Risk of Upper Extremity Musculoskeletal Injury Within the First Year After a Concussion

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Background: Emerging evidence suggests that athletes and military personnel are at increased risk for lower extremity musculoskeletal injury after a concussion; however, the association between concussion and subsequent upper extremity (UE) musculoskeletal injury is unknown.

Purpose: To prospectively examine the association between concussion and UE musculoskeletal injury risk within the first year after returning to unrestricted activity.

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

Methods: A total of 316 cases of concussion 42% (132/316 women) were observed among 5660 Concussion Assessment, Research and Education Consortium participants at the United States Military Academy from May 2015 to June 2018. Active injury surveillance within the cohort was conducted for 12 months after unrestricted return to activity to identify any incident cases of acute UE musculoskeletal injury. Injury surveillance during the follow-up period was also conducted for nonconcussed controls who were matched by sex and competitive sport level. Univariate and multivariable Cox proportional hazards regression models were used to estimate hazard ratios between concussed cases and nonconcussed controls for time to UE musculoskeletal injury.

Results: During the surveillance period, 19.3% of concussed cases and 9.2% of nonconcussed controls sustained a UE injury. In the univariate model, concussed cases were 2.25 times (95% CI, 1.45-3.51) more likely to sustain a UE injury during the 12-month follow-up period when compared with the nonconcussed controls. In the multivariable model, adjusted for history of concussion, sport level, somatization, and history of UE injury, concussed cases were 1.84 times (95% CI, 1.10-3.07) more likely to sustain a UE injury during the surveillance period compared with nonconcussed controls. Sport level remained an independent risk factor for UE musculoskeletal injury; however, concussion history, somatization, and history of UE injury were not independent risk factors.

Conclusion: Concussed cases were more than twice as likely to sustain an acute UE musculoskeletal injury within the first 12 months after unrestricted return to activity when compared with nonconcussed controls. The higher hazard of injury remained in the concussed group after adjusting for other potential risk factors.

Keywords: athletic injuries; head injury; mild traumatic brain injury; tactical athlete

Concussions are common in athletes[18] and military Service members,[21,57] placing a significant burden on these populations. Since 2000, more than 369,000 Service members have been diagnosed with a concussion.[14] In collegiate athletics, concussions account for roughly 6% of all student-athlete injuries each year.[61] Concussions are typically associated with transient symptoms, neurological deficits, and cognitive impairment[1]; however, a growing body of evidence has focused on subsequent musculoskeletal injury risk after postconcussion unrestricted return to activity.[30,39,52] Musculoskeletal injuries are a major source of time loss among athletes as well as limited duty days and attrition in military Service members,[10,19,46] and thus, the association between these 2 injuries is a fundamental concern for athletes and Service members alike.

Based on the existing injury surveillance studies, collectively analyzed, athletes and Service members are at significantly greater risk for subsequent musculoskeletal injury after a concussion.[30,39,52] The odds that an athlete or Service member will sustain a subsequent lower extremity (LE) musculoskeletal injury in the year after a concussion are roughly 2-fold higher than those without

The Orthopaedic Journal of Sports Medicine, 11(5), 23259671231163570
DOI: 10.1177/23259671231163570

a concussion.[39,52] Pooled estimates suggest that the odds of LE injury are 1.60 to 2.11 times greater in those with a history of concussion compared with those without.[39,52] While the rate of subsequent LE injury is consistent across studies,[26] limited evidence exists for upper extremity (UE) musculoskeletal injury risk after a concussion. The few studies[32,59] that have included UE injuries catalogued UE and LE injuries collectively, making it difficult to conclude the effects of concussion exclusively on UE musculoskeletal injury risk.

UE musculoskeletal injuries account for roughly 18.3% and 21.4% of collegiate game and practice injuries while participating in sports.[22] Likewise, in a military cohort, 19.1% of all reported injuries involved the UE.[31] While UE injuries generally account for a lower percentage of musculoskeletal injuries reported in active populations,[22,31] they can contribute to negative health outcomes and long-term disability.[9,15] In particular, injuries to the glenohumeral joint have been associated with chronic recurrent instability,[40] glenoid and humeral head bone loss,[42] and osteoarthritis.[5,25,43] Understanding the association between concussion and subsequent UE injury could aid intervention strategies to mitigate UE injuries and avoid long-term health consequences.

