Less Than Half of Patients Recover Within 2 Weeks of Injury After a Sports-Related Mild Traumatic Brain Injury: A 2-Year Prospective Study

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Abstract

Objective: To describe clinical recovery time and factors that might impact on recovery after a sports-related mild traumatic brain injury (SR-mTBI; concussion). **Design:** Prospective cohort study (level IV evidence). **Setting:** New Zealand Sports Concussion Clinic. **Participants:** Eight hundred twenty-two patients presenting within 14 days of a SR-mTBI/concussion over a 2-year period. **Main Outcome Measures:** Clinical recovery measured as number of days after injury. **Interventions Methods:** Participants were assessed and managed using a standardized protocol consisting of relative rest followed by controlled cognitive and physical loading. A reassessment was performed 14 days after injury with initiation of an active rehabilitation program consisting of a subsymptom threshold exercise program ± cervicovestibular rehabilitation (if required) for participants who remained symptomatic. Participants were then assessed every 2 weeks until clinical recovery. **Results:** A total of 594 participants were eligible for analysis (mean age 20.2 ± 8.7 years, 77% males) and were grouped into 3 age cohorts: children (≤12 years), adolescents (13-18 years), and adults (≥19 years). Forty-five percent of participants showed clinical recovery within 14 days of injury, 77% by 4 weeks after injury, and 96% by 8 weeks after injury. There was no significant difference in recovery time between age groups. Prolonged recovery was more common in females ($P = 0.001$), participants with "concussion modifiers" ($P = 0.001$), and with increased time between injury and the initial appointment ($P = 0.003$). **Conclusions:** This study challenges current perceptions that most people with a SR-mTBI (concussion) recover within 10 to 14 days and that age is a determinant of recovery rate. Active rehabilitation results in high recovery rates after SR-mTBI.

Key Words: sports-related concussion, sports-related mTBI, recovery, rehabilitation

(*Clin J Sport Med* 2020;30:96–101)

INTRODUCTION

Since 2001, the concussion in sport group (CISG) has met regularly to debate and define best practice relating to the assessment and management of sport-related concussion (SRC).[1] At the conclusion of each meeting, an international consensus statement is produced and published. This document is an important guide for clinicians and has been integrated into this study.

Until recently, CISG statements have stressed the importance of cognitive and physical rest until symptom resolution, widely reported to occur in most people within 7 to 10 days.[2–4] The most recent consensus statement reported the marked change in direction that SRC management had taken in the intervening 4 years.[5] It highlighted the limited evidence to support rest and recommended that this was kept to a brief period of 24 to 48 hours. After this period, patients are encouraged to become more active with potential treatment options including subsymptom threshold exercise (SSTE) programs, vestibular and cervical therapies, and targeted cognitive behavioral therapy approaches. Adoption of active management strategies for patients with a SRC has been internationally accepted,[6,7] with trials confirming the safety of such interventions.[8,9] A recent systematic review[10] reporting on the approach to treatment and management of persistent postconcussive symptoms found only 25 studies for inclusion, highlighting the relatively limited data available. This review included only 3 RCTs, whereas the remainder were level IV evidence cross-sectional studies, historical cohorts, and case series ranging from 6 to 128 patients.

The consensus statements have widely reported that 80% to 90% of patients show symptom resolution over a short time period of 7 to 10 days and that children and adolescents may

Submitted for publication May 31, 2019; accepted November 15, 2019.

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The clinic was supported by funding from the Accident Compensation Corporation (ACC), NZ. The content is solely the responsibility of the authors and does not necessarily represent the official views of ACC, NZ.

One of the authors (M. Fulcher) works for New Zealand Football and is a member of the FIFA Medical Committee. The remaining authors report no conflicts of interest.

According to the definition given by the International Committee of Medical Journal Editors (ICMJE), the authors listed above qualify for authorship based on making one or more of the substantial contributions to the intellectual content of (1) conception and design (S. Kara and M. Fulcher), (2) acquisition of data (S. Kara, H. Crosswell, and K. Forch), (3) analysis and interpretation of data (S. Kara and A. Cavadino), (4) participated in drafting of the manuscript (S. Kara),and/or (5) critical revision of the manuscript for important intellectual content (S. Kara; H. Crosswell, K. Forch, A. Cavadino, J. McGeown, and M. Fulcher).

