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Abstract

Background: There is growing awareness and clinical interest in athletes with affective symptoms after sport-related concussion (SRC), as these symptoms may contribute to overall symptoms and represent a modifiable risk factor of longer recovery. However, evidence of their effects on the entire return-to-play (RTP) trajectory, particularly among women and men, is limited.

Purpose/Hypothesis: To examine the relationship between affective symptom reporting and RTP progression after SRC among a cohort of Division 1 student-athletes. We hypothesized that those endorsing affective symptoms, specifically nervous-anxious symptoms, spend more time in RTP progression and recovery.

Study Design: Cohort study; Level of evidence, 3.

Methods: Using SRC data from the Ivy League–Big Ten Epidemiology of Concussion Study among varsity athletes through February 2020, we identified the 4 affective symptoms from the Sport Concussion Assessment Tool symptom inventory. We modeled the relationship between a 4-category affective symptom variable and time to symptom resolution, RTP, and RTP progression, adjusting for nonaffective symptom prevalence and concussion history. Cox regressions were used to estimate hazard ratios for time to event outcomes, and linear regressions were used to evaluate mean differences for continuous outcomes.

Results: Among 2077 student-athletes (men, 63.5%) with SRC symptoms, affective symptom prevalence was 47.6% and 44.3% in women and men, respectively, and nervous-anxious prevalence was 24.2% and 22.5%, respectively. When comparing women with and without co-occurring affective symptoms, rates of symptom resolution and RTP were significantly lower in those with affective symptoms, and women with nervous-anxious symptoms spent significantly longer in RTP progression. When comparing men with and without co-occurring affective symptoms, rates of symptom resolution and RTP were significantly lower in those with co-occurring affective symptoms, and affective symptoms were not associated with time in RTP progression.

Conclusion: Student-athletes with affective symptoms and nervous-anxious symptoms exhibited delayed clinical recovery and RTP timelines, particularly for time in RTP. Symptom prevalence and concussion history contributed

to this; however, unmeasured confounding remains, as indicated by the poor model fit. This study motivates future work to explore affective symptoms and RTP timelines, considering anxiety and risk/protective factors over time.

Keywords: affective symptoms; anxiety; athletics; female; mild TBI; symptomology; traumatic brain injury

Sport-related concussion (SRC) is a relatively common injury in collegiate athletic populations; from 2009 to 2014, SRCs accounted for 6.2% of athletic injuries across the National Collegiate Athletic Association (NCAA)—a 5-year injury rate of 4.47 per 10,000 athlete exposures.[51] Increases in rates over time can likely be attributed to improved detection and ease of reporting of incident cases of SRC through emergent university, athletic conference, and national-level surveillance studies,[23,37,51] in addition to developments in guidelines and protocols for managing SRC.[10,32,33]

Symptom assessment, albeit subjective, is one of the most common management practices after SRC, employed during initial injury evaluation (86.7%), return to learn, and return to play (RTP) decision making (57.3%) by athletic trainers in a variety of settings.[28] Subjective symptom reports that include a symptom inventory, such as the Sport Concussion Assessment Tool (SCAT-5), are important instruments in identifying and managing athletes with concussions.[12] However, athletes report various types of symptoms after SRC. Common symptoms reported by collegiate athletes after a concussion include headache (92.2%), dizziness (68.9%), difficulty concentrating (58.3%), sensitivity to light (49.1%), and loss of balance[50] (36.7%). Moreover, symptom presentation often differs in women and men.[4,5,11,18] Evidence suggests that women exhibit more physical, somatic, and emotional symptoms than men.[16] Among collegiate athletes, women and those with a history of concussion exhibit greater symptom severity in the initial 3 days after injury, relative to men,[24] warranting further exploration of symptom experiences of student- athletes in women's and men's sports separately. Further, almost one-third of collegiate athletes (30.7% [32.6% women; 29.5% men]) experience symptoms for longer than 2 weeks, and over 20% (23% women; 19.9% men) endure 3 or more weeks of symptoms after concussion.[8] In sport-specific analyses, such as a sample of Division 1 ice hockey players, women demonstrated significantly longer times to symptom resolution and RTP

clearance than men.[48] These findings support further study of symptom type and duration after a concussion among collegiate athletes to understand underlying mechanisms and identify appropriate and actionable management approaches.

Besides female sex, researchers suggest that collegiate student-athletes with attention deficit hyperactive disorder, history of motion sickness, and higher initial postinjury symptom scores present with greater symptom severity within 2 weeks after SRC.[24] In addition to these risk factors, the total number and type of reported SRC symptoms themselves may relate to recovery after SRC. For example, in one study, children with a higher symptom burden indicated by the total number and severity of symptoms at the time of injury, had a prolonged recovery— defined as symptom duration .28 days—compared with children with a lower symptom burden.[40] Similarly, in collegiate athletes with a concussion, a greater symptom burden was related to a longer time to symptom resolution.[38] However, limited research has examined whether the nature or type of symptom experience influences time to recovery outcomes (*e.g.*, symptom resolution, return to full play) in large samples of collegiate student-athletes. This work is compelling and needed because identifying specific symptoms may aid clinicians in easing symptom severity and/or recovery time throughout treatment, particularly in the presence of risk factors that are not easily modifiable during concussion management.

There is growing awareness and clinical interest in examining athletes who experience affective symptoms after SRC, as these symptoms may contribute to overall postconcussive symptoms and represent a potentially modifiable risk factor for a longer recovery. For example, adolescents with affective symptoms—including anxiety and depression at baseline and after SRC—presented with higher symptom burden and poorer cognitive performance. [1] In a small sample of collegiate athletes, Sicard *et al.*[41] reported a greater affective symptom burden in athletes with slower symptomatic recovery compared with asymptomatic athletes with a concussion and with noninjured controls. Still, the relationship between anxiety and postconcussive symptoms remains unclear; and limited empirical evidence in the collegiate athletic setting demonstrates the potential effects of experiencing affective symptoms on the entire RTP trajectory. Importantly, previous work has demonstrated that symptom presence [4,5,11,16,18] and

symptom resolution[8,48] manifest differently between female and male athletes, warranting independent study and analysis separately for these groups. This study aimed to test whether affective symptom reporting and experiencing nervous-anxious symptoms in isolation are related to RTP progression after SRC in Division 1 student-athletes and among women and men separately. We hypothesized that those endorsing affective symptoms—specifically the nervous-anxious symptom—would spend a longer amount of time in RTP progression and have a longer recovery after SRC.

Methods

Data Source

We used data from the Ivy League–Big Ten Epidemiology of Concussion Study (Ivy–B1G Study)—a prospective, multisite, observational study and repository of student-athlete concussions across 19 Ivy League–Big Ten universities— and included concussions reported in varsity sports through February 2020. Since 2013, athletic trainers and research coordinators identified athletes diagnosed with concussions across 19 participating campuses and collected and submitted cases to the online study database registry. The data form consists of 3 sections about the athletes and their injury: (1) athlete demographic information; (2) circumstances and mechanism of concussion injury and clinical information, including symptomology; and (3) dates of injury, symptom resolution, and return to learn and RTP outcomes. Athletes consented to participation in the study at the beginning of each academic year. The University of Pennsylvania institutional review board serves as the central institutional review board for this study. This study follows the Strengthening the Reporting of Observational Studies in Epidemiology reporting guidelines for cohort studies.[49] Previous publications outline the methods of the study in detail and describe the overall cohort.[13,37] Of note, we present our results referring to sex and using the terms ''women/men'' and ''athletes on women's/men's teams'' throughout to reflect how data are collected in the Ivy–B1G Study. We refer to ''female/male'' athletes when citing previous literature.

Operational Definitions

Symptom Experience. Athletic trainers and research coordinators recorded whether athletes experienced any symptoms from the SCAT-22 symptom inventory at any point throughout their SRC recovery. Here, we selected out the 4 affective symptoms (more emotional, irritability, sadness, and nervous-anxious) based on the Centers for Disease Control and Prevention's Traumatic Brain Injury and Concussion symptom matrix[15,34] and previous literature, [2,25,26,35] and we compared athletes in our cohort who reported experiencing these symptoms after SRC with those who did not—stratified by sex. We also examined the recovery trajectories of female and male athletes who specifically reported the nervous-anxious symptom.

Recovery Outcomes. We defined[13,37] time to the outcome symptom resolution as the number of days between the date of concussion injury and the date when the athlete self-reported being symptom-free. We defined time to return to full play as the number of days between concussion injury and the date the athlete was medically cleared by a physician within the sports medicine or athletics department to return to full athletic participation.[8] We also reported on time in RTP progression—calculated as the number of days between the date of symptom resolution and the date of return to full athletic participation—akin to when the athlete completed their stepwise RTP progression.

