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Predicting Recovery Patterns After Sport-Related Concussion

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Context: Clinicians sometimes treat concussed individuals who have amnesia, loss of consciousness (LOC), a concussion history, or certain symptom types more conservatively, but it is unclear whether recovery patterns differ in individuals with these characteristics.

Objective: To determine whether (1) amnesia, LOC, and concussion history influence the acute recovery of symptoms, cognition, and balance; and (2) cognition and balance are influenced by acute symptom type.

Design: Cohort study.

Setting: Seven sports at 26 colleges and 210 high schools.

Patients or Other Participants: A total of 8905 collegiate (n = 1392) and high school (n = 7513) athletes.

Main Outcome Measure(s): The Graded Symptom Checklist, Standardized Assessment of Concussion, and Balance Error Scoring System were administered to all athletes during the preseason. To allow us to track recovery patterns, athletes diagnosed with a concussion (n = 375) repeated these assessments immediately after the injury, 3 hours postinjury, 1 day postinjury, and at 2, 3, 5, 7, and 90 days after injury.

Results: Athletes who experienced amnesia had markedly greater deficits in and a slower recovery trajectory on measures of symptoms, cognition, and balance. Athletes with 2 or more prior concussions demonstrated poorer balance than those with no previous history. Otherwise, LOC and concussion history largely did not affect symptoms, cognition, or balance. Greater deficits in balance scores were observed in athletes with all symptom types. Regardless of these characteristics, most athletes recovered within 7 to 10 days.

Conclusions: Athletes who experienced amnesia had more symptoms and greater deficits in cognition and balance. Symptoms and cognitive or balance deficits were not consistently associated with LOC or concussion history. Acute symptoms had a strong influence on balance scores and, to a lesser extent, on cognition. However, we found no evidence to support more cautious return-to-play decisions for athletes with these characteristics, as group recovery occurred within normal timelines. Our study supports current clinical practice: recommending that athletes be withheld from activity until they are asymptomatic, followed by a graduated return-to-play progression.

Key Words: traumatic brain injuries, return to play, Standardized Assessment of Concussion, Balance Error Scoring System

Key Points

- Amnesia was the predictor that most influenced clinical recovery from concussion.
- Loss of consciousness, concussion history, and acute symptom group did not substantially affect symptom, cognitive, or balance outcomes.
- Most injured athletes recovered within the normal timelines established for the Graded Symptom Checklist, Standardized Assessment of Concussion, and Balance Error Scoring System.

Over the past 2 decades, the playing fields, athletic training rooms, and sports medicine clinics have served as working laboratories where clinicians and researchers have learned about sport-related concussions. Contrary to popular media stories, the concussion incidence rates reported over the last decade are not alarmingly higher than those previously reported in the literature.[1,2] Although concussion incidence rates have remained relatively stable, the concussion landscape has changed considerably since the first large prospective studies[3,4] on concussions in collegiate athletes were published. All 50 states and the District of Columbia have now passed laws to address sport-related traumatic brain injury; most of these laws target youth sport-related concussions.[5]

Even though incidence rates have remained largely stable, concussions are still prevalent, comprising 13% of all sports injuries in high school athletes.[2] Epidemiologic studies[1,2,6,7] continue to show that football, ice hockey, lacrosse, and soccer athletes have the highest concussion incidence rates per athlete-exposures. Concussion injury rates are higher during competition compared with practice and appear to be higher for females than for males participating in sports with the same rules (eg, basketball and soccer).[1,6] Marar et al[2] found that more than 11% of concussed high school athletes had a concussion history and, in certain sports, 20% of reported concussions were recurrent within the same athletic season. These observations agree with the previous literature,[3] which suggested that a concussion history increases the risk of future concussive events.

Along with a concussion history, on-field variables such as amnesia and loss of consciousness (LOC) have traditionally been thought to represent the most serious signs of concussion,[8] leading clinicians to weigh these characteristics heavily when making return-to-play decisions. The clinical emphasis on the influence of amnesia and LOC stems from earlier concussion-management guidelines, which graded concussion severity primarily on the presence and duration of these factors. With respect to amnesia, both the Cantu Grading System and the Colorado Medical Society classification guidelines were based on its presence and duration, whereas the American Academy of Neurology recommendations were largely unaffected by amnesia.[9] Both the 1991 Colorado Medical Society and the 1997 American Academy of Neurology concussion-grading guidelines classified individuals with any duration of LOC as having a grade 3 (severe) concussion, whereas the Cantu grading scale classified individuals with LOC longer than 1 minute as having a severe concussion.[9] Although these grading scales are no longer recommended for use in clinical concussion diagnosis and management,[10] the unfounded notion that amnesia and LOC are signs of a more serious injury persists.

Deciding when an athlete can safely return to participation after a concussion is perhaps the most challenging task for any sports medicine clinician. In collegiate athletes, concussive symptoms typically resolve within 7 to 10 days of the injury; cognitive functioning generally improves to baseline levels within 10 days when measured by the Standardized Assessment of Concussion (SAC) or computerized neurocognitive tests, and balance deficits typically dissipate within 3 to 5 days postinjury when measured via the Balance Error Scoring System (BESS) or Sensory Organization Test.[11,12] Collegiate football players with a history of 3 or more concussions were more than 3 times as likely to experience a subsequent concussion than players with no such history, and their recoveries were more likely to be slower than the recoveries of those who had fewer prior concussions.[3] These findings are underscored by reports[13,14] indicating an association between repetitive concussions and subconcussive head impacts and long-term neurologic deficits, such as mild cognitive impairment, dementia, depression, and chronic traumatic encephalopathy. Therefore, understanding how various symptoms, on-field markers of injury, and intrinsic factors influence concussion recovery can have important implications in both the acute and later-life settings.