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Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (www.cjsportmed.com).

http://dx.doi.org/10.1097/JSM.0000000000000811

require longer recovery periods.[3,4] The evidence for both of these assertions is limited to referencing an earlier consensus statement that states simple concussions are the most common form of injury and resolve without complication within 7 to 10 days, with no data or references given in support.[2] Despite this lack of evidence, these figures continue to be quoted even in recent guidelines.[11,12] Estimated recovery times, especially for adults, remain vague even in the most recent consensus statement, which states "it is reasonable to conclude that the large majority of injured athletes recover, from a clinical perspective, within the first month after injury." The reliance upon a clinical assessment, and in particular a patient's reported symptoms, as a measure of recovery does have some limitations. For example, it is well known that symptom report is not an effective proxy for concussion diagnosis or treatment. Asymptomatic individuals can have impairments, whereas those who have impairments may report no symptoms.[13] In the absence of a gold standard test for SRC however, current diagnostic criteria rely heavily on these clinical findings. Given that there is increasing concern about the impact that SRC may have, we need to be clear about recovery times and the impact possible treatment options have on this.

Although the CISG have endorsed the label SRC, the Center for Disease Control and Prevention has recently suggested that SRC may be better termed as SR mild traumatic brain injury (SR-mTBI)[14] due to the belief that this better reflects the potential impact of the condition. As a result, the term SR-mTBI will be used in this article.

This prospective cohort, from a single community-based sports concussion clinic, will report outcomes on nearly 600 patients seen over a 2 year period, with the aim of quantifying the length of clinical recovery and identifying factors that may be associated with slower recovery. All patients followed a standardized assessment and an active rehabilitation protocol in line with current best practice methods.

METHODS

Design and Setting

A 2-year prospective observational cohort study (level of evidence IV) was conducted in a dedicated fully funded community–based sports concussion clinic in Auckland, New Zealand. Participants attending the clinic were seen by a sports medicine doctor, exercise physiologist, and a physiotherapist with postgraduate vestibular therapy qualifications.

Patient and Public Involvement

Patients and public were not involved in any way in our work.

Definition

Sports-related mTBI is defined as a traumatic brain injury in line with the latest CISG consensus statements.[5]

Participants and Recruitment

Participants consisted of all people who presented between January 2017 and December 2018 with a possible SR-mTBI. Participants were either referred by general practitioners, physiotherapists, other allied health professionals, school nurses, local and public hospital emergency clinics, team coaches and sports clubs, or could self-refer. Exclusion criteria were people presenting after 14 days after injury and those with a non–SR-mTBI, the latter due to external public funding restrictions. Analysis was limited to participants who achieved clinical recovery as defined below. Participants excluded from analysis (Figure 1) were those not diagnosed with a SR-mTBI during their initial assessment, those who had incomplete clinical data despite being clinically recovered, those who had not yet completed 8 weeks of the model of care (and therefore remained under care), or those referred on as requiring more multidisciplinary care due to persistent symptoms 8 weeks after injury (eg, occupational therapist, psychologist, and neuropsychologist). Ethical approval was obtained via the Accident Compensation Corporation New Zealand Ethics Committee. Informed consent and/or age appropriate assent was obtained from each participant.

Assessment Protocol

Participants followed a standardized assessment and management protocol in line with the latest CISG Statement.[5] The initial consultation involved an injury history, previous

