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# Head Injury Testing & Management Protocol

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**Athletic Training Services Head Injury Testing and Management Protocol:**

## Purpose

- To be in accordance with current accepted best practices for head injury and concussion management in sport.
- To obtain medical history of concussion, and possibly baseline cognitive and balance information for patients who, through the normal course of athletic activity, are at increased risk of suffering a concussion.
- To guide patient care decisions for appropriate return to physical and cognitive activity following a concussion.

## Education

- Athletic Training Services will provide and discuss educational information to all varsity and club sports officers, patients, coaches, athletic administrators, team physicians and athletic trainers on a yearly basis including but not limited to, the signs and symptoms of concussion, encouragement to report their own and/or teammate’s/player’s signs and symptoms and the health risks associated with not reporting symptoms. Each student-athlete will initial and sign the Student Athlete Injury and Illness Responsibility Statement (Appendix I), which is collected and held by the Department of Athletics

## Reducing Exposure to Head Trauma

- Athletic Training Services is an autonomous administrative unit, separate from varsity athletics that is supported by the *Inter-Association Consensus: Independent Medical Care for College Student-Athletes Best Practices* and the *Inter-Association Consensus Statement on Best Practices for Sports Medicine Management for Secondary Schools and Colleges.*
- In working with the Departments of Athletics and Physical Education, Recreation and Dance, Athletic Training Services will, through the examination of literature and injury trends at Boston University, emphasize ways to minimize head trauma exposure including, but not limited to:
    - Reducing gratuitous contact during practice
    - Taking a “safety first” approach to sport
    - Taking the head out of contact
    - Coach and student-athlete education regarding safe and proper technique

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## Baseline Testing

- Athletic Training Services will obtain baseline information for patients to aid in clinical decision making for patients who suffer a concussion.
- Patients will be tested with the following tools:
    - Sport Concussion Assessment Tool, 5th Edition (SCAT5) **designed and supported by the Consensus Statement on Concussion in Sport: the 5th International Conference on Concussion in Sport (Berlin 2016)*
    - Immediate Post-Concussion Assessment and Cognitive Testing Program (ImPACT®), **designed and supported by the University of Pittsburgh Medical Center*
    - Biodex Balance System™ SD, **designed and supported by Biodex*
- Patient testing shall be conducted in an area designated by the Department of Athletic Training Services. All reasonable steps will be taken to ensure the patient will not take a test in a distracting environment.
- All patients that are a member of a Boston University varsity sport will receive cognitive and balance baseline testing via the SCAT5 or ImPACT and Biodex completed and reviewed prior to their first physical activity (practice, game or conditioning session) of their first season with the team.
- Patient populations to be tested with the ImPACT and Biodex platforms:
    - Men's Basketball
    - Women's Basketball
    - Cheerleading
    - Dance
    - Men's Diving
    - Women's Diving
    - Women's Field Hockey
    - Men's Ice Hockey
    - Women's Ice Hockey
    - Men's Lacrosse
    - Women's Lacrosse
    - Men's Pole Vaulting
    - Women's Pole Vaulting
    - Men's Soccer
    - Women's Soccer
    - Men's Rugby
    - Women's Rugby
    - Women's Softball
- Further baseline testing will be determined on an individual basis as deemed appropriate by Athletic Training Services.
- Additionally, the following patients from all sports will be tested for baseline levels if any of the following conditions are met:
    - History of head injury or one diagnosed concussion;
    - History of loss of consciousness or "blackouts";
    - History of "getting dinged", "having their bell rung", "feeling foggy" or experiencing remarkable symptoms lasting longer than 20 minutes following a mechanism for head injury;
    - History of cranial surgery;
    - History of seizures

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- Further baseline testing will be determined on an individual basis as deemed appropriate by Athletic Training Services.
- All other patients may receive a baseline test upon request.

## Recognition and Diagnosis of Head Injury

A licensed athletic trainer or appropriate medical designee under the direction of the Medical Director must be "present" at all competitions in the following contact/collision sports sponsored by Boston University: basketball, field hockey, ice hockey, lacrosse, pole vault, rugby and soccer. To be present means to be on site at the campus or arena of competition.

*** In accordance with city of Boston legislation *An Ordinance Creating a College Athlete Head Injury Gameday Safety Protocol***

- All varsity ice hockey and men's lacrosse competitions hosted by Boston University will be staffed with an on-site Neurotrauma Consultant. The Neurotrauma Consultant shall be a physician who is board certified or board eligible in neurology, neurological surgery, emergency medicine, physical medicine and rehabilitation, or primary care CAQ sports medicine certified physician. The Neurotrauma Consultant shall be present at the level of the event's playing surface, and with full access to the benches and/or sidelines of any participating athletic program.
- It will be the procedure of Athletic Training Services to provide written authorization to the Director of Athletics when a patient has been determined by the Medical Director, or his/her appropriately licensed designee, to be medically compliant to return to athletic participation.

A licensed athletic trainer or appropriate medical designee under the direction of the Medical Director must be "available" at all practices in the following contact/collisions sports sponsored by Boston University: basketball, field hockey, ice hockey, lacrosse, pole vault, rugby and soccer. To be available means that, at a minimum, medical personnel can be contacted at any time during the practice via telephone, messaging, email, beeper or other immediate communication means to facilitate case discussion and to formulate immediate arrangements for the patient to be evaluated.

In the event of a suspected head injury, including concussion, stroke and other traumatic brain injury (TBI), an evaluation will be conducted by a licensed athletic trainer or team physician in accordance with the Consensus Statement on Concussion in Sport: the 5$^{th}$ International Conference on Concussion in Sport (Berlin 2016) (Appendix II). The return to activity decision will be made by either a licensed athletic trainer or team physician.