There are currently no established risk factors for musculoskeletal injury after a concussion. Behavioral mechanisms—such as risk-taking behavior as well as loss of motor stability—are speculated to contribute to musculoskeletal injury risk after a concussion, but they remain theoretical at this time.[3,7,41] However, modifiable (ie, training load, anxiety) and nonmodifiable (sex, previous musculoskeletal injury) risk factors for musculoskeletal injury are well-documented.[8,55] Accordingly, there is a need for well-designed prospective studies to control for established predictors of musculoskeletal injury risk. Accounting for factors known to influence musculoskeletal injury risk may help expose the relationship between concussion and subsequent UE musculoskeletal injury after a concussion and unrestricted return to activity.

The purpose of this study was to prospectively examine the association between concussion and UE musculoskeletal injury risk within the first year after returning to unrestricted activity following concussion. We hypothesized that in the first year after returning to unrestricted activity, concussed cases would be at greater risk of UE musculoskeletal injury compared with nonconcussed controls matched by sex and competitive sport level.

METHODS

Study Design and Setting

A nested case-control design was used to examine the association between concussion and subsequent UE musculoskeletal injury among cadets at the United States Military Academy. Nested case-control designs, when drawn from a well-established cohort, provide the efficiency of the case-control design while maintaining the temporal relationship of the prospective cohort design.[54,56] Cases and controls were identified from the National Collegiate Athletic Association–Department of Defense (NCAA-DoD) Concussion Assessment, Research and Education (CARE) cohort at the United States Military Academy. The CARE Consortium is a multisite prospective cohort study designed to investigate the natural history of clinical and neurobiological recovery after a concussion.[4] The CARE Consortium cohort at the academy was used to identify concussed cases during the follow-up postconcussion surveillance period as well as matched nonconcussed controls. The protocol for this study received institutional review board approval.

Participants

All participants were physically active college students (age range, 17-27 years) at the United States Military Academy who enrolled in the CARE Consortium cohort between 2015 and 2017. As part of the clinical standard of care for concussion management, all participants completed an annual concussion baseline assessment before the academic years 2015-2016, 2016-2017, and 2017-2018. Of the 6575 students who completed baseline assessments, 5660 (4477 men, 1183 women) volunteered to participate in the CARE Consortium study. Daily life for all participants included some form of competitive athletics and physical fitness training, with the plurality of the cohort competing in varsity-level athletics (40%), followed by intramural (39%) and club (21%) sports. As part of their 47-month experience at the academy, the participants also completed military training

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Final revision submitted December 6, 2022; accepted January 20, 2023.
One or more of the authors has declared the following potential conflict of interest or source of funding: S.J.S. has received education payments from Arthrex. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.
The views expressed herein are those of the author(s) and do not necessarily reflect the official policy of the Department of the Army, Department of Defense, or the US Government.
Ethical approval for this study was obtained from Naval Medical Center Portsmouth (ref No. RHC-A-20-044).

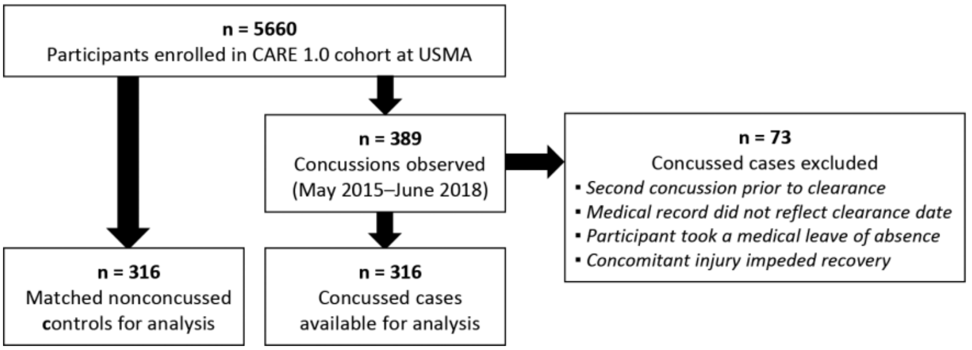

Figure 1. CONSORT (Consolidated Standards of Reporting Trials) flow chart of participant inclusion. USMA, United States Military Academy.