Uncertainty persists surrounding acute concussion-recovery patterns and factors that can assist a clinician in providing a specific prognosis, including a return-to-play timeline. Few researchers have investigated the influence of amnesia, LOC, concussion history, and symptom groups on concussion recovery, and mixed findings were reported. Although some investigators reported no relationship of amnesia[15,16] or LOC[15,16] with concussion history[17,18] or prolonged concussion recovery, others noted that these factors increased the risk of atypical recovery.[18,19] Concussion consensus statements still suggest that these factors, particularly prolonged LOC (>1 minute), should influence concussion management.[20] Previous authors often failed to track athletes frequently over time, providing little information about the typical recovery trajectory for concussed athletes with or without these clinically meaningful factors. Thus, the primary purposes of our study were (1) to compare the recovery patterns of acute symptoms, cognition, and balance in athletes after a sport-related concussion and (2) to better understand the effects of amnesia, LOC, and concussion history on these recovery patterns. As a secondary purpose, we sought to determine whether acute symptom type influenced cognitive or balance recovery.

METHODS

Study Design

For our study, we used existing data from the Concussion Prevention Initiative (CPI), a large (n = 375) case series of concussions collected using standardized procedures and trained data collectors. For a detailed description of the CPI, including the full study design, injury definition used to diagnose concussion, and data-collection procedures, please see Marshall et al.[7] Briefly, between 1999 and 2001, the CPI prospectively enrolled 8905 athletes (1392 collegiate athletes at 26 colleges and 7513 high school athletes at 210 high schools) from schools or colleges with at least 1 certified athletic trainer (AT) on staff. Seven sports (football, men's and women's ice hockey, men's and women's lacrosse, and men's and women's soccer) were studied. To minimize the reporting burden, each school contributed data from no more than 3 sports to the study. The Institutional Review Board at The University of North Carolina at Chapel Hill approved this study, and all participants aged 18 and older provided written informed consent before study enrollment. For athletes younger than 18, written informed assent was collected along with parental consent before enrollment.

Injury Definition

A *concussion* was defined as an injury from a blow to the head that caused an alteration in mental status resulting in 1 or more concussion symptoms. Symptom reporting, in combination with a clinical examination, was used to diagnose concussion, which was the responsibility of the AT. A concussed participant was excluded if there was evidence of associated drug use or concurrent nonconcussive injury (such as a fractured bone).

Data Collection

All athletes on a team who consented were tested at baseline. Each athlete was administered a baseline questionnaire, which included questions regarding concussion history. Athletes at each institution were followed prospectively for concussions through their playing careers.

Table 1. Assessment Measures

Measure	Functional Domain	Description	Score Range	Time to Administer
Graded Symptom Checklist[17]	Postconcussive symptoms	Athlete rates presence and severity of 17 symptoms (eg, headache, dizziness)	Likert scale: 0 (*no symptoms*)–6 (*severe*); total score range = 0–102; higher score indicates more severe symptoms	2–3 min
Standardized Assessment of Concussion[42,a]	Cognitive functioning: Orientation; Immediate and delayed memory; Concentration. Neurologic screening: Strength; Sensation; Coordination	Brief neurocognitive assessment and neurologic screening; documentation of unconsciousness, posttraumatic and retrograde amnesia	Total score range = 0–30; lower score indicates more severe cognitive impairment	5 min
Balance Error Scoring System[41]	Balance	Noninstrumented, clinical assessment of balance in double-legged, single-legged, tandem stances on firm and foam surfaces	Total score range = 0–60; test score = total number of errors; higher score indicates more severe postural instability	5 min

[a] Alternate forms used to minimize practice effects from repeat testing on the Standardized Assessment of Concussion.

Once a concussion was identified, the AT used an assigned testing protocol with assessment measures (Table 1) to evaluate the player at the time of injury, 3 hours postinjury, and at 1, 2, 3, 5, 7, and 90 days postinjury. A symptom (the primary outcome variable for tracking recovery) was scored 0 if *absent* or given a rating between 1 (*mild*) and 6 (*severe*). If the athlete was unavailable for testing on the designated day, the AT collected the data on the next possible day. Additionally, the AT used a standardized form to record details about each injury (mechanism of injury, LOC, presence and duration of amnesia, etc), some of which were used to create groups for the statistical analyses. Individuals were considered to have experienced LOC if the athlete, an AT, or anyone present reported a state of blacking out (being unaware of himself or herself and the surroundings) or the athlete was unresponsive to communication. The AT recorded the presence or absence of LOC and the duration of the event. *Posttraumatic amnesia* was defined as an inability to recall events after the injury, such as exiting the field and questions asked during the medical examination. *Retrograde amnesia* was defined as the inability to recall events preceding the injury, such as details about the play on which the injury occurred, the score or drill at the time of injury, or noteworthy events earlier in the game or practice. Individuals with these deficits were considered to have experienced amnesia. The AT continued to repeat these questions until the athlete could correctly answer them, at which point the amnesia was considered to have cleared. The AT recorded the presence and duration (time in minutes from injury to clearing of the amnesia) when applicable.

Symptoms

Symptoms were assessed using the 7-point Likert scales on the Graded Symptom Checklist (GSC; Table 1). We classified symptoms into 4 groups: somatic (early onset), somatic (evolving onset), cognitive, and neurobehavioral.[7,21] Early-onset somatic symptoms include dizziness, headache, nausea, numbness/tingling, visual disturbances, and vomiting: these somatic symptoms typically decrease during the acute injury period, especially if the patient is properly managed. In contrast, evolving-onset somatic symptoms may increase over the same acute injury period. This group includes drowsiness, fatigue, sensitivity to light, and sensitivity to sound. Cognitive symptoms include feeling "in a fog" and having difficulty concentrating and remembering. Neurobehavioral symptoms include difficulty sleeping, irritability, sadness, and sleeping more than usual. These symptom groups largely mimic the symptom clusters established in the literature.[13,21,22] Symptom scores were missing for 37% of participants at the time of injury, 42% at 3 hours postinjury, 21% at 1 day postinjury, and 13% at 3 days postinjury. We defined the symptom groups using the 1-day postinjury scores because symptoms were elevated at this time point, and fewer data were missing than at the time of injury.