Statistical Analysis

We presented the prevalence of SRC to date across all sports and test for between-sex differences by class year, age, symptom burden (number of symptoms endorsed/ SCAT-22 symptom inventory), and concussion history (≥1 self-reported previous concussions, diagnosed by a medical provider) using Wilcoxon rank-sum tests and chi-square tests for categorical variables. To determine the internal consistency of our affective symptom domain, we calculated the Kuder-Richardson coefficient for the 4 affective symptoms. We used logistic regression to estimate the likelihood of reporting a nervous-anxious symptom. With survival analysis, we estimated the time to the 3 outcomes of

interest: (1) symptom resolution, (2) return to full play, and (3) time in RTP progression. We reported the proportion of athletes whose RTP occurred on the same day (0) and before (–) reporting symptom resolution. Crude and adjusted Kaplan-Meier curves with log-rank tests presented and tested differences between symptom burden (median number of symptoms; >11 or ≤11 symptoms) and between concussion history (≥1 previous concussion) separately by sex. Student-athletes were censored at the end of each academic year of participation; thus, they may have reached their outcomes at a later date. Additional independent right censoring may have occurred in cases where athletes were lost to follow-up at the end of an athletic season or from leaving sports or school altogether. We examined Kaplan-Meier curves for violations of the proportional hazards assumption and assessed the correlation between the scaled Schoenfeld residuals and time using the Schoenfeld test.

We used Cox proportional hazards regressions to estimate hazard ratios (*i.e.*, rate ratios) for symptom resolution, return to full play, and time in RTP progression during 7 weeks after injury in women and men, separately. Our main predictor of interest was a 4-level categorical measure of symptoms experienced in the affective domain: (1) no affective symptoms; (2) co-occurring affective symptoms— nervous-anxious and irritability, and/or sadness, and/or more emotional; (3) only nervous-anxious symptoms; and (4) no nervous-anxious symptoms—irritability and/or sadness and/or more emotional. We presented crude, univariate models and included non-affective symptom burden, the number of 18 non-affective symptoms endorsed to mitigate the risk of multicollinearity, and concussion history (≥1) as covariates in the Cox multiple adjusted models.

As a second analysis, we used linear regression to model the crude and adjusted relationship between our 4-level measure of affective domain and days in RTP progression by sex. Skewness and kurtosis were tested to evaluate the RTP progression variable for normality. The statistical analysis was performed using Stata 16.1 (StataCorp).[43]

Results

SRC Prevalence

A total of 2077 SRCs (women, n = 759; men, n = 1318) occurred from November 2013 to February 2020, across 25 varsity sports at participating sites (**Appendix Table A1**). For women, the top 3 sports with the largest number of SRCs included soccer (n = 149 [19.6%]), lacrosse (n = 88 [11.6%]), and basketball (n = 78 [10.3%]). For men, half of SRCs occurred in football (n = 665 [50.5%]), followed by wrestling (n = 127 [9.6%]) and lacrosse (n = 124 [9.4%]). The distribution of SRCs was different across class year when injured (P = .03), with the freshman year making up the largest proportion for women (n = 231 [30.6%]) and sophomore year making up the largest proportion for men (n = 406 [31.0%]). The median age at the time of SRC was different between women (median, 19; interquartile range [IQR], 19-20) and men (median, 20; IQR, 19-21) (P < .001). Student-athlete SRC characteristics are presented in **Table 1**.

Table 1 Student-Athlete SRC Characteristics[a]

Characteristic	*Women*	*Men*	*P*[b]
Total	759 (36.5)	1318 (63.5)	
Class year[c]			.03
Freshman	231 (30.6)	324 (24.8)	
Sophomore	218 (28.8)	406 (31.0)	
Junior	176 (23.3)	324 (24.8)	
Senior	126 (16.7)	235 (18.0)	
Fifth year	5 (0.7)	20 (1.5)	
Age, y	19 (19-20)	20 (19-21)	< .001
Symptom burden	11 (7-15)	11 (7-15)	.93
Affective symptom domain,[d] yes[e]	265 (47.6)	394 (44.3)	.23
Nervous or anxious symptom, yes[e]	135 (24.2)	200 (22.5)	.45
Concussion history (≥1), yes[e]	261 (46.9)	420 (47.2)	.89

a. Data are presented as median and interquartile range, or n (%). SRC, sport-related concussion.

b. Chi-square test; Wilcoxon rank-sum test.

c. Missing data: Women (n=3), Men (n = 9).

d. Affective domain symptoms: irritability, sadness, more emotional, and nervous or anxious.

e. Among those who reported at least one symptom: Women (n = 556), Men (n = 889).

Time to Recovery Outcomes

For women, the median times for symptom resolution, RTP, and RTP progression were 10 (IQR, 4-14), 14 (IQR, 9-23), and 6 (IQR, 4-10) days, respectively. For men, the median times to symptom resolution, RTP, and RTP progression were 10 (IQR, 3-13), 11 (IQR, 9-20), and 6 (IQR, 4-10) days, respectively.

SRC Symptom Burden

The overall number of symptoms after SRC (symptom burden) was comparable between sexes (median, 11 [IQR, 7-15]) (Table 1). Endorsing more symptoms (.11 symptoms) was associated with a median 5-day delay in time to symptoms resolving for women (11 vs 6 days; $P < .0001$) and men (10 vs 5 days; $P < .0001$) (**Figure 1**, A and B). Stratified by concussion history, time to symptom resolution was significantly delayed among women with more symptoms ($P < .0001$) (Figure 1, C and D). Women with a higher symptom burden (.11 symptoms) and a history of concussion demonstrated the longest median time to symptom resolution (12 days). Women with lower symptom burden (≤11 symptoms) and no previous concussion exhibited the shortest median time to symptom resolution (5 days). Among men, higher symptom burden and no history of concussion demonstrated the longest median time to symptom resolution (10 days). Men with lower symptom burden without a history of concussion exhibited the shortest median time to symptom resolution (4 days; $P < .0001$).

For return to full play, having higher symptom burden (>11 symptoms) was associated with a 6-day delay in women (median, 17 vs 11 days; $P < .0001$) and a 4-day delay in men (median, 15 vs 11 days; $P < .0001$) (**Figure 2**, A and B). Stratified by concussion history, women with a higher symptom burden and no concussion history had the longest time to RTP (18 days). Women with lower symptom burden and no history of concussion had the shortest RTP (median, 10 days) (Figure 2C). Half of the men with a higher symptom burden with and without a history of concussion returned to play within 16 and 15 days, respectively. Men with lower symptom burden with and without a history of concussion demonstrated the fastest return to full play