(ie, air assault, airborne, and combat dive training) and physical education (ie, boxing, swimming, and combative training) requirements in addition to having a rigorous academic course load.

A total of 389 incident cases of concussion as defined by the CARE Consortium[4] were extracted for the period between May 2015 and June 2018. Cases were excluded if another concussion occurred before the participant's clearance for unrestricted return to activity (n = 3), if the participant's study and medical records did not reflect a clearance date (n = 64), if the participant took a medical leave of absence (n = 4), or if a concomitant injury may have impeded recovery (n = 2). Thus, 316 concussed cases were enrolled and matched with 316 nonconcussed controls. Figure 1 outlines enrollment and retention for the present study.

The concussion cohort was matched by sex and sport level (ie, intramural, club, and varsity) to participants who had not experienced a concussion since enrolling in CARE and who reported no history of concussion (nonconcussed cohort). Sex served as a matching criterion, as women are at increased risk for concussion and musculoskeletal injury.[35,55] Competitive sport level served as a criterion to control for exposure. Also, $<1.6\%$ (n = 5) of cases could not be matched based on competitive sport level and were thus matched with a sport of comparable contact competing at a different level—for example, club boxing was matched with varsity rugby and intramural swimming was matched with varsity swimming. Club and varsity athletes were also matched by sport when possible. In circumstances in which an exact sport match was not available, a sport of comparable contact as defined by the contact categories (contact, limited contact, and noncontact) in the study by Katz et al[33] was used—for example, ice hockey was matched with lacrosse. Moreover, $>7\%$ (n = 22) of the club and varsity cases required a comparable contact sport match. In cases in which multiple participants were available to serve as a control, the control closest to the case in academic year (ie, freshman, sophomore), age, height, and mass was selected. Also, $>93\%$ of cases were matched on academic year, age (±3 years), height (±7.6 cm), and weight (±6.8 kg).

Data Collection

The framework of the CARE Consortium, in conjunction with local injury surveillance systems, was used to prospectively investigate UE musculoskeletal injury risk after a concussion. The structure and methods of data collection for the CARE Consortium have been previously described[4,24] and are therefore summarized here in relation to the present investigation. All participants who agree to enroll in the CARE Consortium undergo a comprehensive baseline assessment by research staff with a medical background (ie, athletic training, physical therapy, and nursing) and are assessed for incidence of concussion. For this investigation, we extracted demographic variables, self-reported concussion history, and psychological distress as measured using the Brief Symptom Inventory–18 (BSI-18) at the baseline from the CARE database. The BSI-18 includes 3 symptom scales as follows: (1) anxiety, (2) depression, and (3) somatization. Each symptom scale contains 6 items, and thus, scores range[13] from 0 to 24, with lower scores representing lower levels of anxiety, depression, and somatization (ie, the expression of psychological or emotional factors as physical symptoms).

UE musculoskeletal injury was operationally defined as any acute injury (ie, fracture, strain, sprain, dislocation, subluxation, and rupture) to the shoulder, arm, elbow, forearm, wrist, hand, or fingers/thumb and recorded by a medical provider in the participant's medical record. It did not have to result in time loss from activity; however, it did have to be attributed to a single traumatic event.[29] Contusions, blisters, and abrasions were excluded. Diagnoses that could be attributed to a gradual onset without a specific traumatic event were classified as chronic[29] and were excluded. Active injury surveillance during the follow-up period and injury history were also documented for the nonconcussed controls.