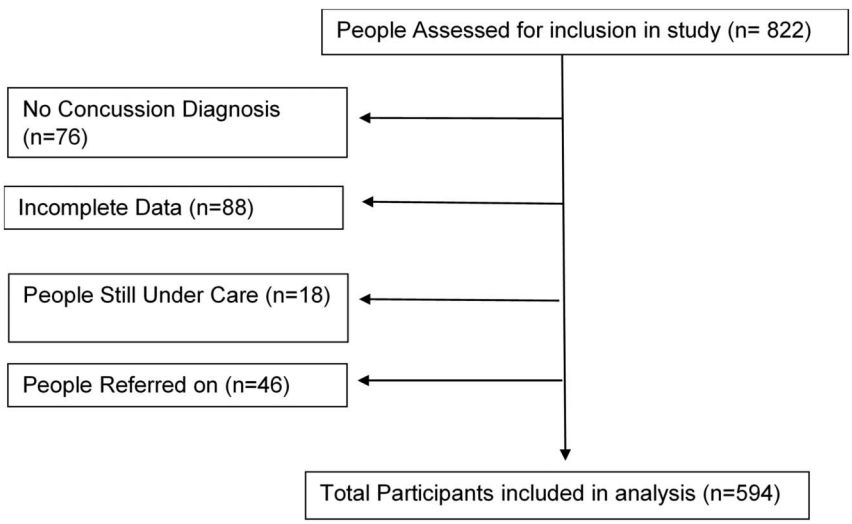

Figure 1. Participant flow within the study.

SR-mTBI history, and an assessment of any "concussion modifiers" (patient-reported preinjury history of migraine or mental health issues).[5] An age-appropriate SCAT5 assessment was performed. Physical examination to screen for more serious pathology such as occult intracranial pathology and cervical spine instability was performed. This involved a cranial nerve assessment (I-XII) and a targeted peripheral neurological assessment of reflexes and motor and sensory function if dictated by patient presentation. A vestibular assessment via the vestibulo-oculomotor screening tool was conducted.[15,16] The cervical spine was assessed using active range of movement with flexion, extension, and lateral rotation. Additional tests assessed cervical alignment to assess cervical joint position error, assessing the patient's ability to relocate their head to a neutral position with less than 5 degrees of error, whereas the cervical flexion head rotation test assessed upper cervical movement.[17,18] Palpation of the cervical spine for tenderness with trigger point reproduction of headache symptoms completed the cervical spine assessment. Autonomic dysfunction was assessed using only supine and standing blood pressure measurements at 1 and 3 minutes. Follow-up consultations involved repeating the SCAT5 symptom evaluation and a review of previous abnormal physical findings.

Management Protocol

After their initial consult, participants were given written and verbal advice consistent with the latest CISG statement.[5] A 24- to 48-hour period of rest followed by controlled cognitive and physical loading, guided by symptom exacerbation, was prescribed to encourage activity, with emphasis on patient education at this initial consult. Participants were re-assessed at day 14 after injury. At this stage, they were defined as being "clinically recovered" or "still symptomatic." If a participant was deemed to have clinically recovered, they commenced a graduated return to a sport (GRTS) program with re-evaluation before return to full training.[5] Those who were "still symptomatic" underwent graded aerobic exercise testing using the Buffalo Concussion Treadmill Test with subsequent development of a SSTE program.[7,19] Adjunct cervical or vestibular physiotherapy was prescribed if appropriate based on relevant clinical signs either at this reassessment or at the initial consultation.[20] Participants were assessed once every 2 weeks until clinical recovery. At this point, they commenced the same GRTS protocol. This standardized model of care and rehabilitation is outlined in **Appendix 1** (see **Supplemental Digital Content 1**, http://links.lww.com/JSM/A219).

Definition of Clinical Recovery

Participants were defined as achieving clinical recovery when both their SCAT5 symptom score and symptom severity score were <5 for males and <6 for females. This distinction is based on normative data for the general population.[21] Participants were also required to have resolution of any previous abnormal clinical examination findings and "normal" exercise tolerance. Normal exercise tolerance was defined as being asymptomatic when exercising at 85% to 90% of predicted heart rate if measured or return to the participants' usual preinjury exercise levels. Length of recovery was a reported measure by participant recall defined as the number of days between injury and the time the participant reached clinical recovery. As participants were assessed once every 2 weeks, this figure permits accuracy for the time intervals measured against (within 2 weeks; 2-4 weeks; 4-8 weeks; and $\geq$8 weeks).

Statistical Analysis

Participant characteristics were assessed for differences according to age groups: children ($\leq$12 years), adolescents (13-18 years), and adults ($\geq$19 years). A Kruskal–Wallis test was used for continuous variables due to their skewed distributions, including days until initial appointment, number of previous concussions, days until asymptomatic, and number of follow-up visits. A χ^2 test was used to assess potential differences in gender, sport type, and concussion modifier by the age group. Length of recovery (measured by time to clinical recovery; within 2, 2-4, 4-8, or $\geq$8 weeks) was summarized overall and within each age group. Multiple linear regression was used to determine mutually adjusted associations of participant characteristics with length of recovery, measured by the number of days to clinical recovery. A natural log transformation was used for the outcome due to a skewed distribution, with the model including all factors that showed an unadjusted association with the outcome. Because the outcome is log-transformed, we calculated the average percentage differences in the length of recovery for each variable in the model using the exponential of the regression coefficients.[22] Statistical analyses were conducted using Stata version 15.1.