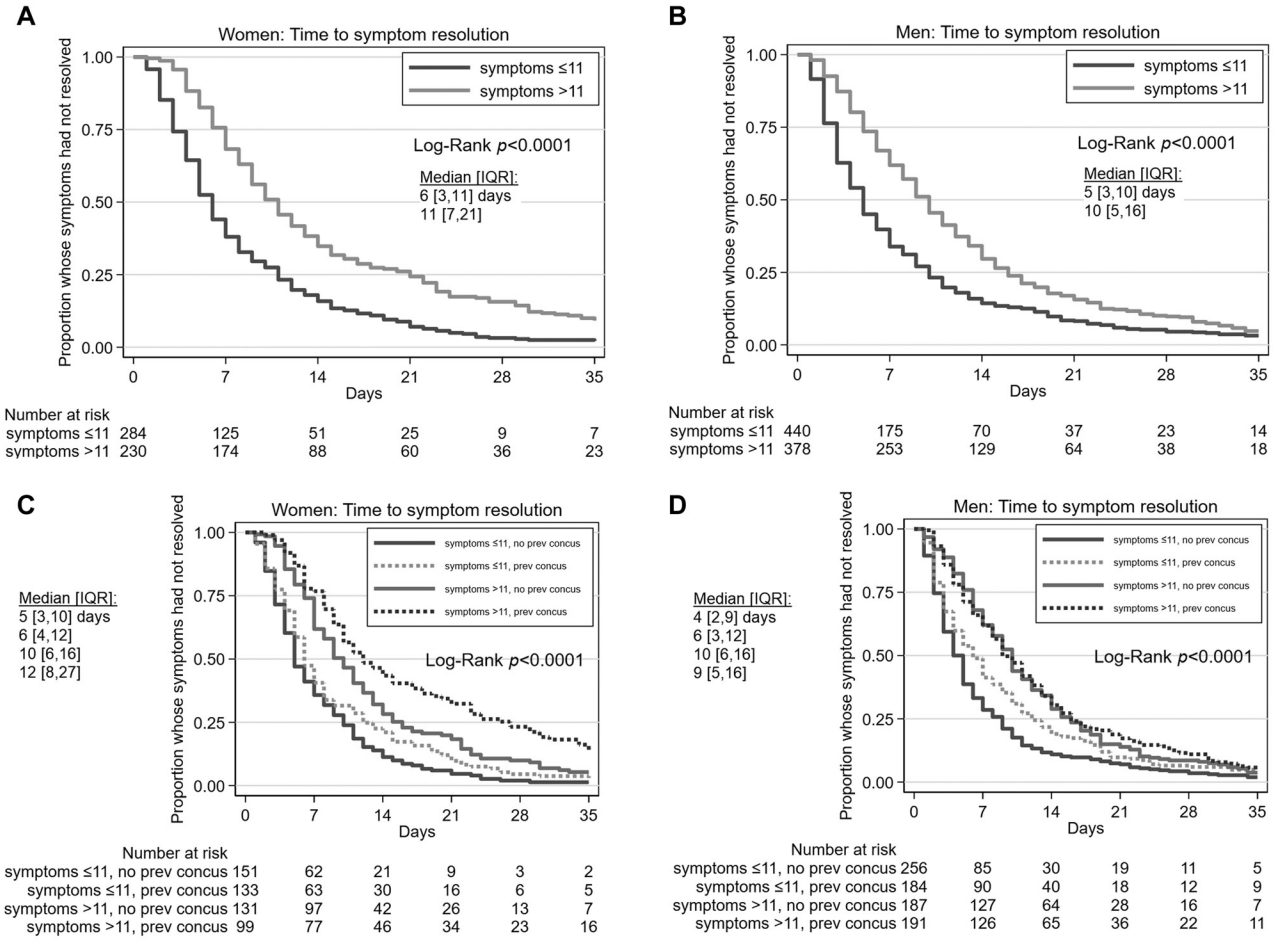

Figure 1. Kaplan-Meier survival curves show differences in time to symptom resolution for (A) women with >11 symptoms (11 vs 6 days); (B) men with >11 symptoms (10 vs 5 days); (C) women with >11 symptoms and ≥1 previous concussion(s) (12 days) or ≤11 symptoms and no previous concussions (5 days); and (D) men with >11 symptoms and no previous concussions (10 days) or ≤11 symptoms and ≥1 previous concussion(s) (4 days). Median days and interquartile ranges (IQRs) are presented for the outcome symptom resolution. Log-rank tests compare differences by symptom burden and concussion history.

(12 and 10 days, respectively [P = .0001]) (Figure 2D). Overall, time to symptom resolution and full play among women with SRC was 1 to 2 days longer than men—regardless of symptom burden and concussion history.

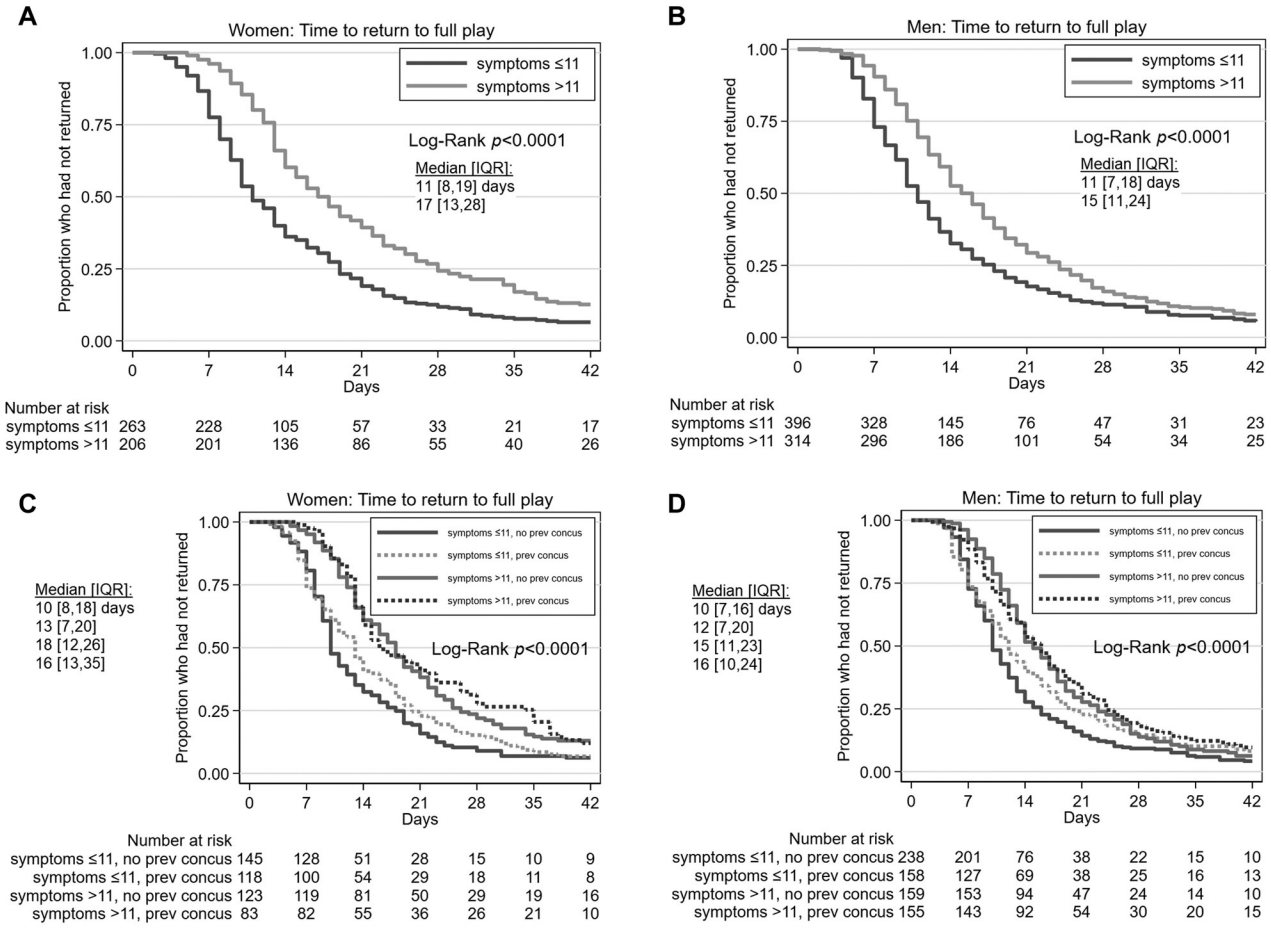

Figure 2. Kaplan-Meier survival curves show differences in time to return to full play for (A) women with >11 symptoms (17 vs 11 days); (B) men with >11 symptoms (15 vs 11 days); (C) women with >11 symptoms and no previous concussions (18 days), or ≥11 symptoms and no previous concussions (10 days); and (D) men with >11 symptoms and ≥1 previous concussion(s) (16 days) or ≤11 symptoms with no previous concussions (10 days). Median days and interquartile ranges (IQRs) are presented for the outcome to return to full play. Log-rank tests compare differences by symptom burden and concussion history.

