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"Playing Through It": Delayed Reporting and Removal From Athletic Activity After Concussion Predicts Prolonged Recovery

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Context: Preclinical research has demonstrated a window of vulnerability in the immediate aftermath of concussion wherein continued activity and stimulation can impair or prolong neurobehavioral recovery. However, this concept has not been quantified in a human population.

Objective: To examine the effect of delayed reporting and removal from athletic activity after concussion on recovery time.

Design: Cross-sectional study.

Setting: A National Collegiate Athletic Association Division I university.

Patients or Other Participants: Ninety-seven athletes who sustained a sport-related concussion between 2008 and 2015 were analyzed (age = 20.4 ± 1.3 years). Athletes were grouped as *immediate removal from activity* (I-RFA) or *delayed removal from activity* (D-RFA).

Main Outcome Measure(s): *Days missed* was defined as the number of days between the concussion-causing event and clearance for return to contact. Associations between RFA group and prolonged (8 or more days') versus normal (7 or fewer days') recovery were also analyzed.

Results: Fifty (51.5%) of the 97 athletes did not immediately report concussion symptoms. The D-RFA athletes averaged 4.9 more days missed than the I-RFA athletes. Membership in the specific RFA group predicted days missed even after controlling for sex, concussion history, learning disability or attention-deficit/hyperactivity disorder diagnosis, diagnosed psychological disorder, and acute symptom severity (R^2 change = 0.097, $\beta = .319$, $P = .002$). The D-RFA athletes were approximately 2.2 times more likely to have a prolonged recovery (8 or more days) compared with the I-RFA athletes ($\chi^2 = 10.268$, $P = .001$, $\phi = 0.325$).

Conclusions: Athletes who do not immediately report symptoms of a concussion and continue to participate in athletic activity are at risk for longer recoveries than athletes who immediately report symptoms and are immediately removed from activity. Continuing to participate in athletic activity during the immediate aftermath of a concussion potentially exposes the already injured brain to compounded neuropathophysiologic processes.

Key Words: symptom reporting, window of vulnerability, mild traumatic brain injuries, collegiate athletes

Key Points

- A substantial number of athletes did not immediately recognize or report concussion symptoms.
- Athletes who delay reporting concussion symptoms are at risk for protracted recoveries.
- Not engaging the medical staff and continuing to participate in athletic activity during the immediate postconcussion period potentially exposes the athlete's already injured brain to additional neuronal stress that can compound injury neuropathophysiologic processes.

Sport-related concussion (SRC) has been increasingly recognized as a significant public health concern over the past decade. Epidemiologic studies of concussion in collegiate athletes describe an increasing rate of diagnosed concussions throughout the past 2 decades.[1,2] Despite increased awareness, research suggests underreporting of concussion symptoms is still widespread. Prior studies[3,4] indicate that between 30% and 50% of concussions go unreported by athletes, highlighting the need for improvements in diagnostic sensitivity, especially in the absence of an objective marker of concussion and the current reliance on subjective self-reported symptoms.

In some instances, athletes may not report an SRC because they do not believe their symptoms are serious enough to warrant medical attention or may be unaware of the potential negative health consequences.[3] Some of these athletes may never report their symptoms, whereas others delay disclosure until their removal is less likely to affect game or practice play or until the symptoms worsen and can no longer be ignored. Previous authors[3,4] have focused on describing a subset of athletes who chose to never report their concussion symptoms; however, a potentially different subset, those who wait to report symptoms until finishing a game or practice, has not been studied.

There is speculation that delayed reporting of concussion by athletes may result in lengthier recoveries and more time lost from academic and athletic participation. According to the pathophysiologic model of concussion, prolonged symptoms from remaining in play may be due to an exacerbation of dysregulated neurometabolic and cellular processes already present from the injury.[5–7] A *window of vulnerability* has been suggested to describe the brain's particular susceptibility to amplified and exponential damage if repeated injuries are sustained shortly after the initial concussion.[8–10] Indeed, continued physical exertion during this acute stage, even in the absence of repeat insults to the brain, may be detrimental to recovery.[11–13] Given the variety of elements associated with differential recovery from concussion, more research is needed to understand potentially controllable factors, such as timely symptom reporting, to possibly prevent prolonged recovery.