Active injury surveillance within the cohort was conducted for 12 months after unrestricted return to activity to identify any incident cases of acute UE musculoskeletal injury. To ensure that the musculoskeletal injury surveillance was conducted during the same 12-month time frame, the return to activity date after concussion served as the musculoskeletal injury surveillance start date for each concussed case and matched control. We also recorded acute UE musculoskeletal injury history from the time of entry to the academy (ie, Reception Day) to the incident concussion.

Musculoskeletal injury surveillance was performed using local injury surveillance systems, including the Armed Forces Health Longitudinal Technology Application (AHLTA), Sports Injury Monitoring System (SIMS), and the Cadet Injury and Illness Tracking System (CIITS). All cadets have access to medical providers and receive care through the closed military health care system, which has been previously described.[45,47,58] All medical care is managed by a member of the medical staff and documented in at least 1 of the 3 systems (ie, AHLTA, SIMS, CIITS). Thus, it is unlikely that any musculoskeletal injuries that required medical attention were not recorded in the participant's medical record. Musculoskeletal injury diagnosis, onset (ie, date of injury), and whether it was a time-loss injury were pulled from the medical records by 1 investigator (M.J.A.) and verified by a separate investigator (J.D.R.). To ensure the accurate merging of the surveillance data from all 3 documentation systems, the second investigator checked for overlap. Both investigators were certified athletic trainers with >7 years of experience. Any discrepancies in a diagnosis, injury onset date, or whether the injury resulted in time lost were discussed among the investigators who pulled the musculoskeletal injury surveillance and resolved by the principal investigator (M.H.R.).

Statistical Analysis

All analyses were performed in StataSE software Version 14.2 (StataCorp). Descriptive statistics were computed as appropriate to describe the demographic and injury characteristics of the concussed and nonconcussed cohorts. Within each cohort, participants with a UE injury were stratified into time-loss and non–time loss categories to determine whether the concussed cohort was more susceptible to time loss (ie, more severe injuries) or whether concussion recovery duration affected injury severity. The association between time-loss UE injuries and group (ie, concussed cases vs nonconcussed controls) was assessed using the chi-square test. The Cramer *V* statistic was calculated to explore the strength of the association. An independent *t* test was used to compare concussion recovery duration (ie, time from initial concussion to return to unrestricted activity) between UE time-loss and non–time loss cohorts within the concussed cohort. Means and standard deviations for recovery duration were used to calculate a Cohen *d* effect size, which were interpreted as small ($\geq$0.1), medium ($\geq$0.3), or large[12,34] ($\geq$0.5).

The primary outcome of interest was time from return to unrestricted activity after a concussion to incident UE musculoskeletal injury during the 12-month follow-up period in the concussed and nonconcussed groups. Kaplan-Meier injury-free survival estimates were calculated by group (concussed vs nonconcussed), sport level (intramural, club, and varsity), and history of concussion (no history, 1 concussion, and $\geq$2 concussions) for time to UE musculoskeletal injury. Univariate and multivariable Cox proportional hazards regression models were used to estimate hazard ratios (HRs) and 95% CIs between concussed cases and nonconcussed controls for time to UE musculoskeletal injury during the surveillance period ($\alpha < .05$). Other potential risk factors were as follows: sport level during the injury surveillance period; history of concussion; baseline BSI-18 anxiety, depression, and somatization scores; and history of UE musculoskeletal injury. Variables that were significant in the univariate models ($P < .05$) were carried over into the multivariable model.