Symptom Prevalence

The most commonly reported symptoms were headache (women, 96%; men, 94%), pressure in the head (women, 81%; men, 77%), and don't feel right (women, 80%; men, 81%) (**Figure 3**). Affective

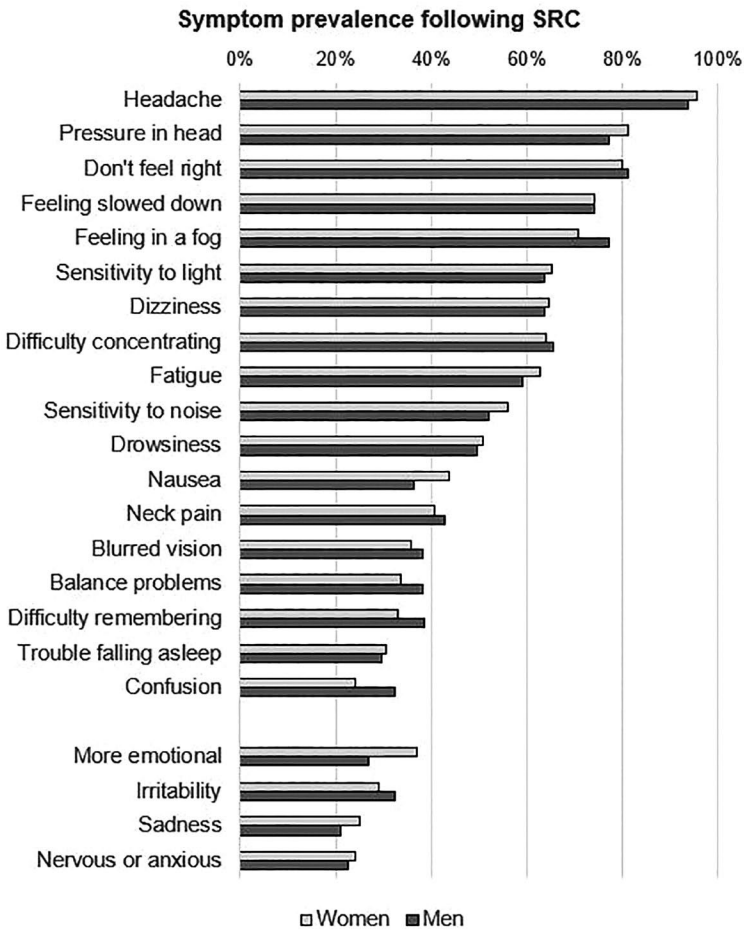

Figure 3. Symptom prevalence among women and men. Symptoms are from the Sport Concussion Assessment Tool–22 symptom inventory. SRC, sport-related concussion.

symptoms were among the least common, with 20% to 40% of athletes reporting feeling more emotional, irritability, sadness, and nervous-anxious after SRC. Affective symptoms had excellent internal consistency (women, $\alpha = .83$; men, $\alpha = .82$), indicating that they are strongly correlated with each other in women and men. The number of athletes who reported at least 1 symptom within the affective domain was also comparable between women and men (women, n = 265; men, n = 394) ($P = .23$). The nervous-anxious symptom always co-occurred with at least 4 other symptoms from the SCAT-22 for women and men. Overall, women were 40% (odds ratio [OR], 1.40

[95% CI, 1.33-1.47]; $P < .001$) and men 33% (OR, 1.33 [95% CI, 1.26-1.40]; $P < .001$) more likely to report nervous-anxious symptoms with each additional symptom they reported.

Affective Symptom Domain

Symptoms took the longest to resolve (median, 11 days) among women with co-occurring affective symptoms, and those without affective symptom endorsement exhibited the shortest time to symptom resolution (median, 6 days; $P < .0001$) (**Figure 4**A). Similarly, men endorsing co-occurring affective symptoms had the longest symptom resolution time (median, 11 days), and those without affective symptoms had the shortest symptom duration (median, 5 days) ($P<.0001$) (Figure 4B).

These patterns persisted for the outcome to return to full play. Women with co-occurring affective symptoms demonstrated the longest time to return to full play (median, 19 days). Half of the women with no affective symptoms returned within 12 days ($P < .0001$) (Figure 4C). Men with co-occurring affective symptoms demonstrated the longest time to return to full play (19 days). Men with no affective symptoms or only nervous-anxious symptoms were the first to return to full play (median, 12 days; $P = .002$) (Figure 4D).

Time to Symptom Resolution

In the Cox multiple regression analysis, compared with women who did not experience any affective domain symptoms, the rate of symptom resolution was 30% lower (hazard ratio [HR], 0.70 [95% CI, 0.54-0.91]; $P < .01$) for women with co-occurring affective symptoms, 36% lower (HR, 0.64 [95% CI, 0.40-1.04]; $P = .07$) for women who experienced nervous-anxious symptoms only, and 26% lower (HR, 0.74 [95% CI, 0.59-0.92]; $P < .01$) for women who experienced other affective symptoms without nervous-anxious symptoms, adjusting for symptom prevalence (HR, 0.94 [95% CI, 0.92-0.96]; $P < .001$) and history of concussion (HR, 0.73 [95% CI, 0.61-0.87]; $P = .001$). For men, the adjusted model did not meet the proportional hazards assumption; complete results are presented in **Table 2.**

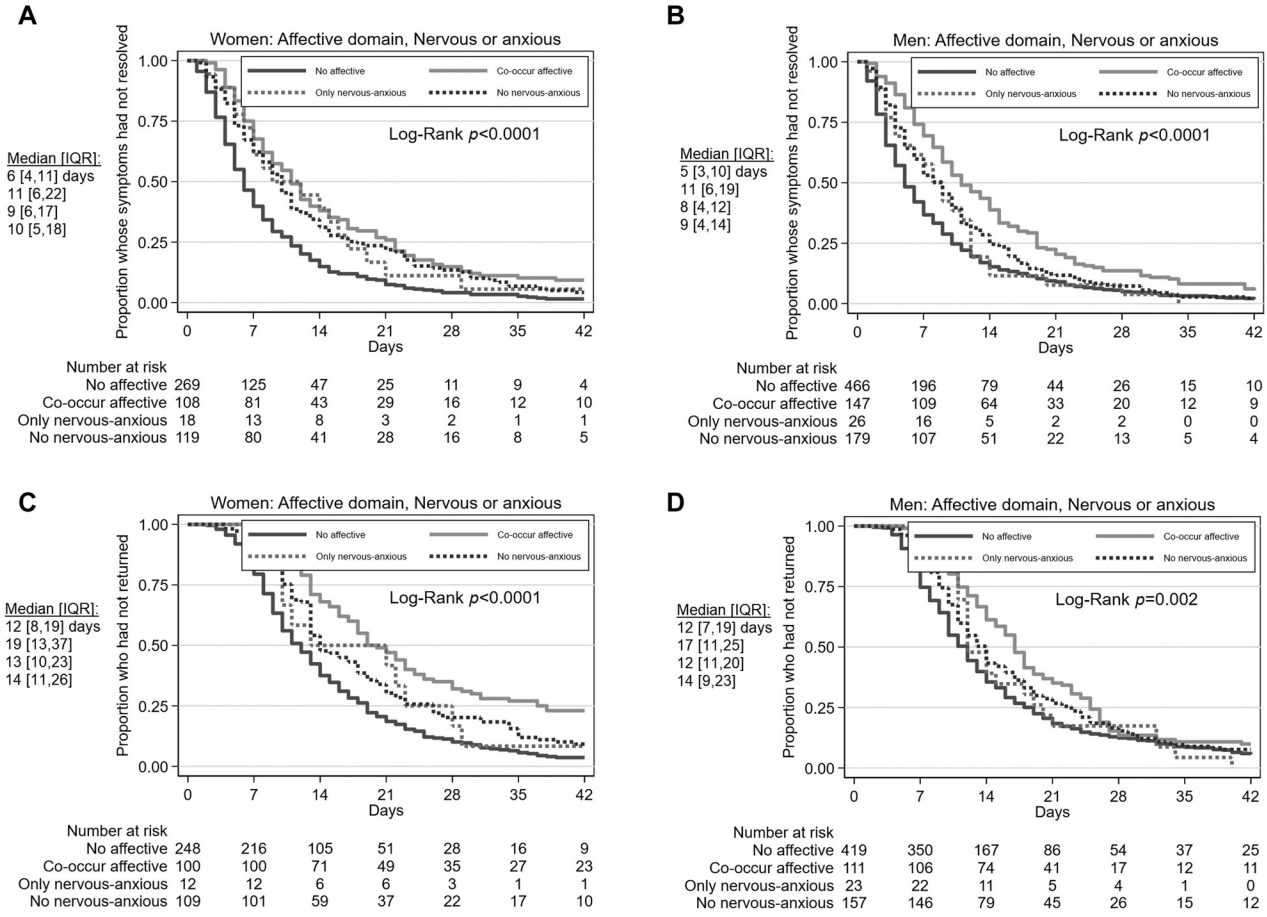

Figure 4. Kaplan-Meier survival curves show differences in time to symptom resolution for (A) women with co-occurring affective symptoms (11 days) or no affective symptoms (6 days); (B) men with co-occurring affective symptoms (11 days) or no affective symptoms (5 days); (C) return to full play for women with co-occurring affective symptoms (19 days) or no affective symptoms (12 days); and (D) men with co-occurring affective symptoms (19 days), no affective symptoms (12 days), or only nervous-anxiety symptoms (12 days). Median days and interquartile ranges (IQRs) are presented for the outcomes of symptom resolution and return to full play. Log-rank tests compare differences by affective domain category.