In the event that a patient exhibits signs or symptoms of head injury, including concussion, stroke or other TBI that occurs during practice or competition, the individual will be removed from participation and a side-line evaluation will be conducted by a licensed athletic

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trainer or team physician in accordance with the Consensus Statement on Concussion in Sport: the 5th International Conference on Concussion in Sport (Berlin 2016) (Appendix II). This initial evaluation must encompass a symptom assessment, physical and neurological exam, cognitive assessment, balance exam, and clinical assessment for cervical spine trauma, skull fracture and intracranial bleed. If the result of that evaluation is the suspicion of concussion, the patient will be removed from participation for the remainder of that day and a more comprehensive evaluation will be conducted if deemed appropriate. This will include all patients who, for any amount of time, become unconscious following a suspected head injury. The results of all evaluations will be reported to the Medical Director and the treating clinician will follow the Clinician Concussion Management Checklist (Appendix III).

The Emergency Action Plan will be activated when a patient requires transportation for further immediate medical care for any of the following: Glasgow Coma Scale <13, prolonged loss of consciousness, focal neurological deficit suggesting intracranial trauma, repetitive emesis, persistently diminishing/worsening mental status or other neurological signs/symptoms and spine injury.

## Post-Injury Management

If a patient is determined unable to return to play due to head injury, they will be monitored serially throughout the remainder of the event for deterioration and referred to emergency medical services if warranted as mentioned above. All patients will be provided with an Informational Handout (Appendix IV) about their injury and recommendations for their review as well as Cognitive Rest Letters (Appendix V) that may be presented to their instructors that outlines the importance of cognitive rest including, but not limited to, classroom activity on the day of injury. In addition, Athletic Training Services will document oral and/or written care guidelines presented to both the patient and another responsible adult following diagnosis. This injury will be recorded in the Electronic Health Record (EHR) and entered into the disease management module within the EHR to ensure that healthcare providers in primary care and behavioral medicine at Student Health Services (SHS) can assist in monitoring the patient's condition.

A comprehensive follow up evaluation may occur every 24 hours following injury, and/or more/less frequently at the discretion of Athletic Training Services to consider additional diagnoses and best management options. Components of this evaluation can include a graded symptom checklist as outlined in the SCAT5 (Appendix VI), the Buffalo Concussion Treadmill Test (Appendix VII), the Vestibular-Oculomotor Screening (Appendix VIII), and/or other clinically relevant assessment tools. Information gathered from these assessment tools will aid in the development of individualized care plans targeted to each patient's specific clinical trajectory in an effort to introduce symptom limited physical activity and therapeutic exercise. All treatment decisions will be rendered based on clinical discretion with approval from the Medical Director. Athletic Training Services and, the Medical Director, or another team physician will, at any time during the rehabilitation process, refer the patient to a neuro-psychological specialist if deemed appropriate.

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## Return to Learn

The patient will be responsible for all academic requirements and coordinating any missed class time or assignments with their instructors. Athletic Training Services will notify the Director of Student-Athlete Support Services following the diagnosis of a head injury to identify a point-person to navigate the return to learn process with all patients that are members of varsity teams. Specific recommendations regarding appropriate return to learn progressions will be made on an individual basis through the collaboration between the patient, Athletic Training Services, the Medical Director, and other appropriate members of the multidisciplinary care team as deemed necessary. Continued or worsening symptoms with light cognitive activity and a gradual return to classroom/studying will prompt a re-evaluation by the coordinating team physician to determine if further schedule/academic accommodations are needed. In cases that require modifications beyond 10 days, patients will be referred to a campus resources such as the Office of Disability Services, learning specialists, and/or the Americans with Disabilities Amendments Act office.

## Return to Sport

The patient's return to sport progression will be managed in accordance to the Graduated Return to Sport Strategy located at the end of this document. The first stage in this stepwise progression is symptom limited physical and cognitive activity. Therefore, the patient will be withheld from all athletic related physical activity, which includes, but is not limited to; practice, games, weight lifting, conditioning, etc. until they are deemed fit to progress by Athletic Training Services. Furthermore, it will be the recommendation of Athletic Training Services that the patient avoid all symptom-provoking cognitive stressors, which include, but are not limited to; reading, extended time in front of computers or television, video games, cell phone and iPod use, etc. until deemed fit to progress by Athletic Training Services.

At the time the patient is evaluated as asymptomatic at rest, the next rehabilitation stage will be initiated in the Graduated Return to Sport Strategy located at the end of this document. Furthermore, Athletic Training Services will administer neurocognitive testing (ImPACT® and Biodex balance tests) and their scores will be compared to their baseline test scores when applicable. In the event that a patient without a baseline exam suffers a head injury, their results will be compared to national norms as provided by the University of Pittsburgh Medical Center and ImPACT® and Biodex respectively. These normative values can be found at www.impacttest.com for the ImPACT® test and are included in the report generated by the Biodex Balance System™ SD. Follow-up neurocognitive testing (ImPACT® and Biodex tests) will be administered by Athletic Training Services at their discretion until results return to baseline. Each patient suffering a concussion will be progressed through the Graduated Return to Sport Strategy at a pace deemed appropriate by Athletic Training Services. This pace may differ on a case-by-case basis. In the event that a patient reports a return of symptoms during the Graduated Return to Sport Strategy they will be regressed to the previous rehabilitation stage until they have been evaluated as asymptomatic for a period of at least 24 hours.

