Consensus statement on concussion in sport—the 5th international conference on concussion in sport held in Berlin, October 2016

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PREAMBLE

The 2017 Concussion in Sport Group (CISG) consensus statement is designed to build on the principles outlined in the previous statements[1–4] and to develop further conceptual understanding of sport-related concussion (SRC) using an expert consensus-based approach. This document is developed for physicians and healthcare providers who are involved in athlete care, whether at a recreational, elite or professional level. While agreement exists on the principal messages conveyed by this document, the authors acknowledge that the science of SRC is evolving and therefore individual management and return-to-play decisions remain in the realm of clinical judgement.

This consensus document reflects the current state of knowledge and will need to be modified as new knowledge develops. It provides an overview of issues that may be of importance to healthcare providers involved in the management of SRC. This paper should be read in conjunction with the systematic reviews and methodology paper that accompany it. First and foremost, this document is intended to guide clinical practice; however, the authors feel that it can also help form the agenda for future research relevant to SRC by identifying knowledge gaps.

A series of specific clinical questions were developed as part of the consensus process for the Berlin 2016 meeting. Each consensus question was the subject of a specific formal systematic review, which is published concurrently with this summary statement. Readers are directed to these background papers in conjunction with this summary statement as they provide the context for the issues and include the scope of published research, search strategy and citations reviewed for each question. This 2017 consensus statement also summarises each topic and recommendations in the context of all five CISG meetings (that is, 2001, 2004, 2008, 2012 as well as 2016). Approximately 60 000 published articles were screened by the expert panels for the Berlin meeting. The details of the search strategies and findings are included in each of the systematic reviews.

The details of the conference organisation, methodology of the consensus process, question development and selection on expert panellists and observers is covered in detail in an accompanying paper in this issue.[5] A full list of scientific committee members, expert panellists, authors, observers and those who were invited but could not attend are detailed is at the end of the summary document. The International Committee of Medical Journal Editors conflict of interest declaration for all authors is provided in Appendix 1.

Medical legal considerations

The consensus statement is not intended as a clinical practice guideline or legal standard of care, and should not be interpreted as such. This document is only a guide, and is of a general nature, consistent with the reasonable practice of a healthcare professional. Individual treatment will depend on the facts and circumstances specific to each individual case. It is intended that this document will be formally reviewed and updated before 31 December 2020.

SRC AND ITS MANAGEMENT

The paper is laid out following the CISG's 11 'R's of SRC management to provide a logical flow of

clinical concussion management. *The new material recommendations determined at the Berlin 2016 meeting are italicised*, and any background material or unchanged recommendations from previous meetings are in normal text.

The sections are: Recognise; Remove; Re-evaluate; Rest; Rehabilitation; Refer; Recover; Return to sport; Reconsider; Residual effects and sequelae; Risk reduction.

Recognise

What is the definition of SRC?

In the broadest clinical sense, SRC is often defined as representing the immediate and transient symptoms of traumatic brain injury (TBI). Such operational definitions, however, do not give any insights into the underlying processes through which the brain is impaired, nor do they distinguish different grades of severity, nor reflect newer insights into the persistence of symptoms and/or abnormalities on specific investigational modalities. This issue is clouded not only by the lack of data, but also by confusion in definition and terminology. Often the term mild traumatic brain injury (mTBI) is used interchangeably with concussion; however, this term is similarly vague and not based on validated criteria in this context.

One key unresolved issue is whether concussion is part of a TBI spectrum associated with lesser degrees of diffuse structural change than are seen in severe TBI, or whether the concussive injury is the result of reversible physiological changes. The term concussion, while useful, is imprecise, and because disparate author groups define the term differently, comparison between studies is problematic. In spite of these problems, the CISG has provided a consistent definition of SRC since 2000.[1]

The Berlin expert panel modified the previous CISG definition as follows:

Sport related concussion is a traumatic brain injury induced by biomechanical forces. Several common features that may be utilised in clinically defining the nature of a concussive head injury include:

- *SRC may be caused either by a direct blow to the head, face, neck or elsewhere on the body with an impulsive force transmitted to the head.*
- *SRC typically results in the rapid onset of short-lived impairment of neurological function that resolves spontaneously. However, in some cases, signs and symptoms evolve over a number of minutes to hours.*
- *SRC may result in neuropathological changes, but the acute clinical signs and symptoms largely reflect a functional disturbance rather than a structural injury and, as such, no abnormality is seen on standard structural neuroimaging studies.*
- *SRC results in a range of clinical signs and symptoms that may or may not involve loss of consciousness. Resolution of the clinical and cognitive features typically follows a sequential course. However, in some cases symptoms may be prolonged.*

The clinical signs and symptoms cannot be explained by drug, alcohol, or medication use, other injuries (such as cervical injuries, peripheral vestibular dysfunction, etc) or other comorbidities (eg, psychological factors or coexisting medical conditions).

Do the published biomechanical studies inform us about the definition of SRC?