Statistical Analysis

The GSC, SAC, and BESS data were analyzed using a general linear mixed model with random intercepts and random slopes with correction for first-order autoregressive serial correlation.[23] This model allowed us to account for repeated measures with intermittently missing and irregularly timed GSC, SAC, and BESS measurements over time, while accounting for within-athlete measurements of serial correlation. Polynomial terms representing time, $time^2$, $time^3$, and $time^4$ were included to represent the recovery curves. Higher-order polynomials were removed if fewer terms improved the model fit (assessed using the Akaike Information Criterion). Each athlete had his or her own intercept in the analysis (random intercept), so that the change from baseline due to injury for each person had its own starting response at the time of injury and was allowed to vary among players. In addition, the rate of recovery after concussion was allowed to vary among participants (random slopes for time). These random-effects models were assumed to follow a normal distribution.

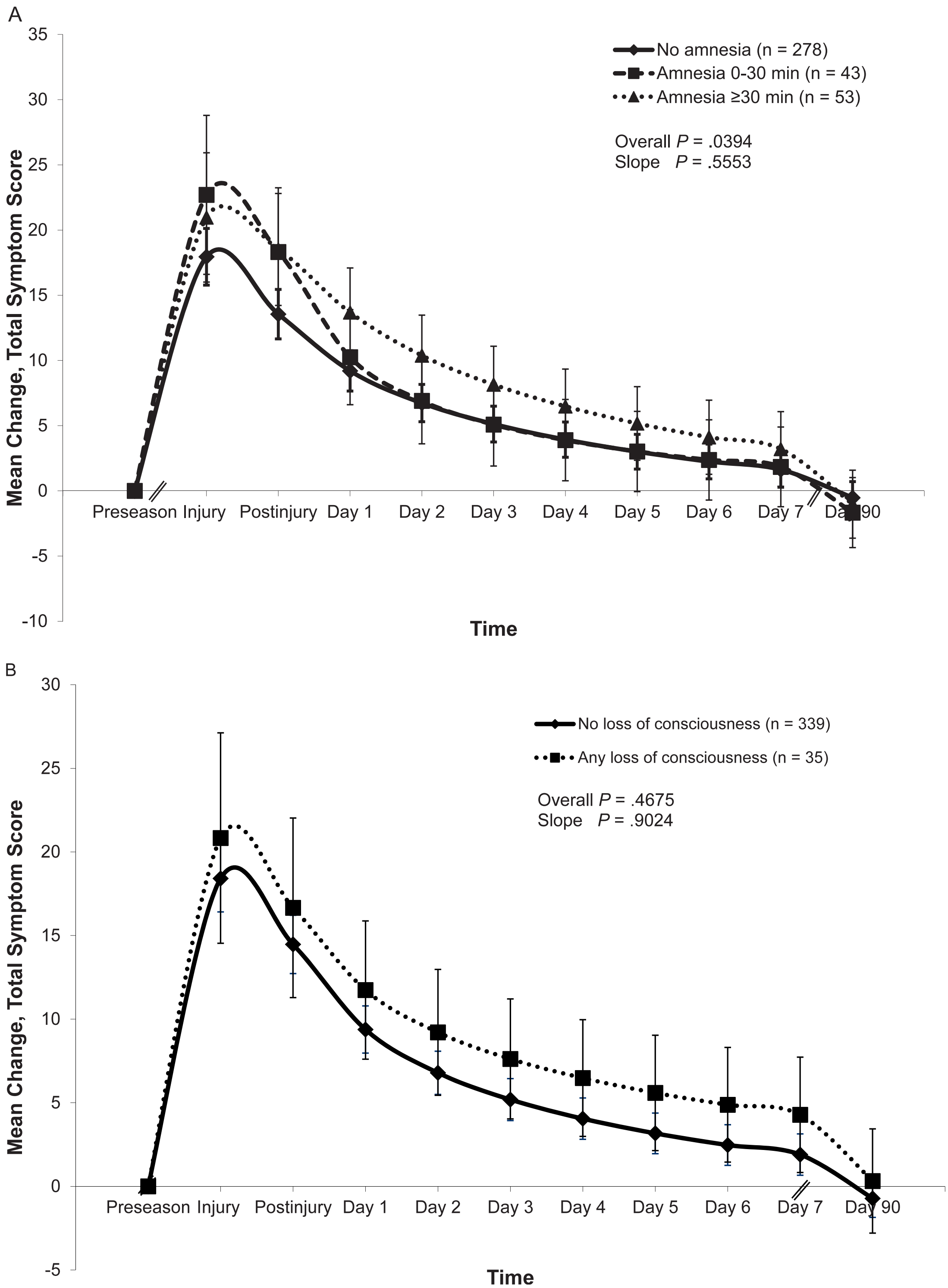
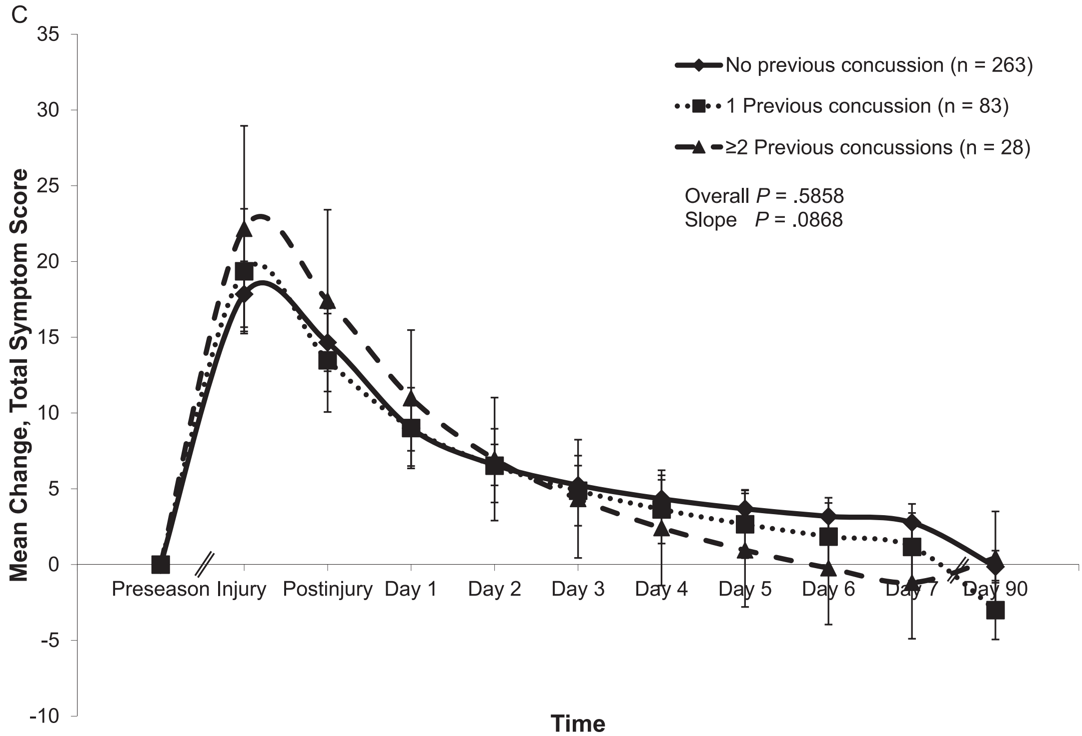