Time to Return to Full Play

Compared with women who did not experience any affective domain symptoms, the rate of return to full play was 46% lower (HR, 0.54 [95% CI, 0.41-0.71]; $P < .001$) for women with co-occurring affective symptoms, 28% lower (HR, 0.72 [95% CI, 0.40-1.29]; $P = .27$) for women who experienced nervous-anxious symptoms only, and 29%

Table 2. Cox Proportional Hazards Regression—Breslow Method for Ties[a]

2.1 Outcome: Time to Symptom Resolution

	Women			*Men*		
Variable	*HR*	*95% CI*	*P*	*HR*	*95% CI*	*P*
Univariate Cox Regression						
Affective domain						
No affective	Ref	Ref	Ref	Ref	Ref	Ref
Co-occur affective	0.53	0.42-0.66	−.001	0.58[b]	0.48-0.70	−.001
Only nervous-anxious	0.63	0.39-1.01	.39	0.87	0.59-1.30	.50
No nervous-anxious	0.63	0.50-0.78	−.001	0.78[b]	0.66-0.93	.01
Symptom prevalence (18)	0.93	0.91-0.95	−.001	0.93[b]	0.92-0.95	−.001
Concussion history (11)	0.76	0.64-0.91	−.01	0.84	0.73-0.96	.01
Cox Multiple Regression						
Affective domain						
No affective	Ref	Ref	Ref	Ref	Ref	Ref
Co-occur affective	0.70	0.54-0.91	−.01	0.79[b]	0.64-0.98	.03
Only nervous-anxious	0.64	0.40-1.04	.07	0.93[b]	0.62-1.38	.71
No nervous-anxious	0.74	0.59-0.92	−.01	0.95[b]	0.79-1.14	.62
Symptom prevalence (18)	0.94	0.92-0.96	−.001	0.94[b]	0.92-0.96	−.001
Concussion history (11)	0.73	0.61-0.87	.001	0.83[b]	0.73-0.96	.01

2.2 Outcome: Time to Return to Full Play

	Women			*Men*		
Variable	*HR*	*95% CI*	*P*	*HR*	*95% CI*	*P*
Univariate Cox Regression						
Affective domain						
No affective	Ref	Ref	Ref	Ref	Ref	Ref
Co-occur affective	0.46	0.36-0.59	−.001	0.68	0.55-0.83	−.001
Only nervous-anxious	0.72	0.40-1.28	.26	0.91	0.60-1.39	.67
No nervous-anxious	0.64	0.51-0.80	−.001	0.86	0.71-1.03	.10
Symptom prevalence (18)	0.94[b]	0.92-0.96	−0.001	0.95[b]	0.93-0.96	−.001
Concussion history (11)	0.89	0.74-1.07	.22	0.87	0.75-1.01	.07
Cox Multiple Regression						
Affective domain						
No affective	Ref	Ref	Ref	Ref	Ref	Ref
Co-occur affective	0.54	0.41-0.71	−.001	0.87	0.68-1.11	.27
Only nervous-anxious	0.72	0.40-1.29	.27	1.02	0.66-1.55	.94
No nervous-anxious	0.71	0.55-0.91	−.01	0.99	0.82-1.21	.95
Symptom prevalence (18)	0.97	0.94-0.99	−.01	0.95[b]	0.93-0.97	−.001
Concussion history (11)	0.85	0.71-1.03	.09	0.87	0.75-1.01	.07

(continued)

Table 2. *Continued*

2.3 Outcome: Days in RTP Progression

	Women			*Men*		
Variable	*HR*	*95% CI*	*P*	*HR*	*95% CI*	*P*
Univariate Cox Regression						
Affective domain						
No affective	Ref	Ref	Ref	Ref	Ref	Ref
Co-occur affective	0.63[b]	0.50-0.80	–.001	0.91	0.74-1.12	.38
Only nervous-anxious	0.59	0.34-1.01	.06	1.00	0.65-1.53	.99
No nervous-anxious	0.85	0.67-1.07	.16	0.97	0.80-1.16	.72
Symptom prevalence (18)	0.97	0.95-0.99	.02	0.99	0.97-1.01	.31
Concussion history (11)	0.87	0.72-1.04	.13	0.86	0.74-1.00	.06
Cox Multiple Regression						
Affective domain						
No affective	Ref	Ref	Ref	Ref	Ref	Ref
Co-occur affective	0.65	0.49-0.84	.001	0.93	0.73-1.19	.57
Only nervous-anxious	0.61	0.35-1.06	.08	1.00	0.65-1.55	.99
No nervous-anxious	0.86	0.67-1.10	.22	0.99	0.82-1.21	.95
Symptom prevalence (18)	0.99	0.97-1.02	.63	0.99	0.97-1.01	.61
Concussion history (11)	0.85	0.71-1.02	.09	0.87	0.74-1.01	.06

a. HR, hazard ratio; Ref, reference; RTP, return to play.
b. Did not meet proportional hazards assumption.

lower (HR, 0.71 [95% CI, 0.55-0.91]; $P < .01$) for women who experienced other affective symptoms without nervous-anxious symptoms, adjusting for symptom prevalence (HR, 0.97 [95% CI, 0.94-0.99]; $P < .01$) and history of concussion (HR, 0.85 [95% CI, 0.71-1.03]; $P = .09$). For men, estimated HRs were 0.87 (95% CI, 0.68-1.11; $P = .27$) for those with co-occurring affective symptoms, 1.02 (95% CI, 0.66-1.55; $P = .94$) for men who experienced nervous-anxious symptoms only, and 0.99 (95% CI, 0.82-1.21; $P = .95$) for men who experienced other affective symptoms without nervous-anxious symptoms, adjusting for symptom prevalence (HR, 0.95 [95% CI, 0.93-0.97]; $P < .001$) and history of concussion (HR, 0.87; 95% CI, 0.75-1.01; $P = .07$).

Time in RTP Progression

RTP was reported to have occurred on the same day as symptom resolution for 27 (1.87%) student-athletes and RTP occurred before

symptom resolution for 12 (0.83%) student-athletes. Compared with women who did not experience any affective domain symptoms, the rate of time in RTP progression was 35% lower (HR, 0.65 [95% CI, 0.49- 0.84]; P = .001) for women with co-occurring affective symptoms, 39% lower (HR, 0.61 [95% CI, 0.35-1.06]; P = .08) for women who experienced nervous-anxious symptoms only, and 14% lower (HR, 0.86 [95% CI, 0.67-1.10]; P = .22) for women who experienced other affective symptoms without nervous-anxious symptoms, adjusting for symptom prevalence (HR, 0.99 [95% CI, 0.97-1.02]; P = .63) and history of concussion (HR, 0.85 [95% CI, 0.71- 1.02]; P = .09). For men, estimated HRs were 0.93 (95% CI, 0.73-1.19; P = .57) for those with co-occurring affective symptoms, 1 (95% CI, 0.65-1.55; P = .99) for men who experienced nervous-anxious symptoms only, and 0.99 (95% CI, 0.82-1.21; P = .95) for men who experienced other affective symptoms without nervous-anxious symptoms, adjusting for symptom prevalence (HR, 0.99 [95% CI, 0.97-1.01]; P = .61) and history of concussion (HR, 0.87 [95% CI, 0.74- 1.01]; P = .06).

In the secondary analysis of the number of days in RTP progression using linear regression, women who reported experiencing nervous-anxious symptoms alone spent, on average, 38 days (β = 38.46 [95% CI, 7.11-69.80]; P = .02) longer in RTP progression than those who reported no affective symptoms, holding other covariates constant. Women with co-occurring affective symptoms took, on average, 10 additional days in RTP progression; however, this was not statistically significant. For men, the measures of anxiety and days in RTP progression were not associated. For women and men, history of ≥1 previous concussion(s) was significantly associated with a longer mean time in RTP progression: 15 days (β = 14.60 [95% CI, 3.94-23.29]; P < .01; R^2 = 0.03) for women and 7 days (β = 6.90 [95% CI, 3.42-18.24]; P = .02; R^2 = 0.01) for men. Overall, the fit of the linear models was poor; results are presented in **Appendix Table A2**.

Discussion

This study extends previous literature examining the influence of higher symptom burden on concussion recovery outcomes by assessing the role of affective symptom reporting overall, and the nervous

or anxious symptom alone on timelines to symptom resolution and return to full play outcomes after SRC. We explored these relationships separately among women and men in a homogeneous sample of student-athletes, collected via a large, multisite surveillance study of SRC in the Ivy League–Big Ten athletic conferences.