Many studies have reported head-impact-exposure patterns for specific sports—for example, American football, ice hockey and Australian football. Those studies report head-impact characteristics including frequency, head kinematics, head-impact location, and injury outcome. In these studies, the use of instrumented helmets has provided information on head-impact exposures, although there remains some debate about the accuracy and precision of the head kinematic measurements. To quantify head impacts, studies have used helmet-based systems, mouthguard/headband/skin sensors and videometric studies; however, reported mean peak linear and rotational acceleration values in concussed players vary considerably.

Although current helmet-based measurement devices may provide useful information for collision sports, these systems do not yet provide data for other (non-collision) sports, limiting the value of this approach. Furthermore, accelerations detected by a sensor or video-based systems do not necessarily reflect the impact to the brain itself, and values identified vary considerably between studies. The use of helmet-based or other sensor systems to clinically diagnose or assess SRC cannot be supported at this time.

Sideline evaluation

It is important to note that SRC is an evolving injury in the acute phase, with rapidly changing clinical signs and symptoms, which may reflect the underlying physiological injury in the brain. SRC is considered to be among the most complex injuries in sports medicine to diagnose, assess and manage. The majority of SRCs occur without loss of consciousness or frank neurological signs. At present, there is no perfect diagnostic test or marker that clinicians can rely on for an immediate diagnosis of SRC in the sporting environment. Because of this evolving process, it is not possible to rule out SRC when an injury event occurs associated with a transient neurological symptom. In all suspected cases of concussion, the individual should be removed from the playing field and assessed by a physician or licensed healthcare provider as discussed below.

Sideline evaluation of cognitive function is an essential component in the assessment of this injury. Brief neuropsychological (NP) test batteries that assess attention and memory function have been shown to be practical and effective. Such tests include the SCAT5, which incorporates the Maddocks' questions[6 7] and the Standardised Assessment of Concussion (SAC).[8–10] It is worth noting that standard orientation questions (eg, time, place, person) are unreliable in the sporting situation when compared with memory assessment.[7 11] It is recognised, however, that abbreviated testing paradigms are designed for rapid SRC screening on the sidelines and are not meant to replace a comprehensive neurological evaluation; nor should they be used as a standalone tool for the ongoing management of SRC.

A key concept in sideline assessment is the rapid screening for a suspected SRC, rather than the definitive diagnosis of head injury. Players manifesting clear on-field signs of SRC (eg, loss of consciousness, tonic posturing, balance disturbance) should immediately be removed from sporting participation. Players with a suspected SRC following a significant head impact or with symptoms can proceed to sideline screening using appropriate assessment tools—for example, SCAT5. Both groups can then proceed to a more thorough diagnostic evaluation, which should be performed in a distraction-free environment (eg, locker room, medical room) rather than on the sideline.

In cases where the physician may have been concerned about a possible concussion, but after the sideline assessment (including additional information from the athlete, the assessment itself and/or inspection of videotape of the incident) concussion is no longer suspected, then the physician can

Table 1 Graduated return-to-sport (RTS) strategy

Stage	Aim	Activity	Goal of each step
1	Symptom-limited activity	Daily activities that do not provoke symptoms	Gradual reintroduction of work/school activities
2	Light aerobic exercise	Walking or stationary cycling at slow to medium pace. No resistance training	Increase heart rate
3	Sport-specific exercise	Running or skating drills. No head impact activities	Add movement
4	Non-contact training drills	Harder training drills, eg, passing drills. May start progressive resistance training	Exercise, coordination and increased thinking
5	Full contact practice	Following medical clearance, participate in normal training activities	Restore confidence and assess functional skills by coaching staff
6	Return to sport	Normal game play	

NOTE: An initial period of 24–48 hours of both relative physical rest and cognitive rest is recommended before beginning the RTS progression.
There should be at least 24 hours (or longer) for each step of the progression. If any symptoms worsen during exercise, the athlete should go back to the previous step.
Resistance training should be added only in the later stages (stage 3 or 4 at the earliest). If symptoms are persistent (eg, more than 10–14 days in adults or more than 1 month in children), the athlete should be referred to a healthcare professional who is an expert in the management of concussion.

determine the disposition and timing of return to play for that athlete.

We acknowledge that many contact sports are played at a fast pace in a disorganised environment, where the view of on-field incidents is often obscured and the symptoms of SRC are diverse, all of which adds to the challenge of the medical assessment of suspected SRC. Furthermore, evolving and delayed-onset symptoms of SRC are well documented and highlight the need to consider follow-up serial evaluation after a suspected SRC regardless of a negative sideline screening test or normal early evaluation.

The recognition of suspected SRC is therefore best approached using multidimensional testing guided via expert consensus. The SCAT5 currently represents the most well-established and rigorously developed instrument available for sideline assessment. There is published support for using the SCAT and Child SCAT in the evaluation of SRC. The SCAT is useful immediately after injury in differentiating concussed from non-concussed athletes, but its utility appears to decrease significantly 3–5 days after injury. The symptom checklist, however, does demonstrate clinical utility in tracking recovery. Baseline testing may be useful, but is not necessary for interpreting post-injury scores. If used, clinicians must strive to replicate baseline testing conditions. Additional domains that may add to the clinical utility of the SCAT tool include clinical reaction time, gait/balance assessment, video-observable signs and oculomotor screening.