RESULTS

All 822 participants presenting with a possible SR-mTBI during the study period from January 2017 to December 2018 were assessed for inclusion in this study. A total of 594 (77% males) with age range 7 to 64 years (average age 20.2 years) were included in the analysis as presented in Table 1. Figure 1 shows that 28% of people presenting were not eligible for inclusion, with 39% (n = 88) of these being ineligible due to incomplete or missing information in relevant data fields rather than loss to follow-up. Five percent of participants were referred on as they did not achieve clinical recovery under this model of care and were assessed as requiring additional input. Those not included in the analysis due to incomplete data (n = 88) did not differ significantly from those eligible in terms of any of the characteristics described in Table 1.

The average number of days until the initial consultation was 8.7 days after injury, whilst Rugby Union accounted for 54% of the all consultations. The $\leq$12 years age group had a significantly lower proportion of females ($P = 0.008$) than the older age groups. There was also an association between age group and the number of previous concussions, with older participants having had more previous concussions ($P = 0.0001$). There were no statistically significant differences by the age group in terms of days until initial assessment, days until clinical recovery, number of follow-up visits, sport type, or presence of a concussion modifier ($P > 0.05$ for all comparisons). Only 45% of participants across all age groups had clinical recovery within 2 weeks after injury, increasing to 77% by 4 weeks, and 94% by 8 weeks (Table 2). All participants included in the analysis achieved clinical recovery within the study period.

TABLE 1. Descriptive Summary of Eligible Participants by the Age Group

	Age ≤12 years (n = 45)	Age 13-18 years (n = 290)	Age ≥19 years (n = 259)	All (n = 594)
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Age (yr)	10.7 ± 1.4	15.8 ± 1.6	26.8 ± 9.0	20.2 ± 8.5
Days until initial assessment	8.4 ± 4.5	8.2 ± 4.9	9.2 ± 7.1	8.7 ± 6.0
No. of previous concussions	0.4 ± 0.9	0.7 ± 1.1	1.2 ± 1.8	0.9 ± 1.5
Days until asymptomatic	16.2 ± 14.6	18.3 ± 13.3	21.6 ± 22.3	19.5 ± 18.0
No. of follow-up visits	1.7 ± 1.1	1.9 ± 1.2	1.8 ± 1.5	1.9 ± 1.3
	N (%)	N (%)	N (%)	N (%)
Sex				
Female	2 (4.4)	70 (24.1)	66 (25.5	138 (23.2)
Male	43 (95.6)	220 (75.9)	193 (74.5)	456 (76.8)
Sport				
Rugby union	25 (55.6)	149 (51.4)	148 (57.1)	322 (54.2)
Rugby league	1 (2.2)	21 (7.2)	15 (5.8)	37 (6.2)
Football (soccer)	7 (15.6)	38 (13.1)	24 (9.3)	69 (11.6)
Field hockey	1 (2.2)	9 (3.1)	4 (1.5)	14 (2.4)
Netball	0 (0.0)	6 (2.1)	4 (1.5)	10 (1.7)
Other	11 (24.4)	67 (23.1)	64 (24.7)	142 (23.9)
Concussion modifier				
Not present	44 (97.8)	246 (85.1)	219 (84.9)	509 (86.0)
Present	1 (2.2)	43 (14.9)	39 (15.1)	83 (14.0)

In unadjusted analysis, there was no association between the length of recovery and the number of previous concussions ($P = 0.92$) or age group ($P = 0.36$). A multiple linear regression model showed that females, those with injuries from sports other than Rugby Union, those with a concussion modifier, and those with more time between their injury and the initial appointment had significantly longer recovery times (Table 3). On average, the number of days until clinical recovery was 43% (exp (0.36) = 1.43, or a 43% increase) longer for females, whereas those with modifiers had a 48% longer recovery time. For each additional day between injury and the initial appointment, there was an increase in the average recovery time; for a 7-day increase in time to the initial appointment, we could expect an approximate 15% increase in the number of days until clinical recovery ($\exp(0.02 \times 7) = 1.15$).