Our findings suggest that the total number of symptoms during recovery from SRC did not differ by sex; however, both women and men experiencing .11 symptoms endured a 5-day delay in symptom resolution compared with those with fewer symptoms. Headache, pressure in the head, and don't feel right were the most commonly reported symptoms, whereas affective symptoms were the least common in women and men alike which is comparable with a previous report of collegiate student-athletes with SRC.[25] Although 20% to 40% of concussed athletes experienced affective symptoms, women and men were 40% and 33%, respectively, more likely to experience nervous-anxious symptoms with each additional symptom endorsed. For women and men, athletes with no affective symptoms experienced the fastest median recovery; in contrast, those experiencing nervous-anxious symptoms that co-occurred with at least 1 other affective symptom demonstrated the longest recovery outcomes. These results suggest that total symptom burden may not be the only factor for longer recovery times after SRC; however, symptom type does matter and may direct modifiable efforts to prevent prolonged recovery.

We observed a significant association between higher symptom burden paired with concussion history and longer times to symptom resolution and return to full play for women and men. These results are unsurprising because previous literature suggests that children and collegiate athletes with a higher symptom burden experience longer recovery.[24,40] Other factors, including female sex, attention deficit hyperactive disorder, and history of migraines, may be influential in an athlete's recovery timeline [24]; however, these factors are not as easily modifiable during concussion management, warranting continued study. Regardless of these risk factors, women lag behind men in their time to symptom resolution and return to full play. These results reflect previous findings that identify sex differences in overall clinical recovery timelines. [6-8,48] Importantly, contrasting findings suggest recovery differences do not exist when controlling for injury severity,[22] the level of contact and division of play,[31] sport,[19] faster initial

evaluation,[36] earlier presentation to specialized care,[20] or clearance from a medical provider.[9] This may highlight differences in concussion management between women and men (or even a need in women) at earlier stages and warrants further attention, as both displayed seemingly similar time in their RTP progression (median, 6 days) in the present study. We found that women with affective symptoms, including experiencing nervous-anxious symptoms, appeared in RTP progression longer than those without nervous-anxious symptoms, emphasizing the importance of identifying symptom type in addition to total symptoms to modify concussion management efforts.

Aligning with previous studies,[50] we found that female and male athletes commonly experienced headaches, pressure in the head, don't feel right, feeling slowed down, and feeling in a fog; some researchers highlight the emotional response that athletes experience after a concussion relative to controls.[29,47] In our sample, 20% to 40% of athletes experienced 1 or more affective symptoms—including more emotional, irritability, sadness, and nervous-anxiousness—and the likelihood of experiencing nervous-anxious symptoms significantly increased with each additional symptom. A recent study on children with preexisting, diagnosed anxiety disorders reported greater symptom burden and delayed recovery outcomes (*e.g.*, symptom resolution, return to school, and return to physical activity) after a concussion compared with those without anxiety disorders.[30] Alternatively, Ali *et al.*[1] reported that in those with diagnosed depression or anxiety, the existence of premorbid depression or anxiety alone did not influence postinjury cognitive or symptom recovery; yet, those with preexisting conditions treated with antidepressants had higher symptom burden and worse cognitive scores after a concussion. Although the present study did not account for preexisting conditions or medication (prescription or usage), we see that those who reported experiencing affective symptoms, including nervous- anxious symptoms, demonstrated significant delays in time to symptom resolution and timelines to return to full play. A higher symptom burden overall and, importantly, the collection of affective symptoms seems to drive this delay, as endorsing the nervous-anxious symptom alone is comparable with endorsing any other of the affective symptoms. This finding supports the importance of assessing comorbid affective symptoms, as these may influence recovery outcomes after SRC. A study of healthy

participants at baseline assessment demonstrated worse scores for attention and processing speed in athletes with comorbid depression or anxiety symptoms compared with controls.[44] It seems that affective symptoms may also influence cognitive performance outcomes even in athletes without a concussion, indicating that the presence of comorbid affective symptoms should be a consideration during concussion management.

We found that men and women with no affective symptom experienced during their SRC recovery demonstrated the fastest recovery. Specifically, men and women with no affective symptoms had a median symptom resolution in 5 and 6 days, respectively, and both returned to play in a median of 12 days after SRC. Relative to those without affective symptoms, men and women experiencing nervous-anxious symptoms alone both had a median 3-day delay in symptom resolution, and those with nervous-anxious and co-occurring affective symptoms experienced symptoms a median 4 days longer. These results align with previous literature suggesting that athletes who are slow to recover from their concussion demonstrate higher affective symptom burden, measured with the Beck Depression Inventory–II, relative to asymptomatic concussed athletes and non-concussed control athletes.[41] In addition, in a study by Turner *et al.*,[46] upward of 70% of concussed athletes exceeded the threshold of clinical state anxiety—defined as a score ≥38 on the State-Trait Anxiety Inventory for Adults[42]—acutely after their injury. However, over half of athletes still displayed state anxiety above clinical thresholds at RTP, suggesting that affective symptoms may last longer than other symptom subtypes.[46] Moreover, in a study of adults with concussions seen by a primary care physician or emergency department, premorbid psychiatric conditions (*e.g.*, depression and anxiety) were a predictor of longer recovery, along with older age, comorbid personality disorders, and preinjury health care utilization.[27] Similarly, pediatric patients, aged 12 to 18 years, with preexisting emotional distress (*e.g.*, depression and anxiety) exhibited longer symptom resolution relative to patients without a history of depression or anxiety.[39] Importantly, the authors also reported that girls and women experienced longer recovery times as well as higher percentages of preexisting anxiety compared with men. However, this study included patients presenting to a specialty concussion clinic at a median of 16 days after injury. Therefore, the

aforementioned studies may not be representative of student-athletes experiencing SRC in the collegiate-athletic setting. One cross-sectional between-group study of collegiate athletes found that concussion was associated with elevated anxiety, but not attentional bias to threat — defined as focused awareness of threat-related stimuli, which has been considered a hallmark symptom, and in some cases, a potential causal factor of anxiety.[14] Authors suggest that this has important implications for understanding not only the nature and source of anxiety after a concussion, but also the best treatment options, and they urge further studies to investigate these complex relationships.[14] Alternatively, Covassin *et al.*[17] demonstrated the importance of social support in mitigating state anxiety after a concussion, as concussed athletes with greater satisfaction with social support had lower state anxiety levels, particularly at RTP time in concussed athletes. Further, in a qualitative study, Todd *et al.*[45] showed how ice hockey players experienced extreme feelings of compromised identity after a concussion, exacerbated by feelings of isolation and stigmatization. Participants cited support from peers, family, and health care providers as key to their success moving forward after an injury.[45] Therefore, adding social support and psychological intervention practices integrated into concussion management may benefit athletes, especially those with affective and persisting symptoms.

These findings also have important implications for detection and identification for treatment, as feeling nervous or anxious, or rather anxiety itself, has clear screening, diagnostic, and management protocols that can be integrated into concussion management. Still, existing studies that have evaluated affective symptoms, specifically anxiety, after concussion have focused on the acute postconcussion period; few have considered the role of preinjury or long-term symptoms.[3,21] Thus, additional work is needed to determine the appropriate type and timing of affective symptom assessments, and how they can best be applied in different settings and contexts, alongside clinical judgment. However, in contexts where formal screening and/or diagnostic measures may not be feasible, it may prove useful to first utilize and inspect symptom assessment tools used during SRC management (*e.g.*, SCAT-22) to help identify athletes after SRC who may be at risk for prolonged symptoms and recovery—as demonstrated here.

Limitations

Our study makes important contributions by examining the role of affective symptoms on timelines to symptom resolution, RTP, and time within RTP progression after SRC, highlighting key differences among athletes in women's and men's sports; however, some limitations must be considered. In modeling the relationship between experiencing symptoms in the affective domain and time to symptom resolution among men, our Cox multiple regression model did not meet the proportionality assumption; thus, our estimate of the rate ratio cannot be assumed to be constant throughout the follow-up time. In this case, alternative survival analysis methods may be more appropriate and will be explored in future analyses. For the outcome time in RTP progression, linear regression models demonstrated poor fit among women (R^2 = 0.03) and men (R^2 = 0.01), suggesting that there are additional, uncontrolled factors contributing to time in RTP progression among athletes with anxiety. This warrants continued study of student-athletes experiencing longer recovery to identify potential preventative/actionable factors. We were not able to consider preexisting mental health conditions, anxiety/depression screening assessments or previous/ current receipt of mental health services; thus, future research should consider their relationship with recovery outcomes. We were limited to considering symptom burden, as symptom data from the Ivy-B1G Study are collected via a dichotomized checklist from the SCAT–22 inventory. We hope that this analysis inspires future examinations of symptom severity among those who endorse affective symptoms. In addition, consideration should be given to the temporality of experiencing the nervous- anxious symptom and time-dependency of this exposure and potential covariates; it may be that higher symptom burden and/or experiencing symptoms over a longer period exacerbates feelings of nervousness and anxiousness and/ or anxiety. Attention should also be given to potential sources of nervous-anxious symptoms, particularly if they are related to the athlete's injury and/or RTP.