The final return to play decision will be made by the Medical Director, or his/her appropriately licensed designee, following consideration of the completion of the Graduated

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Return to Sport Strategy to the satisfaction of Athletic Training Services, comparison of current neuro-cognitive and balance testing results with respect to baseline/norms, and the recommendation of any and all specialists involved in the management of the case.

In the event of a patient's evaluation not returning to baseline they will be referred to the appropriate specialist as seen fit by Athletic Training Services under the direction of the Medical Director.

Patients with previous concussion over the past year who had not retested back to baseline or who had persistent symptoms which had not completely resolved prior to the end of the academic year, should be retested prior to the onset of activity.

## Management of Persistent Symptoms:

Athletic Training Services, under the direction of the Medical Director, will manage patients who suffer persistent symptoms following concussion according to the Buffalo Concussion Treadmill Test (Appendix VII) to both differentiate and diagnose each patient's symptoms, and to appropriately introduce symptom-limited physical activity. Vestibular Oculo-Motor Screening (Appendix VIII) and further assessment will also be completed with all patients. The timing for implementation of this test or other post-concussion screenings and treatments will be determined on a case-by-case basis.

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Graduated Return to Sport Strategy

| Stage | Aim | Activity | Goal of each step |
|---|---|---|---|
| 1 | Symptom-limited activity | Daily activities that do not provoke symptoms | Gradual introduction 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 | Full return |

**Appendix I:** Student-Athlete Injury and Illness Responsibility Statement
**Appendix II:** Consensus Statement on Concussion in Sport: the 5th International Conference on Concussion in Sport held in Berlin, October 2016
**Appendix III**: Clinician Concussion Management Checklist
**Appendix IV:** Informational Handout
**Appendix V:** Cognitive-Rest Letter
**Appendix VI:** Sport Concussion Assessment Tool, 5th Edition (SCAT5)
**Appendix VII:** Buffalo Concussion Treadmill Test (BCTT)
**Appendix VIII:** Vestibular Oculo-Motor Screening (VOMS)

# **Appendix I:** Student-Athlete Injury and Illness Responsibility Statement

## Boston University
## Student-Athlete Injury and Illness Responsibility Statement

______ Initial — As a student-athlete at Boston University, I understand that it is my responsibility to report all injuries and illness to an athletic trainer and/or team physician.

______ Initial — I have been provided with educational material on concussions and understand the importance of reporting all symptoms to an athletic trainer and/or team physician.

After receiving the provided information on concussions, I am aware of the following information:

______ Initial — A concussion is a brain injury and it is my responsibility to report all symptoms to an athletic trainer and/or team physician.

______ Initial — A concussion can affect my ability to perform everyday activities, and affect reaction time, balance, sleep and classroom performance.

______ Initial — I will not return to play in a game or practice if I have received a blow to the head or body that results in concussion-related symptoms.

______ Initial — If I acquire an injury that results in concussion-related symptoms I will follow all instructions relating to the treatment of my injury given to me by a member of Athletic Training Services and team physicians.

______ Initial — If I suspect a teammate or fellow athlete has a concussion, I am responsible for reporting this information to an athletic trainer and/or team physician.

______ Initial — Following a concussion the brain needs time to heal. Returning to activity before the brain has fully healed increases the risk of having a repeat concussion. In rare cases, repeat concussions can cause permanent brain damage and even death.

______________________________ ______________
Signature of Student-Athlete Date

______________________________ ______________
Printed Name of Student-Athlete Sport

# **Appendix II:** Consensus Statement on Concussion in Sport: the 5th International Conference in Sport held in Berlin, October 2016

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# 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.

Readers are encouraged to copy and freely distribute this Berlin Consensus Statement on Concussion in Sport, the Concussion Recognition Tool version 5 (CRT5), the Sports Concussion Assessment Tool version 5 (SCAT5) and/or the Child SCAT5. None of these are subject to copyright restriction, provided they are used in their complete format, are not altered in any way, not sold for commercial gain or rebranded, not converted into a digital format without permission, and are cited correctly.

### 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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## APPENDIX 1

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BJSM

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

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# **Appendix III**: Clinician Concussion Management Checklist

**Clinician Concussion Immediate Management Checklist:**

- Educate the patient on pathology, prognosis and acute management (24-72 hours)
- Provide patient with printed concussion handout (found on the J-Drive)
- Provide patient with printed cognitive rest letters (for all professors)
- Alert Medical Director, Dr. Comeau, to patient's injury and relevant plans (can be done through a PNC message)
- Alert Student Athlete Support Services to patient's injury to discuss academic accommodations (if varsity athlete)
- Establish plan for patient to be physically seen by a physician in clinic prior to return to play (does not need to be Dr. Comeau)
- Answer all relevant patient questions
- Establish specific follow up plans with patient and pertinent clinicians
- Provide patient with AT contact information
- Educate roommate on pertinent information if available
- Create a problem for this head injury in the patient's problem list (document with onset date and denote concussion as *active*)
- When documenting, CC Neurotrauma Resident on initial visit note and all subsequent notes in PNC