Figure 1. Recovery patterns of the Graded Symptom Checklist based on, A, amnesia, B, loss of consciousness, and C, concussion history. Athletes who experienced amnesia for 30 minutes or longer had greater overall symptom scores ($P < .05$) than those who experienced no or 30 minutes or less of amnesia. The groups did not differ based on loss of consciousness or concussion history. Symptoms for all groups returned to baseline by day 7 postinjury. Values estimated from linear mixed model with x-axis in log (time in hours +1). Continued on next page.

Indicator terms were included for amnesia, LOC, and concussion history to explore the interaction of those predictors with recovery time. We used customized Wald statistics to test for statistical differences among groups. Specifically, we produced 2 *P* values: overall group difference and slope group difference. The *P* value for overall group difference tested the hypothesis that there were statistical differences in recovery trajectories among groups (including both the time-of-injury effect and the recovery slope). The slope difference tested the subhypothesis that the recovery slopes differed (ie, the overall group difference without the time-of-injury effect).



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A natural log-transformation of time (measured in hours, with 1 added to avoid taking the $\log_e$ of zero) was used to improve the fit of the model. The model was fitted using restricted maximum likelihood estimation and the Kenward-Roger adjustment for denominator degrees-of-freedom correction. Models for amnesia and LOC included concussion history as a covariate. Previous authors[24] indicated that recovery trajectories were similar between high school and collegiate athletes for the symptom checklist, SAC, and BESS outcomes; therefore, similar to other researchers,[18] we did not include setting (high school or college) as a covariate.

RESULTS

In this study, we followed approximately the same number of football (n = 110), men's soccer (n = 105), and women's soccer (n = 103) teams and significantly fewer men's lacrosse (n = 44), women's lacrosse (n = 32), men's ice hockey (n = 5), and women's ice hockey (n = 5) teams. A total of 375 concussions were observed among the 8905 enrolled athletes, with football (n = 239), men's soccer (n = 54), women's soccer (n = 35), and women's lacrosse (n = 26) contributing the majority of concussions (94.4%) in our study. The average overall incidence rate was 26.1 per 100 000 athlete-exposures, and the overall risk for an average season was 1.8 per 100 athletes.[7] For more information regarding the epidemiologic findings of our study, please see Marshall et al.[7]

Concussion Incidence

The risk of sustaining an incident concussion was associated with a history of self-reported concussion. Of the 352 concussed players, 103 (29.3%) reported sustaining at least 1 concussion within the last 2 years. Players with 1 previous concussion during this period were 2.2 times more likely to sustain a concussion than those with no concussion history, and players with a history of 2 or more previous concussions were 4.2 times more likely to sustain a concussion than those with no concussion history.

Graded Symptom Checklist Scores

We observed increases from baseline in postconcussion symptoms on the GSC during the initial 7 days postinjury. Athletes who experienced 0 to 30 minutes of amnesia tended to have higher symptom-severity scores at the time of injury and at 3 hours postinjury (Figure 1A), and athletes whose amnesia lasted longer than 30 minutes tended to have higher symptom-severity scores for more than 6 days postinjury: group differences achieved statistical significance ($P = .04$). However, we did not observe any GSC recovery differences for LOC (Figure 1B) or concussion history (Figure 1C). Thus, the symptoms of athletes who experienced LOC or had a positive concussion history were similar to those of athletes without these factors.