The Ivy League and Big Ten conferences include programs where SRC detection and management protocols are enforced, requiring immediate removal of athletes with suspected or reported SRC, and injured athletes are progressed through RTP protocols. Therefore, this

study extends research on patients presenting to emergency departments, primary care, and specialty clinics, while limiting the generalizability beyond similar athletic conferences to other competitive divisions and levels of play.

Conclusion

Affective symptom endorsement was relatively common in collegiate athletes after SRC, and these symptoms do play a role in delayed clinical recovery and RTP. Differences were evident among both female and male athletes, particularly with total time in RTP progression. Collegiate sports are a unique setting where the breadth and timeliness of health care resources after injury may differ compared with previous studies of patients seeking care for prolonged symptoms at specialty clinics. By identifying the nature and extent of collegiate athletes who experience affective and nervous-anxious symptoms after SRC, we afford clinical care teams opportunities to prioritize and mobilize mental health resources and tailor treatments to athletes. The factors measured here (sex, symptom prevalence, and concussion history) contribute to this relationship; however, significant unmeasured confounding remains, as indicated by the poor fit of our Cox and linear models. This study establishes a precedent for future work to explore affective symptoms and RTP timelines, considering the role of anxiety and other risk/protective factors collected over time.

* * * *

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References

1. Ali M, Asghar N, Li A, *et al.* Incidence of concussion and recovery of neurocognitive dysfunction on ImPACT assessment among youth athletes with premorbid depression or anxiety taking antidepressants. *J Neurosurg Pediatr*. 2021;28(1):69-75. https://doi.org/10.3171/2020.11.PEDS20821
2. Anderson M, Petit KM, Bretzin AC, *et al.* Sport Concussion Assessment Tool Symptom Inventory: healthy and acute postconcussion symptom factor structures. *J Athl Train*. 2020;55(10):1046-1053.
3. Arnett PA, Guty E, Bradson M. Assessment of depression and anxiety in sports concussion evaluations. In: Arnett PA, ed. Neuropsychology of Sports-Related Concussion. American Psychological Association; 2019:71-94. https://doi.org/10.1037/0000114-004
4. Baker JG, Leddy JJ, Darling SR, *et al.* Gender differences in recovery from sports-related concussion in adolescents. *Clin Pediatr (Phila)*. 2016;55(8):771-775.
5. Berz K, Divine J, Foss KB, *et al.* Sex-specific differences in the severity of symptoms and recovery rate following sports-related concussion in young athletes. *Phys Sportsmed*. 2013;41(2):58-63.
6. Bretzin AC, Covassin T, Fox ME, *et al.* Sex differences in the clinical incidence of concussions, missed school days, and time loss in high school student-athletes: part 1. *Am J Sports Med*. 2018;46(9):2263-2269.
7. Bretzin AC, Covassin T, Wiebe DJ, Stewart W. Association of sex with adolescent soccer concussion incidence and characteristics. *JAMA Netw Open*. 2021;4(4):e218191.
8. Bretzin AC, Esopenko C, D'Alonzo BA, Wiebe DJ. Clinical recovery timelines following sport-related concussion in men's and women's collegiate sports. Published online February 24, 2021. *J Athl Train*. https://doi.org/10.4085/601-20
9. Bretzin AC, Zynda AJ, Wiebe DJ, Covassin T. Time to authorized clearance from sport-related concussion: the influence of healthcare provider and medical facility. *J Athl Train*. 2020;56(8):869-878.
10. Broglio SP, Cantu RC, Gioia GA, *et al.* National Athletic Trainers' Association Position Statement: management of sport concussion. *J Athl Train*. 2014;49(2):245-265.

11. Broshek DK, Kaushik T, Freeman JR, *et al.* Sex differences in outcome following sports-related concussion. *J Neurosurg*. 2005;102(5):856-863.
12. Bruce JM, Thelen J, Meeuwisse W, *et al.* Use of the Sport Concussion Assessment Tool 5 (SCAT5) in professional hockey, part 2: which components differentiate concussed and non-concussed players? *Br J Sports Med*. 2021;55(10):557-565.
13. Campbell-McGovern C, D'Alonzo BA, Cooper M, Putukian M, Wiebe DJ. Ivy League-Big Ten Epidemiology of Concussion Study. *Inj Prev*. 2018;24(4):319-320.
14. Carlson JM, Kangas KJ, Susa TR, Fang L, Moore MT. Sport-related concussion is associated with elevated anxiety, but not attentional bias to threat. *Brain Inj*. 2020;34(3):363-368.
15. Centers for Disease Control and Prevention. *Surveillance Report of Traumatic Brain Injury-Related Emergency Department Visits, Hospitalizations, and Deaths—United States, 2014*. Centers for Disease Control and Prevention, U.S. Department of Health and Human Services; 2019.
16. Clair R, Levin Allen S, Goodman A, McCloskey G. Gender differences in quality of life and symptom expression during recovery from concussion. *Appl Neuropsychol Child*. 2020;9(3):206-214.
17. Covassin T, Crutcher B, Bleecker A, *et al.* Postinjury anxiety and social support among collegiate athletes: a comparison between orthopaedic injuries and concussions. *J Athl Train*. 2014;49(4):462-468.
18. Covassin T, Elbin RJ, Bleecker A, Lipchik A, Kontos AP. Are there differences in neurocognitive function and symptoms between male and female soccer players after concussions? *Am J Sports Med*. 2013;41(12):2890-2895.
19. Covassin T, Moran R, Elbin RJ. Sex differences in reported concussion injury rates and time loss from participation: an update of the National Collegiate Athletic Association Injury Surveillance Program from 2004-2005 through 2008-2009. *J Athl Train*. 2016;51(3):189-194.
20. Desai N, Wiebe DJ, Corwin DJ, *et al.* Factors affecting recovery trajectories in pediatric female concussion. *Clin J Sport Med*. 2019;29(5):361-367.
21. Gornall A, Takagi M, Morawakage T, Liu X, Anderson V. Mental health after paediatric concussion: a systematic review and metaanalysis. *Br J Sports Med*. 2021;55(18):1048-1058.
22. Hannah TC, Li AY, Spiera Z, *et al.* Sex-related differences in the incidence, severity, and recovery of concussion in adolescent student-athletes between 2009 and 2019. *Am J Sports Med*. 2021;49(7):1929-1937.
23. Hootman JM, Dick R, Agel J. Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives. *J Athl Train*. 2007;42(2):311-319.
24. Houck Z, Asken B, Bauer R, Clugston J. Predictors of post-concussion symptom severity in a university-based concussion clinic. *Brain Inj*. 2019;33(4):480-489.
25. Joyce AS, Labella CR, Carl RL, Lai JS, Zelko FA. The Postconcussion Symptom Scale: utility of a three-factor structure. *Med Sci Sports Exerc*. 2015;47(6):1119-1123.

26. Langdon S, Königs M, Adang EAMC, Goedhart E, Oosterlaan J. Subtypes of sport-related concussion: a systematic review and metacluster analysis. *Sports Med*. 2020;50(10):1829-1842.

27. Langer LK, Alavinia SM, Lawrence DW, *et al.* Prediction of risk of prolonged post-concussion symptoms: derivation and validation of the TRICORDRR (Toronto Rehabilitation Institute Concussion Outcome Determination and Rehab Recommendations) score. *PLoS Med*. 2021;18(7):e1003652.

28. Lempke LB, Schmidt JD, Lynall RC. Athletic trainers' concussion-assessment and concussion-management practices: an update. *J Athl Train*. 2020;55(1):17-26.

29. Mainwaring LM, Hutchison M, Bisschop SM, Comper P, Richards DW. Emotional response to sport concussion compared to ACL injury. *Brain Inj*. 2010;24(4):589-597.