A total of 5% of participants received cervical rehabilitation, 28% received vestibular rehabilitation, and 10% received combined cervicovestibular rehabilitation as part of their individualized management. A smaller proportion of children (≤12 years) required cervicovestibular rehabilitation (n = 4, 17%) than adolescents (13-18 years, n = 69, 42%) or adults (≥19 years, n = 63, 50%). Vestibular rehabilitation alone or in combination with cervical rehabilitation was more likely in adults (44% of patients) than younger age groups.

DISCUSSION

The current study shows that less than half of those presenting acutely with a SR-mTBI show clinical recovery within 14 days and therefore, at best, may be cleared to return to play at 21 days following the accepted GRTS program. This rate of recovery is slower than described in previous CISG and other position statements.[3,4,11,12] It is only at 28 days postinjury does this figure rise to be comparable with the recovery rates quoted in these publications. Those participants referred on are not represented in this figure and if accounted for would only strengthen our case by adding to the number who had not recovered within certain time frames.

As previously stated, recovery rates of 80% to 90% within 7 to 10 days appeared first in the third consensus statement on concussion in sport[4] referenced to the second consensus statement that has no supportive data.[2] A review of references from this

TABLE 2. Recovery of all Patients by the Age Group, Measured as the Number of Weeks After Injury Until Asymptomatic

	No. of Days After injury Until Asymptomatic			
Age Group	**<2 wk**	**2-4 wk**	**4-8 wk**	**≥ 8 wk**
≤12 yrs	22 (48.9%)	16 (35.6%)	6 (13.3%)	1 (2.2%)
13-18 yrs	116 (40.0%)	117 (40.3%)	49 (16.9%)	8 (2.8%)
>18 yrs	130 (50.2%)	58 (22.4%)	46 (17.8%)	25 (9.6%)
All ages	268 (45.1%)	191 (32.2%)	101 (17.0%)	34 (5.7%)

TABLE 3. Multiple Linear Regression of Factors Associated With Length of Recovery, Measured by the Number of Days After Injury to Asymptomatic Status

Variable	Category/Unit	Coefficient (95% CI)	*P*
Sex	Male	Reference	
	Female	0.36 (0.15 to 0.57)	0.001
Sport	Rugby union	Reference	
	Rugby league	0.16 (−0.17 to 0.51)	0.339
	Football (soccer)	0.57 (0.30 to 0.83)	<0.001
	Other*	0.64 (0.44 to 0.86)	<0.001
Modifiers	No	Reference	
	Yes	0.39 (0.15 to 0.62)	0.001
Time from injury to initial appointment	Days	0.02 (0.01 to 0.03)	0.003

*Including hockey, netball, bike sports, water sports, snow sports, lacrosse, and combat sports such as martial arts and boxing.

early consensus paper highlight only opinion pieces[23] or small cohort studies within single sports discussing concussion grading and postinjury symptomatology.[24,25] In fact, data within the second international conference on concussion in sport[2] cites a rugby league study showing that 50% of players still demonstrated impaired neurocognitive performance on testing 10 days after injury.[24] A systematic review has estimated the prevalence of prolonged recovery (defined as >14 days in adults and >28 days in children) to be between 10% and 30%, after SR-mTBI.[10] Unfortunately, only 25 studies met the inclusion criteria. These studies generally had relatively small sample sizes, (n = 6-128, mean age 20.1 years, duration of symptoms 10-226 days), were of relatively poor quality, and had an inconsistent definition of persistent symptoms. Outside sport, there are data supporting a more prolonged recovery time after mTBI. A 2-year multicenter retrospective electronic health record review analyzed the injury and treatment history of 1840 adolescent patients (10-17 years),[26] showing a similar duration of recovery as presented in the current study. In this study, 75% of patients were symptom-free or had returned to preinjury symptom levels 4 weeks after injury. Only 16% had recovered within the first week, whereas 6.7% remained symptomatic at 8 weeks. A large multicenter Canadian study also reported persistent symptoms at 4 weeks in 30% of patients.[27] We believe that our data may reflect the natural recovery timeline for those with a SR-mTBI and that recovery rates may be slower than previously reported. Given the uncertainty around the original statements, and increasing data suggesting that many people have a more prolonged recovery, more conservative recommendations may need to be made in future consensus statements.