RESULTS

The 316 concussed cases had a mean age of 20.05 ± 1.64 years, a height of 174.14 ± 9.80 cm, and a weight of 75.60 ± 14.03 kg, and the 316 matched nonconcussed controls had a mean age of 19.88 ± 1.51 years, a height of 174.13 ± 9.35 cm, and a weight of 74.78 ± 13.24 kg. During the musculoskeletal injury surveillance period, 19.3% (61/316) of concussed cases and 9.2% (29/316) of nonconcussed controls sustained an incident UE injury. In both groups, the majority of the UE injuries occurred to the shoulder joint. Table 1 contains a complete breakdown of the types of UE injuries documented. Roughly 61% of concussed cases and 52% of controls experienced a time-loss UE injury; however, there was no significant association and there was a weak effect between time-loss injury and group ($\chi^2 = 0.69$; $P = .406$; Cramer $V = .09$). Within the concussed cohort, an independent *t* test did not detect a significant difference ($t(57) = -0.887$; $P = .379$) between concussion recovery time for those with a time-loss UE injury (29.28 ± 24.91 days) compared with those with a non–time loss UE injury (23.61 ± 22.30 days), although a small effect was found (Cohen $d = 0.24$).

Kaplan-Meier injury-free survival estimates for UE injury during the surveillance period are presented in Figure 2. The results of the univariate analysis are presented in Table 2. In the univariate models, concussed cases were 2.25 times more likely to sustain a UE injury during the 12-month follow-up period when compared with the nonconcussed controls ($P < .001$). Varsity sport level ($P < .001$), history of $\geq$2 concussions ($P = .013$), BSI-18 somatization score ($P = .029$), and history of UE injury ($P = .013$) were identified as independent risk factors.

In the multivariable analysis—adjusted for sport level, concussion history, BSI-18 somatization scores, and history of UE injury—concussed cases were 1.84 times more likely to sustain a UE injury during the surveillance period compared with nonconcussed controls ($P = .019$). Varsity sport level remained an independent risk factor for UE musculoskeletal injury ($P < .001$); however, concussion history, somatization, and history of UE injury were not independent risk factors.

DISCUSSION

The present study utilized the CARE Consortium cohort at the United States Military Academy to prospectively

TABLE 1
Breakdown of UE Musculoskeletal Injuries[a]

	Nonconcussed (n = 316)	Concussed (n = 316)
History of acute UE musculoskeletal injury		
Yes	45 (14.2)	67 (21.2)
No	271 (85.8)	249 (78.8)
UE musculoskeletal injury during the surveillance period[b]		
Time-loss injury	15 (51.7)	36 (61.0)
Non–time loss injury	14 (48.3)	23 (39.0)
Shoulder injuries (n = 41)		
Acromioclavicular sprain	1 (3.4)	2 (3.2)
Acromial fracture	1 (3.4)	—
Biceps tendon subluxation	1 (3.4)	—
Glenohumeral dislocation	1 (3.4)	3 (4.9)
Glenohumeral subluxation	3 (10.3)	9 (14.8)
Labral tear	1 (3.4)	3 (4.9)
Muscle strain	4 (13.8)	10 (16.4)
Sternoclavicular sprain	—	2 (3.2)
Elbow injuries (n = 12)		
Humeroulnar dislocation	—	1 (1.6)
Muscle strain	—	2 (3.2)
Neurapraxia	—	1 (1.6)
Olecranon bursitis	—	1 (1.6)
RCL sprain	1 (3.4)	1 (1.6)
UCL sprain	—	4 (6.6)
Cubital tunnel syndrome	1 (3.4)	—
Forearm injury (n = 1)		
Ulnar fracture	1 (3.4)	—
Wrist injuries (n = 9)		
Muscle strain	—	1 (1.6)
Radial fracture	—	1 (1.6)
Sprain	5 (17.2)	2 (3.2)
Hand injuries (n = 14		
Carpal fracture	—	1 (1.6)
Metacarpal fracture	2 (6.9)	4 (6.6)
Metacarpophalangeal sprain	3 (10.3)	4 (6.6)
Finger/thumb injuries (n = 13)		
Boutonniere deformity	—	1 (1.6)
Interphalangeal dislocation	1 (3.4)	2 (3.2)
Interphalangeal sprain	—	4 (6.6)
Phalangeal fracture	1 (3.4)	—
Thumb sprain	2 (6.9)	2 (3.2)

[a]Data are reported as n (%). Dashes indicate areas not applicable. RCL, radial collateral ligament; UCL, ulnar collateral ligament; UE, upper extremity

[b]Time-loss information for musculoskeletal injury was not available for 2 participants in the concussed group.

examine the association between concussion and subsequent UE musculoskeletal injury risk within the first year of unrestricted activity after a concussion. Participants who sustained a concussion were 2.25 times more likely to sustain a UE injury within a year of their unrestricted return to activity date. The risk of UE injury remained elevated after controlling for sport level, history of concussion, somatization scores, and history of UE injury. These findings support our hypothesis that in the first year after returning to unrestricted activity, concussed cases will be at greater risk of UE musculoskeletal injury compared with nonconcussed controls.