30. Martin AK, Petersen AJ, Sesma HW, *et al.* Concussion symptomology and recovery in children and adolescents with pre-existing anxiety. *J Neurol Neurosurg Psychiatry*. 2020;91(10):1060-1066.

31. Master CL, Katz BP, Arbogast KB, *et al.* Differences in sport-related concussion for female and male athletes in comparable collegiate sports: a study from the NCAA-DoD Concussion Assessment, Research and Education (CARE) Consortium. *Br J Sports Med*. 2021;55(24):1387-1394.

32. McCrory P, Meeuwisse W, Dvorak J, *et al.* Consensus statement on concussion in sport—the 5th International Conference on Concussion in Sport held in Berlin, October 2016. *Br J Sports Med*. 2017;51(11):838-847.

33. McCrory P, Meeuwisse WH, Aubry M, *et al.* Consensus statement on concussion in sport: the 4th International Conference on Concussion in Sport held in Zurich, November 2012. *Br J Sports Med*. 2013;47(5):250.

34. National Center for Injury Prevention and Control. *Report to Congress on Mild Traumatic Brain Injury in the United States: Steps to Prevent a Serious Public Health Problem*. Atlanta, GA: Centers for Disease Control and Prevention; 2003.

35. Nelson LD, Kramer MD, Patrick CJ, McCrea MA. Modeling the structure of acute sport-related concussion symptoms: a bifactor approach. *J Int Neuropsychol Soc*. 2018;24(8):793-804.

36. Pratile T, Marshall C, DeMatteo C. Examining how time from sport-related concussion to initial assessment predicts return-to-play clearance. *Phys Sportsmed*. 2022;50(2):132-140.

37. Putukian M, D'Alonzo BA, Campbell-McGovern CS, Wiebe DJ. The Ivy League-Big Ten Epidemiology of Concussion Study: a report on methods and first findings. *Am J Sports Med*. 2019;47(5):1236-1247.

38. Putukian M, Riegler K, Amalfe S, Bruce J, Echemendia R. Preinjury and postinjury factors that predict sports-related concussion and clinical recovery time. *Clin J Sport Med*. 2021;31(1):15-22.

39. Rosenbaum PE, Locandro C, Chrisman SPD, *et al.* Characteristics of pediatric mild traumatic brain injury and recovery in a concussion clinic population. *JAMA Netw Open*. 2020;3(11):e2021463.

40. Schilling S, Mansour A, Sullivan L, *et al.* Symptom burden and profiles in concussed children with and without prolonged recovery. *Int J Environ Res Public Health*. 2020;17(1):351.

41. Sicard V, Harrison AT, Moore RD. Psycho-affective health, cognition, and neurophysiological functioning following sports-related concussion in symptomatic and asymptomatic athletes, and control athletes. *Sci Rep*. 2021;11(1):13838.

42. Spielberger C, Gorsuch R, Lushene R. *State-Trait Anxiety Inventory for Adults*. Consulting Psychologists Press; 1970.

43. StataCorp. 2019. Stata Statistical Software: Release 16. College Station, TX: StataCorp LLC.

44. Thomas GA, Guty ET, Riegler KE, Arnett PA. Comorbid affective symptomatology and neurocognitive performance in college athletes. *J Int Neuropsychol Soc*. 2022;28(2):177-187.

45. Todd R, Bhalerao S, Vu MT, Soklaridis S, Cusimano MD. Understanding the psychiatric effects of concussion on constructed identity in hockey players: implications for health professionals. *PLoS One*. 2018;13(2):e0192125.

46. Turner S, Langdon J, Shaver G, *et al.* Comparison of psychological response between concussion and musculoskeletal injury in collegiate athletes. *Sport Exerc Perform Psychol*. 2017;6(3):277-288.

47. Valovich McLeod TC, Wagner AJ, Bacon CEW. Lived experiences of adolescent athletes following sport-related concussion. *Orthop J Sports Med*. 2017;5(12):232596711774503.

48. Van Pelt KL, Caccese JB, Eckner JT, *et al.* Detailed description of Division I ice hockey concussions: findings from the NCAA and Department of Defense CARE Consortium. *J Sport Health Sci*. 2021;10(2):162-171.

49. von Elm E, Altman DG, Egger M, *et al.* The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *The Lancet*. 2007;370(9596):1453-1457.

50. Wasserman EB, Kerr ZY, Zuckerman SL, Covassin T. Epidemiology of sports-related concussions in National Collegiate Athletic Association athletes from 2009-2010 to 2013-2014: symptom prevalence, symptom resolution time, and return-to-play time. *Am J Sports Med*. 2016;44(1):226-233.

51. Zuckerman SL, Kerr ZY, Yengo-Kahn A, *et al.* Epidemiology of sports-related concussion in NCAA athletes from 2009-2010 to 2013-2014: incidence, recurrence, and mechanisms. *Am J Sports Med*. 2015;43(11):2654-2662.

The Role of Reported Affective Symptoms and Anxiety in Recovery Trajectories After Sport-related Concussion

APPENDIX

Table A1. Sport-related Concussions Across Varsity Sports
for Academic Years 2013-14 to 2019-20 (November 2013 through February 2020)

	Women	Men	Total
Sport	(n=759, 36.5%)	(n=1318, 63.5%)	(n=2077, 100%)
football	0 (0.0)	665 (50.5)	665 (32.0)
soccer	149 (19.6)	118 (9.0)	267 (12.9)
lacrosse	88 (11.6)	124 (9.4)	212 (10.2)
basketball	78 (10.3)	70 (5.3)	148 (7.1)
wrestling	0 (0.0)	127 (9.6)	127 (6.1)
gymnastics	73 (9.6)	7 (0.5)	80 (3.9)
volleyball	69 (9.1)	6 (0.5)	75 (3.6)
field hockey	71 (9.4)	0 (0.0)	71 (3.4)
water polo	30 (4.0)	40 (3.0)	70 (3.4)
sprint football	0 (0.0)	59 (4.5)	59 (2.8)
softball	58 (7.6)	0 (0.0)	58 (2.8)
baseball	0 (0.0)	38 (2.9)	38 (1.8)
swimming	26 (3.4)	8 (0.6)	34 (1.6)
track&field/cross country	17 (2.2)	17 (1.3)	34 (1.6)
diving	19 (2.5)	7 (0.5)	26 (1.3)
rowing	15 (2.0)	6 (0.5)	21 (1.0)
fencing	7 (0.9)	10 (0.8)	17 (0.8)
squash	12 (1.6)	4 (0.3)	16 (0.8)
sailing	12 (1.6)	3 (0.2)	15 (0.7)
cheerleading	10 (1.3)	3 (0.2)	13 (0.6)
skiing	7 (0.9)	2 (0.2)	9 (0.4)
tennis	7 (0.9)	2 (0.2)	9 (0.4)
equestrian	8 (1.1)	0 (0.0)	8 (0.4)
polo	2 (0.3)	1 (0.1)	3 (0.1)
golf	1 (0.1)	1 (0.1)	2 (0.1)

Table A2. Linear regression
Outcome: days in RTP progression

	Women				Men			
Variable	β	95% CI	p-value	R^2	β	95% CI	p-value	R^2
Univariate linear regression								
Affective domain								
No affective	ref	ref	ref		ref	ref	ref	
Co-occur affective	10.82	-2.90-24.54	0.12	0.02	4.00	-3.80-11.79	0.31	0.002
Only nervous-anxious	38.41	7.15-69.67	0.02		-4.71	-20.46-11.05	0.56	
No nervous-anxious	3.83	-9.49-17.15	0.57		-0.10	-6.93-6.74	0.98	
Symptom prevalence (18)	0.72	-0.58-2.02	0.28	0.002	0.07	-0.58-0.71	0.84	0.008
Concussion history	14.44	3.74-25.15	<0.01	0.01	6.80	1.30-12.31	0.02	0.007
Multivariable linear regression								
Affective domain								
No affective	ref	ref	ref		ref	ref	ref	
Co-occur affective	9.66	-5.99-25.32	0.23		4.90	-4.05-13.86	0.28	
Only nervous-anxious	38.46	7.11-69.80	0.02	0.03	-3.71	-19.57-12.14	0.65	0.01
No nervous-anxious	3.06	-10.80-16.91	0.67		-0.15	-7.40-7.10	0.97	
Symptom prevalence (18)	0.21	-1.28-1.70	0.78		-0.16	-0.92-0.60	0.68	
Concussion history	14.60	3.94-23.29	<0.01		6.90	3.43-18.24	0.02	

Abbreviation: CI=confidence interval