The purpose of our study was to examine the effect of delayed reporting and removal from athletic activity after concussion on postinjury recovery time. Specifically, we compared the recovery times of athletes who were immediately removed from athletic activity after concussion with those of athletes who delayed reporting concussion symptoms to medical personnel and therefore were not immediately removed from activity. We hypothesized that athletes who continued to physically exert and, in some cases, sustained subsequent head impacts, would take longer to recover than athletes who were immediately removed from activity. Previous studies and consensus statements have identified sex,[14,15] history of psychological (eg, depression, anxiety) or neurodevelopmental (eg, attention-deficit/hyperactivity disorder [ADHD], learning disability [LD]) disorders,[15–18] history of concussion,[19–21] and acute symptom severity[21–24] as potential modifiers of concussion recovery. Our aim was to evaluate the contribution of delayed reporting and removal from athletic activity to recovery time variability. Such data could provide clinicians with information to help educate athletes on the importance of immediate symptom reporting and its relation to the time required to return to athletic and academic activity.

METHODS

This study used a cross-sectional, retrospective approach. Data were obtained from the University of Florida Concussion Databank, which contains concussion-related medical history, injury-event details, and assessment data on student-athletes participating in the university's varsity athletic programs. The University of Florida Institutional Review Board approved access to the Concussion Databank to obtain relevant athlete records for analysis. Athletes with concussions sustained between 2008 and 2015 were considered for analysis.

For the purposes of this study, an *SRC* was defined as a brain injury sustained during athletic activity (game or practice) that was supervised by a sports medicine clinician (athletic trainer or team physician or both) and also diagnosed by a sports medicine clinician. The clinical definition used for a concussion was dictated in the university's concussion-management protocol, which has remained consistent with the Concussion in Sport Group consensus statements[15,25] as developed by internationally renowned clinicians and researchers. A *game* was defined as a National Collegiate Athletic Association–sanctioned athletic event in which the University of Florida competed against another college or university. A *practice* was defined as any nongame athletic event supervised by a sports medicine clinician. Practices included all in-season and out-of-season practices, intrasquad scrimmages, and weight-lifting and conditioning sessions. If an athlete sustained multiple SRCs while participating on a university athletic team, only the first was considered for analysis. Concussions sustained outside of athletic activities were not included.

Sample Characteristics

Athlete medical charts were reviewed for diagnosed SRCs between 2008 and 2015. Athletes were excluded if the concussion mechanism was not sport related (eg, motor vehicle crash or bicycle accident) or if the timing of removal from athletic activity was not clearly indicated in the medical note. In total, data from 97 athletes who sustained an SRC between spring 2008 and spring 2015 were analyzed (age = 20.4 ± 1.3 years). The sample consisted of athletes from the following varsity sports: football (67), men's basketball (6), men's swimming and diving (2), women's lacrosse (7), women's soccer (5), women's basketball (4), women's volleyball (3), women's track and field (1), women's gymnastics (1), and women's swimming and diving (1). Additional description of the sample is provided in Table 1.

Definitions

Variables of Primary Interest. ***Immediate Removal From Activity Group.*** Athletes who were immediately removed from athletic participation after the concussion-causing event were coded as *immediate removal from activity* (I-RFA). These athletes were not exposed to any further physical exertion or head impacts after the concussion-causing event. In the context of football, it is conceivable that an athlete who sustained a concussive blow in the middle of a play but finished the specific play before being removed would still be categorized as I-RFA. For nonfootball sports that do not have frequent stoppages and opportunities for removal, I-RFA grouping was more limited to instances in which the injury caused a stoppage of play (ie, the athlete remained down on the field) or the athlete immediately reported to the sidelines and was removed before continuing participation in athletic activity.

Delayed Removal From Activity Group. Athletes who continued to participate in athletic activity beyond their concussive event were coded as *delayed removal from activity* (D-RFA). These athletes did not report their symptoms and were not identified by a sports medicine professional as having sustained a concussion at the time of the concussion-causing event. The initial injury note for these athletes identified an injury mechanism and symptom onset some time before the athlete reported symptoms according to the athlete's subjective recall. For many of these athletes, the specific amount of continued exposure could not be quantified.

Table 1. Sample Characteristics[a]

Participants	Total (N = 97)	Learning Disability/Attention-Deficit Hyperactivity Disorder	Psychological Disorder	Prior Concussions		
				0	1	2+
Male	75/97	18/71	2/71[b]	37/73	28/73	8/73
Female	22/97	9/22	6/21[b]	10/22	8/22	4/22
Overall	97	27/93	8/92	47/95	36/95	12/95
Missing		4	5		2	

[a] Fractions represent the number of athletes meeting criteria for a given variable over the number of athletes in our sample for which this information was available.
[b] Female participants were more likely to report a history of diagnosed psychological disorder ($\chi^2 = 13.540$, $P = .002$ with Fisher exact correction for low cell count).