To our knowledge, this is the first study to exclusively examine UE injury risk after a concussion in a young active cohort. The increased hazard observed in the present study is in line with prior observations for both general musculoskeletal injury risk and LE injury risk after a concussion.[39,52] In a prior meta-analysis,[39] athletes with concussions had 2.11 times greater odds of sustaining a musculoskeletal injury compared with controls. A more recent meta-analysis[52] observed a pooled HR of 1.39 (95% CI, 1.31-1.47) for LE injury in athletes and Service members with concussions compared with those with no previous concussions. Thus, regardless of the extremity, there appears to be a link between concussion and subsequent musculoskeletal injury in physically active cohorts.

A major strength of this study is that we were able to explore and control for the influence of additional risk factors for musculoskeletal injury. Independently, varsity-level athletes, those with a history of ≥2 concussions, those

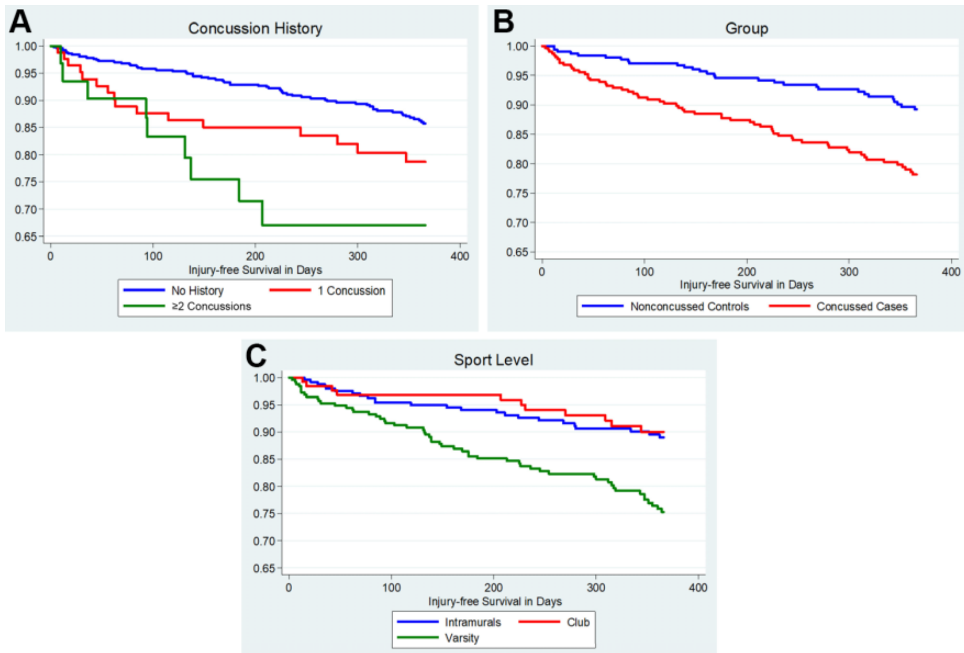

Figure 2. Kaplan-Meier injury-free survival estimates by (A) history of concussion, (B) group, and (C) sport level for incident upper extremity musculoskeletal injury during the 12-month follow-up period.