The addition of sideline video review offers a promising approach to improving identification and evaluation of significant head-impact events, and a serial SRC evaluation process appears to be important to detect delayed-onset SRC. Other tools show promise as sideline screening tests but require adequately powered diagnostic accuracy studies that enrol a representative sample of athletes with suspected SRC. Collaboration between sporting codes to rationalise multimodal diagnostic sideline protocols may help facilitate more efficient application and monitoring. Current evidence does not support the use of impact sensor systems for real-time SRC screening.

Symptoms and signs of acute SRC

Recognising and evaluating SRC in the adult athlete on the field is a challenging responsibility for the healthcare provider. Performing this task often involves a rapid assessment in the midst of competition with a time constraint and the athlete eager to play. A standardised objective assessment of injury that excludes more serious injury is critical in determining disposition decisions for the athlete. The sideline evaluation is based on recognition of injury, assessment of symptoms, cognitive and cranial nerve function, and balance. Serial assessments are often necessary. Because SRC is often an evolving injury, and signs and symptoms may be delayed, erring on the side of caution (ie, keeping an athlete out of participation when there is any suspicion of injury) is important.

The diagnosis of acute SRC involves the assessment of a range of domains including clinical symptoms, physical signs, cognitive impairment, neurobehavioral features and sleep/wake disturbance. Furthermore, a detailed concussion history is an important part of the evaluation both in the injured athlete and when conducting a pre-participation examination.

The suspected diagnosis of SRC can include one or more of the following clinical domains:

a. Symptoms: somatic (eg, headache), cognitive (eg, feeling like in a fog) and/or emotional symptoms (eg, lability)
b. Physical signs (eg, loss of consciousness, amnesia, neurological deficit)
c. Balance impairment (eg, gait unsteadiness)
d. Behavioural changes (eg, irritability)
e. Cognitive impairment (eg, slowed reaction times)
f. Sleep/wake disturbance (eg, somnolence, drowsiness)

If symptoms or signs in any one or more of the clinical domains are present, an SRC should be suspected and the appropriate management strategy instituted. It is important to note, however, that these symptoms and signs also happen to be non-specific to concussion, so their presence simply prompts the inclusion of concussion in a differential diagnosis for further evaluation, but the symptom is not itself diagnostic of concussion.

Remove

When a player shows any symptoms or signs of an SRC:

a. The player should be evaluated by a physician or other licensed healthcare provider on site using standard emergency management principles, and particular attention should be given to excluding a cervical spine injury.
b. The appropriate disposition of the player must be determined by the treating healthcare provider in a timely manner. If no healthcare provider is available, the player should be safely removed from practice or play and urgent referral to a physician arranged.
c. Once the first aid issues are addressed, an assessment of the concussive injury should be made using the SCAT5 or other sideline assessment tools.
d. The player should not be left alone after the injury, and serial monitoring for deterioration is essential over the initial few hours after injury.
e. A player with diagnosed SRC should not be allowed to return to play on the day of injury.

Table 2 Graduated return-to-school strategy

Stage	Aim	Activity	Goal of each step
1	Daily activities at home that do not give the child symptoms	Typical activities of the child during the day as long as they do not increase symptoms (eg, reading, texting, screen time). Start with 5–15 min at a time and gradually build up	Gradual return to typical activities
2	School activities	Homework, reading or other cognitive activities outside of the classroom	Increase tolerance to cognitive work
3	Return to school part-time	Gradual introduction of schoolwork. May need to start with a partial school day or with increased breaks during the day	Increase academic activities
4	Return to school full time	Gradually progress school activities until a full day can be tolerated	Return to full academic activities and catch up on missed work

When a concussion is suspected, the athlete should be removed from the sporting environment and a multimodal assessment should be conducted in a standardised fashion (eg, the SCAT5). Sporting bodies should allow adequate time to conduct this evaluation. For example, completing the SCAT alone typically takes 10 min. Adequate facilities should be provided for the appropriate medical assessment both on and off the field for all injured athletes. In some sports, this may require rule changes to allow an appropriate off-field medical assessment to occur without affecting the flow of the game or unduly penalising the injured player's team. The final determination regarding SRC diagnosis and/or fitness to play is a medical decision based on clinical judgement.

Re-evaluate

An athlete with SRC may be evaluated in the emergency room or doctor's office as a point of first contact after injury or may have been referred from another care provider. In addition to the points outlined above, the key features of follow-up examination should encompass:

a. A medical assessment including a comprehensive history and detailed neurological examination including a thorough assessment of mental status, cognitive functioning, sleep/wake disturbance, ocular function, vestibular function, gait and balance.
b. Determination of the clinical status of the patient, including whether there has been improvement or deterioration since the time of injury. This may involve seeking additional information from parents, coaches, teammates and eyewitnesses to the injury.
c. Determination of the need for emergent neuroimaging to exclude a more severe brain injury (eg, structural abnormality).