Standardized Assessment of Concussion Scores

Even more than for GSC score, major deficits on SAC scores during the initial 24 to 72 hours postinjury compared with baseline were evident in athletes who had experienced amnesia. For SAC scores, both the 0- to 30-minute group and the longer-than-30-minute group showed much greater deficits at the time of injury than the no-amnesia group (Figure 2A). Similar to the GSC findings, there were no statistical differences in SAC recovery with respect to LOC

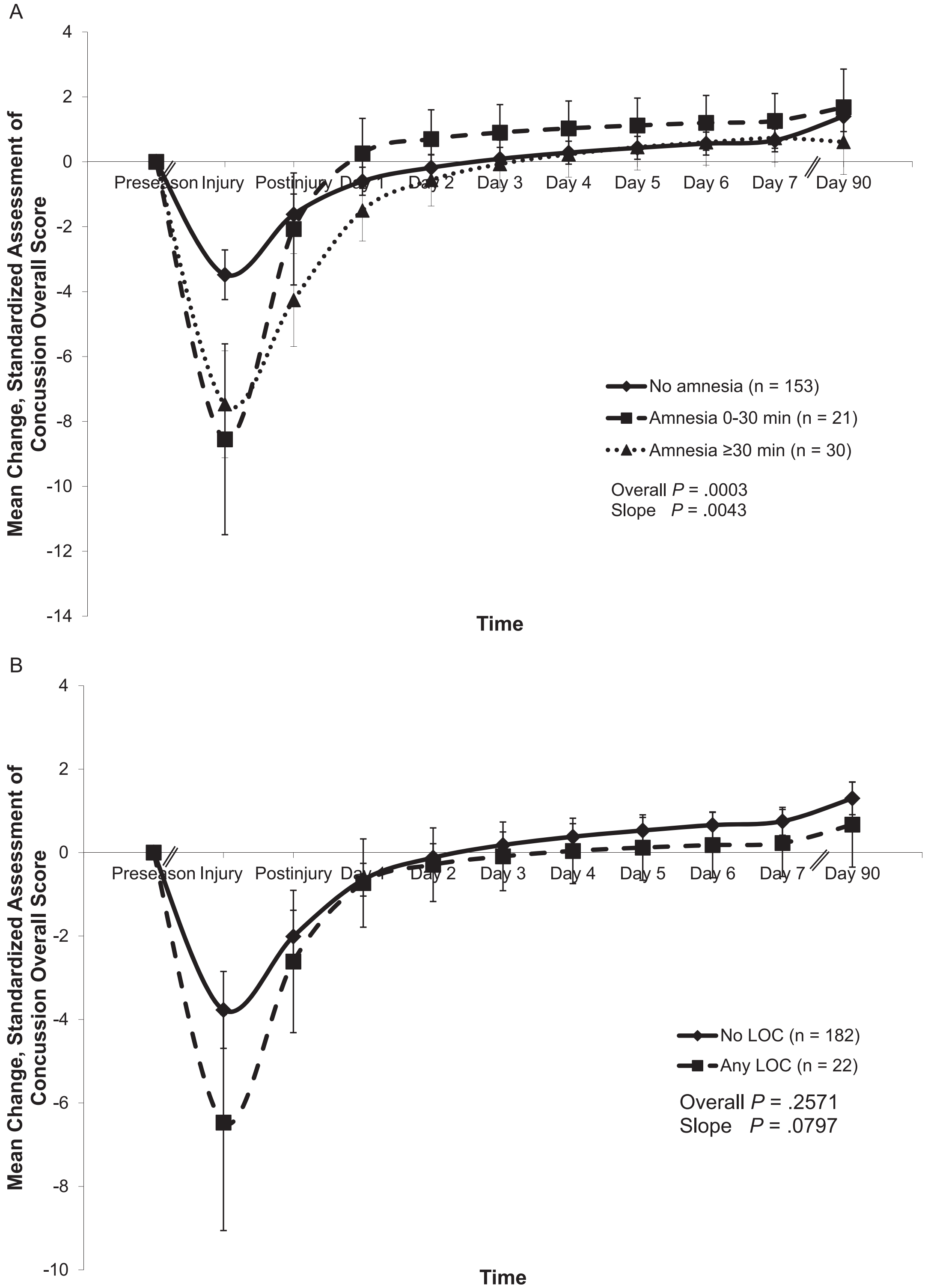
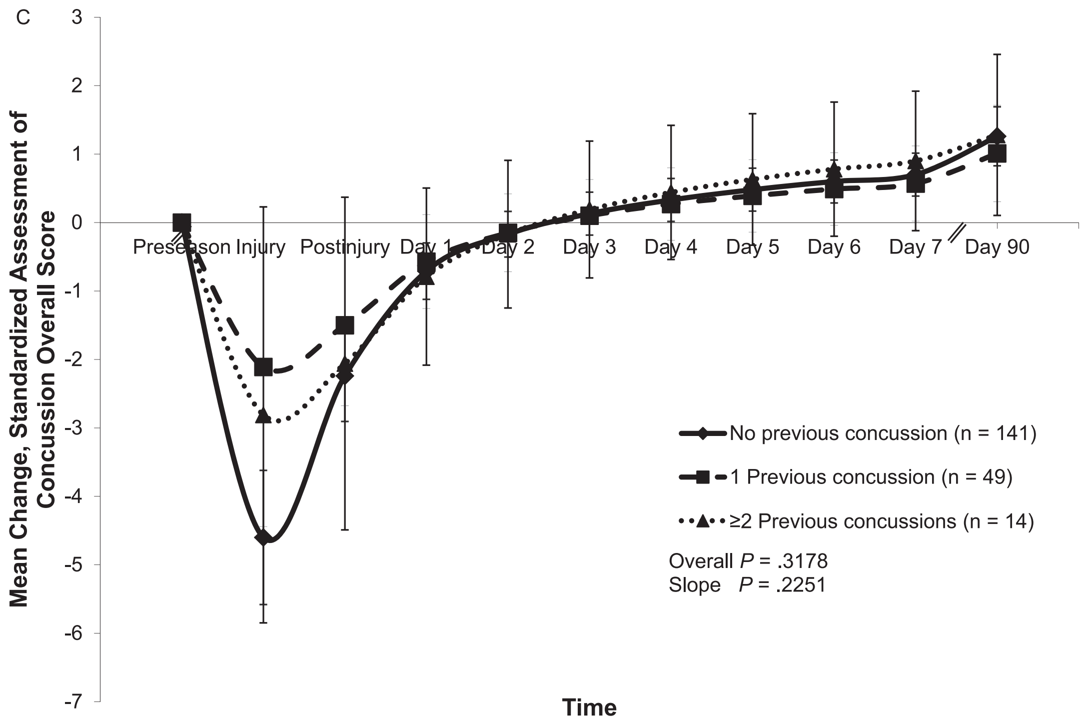