Other Variables Predicting Recovery Time. ***Diagnosed LD/ADHD.*** Athletes were grouped according to whether they self-reported a diagnosis of LD or ADHD during preparticipation screenings or before sustaining the concussion. Details regarding past or current medication use were unavailable for consideration.

Diagnosed Psychological Disorder. Athletes were grouped according to whether they self-reported a previously diagnosed psychological condition such as depression, anxiety, or another disorder. This was a dichotomous *yes/no* response. Details regarding past or current medications or previous psychotherapy treatment were unavailable for consideration.

Concussion History. For self-reported concussion history, each athlete was grouped as having 0, 1, or 2+ previous concussions before the concussion in this analysis. As mentioned previously, only the athlete's first SRC diagnosed at the University of Florida was analyzed; therefore, *concussion history* describes the number of reported concussions before matriculation at the University of Florida. For hierarchical regression analysis, the concussion-history variable was split into concussion-history group 1 (CHG1) and concussion-history group 2 (CHG2), with athletes having no concussions serving as the reference group so that any significant results were interpretable. In other words, athletes who had 1 previous concussion (CHG1) or 2+ concussions (CHG2) would both be compared with athletes who had no history of concussion. The length of time between the previous concussion(s) and the SRC used for analysis was not available.

Acute Symptom Severity. Athletes' symptoms were evaluated with either the Post-Concussion Symptom Scale (PCSS; n = 78, 80.4%) or Sport Concussion Assessment Tool 3 (SCAT3) Symptom Evaluation (S3SE; n = 18, 18.6%; n = 1 missing). The PCSS and S3SE are considered reliable measures for symptom assessment, and their use is endorsed by the Concussion in Sport Group.[15,26,27] Both the PCSS and S3SE are 22-item symptom inventories rated on a severity scale from 0 to 6. The total symptom severity (maximum score of 132) during the first symptom assessment after concussion was considered the athlete's acute symptom severity (median time from injury = 0.0 days [day of injury]; range = 0–4 days; mean symptom severity = 28.8 ± 18.5).

Outcome Measures. ***Days Missed.*** The time interval (days) between the date of the athlete's concussion and the date of clearance for return to contact activities was the primary outcome measure. Beginning in 2009, clearance for return to contact coincided systematically with stage 5 of the university's concussion-management and graduated return-to-play protocol and the Concussion in Sport Group's consensus statement.[15,25] For concussions sustained in 2008 (n = 9), an informal stepwise progression was performed for each athlete and a specific clearance date for return to contact activities was documented in the medical record.

We conducted separate analyses to investigate the potential influence of increased recognition and caution related to SRC or changes in management protocols over time for days missed. The numbers of concussions for each year of the study were as follows: 2008 = 9 (9.3%), 2009 = 7 (7.2%), 2010 = 19 (19.6%), 2011 = 7 (7.2%), 2012 = 15 (15.5%), 2013 = 14 (14.4%), 2014 = 18 (18.6%), and 2015 = 8 (8.2%). Year of injury and days missed were not correlated ($r = 0.090$, $P = .379$) and year of injury and likelihood of normal versus prolonged recovery were not associated ($\chi^2 = 5.781$, $P = .566$). The initiation of a graduated return-to-play protocol coincided with the May 2009 publication of the "Consensus Statement on Concussion in Sport"[25] from the 3rd International Conference on Concussion in Sport. Average days missed before and after the implementation of a graduated return-to-play protocol did not differ ($t_{95} = -0.760$, $P = .449$). Previous researchers[2] suggested that the release of a National Collegiate Athletic Association mandate on concussion management in April 2010 significantly affected subsequent reporting rates. However, we found no difference between days missed before and after this mandate ($t_{95} = -1.043$, $P = .299$).

Normal Versus Prolonged Recovery. Normal and prolonged recovery definitions were based on the median days missed for the sample (median = 7). This finding was consistent with the results of previous investigators[24] who described normal versus prolonged symptom resolution timelines, though the days-missed variable in our study also included the time needed to achieve stage 5 of the graduated return-to-play protocol. *Normal recovery* was defined as 7 or fewer days missed; *prolonged recovery* was defined as 8 or more days missed.

