol periods. We found unique associations among individual, injury, and external factors within each portion of concussion recovery, supporting the hypothesis that symptom and RTA-protocol durations are distinct elements of total recovery. For example, although varsity status and SCAT3 symptom severity score were both associated with symptom and RTA-protocol durations, site was only associated with RTA-protocol duration.

The Symptom Duration

Across all injury activities, different individual, injury, and external characteristics estimated symptom and RTA-protocol durations. In their systematic review, Iverson et al[8] noted that preinjury individual factors, including sex, BSI 18 Somatization scale score, and concussion history, were associated with recovery. We hypothesized that men would have shorter recovery durations after a concussion; however, using multivariate models, we found no sex effect. This result is contrary to previous observations[5,20,23] of athlete recovery. However, in studies with populations similar to ours, no sex effect was present.[16,24] Moreover, other investigators[3,16] using multivariate models demonstrated no sex effect. Overall, little evidence exists for a sex effect on symptom duration when accounting for other variables.

The BSI 18 Somatization scale score has been thought to mediate the relationship between acute symptom burden and recovery.[16] Furthermore, this effect has been thought to be unique and unrelated to other psychological symptoms, including depression and anxiety.[16] We identified no multivariate effect of somatization. Therefore, unlike Nelson et al,[16] we determined that somatization symptoms were not associated with symptom recovery.

Concussion history has been hypothesized to increase recovery time.[8] Eisenberg et al[25] investigated how the time between concussions affected symptom duration. Individuals with >1 concussion or a concussion within the previous year were more likely to have longer symptom durations.[25] Although we did not evaluate time since a previous concussion, we did assess the effect of multiple concussions and observed that having a previous concussion was not associated with symptom duration for any concussion activity, which was contrary to the hypothesis. The reason for this result is not entirely clear, but psychological factors may contribute. Researchers[26] have shown that athletes' reluctance to report a new concussion increases as the number of concussions increases. Cadets may also be concerned about how a concussion could influence their military placement. A cadet with a previous concussion may have increased concussion knowledge that alters his or her disclosure behavior. For example, Foster et al[27] found that US Air Force cadets were concerned that having a concussion would prohibit them from becoming pilots. Thus, because concussions are perceived to influence military placement, disclosure was also a concern among cadets. Register-Mihalik et al[28] reported that high school athletes with previous concussions were 125% more likely to participate in practices and 67% more likely to participate in games while experiencing symptoms. This suggests that cadets might conceal concussion symptoms, making it appear that they recovered more quickly.

We reinforced the concept that acute symptom severity is associated with recovery, and several differences provide subtle distinctions.[3,16] Varsity status was another strong estimator of symptom duration. In a recent study of a similar subset of cadets who sustained concussions due to the same activities as in our study, D'Lauro et al[29] also determined that varsity status was associated with less total time loss. However, the authors did not complete multivariate analyses or explore symptom duration separately from an RTA protocol.[29] Whereas they investigated cadet concussions at a single institution, we found that varsity status was a predictor of symptom and RTA-protocol durations across multiple service academies.

Time-dependent effects in our study may explain the heterogeneity of factors associated with recovery.[8] Varsity status and SCAT3 total number of symptoms were associated with symptom duration, but their effects decreased over time and were no longer present after 21 days. Therefore, if recovery up to 21 days was examined in one study and recovery up to 90 days in another study, the authors of each study might reach different conclusions regarding the SCAT3 symptom severity score because of the decreasing effect of SCAT3 symptom severity score over time. Learning how these variables change over time is important and adds to our understanding of the natural history of concussion. For example, our observation that varsity status was a predictor of recovery but only up to 21 days indicated 2 factors. First, given that the biomechanics of concussion in varsity and nonvarsity athletes were assumed to be similar, other properties of varsity status influenced recovery. For example, more frequent interactions with the sports medicine staff might influence recovery or the motivation to return to competition. Second, cadets and athletic trainers might experience internal and external motivations to return individuals to activity. Disassociating physiological from environmental factors was essential to understanding the natural history of concussion.

The RTA-Protocol Duration

Researchers[4–7] have investigated total time loss due to concussion, which includes both symptom and RTA-protocol durations. To our knowledge, no one has evaluated factors related to RTA-protocol duration, which is associated with a different pattern than symptom duration. In our study, cadets who had a greater SCAT3 symptom severity score within 48 hours of injury were more likely to have longer RTA-protocol durations.

Limitations

Our study had limitations. First, whereas we prospectively collected information about concussive injuries across sport and nonsport domains, it is possible that we did not collect information about all patients with concussions. Underreporting[30] or delayed reporting may have caused some injuries to be missed. Data were also missing for symptom and RTA-protocol durations. These missing data were assumed to be missing at random, as no clear pattern existed between missing data and recovery-time predictors. In addition, using clinical judgment, each clinician determined when the patient became asymptomatic. The absence of a purely objective indicator of when the patient became asymptomatic may have influenced our results. Although we used the SCAT3, the Sport Concussion Assessment Tool, fifth edition (SCAT5), was released since the start of the study.[31] The major modifications to the SCAT5 are (1) specifying that the symptom scale should be completed during a resting state, (2) altering the Standardized Assessment of Concussion word and digit-backward lists to minimize practice and ceiling effects, and (3) changing the instructions for the baseline symptom checklist to ask examinees to rate how they "typically" feel rather than "how you feel right now."[31] In recent work comparing baseline symptoms between the SCAT3 and SCAT5, Asken et al[32] found adequate convergent validity for symptom severity score with no difference when assessing symptoms on the SCAT3 or SCAT5. Therefore, despite the differences between the SCAT3 and SCAT5, we expect that our major finding that the acute concussion symptoms most strongly associated with recovery will generalize to future studies using the SCAT5. In addition, the study design should be considered when interpreting these results. Postinjury assessments were conducted daily only for the first 2 weeks and then weekly. It is possible that the effect of varsity status on recovery reflected more frequent assessments, which led to earlier determinations of symptom resolution due to more frequent visits with the clinical staff. We suggest that site is a surrogate measure for differences in clinical management, but it likely reflects other factors. Finally, we investigated the first concussion sustained. Multiple concussions may induce different recovery patterns.

CONCLUSIONS

We identified recovery patterns and subtypes after a concussion among US military service academy cadets. Moreover, specific factors were associated with symptom and RTA-protocol durations. Acute symptom severity and varsity status were the most consistent and robust predictors of symptom and RTA-protocol durations. Whereas site was associated with RTA-protocol duration, it remains unclear whether this reflected differences in clinical management or another unmeasured construct. Finally, the time-dependent effects of varsity status and SCAT3 symptom burden indicated that different factors might be associated with typical versus atypical recovery.

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