**Clinician Concussion Follow-up Management Checklist:**

- Daily SCAT 5 Symptom Evaluations should be completed by the patient during their symptomatic period and should be scanned into patient chart
- When documenting, progress notes should be completed in PNC weekly during the symptomatic period, or sooner if pertinent changes occur in the patient's recovery timeline
- If care is required longer than 10 days a plan should be established for a referral to disability services
- Once asymptomatic, separate documentation for each stage of the RTP should be completed in PNC
- Post-injury neurocognitive testing should be completed before the patient's return to full contact activity and should be review by a physician before full clearance – documentation of this physician encounter as well as the post-injury tests should be located in the patient's chart
- Upon discharge of this patient, the problem in this patient's problem list should be denoted as *resolved*, and an email to buathdir@bu.edu stating that the patient has been fully discharged and cleared for full activity should be completed in addition to the patient's discharge note in PNC

*** Neurotrauma Resident and Staff Experts should be consulted when structuring treatment plans as patient transitions from acute to sub-acute/chronic phases ***

# **Appendix IV:** Informational Handout

# WHAT TO KNOW ABOUT YOUR CONCUSSION

A concussion is a brain injury that disrupts the normal physical, mental and emotional functions of your brain. A period of physical and cognitive rest paired with rehabilitation can help with your recovery. Remember — communication is key! Here is some more information on the first few days of recovery.

## COMMON SIGNS AND SYMPTOMS

**PHYSICAL**

- Headache
- Nausea
- Dizziness
- Light sensitivity
- Noise sensitivity
- Visual problems
- Balance problems

**COGNITIVE**

- Mental fogginess
- Slowed down
- Hard to concentrate
- Hard to remember
- Forgetfulness
- Confusion

**EMOTIONAL**

- Irritability
- Sadness
- Nervousness
- Anxiousness
- More emotional

**SLEEP**

- Drowsiness
- Fatigue
- Sleeping less
- Sleeping more
- Trouble falling asleep

## WHAT TO DO

- ✅ Report all changes in signs and symptoms
- ✅ Get plenty of regularly scheduled sleep at night
- ✅ Eat a regular and nutritious diet
- ✅ Maintain adequate levels of hydration
- ✅ Alert all of your professors, coaches and employers of your injury
- ✅ Take frequent breaks when completing school work
- ✅ Call your healthcare provider with any questions

BOSTON UNIVERSITY TERRIERS

## WHAT TO AVOID

- ❌ Consuming alcohol and drugs
- ❌ Taking NSAIDs (ibuprofen, Advil, Motrin)
- ❌ Loud and excessively stimulating environments such as parties, bars, clubs
- ❌ Excessive screen time (TV, cellphone, iPad, etc.)
- ❌ Physical activity (running, biking, weight lifting, sports, etc.)
- ❌ Operating motor vehicles and heavy machinery

## WHEN TO GO TO THE EMERGENCY ROOM

Intense headache that continues to get worse and does not get better

Weakness, numbness or decreased coordination

Repeated vomiting or nausea

Slurred speech

One pupil is larger than the other

Convulsions or seizures

Cannot recognize people or places

Worsening confusion, restlessness or agitation

Loss of or altered level of consciousness

**Please do not hesitate to call and ask any questions!**

Athletic Training
Case ATR: (617) 353-2746
FitRec ATR: (617) 353-7377
Agganis ATR: (617) 353-7326

Campus Wide
BUPD: (617) 353-2121
SHS: (617) 353-3575

**NEUROCOGNITIVE TESTING**
Balance, cognitive and neurological tests that help medical staff manage and diagnose a concussion

**CONCUSSION**
A traumatic brain injury from a blow to the head or body that results in the rapid onset of short-lived impairment of neurological function that resolves spontaneously.

**RECOVERY**
Structured physical and cognitive rest combined with impairment-based rehabilitation can help promote the best environment for your recovery.

**RETURN TO LEARN**
Return to school should be done in a step-by-step progression in which adjustments are made as needed to manage your symptoms.

**RETURN TO PLAY**
Return to play only happens after you have returned to your pre-concussion baseline and you've gone through a step-by-step progression of increasing activity.

## CONCUSSION TIMELINE

# **Appendix V:** Cognitive-Rest Letter

**Boston University**
Athletic Training Services

285 Babcock Street
Boston, Massachusetts 02215
T: 617-353-2746 F: 617-353-7579
athtrn@bu.edu

*September 20, 2017*

Dear Professor,

This letter is to inform you that *Test-Our, Digna (Test-Id), U88012236* sustained a concussion on **DATE**. As with all injuries, concussions require a period of rest and rehabilitation to heal properly. The function of the brain requires that this rest be from both physical and cognitive exertion. We ask that you please consider these stressors and the overall well-being of *Digna* should they contact you regarding rescheduling academic requirements that may occur during this period of cognitive rest.

Please be aware that our recommendation is for complete physical and cognitive rest until the student is asymptomatic at rest. The student has not been instructed to disregard any academic requirement, but rather to work with each professor to identify a possible adjustment. The student has also been advised that cognitive rest consists of: avoiding unnecessary talking on the phone, text messaging, sitting in front of a computer, watching television and reading. If the period of rest exceeds 7 days, the student will be directed to the Office of Disability Services to determine formal accommodations. If there are questions about course requirements during this period please contact Disability Services at 617-353-3658.

We appreciate your understanding in this matter. If you have any further questions about the nature of this letter or the importance of cognitive rest in the rehabilitation from head injuries, please feel free to contact us.