The literature focuses on slower recovery times in younger patients.[3–5] Existing data compare adolescents with children[28] and high school athletes with collegiate athletes.[29] Interpreting these data is however difficult due to inconsistencies between study designs.[28] Age showed no significant association with recovery in our cohort, a finding consistent with another larger study.[30] Our results suggest that the natural recovery timeline for SR-mTBI is similar irrespective of age. It is possible that the current data may more accurately represent the true recovery trajectory for SR-mTBI, given that all participants, regardless of age or level of sport, followed a standardized treatment protocol including early active rehabilitation and equal access to medical resources, with similar recovery times across groups. Given these findings, we would suggest a more conservative approach across all age groups and not just younger groups.

Gender and "concussion modifiers" represent well-published risk factors for recovery,[5] and our results further support this. It is unclear why the Rugby Union seems to represent less risk of prolonged recovery compared with other sports. This might reflect a proactive system wide approach from within this sport, with education, clear advice, and early management, resulting in less overall morbidity.[31] It is also possible that this is due to an under-reporting of concussion symptoms and not true recovery among those who play rugby.[32] There are a number of other factors that might influence recovery. We have found a positive association between persistent symptoms and a higher initial symptom burden (SCAT5 symptom score/severity score) with this being the subject of another publication.[33]

This current study suggests that those who are seen more quickly after a SR-mTBI may have a faster recovery. This is consistent with existing data demonstrating that earlier assessment may reduce the severity of persistent symptoms and enhance recovery.[26,34] Many patients with a SR-mTBI do not appreciate the value of a medical assessment and do not present for an assessment until their symptoms fail to resolve. Others return to sport before their injury has resolved and are at an increased risk of a further SR-mTBI or other types of injury.[35] It is possible these attitudes and behaviors are partly driven by the perception that SR-mTBI is a self-limiting problem. The results of this study challenge this perception and illustrate a need for more education for those involved in sport.

STRENGTHS AND LIMITATIONS

The main strength of this study is in the prospectively collected data from a large sample of participants with a SR-mTBI. Participants were assessed and managed using a standardized, best practice model of care. We acknowledge that SR-mTBI may be a different clinical entity to mTBI sustained outside sport; hence, results may not be applicable to this group. The lack of a gold standard test and the reliance on symptom reporting will continue to be a limitation for all clinical research in this area. Our definition of clinical recovery allows participants to have some symptoms reflecting the nonspecific nature of symptom reporting. Mandatory use of the Buffalo Concussion Treadmill Test before the GRTS program may provide a more objective measure of physiological recovery, but the logistical nature of this is difficult to achieve outside of the research setting. Another potential limitation relates to the use of the SCAT5. This tool is a validated diagnostic support

tool designed for use on the sideline and was not designed for specific clinical setting use,[36] although use is widespread. The lack of baseline comparison neurocognitive scores is also a potential limitation. Further limitations relate to the discharge criteria used; although participants were followed up until their clearance to return to normal sporting activity, it is not clear whether they did this successfully or not. This methodology was used for logistical reasons and has been used in other papers.[20] There is the potential for selection bias in this study. Patients were able to self-refer, which could indicate higher motivation to return to sport but equally reflect patient fear or catastrophizing, both of which could influence recovery duration. Finally, the overall number of participants younger than 12 years is very small and does not permit any meaningful analysis. We continue to collect prospective data and now have a larger cohort of pediatric patients. In time, we are hoping to be able to publish some more meaningful data on this group in a separate paper. We believe that this will be more useful.

CONCLUSIONS

Recovery from a SR-mTBI is slower than previous international consensus statements have indicated. Less than half of all participants in this study recovered within 2 weeks after injury, and it is only at 28 days after injury do recovery rates match those quoted in these statements. This is irrespective of age with adults, adolescents, and children showing similar recovery rates within 2 weeks, by 4 weeks, and by 8 weeks after injury with best practice clinical care delivered across all age groups. Delay to presentation leads to delay in recovery with the message of early access to care needing to be mandated within individual sports.

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