Statistical Analyses

A 2-step hierarchical regression analysis was conducted to evaluate the unique contribution of removal from activity to predicting days missed. Model 1 of the regression included variables described in the literature as significant modifiers of recovery after concussion: (1) sex, (2) concussion history (0, 1, or 2+ previous concussions), (3) LD/ADHD diagnosis, (4) psychological disorder, and (5) acute symptom severity. Model 2 added RFA group and

Table 2. Descriptive Statistics and Odds Ratio Analyses

Group	No.	Days Missed		Recovery Length		Activity Type		Concussion History[a]					Sex	
		Median (Range)	Mean ± SD	Prolonged, %	Odds Ratio	Game, %	Odds Ratio	0	1	2+	χ^2	P	Male, %	Odds Ratio
Total	97	7 (3–67)	9.6 ± 9.3	44.3		22.7		49.5	37.9	12.6			77.3	
Immediate removal from activity	47	6 (3–15)	6.8 ± 2.6	27.7	2.17[a]	27.7	1.54	48.9	40.4	14.6	0.455	.796	70.2	1.20
Delayed removal from activity	50	9 (3–67)	12.3 ± 12.2	60.0		18.0		50.0	35.4	10.6			84.0	

[a] $P = .001$.

included all variables from model 1 as covariates. The odds ratio of having a normal versus prolonged recovery based on RFA group was also evaluated using a χ^2 test.

We performed additional exploratory analyses using χ^2 tests to evaluate the associations between different demographic and activity-related factors and RFA group. Associations were investigated between RFA group and (1) sex, (2) activity type (game versus practice setting), and (3) concussion-history group (0, 1, or 2+).

Significance was defined as a $P < .05$ confidence level. All data were assessed for normality and linearity before analyses. Days missed was highly positively skewed (z[skew] = 17.24, $P < .001$). Therefore, we applied a Blom normalization to the days-missed outcome variable.[28] Statistical analyses were conducted using SPSS software (version 22.0; IBM Corporation, Armonk, NY).[29]

RESULTS

Descriptive statistics for the RFA groups and associations with the variables of interest are shown in Table 2.

Days Missed

Model 1 of the hierarchical regression contained variables shown in previous research to modify recovery from concussion: sex, CHG1, CHG2, LD/ADHD diagnosis, psychological disorder diagnosis, and acute symptom severity. The overall model was not a significant predictor of days missed ($F_{6,84} = 1.509$, $P = .185$). None of the variables in the model were significant unique predictors of days missed. However, given the preponderance of evidence supporting the influence of these factors on recovery, we elected to include the variables as model 2 covariates to account for the amount of variance they explained, albeit minimal, in days missed.

Overall, model 2 was a significant predictor of days missed ($F_{7,83} = 2.858$, $P = .010$). Addition of the RFA group variable represented an improvement in predicting days missed compared with model 1 (R^2 change = 0.097, $P = .002$). The RFA group predicted days missed after controlling for all model 1 variables ($\beta = .319$). Specifically, athletes in the D-RFA group averaged 4.9 more days missed than I-RFA athletes even after we controlled for sex, concussion history, LD/ADHD diagnosis, psychological conditions, and acute symptom severity (B = 4.944).

Additionally, D-RFA athletes were approximately 2.2 times more likely to have a prolonged recovery (8 or more days) after concussion compared with I-RFA athletes (odds ratio = 2.17, $\chi^2 = 10.268$, $P = .001$, $\phi = 0.325$, medium effect size). The Figure shows the recovery curves for each RFA group over time.

Demographic and Event-Type Associations

No associations were observed between RFA group and sex ($\chi^2 = 2.626$, $P = .105$), history of concussion ($\chi^2 = 0.455$, $P = .796$), or game versus practice event ($\chi^2 = 1.289$, $P = .256$; Table 2). Athletes with a previously diagnosed psychological condition were 2.1 times more likely to have a prolonged recovery than those with no previously diagnosed psychological condition ($\chi^2 = 6.538$, $P = .020$ with Fisher exact correction for small cell size, $\phi = 0.267$, small–medium effect size). We found no association between previous diagnosis of LD/ADHD ($\chi^2 = 1.784$, $P = .182$) or concussion history ($\chi^2 = 1.150$, $P = .563$) and prolonged versus normal recovery.