Sincerely,

Doug Comeau, DO
Medical Director
dcomeau@bu.edu
617-353-2746

PFEIFER, NICHOLAS
Athletic Trainer
NPFEIFER@BU.EDU
617-353-2746

**Referring MD**
Team Physician
atdr@bu.edu
617-353-2746

# **Appendix VI:** Sport Concussion Assessment Tool, 5th Edition (SCAT5)

BJSM Online First, published on April 28, 2017 as 10.1136/bjsports-2017-097506SCAT5

# SCAT5©

**SPORT CONCUSSION ASSESSMENT TOOL — 5TH EDITION**
DEVELOPED BY THE CONCUSSION IN SPORT GROUP
FOR USE BY MEDICAL PROFESSIONALS ONLY

supported by

FIFA

**Patient details**

Name: ______________________________

DOB: ______________________________

Address: ______________________________

ID number: ______________________________

Examiner: ______________________________

Date of Injury: ____________________ Time: ____________________

## WHAT IS THE SCAT5?

**The SCAT5 is a standardized tool for evaluating concussions designed for use by physicians and licensed healthcare professionals[1]. The SCAT5 cannot be performed correctly in less than 10 minutes.**

If you are not a physician or licensed healthcare professional, please use the Concussion Recognition Tool 5 (CRT5). The SCAT5 is to be used for evaluating athletes aged 13 years and older. For children aged 12 years or younger, please use the Child SCAT5.

Preseason SCAT5 baseline testing can be useful for interpreting post-injury test scores, but is not required for that purpose.Detailed instructions for use of the SCAT5 are provided on page 7. Please read through these instructions carefully before testing the athlete. Brief verbal instructions for each test are given in italics. The only equipment required for the tester is a watch or timer.

**This tool may be freely copied in its current form for distribution to individuals, teams, groups and organizations. It should not be altered in any way, re-branded or sold for commercial gain. Any revision, translation or reproduction in a digital form requires specific approval by the Concussion in Sport Group.**

## Recognise and Remove

A head impact by either a direct blow or indirect transmission of force can be associated with a serious and potentially fatal brain injury. If there are significant concerns, including any of the red flags listed in Box 1, then activation of emergency procedures and urgent transport to the nearest hospital should be arranged.

**Key points**

- Any athlete with suspected concussion should be REMOVED FROM PLAY, medically assessed and monitored for deterioration. No athlete diagnosed with concussion should be returned to play on the day of injury.
- If an athlete is suspected of having a concussion and medical personnel are not immediately available, the athlete should be referred to a medical facility for urgent assessment.
- Athletes with suspected concussion should not drink alcohol, use recreational drugs and should not drive a motor vehicle until cleared to do so by a medical professional.
- Concussion signs and symptoms evolve over time and it is important to consider repeat evaluation in the assessment of concussion.
- The diagnosis of a concussion is a clinical judgment, made by a medical professional. The SCAT5 should NOT be used by itself to make, or exclude, the diagnosis of concussion. An athlete may have a concussion even if their SCAT5 is "normal".

**Remember:**

- The basic principles of first aid (danger, response, airway, breathing, circulation) should be followed.
- Do not attempt to move the athlete (other than that required for airway management) unless trained to do so.
- Assessment for a spinal cord injury is a critical part of the initial on-field assessment.
- Do not remove a helmet or any other equipment unless trained to do so safely.

1

## IMMEDIATE OR ON-FIELD ASSESSMENT

The following elements should be assessed for all athletes who are suspected of having a concussion prior to proceeding to the neurocognitive assessment and ideally should be done on-field after the first first aid / emergency care priorities are completed.

If any of the "Red Flags" or observable signs are noted after a direct or indirect blow to the head, the athlete should be immediately and safely removed from participation and evaluated by a physician or licensed healthcare professional.

Consideration of transportation to a medical facility should be at the discretion of the physician or licensed healthcare professional.

The GCS is important as a standard measure for all patients and can be done serially if necessary in the event of deterioration in conscious state. The Maddocks questions and cervical spine exam are critical steps of the immediate assessment; however, these do not need to be done serially.

## STEP 1: RED FLAGS

**RED FLAGS:**

- Neck pain or tenderness
- Double vision
- Weakness or tingling/ burning in arms or legs
- Severe or increasing headache
- Seizure or convulsion
- Loss of consciousness
- Deteriorating conscious state
- Vomiting
- Increasingly restless, agitated or combative

## STEP 2: OBSERVABLE SIGNS

Witnessed ☐ Observed on Video ☐

| | | |
|---|---|---|
| Lying motionless on the playing surface | Y | N |
| Balance / gait difficulties / motor incoordination: stumbling, slow / laboured movements | Y | N |
| Disorientation or confusion, or an inability to respond appropriately to questions | Y | N |
| Blank or vacant look | Y | N |
| Facial injury after head trauma | Y | N |

## STEP 3: MEMORY ASSESSMENT MADDOCKS QUESTIONS[2]

*"I am going to ask you a few questions, please listen carefully and give your best effort. First, tell me what happened?"*

______________________________

______________________________

**Mark Y for correct answer / N for incorrect**

| | | |
|---|---|---|
| What venue are we at today? | Y | N |
| Which half is it now? | Y | N |
| Who scored last in this match? | Y | N |
| What team did you play last week / game? | Y | N |
| Did your team win the last game? | Y | N |