Neuropsychological assessment

Neuropsychological assessment (NP) has been previously described by the CISG as a 'cornerstone' of SRC management. Neuropsychologists are uniquely qualified to interpret NP tests and can play an important role within the context of a multifaceted—multimodal and multidisciplinary approach to managing SRC. SRC management programmes that use NP assessment to assist in clinical decision-making have been instituted in professional sports, colleges and high schools.

The application of NP testing in SRC has clinical value and contributes significant information in SRC evaluation.[12–17] Although in most cases, cognitive recovery largely overlaps with the time course of symptom recovery, cognitive recovery may occasionally precede or lag behind clinical symptom resolution, suggesting that the assessment of cognitive function should be an important component in the overall assessment of SRC and, in particular, any return-to-play protocol.[18 19] It must be emphasised, however, that NP assessment should not be the sole basis of management decisions. Rather, it provides an aid to the clinical decision-making process in conjunction with a range of assessments of different clinical domains and investigational results.

It is recommended that all athletes should have a clinical neurological assessment (including evaluation of mental status/cognition, oculomotor function, gross sensorimotor, coordination, gait, vestibular function and balance) as part of their overall management. This will normally be performed by the treating physician, often in conjunction with computerised NP screening tools.

Brief computerised cognitive evaluation tools are a commonly utilised component of these assessments worldwide given the logistical limitation in accessing trained neuropsychologists. However, it should be noted that these are not substitutes for complete NP assessment.

Baseline or pre-season NP testing was considered by the panel and was not felt to be required as a mandatory aspect of every assessment; however, it may be helpful or add useful information to the overall interpretation of these tests. It also provides an additional educative opportunity for the healthcare provider to discuss the significance of this injury with the athlete.

Post-injury NP testing is not required for all athletes. However, when this is considered necessary, the assessment should optimally be performed by a trained and accredited neuropsychologist. Although neuropsychologists are in the best position to interpret NP tests by virtue of their background and training, the ultimate return-to-play decision should remain a medical one in which a multidisciplinary approach, when possible, has been taken. In the absence of NP and other testing, a more conservative return-to-play approach may be appropriate.

Post-injury NP testing may be used to assist return-to-play decisions and is typically performed when an athlete is clinically asymptomatic. However, NP assessment may add important information in the early stages after injury.[20 21] There may be particular situations where testing is performed early to assist in determining aspects of management—for example, return to school in a paediatric athlete. This will normally be best determined in consultation with a trained neuropsychologist.[22 23]

Concussion investigations

Over the past decade, we have observed major progress in clinical methods for evaluation of SRC and in determining the natural history of clinical recovery after injury. Critical questions remain, however, about the acute neurobiological effects of SRC on brain structure and function, and the eventual time course of physiological recovery after injury. Studies using advanced neuroimaging techniques have demonstrated that SRC is associated with changes in brain structure and function, which

correlate with post-concussive symptoms and performance in neurocognitive testing during the acute post-injury phase.

The assessment of novel and selective fluid (eg, blood, saliva and cerebrospinal fluid) biomarkers and genetic testing for TBI has rapidly expanded in parallel with imaging advances, but this currently has limited application to the clinical management of SRC. Extending from the broader TBI literature, there is also increasing interest in the role of genetics in predicting risk of (i) initial injury, (ii) prolonged recovery and long-term neurological health problems associated with SRC, and (iii) repetitive head-impact exposure in athletes.

Clinically, there is a need for diagnostic biomarkers as a more objective means to assess the presence/severity of SRC in athletes. Beyond the potential diagnostic utility, there is also keen interest in the development of prognostic biomarkers of recovery after SRC. Imaging and fluid biomarkers that reliably reflect the extent of neuronal, axonal and glial damage and/or microscopic pathology could conceivably diagnose and predict clinical recovery outcome and/or determine risk of potential cumulative impairments after SRC.

Advanced neuroimaging, fluid biomarkers and genetic testing are important research tools, but require further validation to determine their ultimate clinical utility in evaluation of SRC.

Rest

Most consensus and agreement statements for managing SRC recommend that athletes rest until they become symptom-free. Accordingly, prescribed rest is one of the most widely used interventions in this population. The basis for recommending physical and cognitive rest is that rest may ease discomfort during the acute recovery period by mitigating post-concussion symptoms and/or that rest may promote recovery by minimising brain energy demands following concussion.

There is currently insufficient evidence that prescribing complete rest achieves these objectives. After a brief period of rest during the acute phase (24–48 hours) after injury, patients can be encouraged to become gradually and progressively more active while staying below their cognitive and physical symptom-exacerbation thresholds (ie, activity level should not bring on or worsen their symptoms). It is reasonable for athletes to avoid vigorous exertion while they are recovering. The exact amount and duration of rest is not yet well defined in the literature and requires further study.