TABLE 2
Cox Proportional HRs for UE Musculoskeletal Injury[a]

		Univariate Model		Multivariable Model	
Variable	n	HR (95% CI)	*P*	HR (95% CI)	*P*
Group					
Nonconcussed	316	Reference		—	—
Concussed	316	2.25 (1.45-3.51)	**<.001**	1.84 (1.10-3.07)	**.019**
Sport level					
Intramural	248	Reference		—	—
Club	129	0.87 (0.44 -1.73)	.689	0.90 (0.45 -1.81)	.778
Varsity	255	2.39 (1.49-3.82)	**<.001**	2.53 (1.52-4.23)	**<.001**
Concussion history					
No history	508	Reference		—	—
1 Concussion	84	1.68 (0.98-2.89)	.062	1.17 (0.64-2.16)	.612
≥2 Concussions	31	3.08 (1.48-6.37)	**.013**	1.52 (0.69-3.33)	.297
Baseline BSI-18 score					
Anxiety	618	1.10 (0.98 -1.24)	.104	—	—
Depression	618	0.99 (0.88 -1.11)	.893	—	—
Somatization	618	1.16 (1.02 -1.32)	**.029**	1.15 (0.99 -1.33)	.068
History of UE injury					
No	520	Reference		—	—
Yes	112	1.84 (1.14-2.97)	**.013**	1.50 (0.91-2.47)	.108

[a]Dashes indicate areas not applicable. Bolded *P* values indicate statistical significance ($P < .05$). BSI-18, Brief Symptom Inventory–18; HR, hazard ratio; UE, upper extremity.

with higher somatization scores on the BSI-18, and those with a history of UE musculoskeletal injury while at the academy were more at risk for UE musculoskeletal injury during the surveillance period. Varsity athletes were more than twice as likely to sustain a UE musculoskeletal injury during the surveillance period compared with intramural athletes. This finding is likely attributed to a combination of exposure to high-risk activities and access to care. Varsity athletes generally engage in a higher intensity of play[17] more frequently and often have direct access to medical staff providing them with more opportunities to divulge injuries.[51] Participants with a history of ≥2 concussions had triple the risk of UE musculoskeletal injury during the follow-up period (HR, 3.08; $P = .013$) compared with participants with no history of concussion. Also, those with a history of UE injury while at the academy had double the risk (HR, 2.25; $P < .001$) compared with those with no history. These findings are not surprising, as prior research has linked concussion frequency to musculoskeletal injury[23,48] and injury history is a known risk factor for subsequent musculoskeletal injury risk.[55] Despite the HRs heading in the same direction, concussion history and UE injury history were not significant risk factors in the multivariable model. It is plausible that concussion history and UE injury history were attenuated by sport level, as varsity athletes may be more likely to have an injury history. Thus, we observed a muted effect once we included the sport level in the model. This, however, is one of the first studies that we are aware of to link psychological distress, specifically somatization, with an increased hazard for UE musculoskeletal injury after a concussion. For every 1-point increase in the BSI-18 somatization score, participants were 16% more likely to sustain a UE injury during the follow-up period. While the literature to date has primarily focused on anxiety and musculoskeletal injury risk,[8] it seems plausible that someone with higher somatization scores may be more likely to seek care for an injury. Collectively, these findings suggest that the risk of UE musculoskeletal injury after a concussion is multifaceted.

Although the present study confirms that patients may be at greater risk for UE musculoskeletal injury after a concussion, very little is known about how long the risk is elevated or whether it ever abates. The Kaplan-Meier curves for group and concussion history suggest a relatively linear survivorship during the entire 1-year follow-up period. This implies that the risk of UE injury may remain consistently elevated out to 1-year postconcussion and thus necessitates further understanding. Furthermore, little is known about the underlying mechanisms associated with this elevated risk. Prior rationales suggest that the increased risk of LE musculoskeletal injury may be attributed to deficits in neuromuscular control,[2,36] such as postural control and gait alterations, which are both known predictors of LE injury.[20,44,49] Such alterations may linger for months and even years after a concussion.[6,27,38,50] It is also plausible that there may be >1 aspect responsible for the increased musculoskeletal injury susceptibility after a concussion, as others have proposed delayed muscle integration owing to motor cortex dysfunction,[60] perception-action coupling deficits,[16] and diminished motor task execution abilities[11] as possible contributors. Mang et al[37] simultaneously evaluated postural and UE movement in concussed athletes performing the object-hit test and identified impairments; however, the majority of concussed athletes displayed impairment in one domain or the other (ie, postural or UE movement), but not both.[37] Improving postural movements with special considerations for the UE motor tasks may aid patients who are returning to physically demanding occupations, athletics, or military service.