**Note: Appropriate sport-specific questions may be substituted.**

Name: ______________________________

DOB: ______________________________

Address: ______________________________

ID number: ______________________________

Examiner: ______________________________

Date: ______________________________

## STEP 4: EXAMINATION GLASGOW COMA SCALE (GCS)[3]

| | | | |
|---|---|---|---|
| **Time of assessment** | | | |
| **Date of assessment** | | | |
| **Best eye response (E)** | | | |
| No eye opening | 1 | 1 | 1 |
| Eye opening in response to pain | 2 | 2 | 2 |
| Eye opening to speech | 3 | 3 | 3 |
| Eyes opening spontaneously | 4 | 4 | 4 |
| **Best verbal response (V)** | | | |
| No verbal response | 1 | 1 | 1 |
| Incomprehensible sounds | 2 | 2 | 2 |
| Inappropriate words | 3 | 3 | 3 |
| Confused | 4 | 4 | 4 |
| Oriented | 5 | 5 | 5 |
| **Best motor response (M)** | | | |
| No motor response | 1 | 1 | 1 |
| Extension to pain | 2 | 2 | 2 |
| Abnormal flexion to pain | 3 | 3 | 3 |
| Flexion / Withdrawal to pain | 4 | 4 | 4 |
| Localizes to pain | 5 | 5 | 5 |
| Obeys commands | 6 | 6 | 6 |
| **Glasgow Coma score (E + V + M)** | | | |

## CERVICAL SPINE ASSESSMENT

| | | |
|---|---|---|
| Does the athlete report that their neck is pain free at rest? | Y | N |
| **If there is NO neck pain at rest**, does the athlete have a full range of ACTIVE pain free movement? | Y | N |
| Is the limb strength and sensation normal? | Y | N |

**In a patient who is not lucid or fully conscious, a cervical spine injury should be assumed until proven otherwise.**

## OFFICE OR OFF-FIELD ASSESSMENT

**Please note that the neurocognitive assessment should be done in a distraction-free environment with the athlete in a resting state.**

## STEP 1: ATHLETE BACKGROUND

Sport / team / school: ____________________

Date / time of injury: ____________________

Years of education completed: ____________________

Age: ____________________

Gender: M / F / Other

Dominant hand: left / neither / right

How many diagnosed concussions has the athlete had in the past?: ____________________

When was the most recent concussion?: ____________________

How long was the recovery (time to being cleared to play) from the most recent concussion?: ____________________ (days)

**Has the athlete ever been:**

| | | |
|---|---|---|
| Hospitalized for a head injury? | Yes | No |
| Diagnosed / treated for headache disorder or migraines? | Yes | No |
| Diagnosed with a learning disability / dyslexia? | Yes | No |
| Diagnosed with ADD / ADHD? | Yes | No |
| Diagnosed with depression, anxiety or other psychiatric disorder? | Yes | No |

Current medications? If yes, please list:

____________________

____________________

____________________

____________________

____________________

____________________

Name: ____________________

DOB: ____________________

Address: ____________________

ID number: ____________________

Examiner: ____________________

Date: ____________________

2

## STEP 2: SYMPTOM EVALUATION

*The athlete should be given the symptom form and asked to read this instruction paragraph out loud then complete the symptom scale. For the baseline assessment, the athlete should rate his/her symptoms based on how he/she typically feels and for the post injury assessment the athlete should rate their symptoms at this point in time.*

**Please Check:** ☐ **Baseline** ☐ **Post-Injury**

Please hand the form to the athlete

| | none | mild | | moderate | | severe | |
|---|---|---|---|---|---|---|---|
| Headache | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| "Pressure in head" | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Neck Pain | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Nausea or vomiting | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Dizziness | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Blurred vision | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Balance problems | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Sensitivity to light | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Sensitivity to noise | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Feeling slowed down | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Feeling like "in a fog" | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| "Don't feel right" | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Difficulty concentrating | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Difficulty remembering | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Fatigue or low energy | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Confusion | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Drowsiness | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| More emotional | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Irritability | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Sadness | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Nervous or Anxious | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Trouble falling asleep (if applicable) | 0 | 1 | 2 | 3 | 4 | 5 | 6 |

| | |
|---|---|
| Total number of symptoms: | of 22 |
| Symptom severity score: | of 132 |
| Do your symptoms get worse with physical activity? | Y N |
| Do your symptoms get worse with mental activity? | Y N |
| If 100% is feeling perfectly normal, what percent of normal do you feel? | |

If not 100%, why?

____________________

____________________

____________________

Please hand form back to examiner

3

## STEP 3: COGNITIVE SCREENING

**Standardised Assessment of Concussion (SAC)**[4]

Name:

DOB:

Address:

ID number:

Examiner:

Date:

### ORIENTATION

| | | |
|---|---|---|
| What month is it? | 0 | 1 |
| What is the date today? | 0 | 1 |
| What is the day of the week? | 0 | 1 |
| What year is it? | 0 | 1 |
| What time is it right now? (within 1 hour) | 0 | 1 |
| Orientation score | | of 5 |

### IMMEDIATE MEMORY

The Immediate Memory component can be completed using the traditional 5-word per trial list or optionally using 10-words per trial to minimise any ceiling effect. All 3 trials must be administered irrespective of the number correct on the first trial. Administer at the rate of one word per second.

**Please choose EITHER the 5 or 10 word list groups and circle the specific word list chosen for this test.**

*I am going to test your memory. I will read you a list of words and when I am done, repeat back as many words as you can remember, in any order. For Trials 2 & 3: I am going to repeat the same list again. Repeat back as many words as you can remember in any order, even if you said the word before.*

| List | Alternate 5 word lists | | | | | Score (of 5) Trial 1 | Trial 2 | Trial 3 |
|---|---|---|---|---|---|---|---|---|
| A | Finger | Penny | Blanket | Lemon | Insect | | | |
| B | Candle | Paper | Sugar | Sandwich | Wagon | | | |
| C | Baby | Monkey | Perfume | Sunset | Iron | | | |
| D | Elbow | Apple | Carpet | Saddle | Bubble | | | |
| E | Jacket | Arrow | Pepper | Cotton | Movie | | | |
| F | Dollar | Honey | Mirror | Saddle | Anchor | | | |
| | | | | | Immediate Memory Score | of 15 | | |
| | | | | | Time that last trial was completed | | | |