Rehabilitation

This summary statement regarding the potential for concussion rehabilitation must be read in conjunction with the systematic review paper, which details the background, search strategy, citations and reasoning for this statement. As 'Rehabilitation' did not exist as a separate section in the previous Consensus Statements, this section is all in italics.

SRCs can result in diverse symptoms and problems, and can be associated with concurrent injury to the cervical spine and peripheral vestibular system. The literature has not evaluated early interventions, as most individuals recover in 10–14 days. A variety of treatments may be required for ongoing or persistent symptoms and impairments following injury. The data support interventions including psychological, cervical and vestibular rehabilitation.

In addition, closely monitored active rehabilitation programmes involving controlled sub-symptom-threshold, submaximal exercise have been shown to be safe and may be of benefit in facilitating recovery. A collaborative approach to treatment, including controlled cognitive stress, pharmacological treatment, and school accommodations, may be beneficial.

Further research evaluating rest and active treatments should be performed using high-quality designs that account for potential confounding factors, and have matched controls and effect modifiers to best inform clinical practice and facilitate recovery after SRC.

Refer

Persistent symptoms

A standard definition for persistent post-concussive symptoms is needed to ensure consistency in clinical management and research outcomes. The Berlin expert consensus is that use of the term 'persistent symptoms' following SRC should reflect failure of normal clinical recovery—that is, symptoms that persist beyond expected time frames (ie, >10–14 days in adults and >4 weeks in children).

'Persistent symptoms' does not reflect a single pathophysiological entity, but describes a constellation of non-specific post-traumatic symptoms that may be linked to coexisting and/or confounding factors, which do not necessarily reflect ongoing physiological injury to the brain. A detailed multimodal clinical assessment is required to identify specific primary and secondary pathologies that may be contributing to persisting post-traumatic symptoms. At a minimum, the assessment should include a comprehensive history, focused physical examination, and special tests where indicated (eg, graded aerobic exercise test). Currently, while there is insufficient evidence for investigations, such as EEG, advanced neuroimaging techniques, genetic testing and biomarkers, to recommend a role in the clinical setting, their use in the research setting is encouraged.

Treatment should be individualised and target-specific medical, physical and psychosocial factors identified on assessment. There is preliminary evidence supporting the use of:

a. *an individualised symptom-limited aerobic exercise programme in patients with persistent post-concussive symptoms associated with autonomic instability or physical deconditioning, and*
b. *a targeted physical therapy programme in patients with cervical spine or vestibular dysfunction, and*
c. *a collaborative approach including cognitive behavioural therapy to deal with any persistent mood or behavioural issues.*

Currently, there is limited evidence to support the use of pharmacotherapy. If pharmacotherapy is used, then an important consideration in return to sport is that concussed athletes should not only be free from concussion-related symptoms, but also should not be taking any pharmacological agents/medications that may mask or modify the symptoms of SRC. Where pharmacological therapy may be begun during the management of an SRC, the decision to return to play while still on such medication must be considered carefully by the treating clinician.

Overall, these are difficult cases that should be managed in a multidisciplinary collaborative setting, by healthcare providers with experience in SRC.

Recovery

There is tremendous interest in identifying factors that might influence or modify outcome from SRC. Clinical recovery is defined functionally as a return to normal activities, including school, work and sport, after injury. Operationally, it encompasses

a resolution of post-concussion-related symptoms and a return to clinically normal balance and cognitive functioning.

It is well established that SRCs can have large adverse effects on cognitive functioning and balance in the first 24–72 hours after injury. Injured athletes report diverse physical, cognitive and emotional symptoms during the initial days after injury, and a greater number and severity of symptoms after an SRC predict a slower recovery in some studies.

For most injured athletes, cognitive deficits, balance and symptoms improve rapidly during the first 2 weeks after injury. Many past studies, particularly those published before 2005, concluded that most athletes recover from SRC and return to sport within 10 days. This is generally true, but that conclusion should be tempered by the fact that many studies reported group-level findings only, not clinical outcomes from individual athletes, and group statistical analyses can obscure subgroup results and individual differences. There is also historical evidence that some athletes returned to play while still symptomatic, well before they were clinically recovered. Moreover, during the past 10 years, there has been a steadily accumulating literature that a sizeable minority of youth, high-school and collegiate athletes take much longer than 10 days to clinically recover and return to sport.

Some authors have suggested that the longer recovery times reported in more recent studies partially reflects changes in the medical management of SRC, with adoption of the gradual return-to-play recommendations from the CISG statements. This seems likely because these return-to-play recommendations include no same-day return to play and a sequential progression through a series of steps before medical clearance for return to sport. Longer recovery times reported by some studies are also significantly influenced by ascertainment bias—that is, studies that rely, or report data, on clinical samples have a major selection bias and will report longer recovery times than those reported from truly incident cohort studies that provide a more accurate estimate of recovery time.