DISCUSSION

Our aim was to describe the effect of delayed symptom reporting and removal from athletic activity after concussion on recovery time. The results supported our hypothesis that athletes who were not immediately removed from activity would ultimately have a lengthier recovery and miss more days of athletic activity compared with those who were immediately removed and evaluated by medical personnel. Delayed reporting of concussion symptoms was associated with a recovery time almost 5 days longer than that of athletes who immediately reported symptoms. Although previous researchers described multiple factors contributing to prolonged recovery (eg, history of concussion,[19–21] diagnosed psychological or neurodevelopmental disorder,[15–18] and acute symptom severity[21–24]), our study demonstrated a unique effect of continuing to play through symptoms. It is important to note that these other factors did not exert a significant effect on recovery time in our sample. The reasons for this are difficult to ascertain, but one possibility is different sample characteristics (ie, demographic makeup, participation level, etc) between the current study and earlier investigations. The particular methods for identifying and defining these factors are also variable among studies. For example, Guskiewicz et al[20] prospectively tracked repeat concussions sustained during collegiate playing careers using defined assessment points and known timelines between concussions, whereas we relied on retrospective reporting of concussions sustained before college with unknown time since last concussion. With regard to psychiatric history, Meares et al[18] conducted structured interviews and required participants to complete detailed questionnaires, thus providing comparatively much more detailed information than our study with regard to preinjury mental health. It may be important to examine the effect of delayed removal from activity in a sample where these other risk factors are shown to be more influential on recovery in order to better gauge the relative importance of timing of removal from activity.

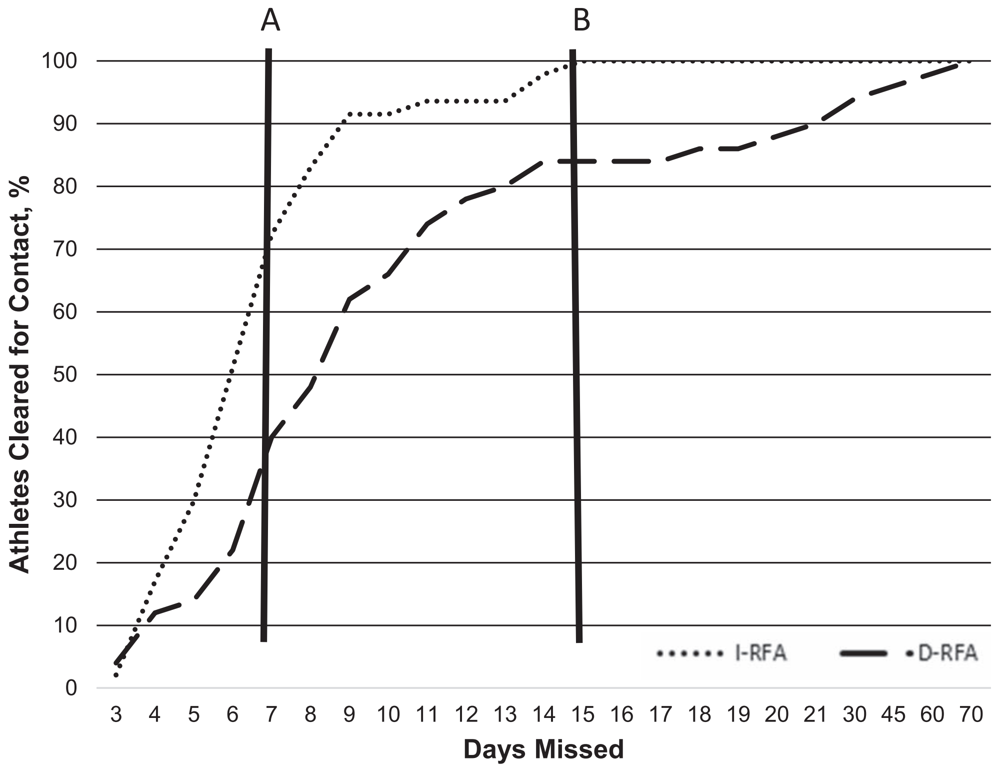

Figure. Percentage of athletes cleared for return to contact over time based on removal-from-activity (RFA) group. By 7 days after injury, 72.3% of immediate-RFA (I-RFA) athletes were cleared for return to contact versus just 40% of delayed-RFA (D-RFA) athletes (line A). All I-RFA athletes had achieved clearance by day 15, whereas 20% of D-RFA athletes required 2 weeks or longer before achieving stage 5 of the graduated return-to-play protocol (line B).