| List | Alternate 10 word lists | | | | | Score (of 10) Trial 1 | Trial 2 | Trial 3 |
|---|---|---|---|---|---|---|---|---|
| G | Finger | Penny | Blanket | Lemon | Insect | | | |
| | Candle | Paper | Sugar | Sandwich | Wagon | | | |
| H | Baby | Monkey | Perfume | Sunset | Iron | | | |
| | Elbow | Apple | Carpet | Saddle | Bubble | | | |
| I | Jacket | Arrow | Pepper | Cotton | Movie | | | |
| | Dollar | Honey | Mirror | Saddle | Anchor | | | |
| | | | | | Immediate Memory Score | of 30 | | |
| | | | | | Time that last trial was completed | | | |

### CONCENTRATION

### DIGITS BACKWARDS

Please circle the Digit list chosen (A, B, C, D, E, F). Administer at the rate of one digit per second reading DOWN the selected column.

*I am going to read a string of numbers and when I am done, you repeat them back to me in reverse order of how I read them to you. For example, if I say 7-1-9, you would say 9-1-7.*

Concentration Number Lists (circle one)

| List A | List B | List C | | | |
|---|---|---|---|---|---|
| 4-9-3 | 5-2-6 | 1-4-2 | Y | N | 0 |
| 6-2-9 | 4-1-5 | 6-5-8 | Y | N | 1 |
| 3-8-1-4 | 1-7-9-5 | 6-8-3-1 | Y | N | 0 |
| 3-2-7-9 | 4-9-6-8 | 3-4-8-1 | Y | N | 1 |
| 6-2-9-7-1 | 4-8-5-2-7 | 4-9-1-5-3 | Y | N | 0 |
| 1-5-2-8-6 | 6-1-8-4-3 | 6-8-2-5-1 | Y | N | 1 |
| 7-1-8-4-6-2 | 8-3-1-9-6-4 | 3-7-6-5-1-9 | Y | N | 0 |
| 5-3-9-1-4-8 | 7-2-4-8-5-6 | 9-2-6-5-1-4 | Y | N | 1 |
| **List D** | **List E** | **List F** | | | |
| 7-8-2 | 3-8-2 | 2-7-1 | Y | N | 0 |
| 9-2-6 | 5-1-8 | 4-7-9 | Y | N | 1 |
| 4-1-8-3 | 2-7-9-3 | 1-6-8-3 | Y | N | 0 |
| 9-7-2-3 | 2-1-6-9 | 3-9-2-4 | Y | N | 1 |
| 1-7-9-2-6 | 4-1-8-6-9 | 2-4-7-5-8 | Y | N | 0 |
| 4-1-7-5-2 | 9-4-1-7-5 | 8-3-9-6-4 | Y | N | 1 |
| 2-6-4-8-1-7 | 6-9-7-3-8-2 | 5-8-6-2-4-9 | Y | N | 0 |
| 8-4-1-9-3-5 | 4-2-7-9-3-8 | 3-1-7-8-2-6 | Y | N | 1 |
| | | Digits Score: | | | of 4 |

### MONTHS IN REVERSE ORDER

*Now tell me the months of the year in reverse order. Start with the last month and go backward. So you'll say December, November. Go ahead.*

| | |
|---|---|
| Dec - Nov - Oct - Sept - Aug - Jul - Jun - May - Apr - Mar - Feb - Jan | 0 1 |
| Months Score | of 1 |
| Concentration Total Score (Digits + Months) | of 5 |

4

## STEP 4: NEUROLOGICAL SCREEN

See the instruction sheet (page 7) for details of test administration and scoring of the tests.

| | | |
|---|---|---|
| Can the patient read aloud (e.g. symptom check-list) and follow instructions without difficulty? | Y | N |
| Does the patient have a full range of pain-free PASSIVE cervical spine movement? | Y | N |
| Without moving their head or neck, can the patient look side-to-side and up-and-down without double vision? | Y | N |
| Can the patient perform the finger nose coordination test normally? | Y | N |
| Can the patient perform tandem gait normally? | Y | N |

## BALANCE EXAMINATION

**Modified Balance Error Scoring System (mBESS) testing[5]**

Which foot was tested (i.e. which is the non-dominant foot) ☐ Left ☐ Right

Testing surface (hard floor, field, etc.) ______

Footwear (shoes, barefoot, braces, tape, etc.) ______

| Condition | Errors |
|---|---|
| **Double leg stance** | of 10 |
| **Single leg stance (non-dominant foot)** | of 10 |
| **Tandem stance (non-dominant foot at the back)** | of 10 |
| **Total Errors** | of 30 |

Name: ______

DOB: ______

Address: ______

ID number: ______

Examiner: ______

Date: ______

5

## STEP 5: DELAYED RECALL:

The delayed recall should be performed after 5 minutes have elapsed since the end of the Immediate Recall section. Score 1 pt. for each correct response.

*Do you remember that list of words I read a few times earlier? Tell me as many words from the list as you can remember in any order.*

**Time Started**

Please record each word correctly recalled. Total score equals number of words recalled.