At present, it is reasonable to conclude that the large majority of injured athletes recover, *from a clinical perspective*, within the first month of injury. Neurobiological recovery might extend beyond clinical recovery in some athletes. Clinicians know that some student athletes report persistent symptoms for many months after injury, that there can be multiple causes for those symptoms, and that those individuals are more likely to be included in studies conducted at specialty clinics. There is a growing body of literature indicating that psychological factors play a significant role in symptom recovery and contribute to risk of persistent symptoms in some cases.

Researchers have investigated whether pre-injury individual differences, initial injury severity indicators, acute clinical effects, or subacute clinical effects or comorbidities influence outcome after SRC. Numerous studies have examined whether genetics, sex differences, younger age, neurodevelopmental factors such as attention deficit hyperactivity disorder or learning disability, personal or family history of migraine, or a personal or family history of mental health problems are predictors or effect modifiers of clinical recovery from SRC. Having a past SRC is a risk factor for having a future SRC, and having multiple past SRCs is associated with having more physical, cognitive and emotional symptoms before participation in a sporting season. Therefore, it is not surprising that researchers have studied whether having prior SRCs is associated with slower recovery from an athlete's next SRC. There have been inconsistent findings regarding whether specific *injury severity characteristics*, such as loss of consciousness, retrograde amnesia, or post-traumatic amnesia, are associated with greater acute effects or prolonged recovery. Numerous *post-injury clinical factors*, such as the initial severity of cognitive deficits, the development of post-traumatic headaches or migraines, experiencing dizziness, difficulties with oculomotor functioning, and experiencing symptoms of depression have all been associated with worse outcomes in some studies.

The strongest and most consistent predictor of slower recovery from SRC is the severity of a person's initial symptoms in the first day, or initial few days, after injury. Conversely, and importantly, having a low level of symptoms in the first day after injury is a favourable prognostic indicator. The development of subacute problems with migraine headaches or depression are likely risk factors for persistent symptoms lasting more than a month. Children, adolescents and young adults with a pre-injury history of mental health problems or migraine headaches appear to be at somewhat greater risk of having symptoms for more than 1 month. Those with attention deficit hyperactivity disorder or learning disabilities might require more careful planning and intervention regarding returning to school, but they do not appear to be at substantially greater risk of persistent symptoms beyond a month. Very little research to date has been carried out on children under the age of 13. There is some evidence that the teenage years, particularly the high-school years, might be the most vulnerable time period for having persistent symptoms—with greater risk for girls than boys.

Establishing time of recovery for SRC

Establishing the time of recovery after an SRC is a difficult task for healthcare providers. These determinations have been limited by lack of a gold standard as well as subjective symptom scores and imperfect clinical and NP testing. In addition, patients frequently experience more persistent symptoms, including, but not limited to, chronic migraines, anxiety, post-traumatic stress disorder (PTSD), attention problems and sleep dysfunction. Clinicians must determine whether these are premorbid maladies, downstream effects of SRC, or unrelated challenges while being mindful of the potential for repeat injuries when returning patients to sport too early. Providers are often left in a quandary with limited data to make decisions. Moreover, recent literature suggests that the physiological time of recovery may outlast the time for clinical recovery. The consequence of this is as yet unknown, but one possibility is that athletes may be exposed to additional risk by returning to play while there is ongoing brain dysfunction.

In a research context, modalities that measure physiological change after SRC can be categorised into the following:

- *functional MRI (fMRI)*
- *diffusion tensor imaging (DTI)*
- *magnetic resonance spectroscopy (MRS)*
- *cerebral blood flow (CBF)*
- *electrophysiology*
- *heart rate*
- *measure of exercise performance*
- *fluid biomarkers*
- *transcranial magnetic stimulation (TMS).*

Owing to differences in modalities, time course, study design and outcomes, it is not possible to define a single 'physiological time window' for SRC recovery. Multiple studies suggest that physiological dysfunction may outlast current clinical measures of recovery, supporting a 'buffer zone' of gradually increasing activity before full contact risk. Future studies need to use generalisable populations, longitudinal designs following

to physiological and clinical recovery, and careful correlation of neurobiological modalities with clinical measures. At this stage, these modalities, while useful as research tools, are not ready for clinical management.

Return to sport

Graduated return to sport

The process of recovery and then return to sport participation after an SRC follows a graduated stepwise rehabilitation strategy, an example of which is outlined in table 1. This table has been modified from previous versions to improve clarity.

After a brief period of initial rest (24–48 hours), symptom-limited activity can be begun while staying below a cognitive and physical exacerbation threshold (stage 1). Once concussion-related symptoms have resolved, the athlete should continue to proceed to the next level if he/she meets all the criteria (eg, activity, heart rate, duration of exercise, etc) without a recurrence of concussion-related symptoms. Generally, each step should take 24 hours, so that athletes would take a minimum of 1 week to proceed through the full rehabilitation protocol once they are asymptomatic at rest. However, the time frame for RTS may vary with player age, history, level of sport, etc, and management must be individualised.