In the current study, a sizeable number of athletes (51.5%) did not immediately report symptoms of a concussion, indicating an ongoing need to educate athletes about the importance of prompt concussion symptom reporting, so clinicians can properly assess and intervene to protect athletes from undue risk.

The significant findings in our study suggest that postponing removal from play may prolong recovery, consistent with research[8–10] describing the brain's window of vulnerability in the acute stage after concussion. Athletes who continue to participate in athletic activity during the immediate aftermath of a concussion are potentially exposing their already injured brains to additional neural stress via continued physical exertion or repeated brain insults (or both) that can compound pathophysiologic processes. Preclinical studies investigating the effects of physical exertion on recovery after brain injury have indicated that exercising too soon after concussion can lead to detrimental outcomes through enhanced inflammatory action, increased excitotoxic effects, prevention of neuroreparative processes, and compounded neurometabolic demand.[11–13] Whereas these previous investigations were strengthened by their prospective and controlled designs, the present study translates some of these earlier preclinical findings into the human population and quantifies the negative effects of continued physical activity immediately after a concussive event. The 5-day extended recovery period experienced by athletes in our study who delayed reporting their concussion symptoms represents a clinically significant time period with potentially substantial consequences for both academic and athletic participation. However, proper management of postconcussion rest is complicated, because extended removal from athletic participation has also been associated with a negative effect on psychosocial functioning.[30,31] For these reasons, it is essential for sports medicine clinicians to manage their athletes' expectations for recovery and be very cautious in providing firm timelines for clearance. Clinicians should emphasize setting short-term, achievable goals, similar to the management and rehabilitation plans for many orthopaedic injuries (eg, highlighting areas of symptom improvement and progression through exertional protocols).

One significant implication of these findings relates to educating athletes and coaches. Athletes are sometimes motivated to hide their symptoms because of both internal and external pressure to perform.[32,33] In most instances, it is likely more beneficial for the team if the athlete misses the shortest amount of time possible after sustaining an injury. Our results suggest that immediately reporting symptoms gives the athlete the best chance to return to sport activity relatively quickly. Immediate symptom reporting is considered best practice for ensuring the overall health and safety of the athlete, and our findings support this approach. Additionally, from a pragmatic perspective, we believe that immediately reporting concussion symptoms is in the best interests of teammates and coaches, so that overall performance is not compromised by the concussion and the athlete will return to a healthy state most efficiently. Athletes are unlikely to understand this intuitively, which further highlights the need for clinicians to provide systematic concussion education about how brain function is inextricably linked with athletic function[34–36] and how they are both negatively affected by a concussion.

It is important to consider that not all athletes delay reporting symptoms for the same reasons. Some athletes believe the symptoms they are experiencing are not significant enough to warrant reporting[3] but then later disclose these symptoms when they worsen or persist. Athletes may not immediately attribute the symptoms to a concussion, but only later are they able to describe a specific blow to the head that precipitated the onset. This is likely due in part to the lack of specificity of concussion-related symptoms and the broad range of potential underlying causes.[37–40] Regardless, athletes should receive clear education regarding the symptoms worthy of immediate reporting, so that a sports medicine clinician can properly evaluate the athlete and make the ultimate determination of whether removal from activity is indicated.

Our study had several limitations that should be considered in interpreting our findings. The retrospective design and reliance on medical-record review did not allow precise quantification of physical exertion or repeat insults sustained immediately after the concussive event. As such, we can make no claims regarding a dose-response relationship between the amount of continued participation and days missed after injury. The sample was limited to collegiate athletes, and male athletes and football players were overrepresented; therefore, the results may not generalize well to other levels of participation, both sexes, or all sports equally. We were also unable to analyze the potential effects of current medication use on recovery, as this information was not available for all athletes. However, to our knowledge, this study is the first to provide clinically meaningful evidence that remaining in play after a concussion carries significant negative consequences in terms of prolonging recovery time. If athletes know that they may be worsening their recoveries by failing to report concussions, they may have incentive to properly disclose suspected injuries in a timely manner. Future authors should investigate the effects of delayed symptom reporting prospectively and attempt to more accurately quantify the amount of exposure during this window of vulnerability. The effect of delayed reporting on other common concussion-assessment domains (eg, cognition, balance, oculomotor function) should also be studied. Replication of these findings may provide the impetus for expert panels to consider a shorter time between symptom onset and symptom reporting as a mitigating factor for reducing recovery time.

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