Figure 2. Recovery patterns of Standardized Assessment of Concussion (SAC) scores based on, A, amnesia, B, loss of consciousness (LOC), and C, concussion history. The overall score and slope of the curve showed deficits in both amnesia groups (0–30 and $\geq$30 minutes) for up to 72 hours postinjury ($P < .05$). Athletes with LOC at time of injury tended to score worse on the SAC than those with no LOC, but this trend failed to reach significance ($P = .08$). No differences in SAC scores were observed based on concussion history. All groups returned to baseline within 72 hours postinjury. Values estimated from linear mixed model with x-axis in log (time in hours $+$1). **Continued on next page.**

or concussion history. We observed a trend by which athletes with LOC scored lower on the SAC than those without LOC at the time of injury, but it was not significant (Figure 2B). Concussion history did not influence recovery on the SAC (Figure 2C).

Balance Error Scoring System Scores

As with the GSC and SAC, athletes whose amnesia lasted longer than 30 minutes demonstrated worse balance deficits, which persisted to the 1-day assessment point,



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relative to those without amnesia or those with short-duration amnesia (Figure 3A). Contrary to our expectations, athletes with LOC tended to demonstrate better balance scores than athletes without LOC, although there was no statistically significant overall group effect (Figure 3B). Concussion history was a significant determinant of BESS scores: athletes with 2 or more prior concussions exhibited greater balance deficits relative to those with no previous concussions or only 1 previous concussion (Figure 3C).

Symptom Type in Relation to SAC and BESS Scores

Overall SAC recovery trajectories were not affected by the presence of evolving-onset somatic and neurobehavioral symptoms. Athletes with early-onset somatic symptoms ($P = .026$) and cognitive symptoms ($P = .019$) demonstrated greater SAC deficits at the time of injury, 3 hours postinjury, and 1 day postinjury than athletes who did not have these symptoms. Greater deficits on BESS scores were observed in the presence of early-onset somatic symptoms (group difference: $P = .0010$), evolving-onset somatic symptoms ($P = .018$), cognitive symptoms ($P = .017$), and neurobehavioral symptoms ($P = .012$). Greater BESS deficits were present at the time of injury, 3 hours postinjury, and 1 day postinjury in athletes with these symptoms relative to athletes without these symptoms.

DISCUSSION

Amnesia, LOC, concussion history, and symptom type have been important clinical considerations in return-to-play decisions. Amnesia and LOC in particular have traditionally been thought to be the most serious signs of concussion[8] and can be identified by ATs and other medical personnel who witness the event or thorough clinical evaluation. Although our findings support the concept that amnesia (particularly amnesia longer than 30 minutes) was associated with more symptoms and greater cognitive and balance deficits, the 3 outcome measures (GSC, SAC, and BESS) did not support differences for LOC, concussion history, or symptom group (Table 2). We observed strong associations between early-onset somatic symptoms and worsening of both cognitive and balance recovery. Evolving-onset somatic symptoms and neurobehavioral symptoms were also associated with poorer balance outcomes.

Given the concussion laws signed in all 50 states and the District of Columbia[5] and continuing policy changes in collegiate and professional sports, concussion evaluation and management continue to be important topics in sports medicine. A new policy of the National Collegiate Athletic Association has mandated a "one-time, preparticipation baseline concussion assessment" that should, at minimum, consist of a clinical interview that includes concussion history and symptom, cognitive, and balance assessments.[25(p58)] As the standardized assessments of symptoms, cognition, and balance have become the standard of care for concussion, the GSC, SAC, and BESS are 3 quickly administered, clinician-friendly sideline-assessment tools that are frequently used in sport medicine settings. These tools capture the domains recommended in the National Collegiate Athletic Association concussion policy changes and a multitude of published concussion position statements and best-practice guidelines.[10,20,26,27] Therefore, it is important to understand not only how these tests are used in concussion evaluation but what information they can provide about concussion prognosis, recovery, and return-to-play activities.

Our results are consistent with those of prior studies[3,28] that demonstrated an increased risk for a future concussion