While we may not know the exact mechanism responsible for the elevated risk of injury after a concussion or how long the risk is elevated, novel rehabilitation strategies to restore function and prevent injuries merit investigation. To date, only 1 study[28] has examined the efficacy of an intervention to mitigate musculoskeletal injuries after a concussion relative to the standard of care. Preliminary findings in a cohort of adolescent athletes suggest that an 8-week neuromuscular intervention protocol (ie, plyometric, strength, technique, and balance training), initiated after unrestricted return to activity, may significantly reduce injuries after a concussion.[28] The hazard of subsequent musculoskeletal injury in adolescents allocated to the standard of care was 3.5 times that of the neuromuscular intervention group.[28] Although preliminary, this evidence is promising and should be considered when rehabilitating concussed patients. Refining concussion management protocols to incorporate interventions effective at reducing injury risk is a critical first step in the process of mitigating musculoskeletal injury risk after a concussion.[2,11]

Limitations and Future Research

Several limitations should be considered when interpreting the results of the present study. First, despite the careful matching criteria including competitive sport level and sport for club and varsity athletes, when possible, complete athletic/military training exposure time in specific events was not available. Thus, there is no guarantee that the concussed cases and nonconcussed controls experienced the same exposure throughout the entire year of follow-up. However, all patients were academy cadets who participated in year-round athletic activities, physical education courses, and military training that were very similar. Second, medical transcription errors may have led to the inclusion or omission of UE musculoskeletal injuries during the postconcussion surveillance period or as part of the injury history. Additionally, concussion history was self-reported; however, before querying the participants on their concussion histories, a standardized definition of both concussion[4] and common symptoms was provided to improve accuracy.[53] Third, while this is one of the first studies to control for prior musculoskeletal injury history, we could not control for UE injuries that were not reported to a medical provider or sustained before entry to the academy. Last, our cohort consisted of academy cadets between the ages of 17 and 27 years; therefore, the results of this investigation may only be generalizable to similar populations.

Despite these limitations, the present study also had several strengths. We believe that this is the largest prospective study to date to exclusively examine UE musculoskeletal injury risk postconcussion in a distinct cohort that regularly engages in athletic activity, physical fitness, and military training. Thus, these findings may have an application to active-duty military Service members and collegiate athletes of comparable age. Future research should explore additional factors, such as physical fitness, care-seeking behavior, and risk-taking behaviors that we were unable to account for in the present study but may contribute to musculoskeletal injury risk. Future work in this area should also focus on identifying the underlying cause of the increased musculoskeletal injury risk after a concussion and determining interventions most effective at mitigating the increased risk for UE musculoskeletal injury after unrestricted return to activity after a concussion. Further investigation into the deficits that may contribute to the increased risk of UE musculoskeletal injury after a concussion observed in the present study is warranted. Interventions to mitigate the increased risk should also be investigated.

CONCLUSION

Participants who sustained a concussion were more than twice as likely to sustain an acute UE musculoskeletal injury within the first 12 months after unrestricted return to activity when compared with nonconcussed matched controls. Similar results were observed in multivariable models after controlling for sport level, concussion history, somatization, and history of UE injury while at the United States Military Academy.

ACKNOWLEDGMENT

The authors acknowledge and thank the following individuals, listed alphabetically, for their roles in supporting the study at the United States Military Academy: Brian Colsant, Jessica Curtin, Travis Fetchko, Stephanie Habecker, Story Miraldi, Karen Peck, Jamie Reilly, Sean Roach, Bridget Sturch, and Jesse Trump. The authors also thank the research and medical staff who assisted with baseline data collection and concussion surveillance.

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