In athletes who experience prolonged symptoms and resultant inactivity, each step may take longer than 24 hours simply because of limitations in physical conditioning and recovery strategies outlined above. This specific issue of the role of symptom-limited exercise prescription in the setting of prolonged recovery is discussed in an accompanying systematic review.[24] If any concussion-related symptoms occur during the stepwise approach, the athlete should drop back to the previous asymptomatic level and attempt to progress again after being free of concussion-related symptoms for a further 24 hour period at the lower level.

Reconsider

The CISG also considered whether special populations should be managed differently and made recommendations for elite and young athletes.

Elite and non-elite athletes

All athletes, regardless of level of participation, should be managed using the same management principles noted above.

The child and adolescent athlete

The management of SRC in children requires special paradigms suitable for the developing child. The paucity of studies that are specific to children, especially younger children, needs to be addressed as a priority, with the expectation that future CISG consensus meetings will have sufficient studies to review that are age-specific, of high quality, and with a low risk of bias.

We recommend that child and adolescent guidelines refer to individuals 18 years or less. Child-specific paradigms for SRC should apply to children aged 5–12 years, and adolescent-specific paradigms should apply to those aged 13–18 years. The literature does not adequately address the question of age groups in which children with SRC should be managed differently from adults. No studies have addressed whether SRC signs and symptoms differ from adults. The expected duration of symptoms in children with SRC is up to 4 weeks, and further research is required to identify predictors of prolonged recovery. It is recommended that age-specific validated symptom-rating scales be used in SRC assessment, and further research is required to establish the role and utility of computerised NP testing in this age group. Similar to adults, a brief period of physical and cognitive rest is advised after SRC followed by symptom-limited resumption of activity.

Schools are encouraged to have an SRC policy that includes education on SRC prevention and management for teachers, staff, students and parents, and should offer appropriate academic accommodation and support to students recovering from SRC. Students should have regular medical follow-up after an SRC to monitor recovery and help with return to school, and students may require temporary absence from school after injury.

Children and adolescents should not return to sport until they have successfully returned to school. However, early introduction of symptom-limited physical activity is appropriate.

An example of the return-to-school progression is in table 2.

Residual effects and sequelae

This summary statement regarding the potential for long-term sequelae following recurrent head trauma must be read in conjunction with the systematic review paper, which details the background, search strategy, citations and reasoning for this statement.[25]

The literature on neurobehavioral sequelae and long-term consequences of exposure to recurrent head trauma is inconsistent. Clinicians need to be mindful of the potential for long-term problems such as cognitive impairment, depression, etc in the management of all athletes. However, there is much more to learn about the potential cause-and-effect relationships of repetitive head-impact exposure and concussions. The potential for developing chronic traumatic encephalopathy (CTE) must be a consideration, as this condition appears to represent a distinct tauopathy with an unknown incidence in athletic populations. A cause-and-effect relationship has not yet been demonstrated between CTE and SRCs or exposure to contact sports. As such, the notion that repeated concussion or subconcussive impacts cause CTE remains unknown.

The new US National Institutes of Neurological Disease and Stroke (NINDS) and National Institute of Biomedical Imaging and Bioengineering (NIBIB) consensus criteria provide a standardised approach for describing the neuropathology of CTE. More research on CTE is needed to better understand the incidence and prevalence, the extent to which the NP findings cause specific clinical symptoms, the extent to which the neuropathology is progressive, the clinical diagnostic criteria, and other risk or protective factors. Ideally, well-designed case–control or cohort studies can begin to answer these important questions.

Risk reduction

Role of pre-participation SRC evaluation

Acknowledging the importance of an SRC history, and appreciating the fact that many athletes will not recognise all the SRCs they may have suffered in the past, a detailed SRC history is of value.[26–29] Such a history may identify athletes who fit into a high-risk category and provides an opportunity for the healthcare provider to educate the athlete as to the significance of concussive injury.

A structured SRC history should include specific questions as to previous symptoms of an SRC and length of recovery, not just the perceived number of past SRCs. Note that dependence on the recall of concussive injuries by teammates or coaches is unreliable.[26] The clinical history should also include information about all previous head, face or cervical spine injuries, as these may also have clinical relevance. In the setting of maxillofacial and cervical spine injuries, coexistent concussive injuries

may be missed unless specifically assessed. Questions pertaining to disproportionate impact versus symptom-severity matching may alert the clinician to a progressively increasing vulnerability to injury. As part of the clinical history, the health practitioner should seek details regarding protective equipment used at the time of injury for both recent and remote injuries.

There is an additional and often unrecognised benefit of the pre-participation physical examination insofar as the evaluation provides an educative opportunity with the player concerned, as well as consideration of modification of playing behaviour if required.

Prevention

While it is impossible to eliminate all concussion in sport, concussion-prevention strategies can reduce the number and severity of concussions in many sports. Until the past decade, there has been a relative paucity of scientifically rigorous evaluation studies examining the effectiveness of concussion-prevention strategies in sport.