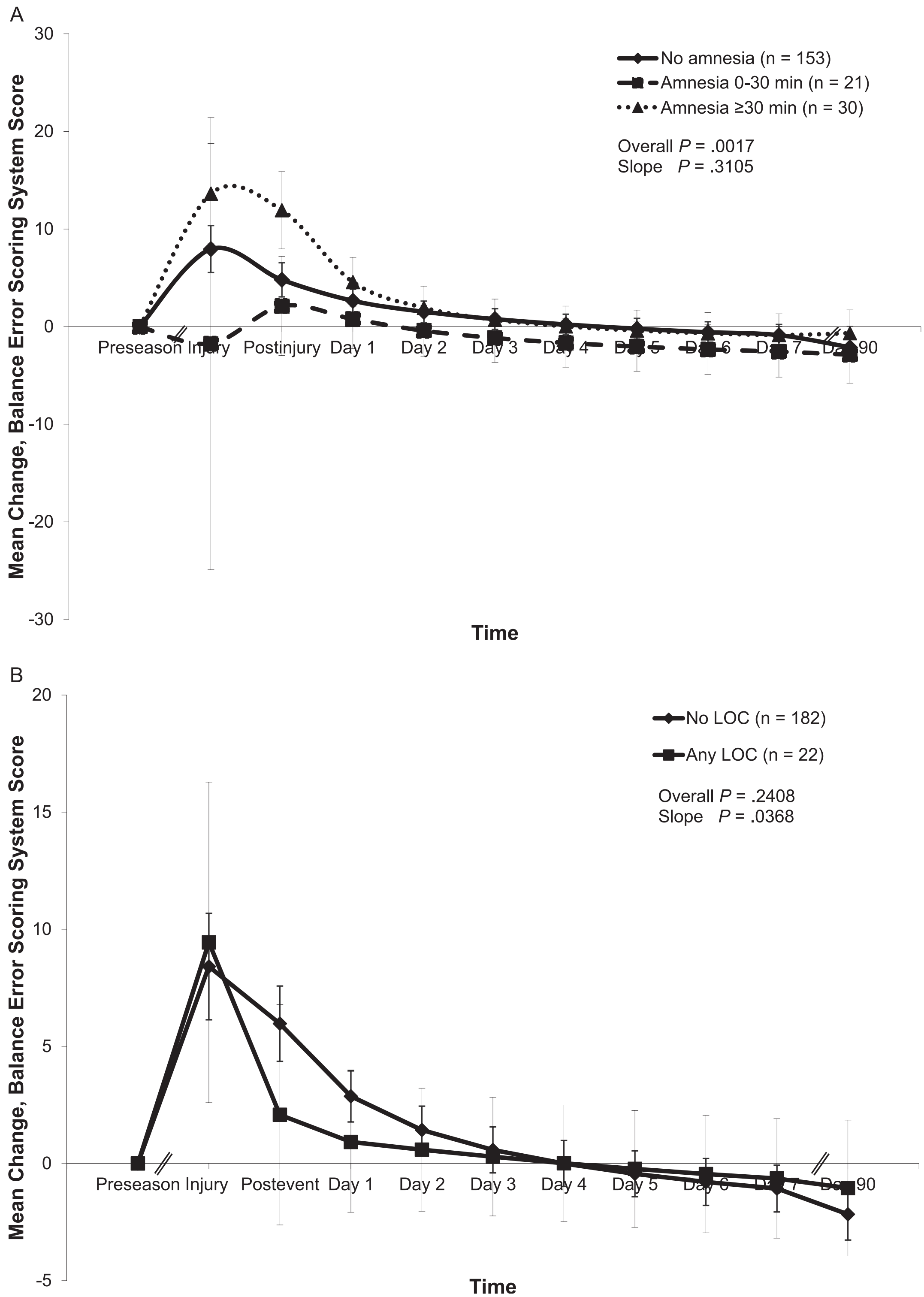
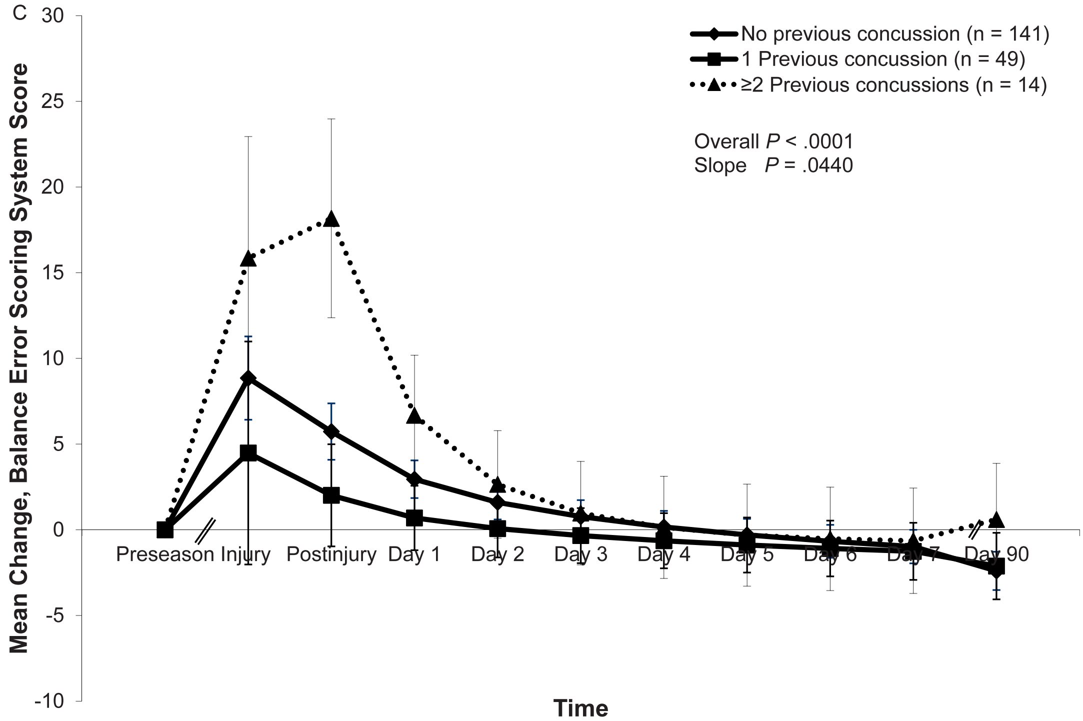


Figure 3. Recovery patterns of Balance Error Scoring System (BESS) scores based on, A, amnesia, B, loss of consciousness (LOC), and C, concussion history. Those athletes with 30 minutes or longer of amnesia had worse BESS scores for the first 48 hours postinjury than the short-duration and no-amnesia groups. The same trend was seen based on concussion history: athletes with 2 or more previous concussions had worse overall BESS scores for up to 48 hours postinjury than athletes with 1 or 0 previous concussions. Athletes with LOC had better scores for the first 48 hours postinjury than athletes who did not sustain LOC. All athletes returned to baseline by 72 hours postinjury. Values estimated from linear mixed model with x-axis in log (time in hours +1). Continued on next page.

in those who had a history of concussion. With growing evidence about the long-term effects of concussion, especially in individuals with a history of multiple concussions,[3,29,30] sports medicine personnel must consider and articulate the risks associated with a return to contact sports. No other authors have serially investigated the recovery of concussive symptoms and SAC and BESS scores using amnesia, LOC, and concussion history as isolated predictors; several groups have looked at the time of resolution from injury to recovery.



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Previous investigators[4,31] have reported the resolution of concussive symptoms on different timelines, with average resolution beginning at about 3 days. For the majority of concussed individuals, resolution of symptoms occurs within 7 to 10 days postinjury.[32] Scores on the SAC return to baseline around 48 hours postconcussion.[33,34] Scores on the BESS return to baseline between 3 and 5 days postinjury.[11,31] Regardless of amnesia, LOC, concussion history, or symptom group, the average group for all domains recovered to baseline within the timelines established by the literature, except that the amnesia group took 1 day longer to recover based on SAC assessment. Although 1 study[35] supported an association between amnesia and prolonged recovery, others[36–38] did not. When examining LOC, McCrea et al[18] found that LOC was the most significant predictor of prolonged concussion recovery. However, most research has shown no relationship between LOC and symptom duration[19,38] or neuropsychological measures.[39,40]

Beyond the on-field signs of concussion (amnesia and LOC), we examined the influence of concussion history,

Table 2. Summary of Clinical Findings

Factor	Overall Group Differences? Graded Symptom Checklist	Standardized Assessment of Concussion	Balance Error Scoring System	Findings in Athletes With Stated Symptom(s)
Amnesia	Yes	Yes	Yes	Particularly with amnesia ≥30 min: greater symptom, cognitive, and balance deficits during the initial 2–3 d postinjury only; by 5 d postinjury, no group differences
Loss of consciousness	No	No	No	Similar recovery curves to those who did not lose consciousness
Concussion history	No	No	Yes	Particularly with ≥2 injuries: poorer balance from time of injury to 2 d postinjury, but all returned to baseline by 3 d postinjury
Somatic (early-onset) symptoms	NA[a]	Yes	NA[a]	Greater cognitive deficits at time of injury and 3 h and 1 d postinjury
Somatic (evolving-onset) symptoms	NA[a]	No	Yes	Greater balance deficits at time of injury and 3 h and 1 d postinjury
Cognitive symptoms	NA[a]	NA[a]	Yes	Greater balance deficits at time of injury and 3 h and 1 d postinjury
Neurobehavioral symptoms	NA[a]	No	Yes	Greater balance deficits at time of injury and 3 h and 1 d postinjury

Abbreviation: NA, not applicable.

[a] Overlap in assessment construct.

separating individuals into groups with 0, 1, or 2 or more previous concussions. Previous authors have found that concussion history can negatively influence the general length of concussion recovery[19] as well as the resolution of symptoms,[3] cognitive functioning,[41] and balance measures[42] individually. However, the literature is mixed, with 2 studies[17,38] showing that a positive concussion history did not predict recovery. In our investigation, the BESS deficits were more prominent in individuals with a higher number of previous concussions. Yet these deficits were observed for only the first 3 days postinjury, indicating that the overall course of balance recovery was not influenced by a history of repeat concussions.

We also took a deeper look at symptom types and how these may influence balance and cognitive outcomes. Somatic (early-onset) and cognitive symptoms significantly influenced SAC recovery up to 1 day postinjury. This result in the cognitive-symptom group is not surprising because difficulty concentrating and remembering are highly correlated with the concentration and recall assessments on the SAC. Additionally, somatic symptoms, such as headache[43] and visual disturbances,[44] are known to influence cognition. All symptom groups (somatic early onset, somatic evolving, cognitive, and neurobehavioral) were associated with worse BESS performance up to the first day after injury. The result for the somatic early-onset group was not unexpected because dizziness can influence performance on postural-stability tasks such as the BESS. Also, although they may not be as intuitive, factors including psychological aspects[45] and disturbed sleep[46] have been shown to influence balance. Additionally, attention is considered to be a fixed capacity.[47] Cognitive symptoms, such as difficulty concentrating, may indicate a reduced attentional capacity after concussion, which may account for poorer balance performance. The different symptom types clearly have unique effects on balance and cognition, suggesting that management techniques may need to be specialized for symptom type. Clinicians should be particularly attentive to the types of symptoms being reported as they manage the athlete's recovery and set expectations for performance on clinical tests of concussion recovery. Anecdotally, we understand that, if somatic symptoms are mitigated, the likelihood of mitigating the deleterious effects of neurobehavioral symptoms is increased, thereby lessening the risk of postconcussion syndrome, which often presents with severe and long-lasting cognitive and neurobehavioral symptoms. Future researchers should continue to investigate the unique effects of various symptom clusters and how they influence symptoms and overall concussion recovery.

CONCLUSIONS

In the absence of sensitive biomarkers, such as blood tests and neuroimaging, to detect concussion and track recovery, refining our understanding of the available valid assessment tools and the expected changes with certain modifiers is paramount. Even though athletes with amnesia, LOC, a concussion history, and early-onset somatic symptoms demonstrated greater deficits on selected assessment measures than athletes without these characteristics, the greater deficits, for the most part, did not persist beyond the initial few days postinjury, and no lingering effects were observed.

Our study is one of few that have used multiple assessment time points to serially investigate the recovery curve from immediately postinjury through recovery and beyond. Overall, amnesia was the predictor that most influenced clinical recovery and LOC; concussion history and acute symptom group did not significantly influence symptom, cognition, or balance outcomes. Importantly, the majority of individuals recovered within the normal timelines established for the GSC (7 days), SAC (2 days), and BESS (3–5 days), except that the amnesia group took 1 day longer to recover on the SAC.

Our findings provide evidence for managing concussion on an individual basis and not assuming that the presence of amnesia and LOC at the time of injury will have deleterious effects on recovery. Current clinical guidelines suggest that athletes be asymptomatic for 24 hours before beginning a graded return-to-play protocol.[26] We found that regardless of amnesia, LOC, or concussion history, the recovery of concussive symptoms often lagged behind the recovery of cognitive and balance deficits. This suggests that following current clinical practice and waiting until symptoms resolve is the best method for returning athletes to activity after concussion.

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