The evidence examining the protective effect of helmets in reducing the risk of SRC is limited in many sports because of the nature of mandatory helmet regulations. There is sufficient evidence in terms of reduction of overall head injury in skiing/snowboarding to support strong recommendations and policy to mandate helmet use in skiing/snowboarding. The evidence for mouthguard use in preventing SRC is mixed, but meta-analysis suggests a non-significant trend towards a protective effect in collision sports, and rigorous case–control designs are required to further evaluate this finding.

The strongest and most consistent evidence evaluating policy is related to body checking in youth ice hockey (ie, disallowing body checking under age 13), which demonstrates a consistent protective effect in reducing the risk of SRC. This evidence has informed policy change in older age groups in non-elite levels, which requires further investigation.

There is minimal evidence to support individual injury-prevention strategies addressing intrinsic risk factors for SRC in sport. However, there is some promise that vision training in collegiate American football players may reduce SRC. Limiting contact in youth football practices has demonstrated some promising results in reducing the frequency of head contact, but there is no evidence to support the translation of these findings to a reduction in SRC. Evaluation of fair play rules in youth ice hockey, tackle training without helmets and shoulder pads in youth American football, and tackle technique training in professional rugby do not lead to a reduction in SRC risk. A recommendation for stricter rule enforcement of red cards for high elbows in heading duels in professional soccer is based on evidence supporting a reduced risk of head contacts and concussion with such enforcement.

Despite a myriad of studies examining SRC-prevention interventions across several sports, some findings remain inconclusive because of conflicting evidence, lack of rigorous study design, and inherent study biases. A clear understanding of potentially modifiable risk factors is required to design, implement and evaluate appropriate prevention interventions to reduce the risk of SRC. In addition, risk factors should be considered as potential confounders or effect modifiers in any evaluation. Biomechanical research (eg, video-analysis) to better understand injury risk behaviour and mechanisms of injury associated with rules will better inform practice and policy decisions. In addition, psychological and sociocultural factors in sport play a significant role in the uptake of any injury-prevention strategy and require consideration.

Knowledge translation

The value of knowledge translation (KT) as part of SRC education is increasingly becoming recognised. Target audiences benefit from specific learning strategies. SRC tools exist, but their effectiveness and impact require further evaluation. The media is valuable in drawing attention to SRC, but efforts need to ensure that the public is aware of the right information, including uncertainties about long-term risks of adverse outcomes. Social media is becoming more prominent as an SRC education tool. Implementation of KT models is one approach organisations can use to assess knowledge gaps, identify, develop and evaluate education strategies, and use the outcomes to facilitate decision-making. Implementing KT strategies requires a defined plan. Identifying the needs, learning styles and preferred learning strategies of target audiences, coupled with evaluation, should be a piece of the overall SRC education puzzle to have an impact on enhancing knowledge and awareness.

As the ability to treat or reduce the effects of concussive injury after the event is an evolving science, education of athletes, colleagues and the general public is a mainstay of progress in this field. Athletes, referees, administrators, parents, coaches and healthcare providers must be educated regarding the detection of SRC, its clinical features, assessment techniques and principles of safe return to play. Methods to improve education, including web-based resources, educational videos and international outreach programmes, are important in delivering the message. Fair play and respect for opponents are ethical values that should be encouraged in all sports and sporting associations. Similarly, coaches, parents and managers play an important part in ensuring these values are implemented on the field of play.[30–43]

In addition, the support and endorsement of sporting bodies such as the International Ice Hockey Federation, Fédération Internationale de Football Association (FIFA) and the International Olympic Committee who initiated this endeavour, as well as organisations that have subsequently supported the CISG meetings, including World Rugby, the International Equestrian Federation and the International Paralympic Committee, should be commended.

CONCLUSION

Since the 1970s, clinicians and scientists have begun to distinguish SRC from other causes of concussion and mTBI, such as motor vehicle crashes. While this seems like an arbitrary separation from other forms of TBI, which account for 80% of such injuries,[44 45] it is largely driven by sporting bodies that see the need to have clear and practical guidelines to determine recovery and safe return to play for athletes with an SRC.

In addition, sports participation provides unique opportunities to study SRC and mTBI, given the detailed SRC phenotype data that are typically available in many sports.[46] Having said that, it is critical to understand that the lessons derived from non-sporting mTBI research informs the understanding of SRC (and vice versa), and this arbitrary separation of sporting versus non-sporting TBI should not be viewed as a dichotomous or exclusive view of TBI. One of the standout features of the Berlin CISG meeting was the engagement by experts from the TBI, dementia, imaging and biomarker world in the process and as coauthors of the systematic reviews, which are published in issue 10 of the *British Journal of Sports Medicine* (Volume 51, 2017).

This consensus document reflects the current state of knowledge and will need to be modified according to the development of new knowledge. It should be read in conjunction with the systematic reviews and methodology papers that accompany this document (*British Journal of Sports Medicine*, issues 11 and 12, 2017). This document is first and foremost intended to inform clinical practice; however, it must be remembered that, while agreement exists on the principal messages conveyed by this document, the authors acknowledge that the science of concussion is incomplete and therefore management and return-to-play decisions lie largely in the realm of clinical judgement on an individualised basis.

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