______

______

______

**Total number of words recalled accurately:** of 5 or of 10

6

## STEP 6: DECISION

| Domain | Date & time of assessment: | | |
|---|---|---|---|
| Symptom number (of 22) | | | |
| Symptom severity score (of 132) | | | |
| Orientation (of 5) | | | |
| Immediate memory | of 15<br>of 30 | of 15<br>of 30 | of 15<br>of 30 |
| Concentration (of 5) | | | |
| Neuro exam | Normal<br>Abnormal | Normal<br>Abnormal | Normal<br>Abnormal |
| Balance errors (of 30) | | | |
| Delayed Recall | of 5<br>of 10 | of 5<br>of 10 | of 5<br>of 10 |

Date and time of injury: ______

If the athlete is known to you prior to their injury, are they different from their usual self?

☐ **Yes** ☐ **No** ☐ **Unsure** ☐ **Not Applicable**

(If different, describe why in the clinical notes section)

Concussion Diagnosed?

☐ **Yes** ☐ **No** ☐ **Unsure** ☐ **Not Applicable**

If re-testing, has the athlete improved?

☐ **Yes** ☐ **No** ☐ **Unsure** ☐ **Not Applicable**

**I am a physician or licensed healthcare professional and I have personally administered or supervised the administration of this SCAT5.**

Signature: ______

Name: ______

Title: ______

Registration number (if applicable): ______

Date: ______

**SCORING ON THE SCAT5 SHOULD NOT BE USED AS A STAND-ALONE METHOD TO DIAGNOSE CONCUSSION, MEASURE RECOVERY OR MAKE DECISIONS ABOUT AN ATHLETE'S READINESS TO RETURN TO COMPETITION AFTER CONCUSSION.**

## CLINICAL NOTES:

Name:

DOB:

Address:

ID number:

Examiner:

Date:

## CONCUSSION INJURY ADVICE

**(To be given to the person monitoring the concussed athlete)**

This patient has received an injury to the head. A careful medical examination has been carried out and no sign of any serious complications has been found. Recovery time is variable across individuals and the patient will need monitoring for a further period by a responsible adult. Your treating physician will provide guidance as to this timeframe.

**If you notice any change in behaviour, vomiting, worsening headache, double vision or excessive drowsiness, please telephone your doctor or the nearest hospital emergency department immediately.**

Other important points:

**Initial rest: Limit physical activity to routine daily activities (avoid exercise, training, sports) and limit activities such as school, work, and screen time to a level that does not worsen symptoms.**

1) Avoid alcohol
2) Avoid prescription or non-prescription drugs without medical supervision. Specifically:
   a) Avoid sleeping tablets
   b) Do not use aspirin, anti-inflammatory medication or stronger pain medications such as narcotics
3) Do not drive until cleared by a healthcare professional.
4) Return to play/sport requires clearance by a healthcare professional.

**Clinic phone number:**

Patient's name:

Date / time of injury:

Date / time of medical review:

Healthcare Provider:



Contact details or stamp

# INSTRUCTIONS

## Words in *Italics* throughout the SCAT5 are the instructions given to the athlete by the clinician

### Symptom Scale

The time frame for symptoms should be based on the type of test being administered. At baseline it is advantageous to assess how an athlete "typically" feels whereas during the acute/post-acute stage it is best to ask how the athlete feels at the time of testing.

The symptom scale should be completed by the athlete, not by the examiner. In situations where the symptom scale is being completed after exercise, it should be done in a resting state, generally by approximating his/her resting heart rate.

For total number of symptoms, maximum possible is 22 except immediately post injury, if sleep item is omitted, which then creates a maximum of 21.

For Symptom severity score, add all scores in table, maximum possible is 22 x 6 = 132, except immediately post injury if sleep item is omitted, which then creates a maximum of 21x6=126.

### Immediate Memory

The Immediate Memory component can be completed using the traditional 5-word per trial list or, optionally, using 10-words per trial. The literature suggests that the Immediate Memory has a notable ceiling effect when a 5-word list is used. In settings where this ceiling is prominent, the examiner may wish to make the task more difficult by incorporating two 5–word groups for a total of 10 words per trial. In this case, the maximum score per trial is 10 with a total trial maximum of 30.

Choose one of the word lists (either 5 or 10). Then perform 3 trials of immediate memory using this list.

Complete all 3 trials regardless of score on previous trials.

*"I am going to test your memory. I will read you a list of words and when I am done, repeat back as many words as you can remember, in any order."* The words must be read at a rate of one word per second.

Trials 2 & 3 MUST be completed regardless of score on trial 1 & 2.

Trials 2 & 3:

*"I am going to repeat the same list again. Repeat back as many words as you can remember in any order, even if you said the word before."*

Score 1 pt. for each correct response. Total score equals sum across all 3 trials. Do NOT inform the athlete that delayed recall will be tested.

### Concentration

### Digits backward

Choose one column of digits from lists A, B, C, D, E or F and administer those digits as follows:

Say: *"I am going to read a string of numbers and when I am done, you repeat them back to me in reverse order of how I read them to you. For example, if I say 7-1-9, you would say 9-1-7."*

Begin with first 3 digit string.

If correct, circle "Y" for correct and go to next string length. If incorrect, circle "N" for the first string length and read trial 2 in the same string length. One point possible for each string length. Stop after incorrect on both trials (2 N's) in a string length. The digits should be read at the rate of one per second.

### Months in reverse order

*"Now tell me the months of the year in reverse order. Start with the last month and go backward. So you'll say December, November ... Go ahead"*

1 pt. for entire sequence correct

### Delayed Recall

The delayed recall should be performed after 5 minutes have elapsed since the end of the Immediate Recall section.

*"Do you remember that list of words I read a few times earlier? Tell me as many words from the list as you can remember in any order."*

Score 1 pt. for each correct response

### Modified Balance Error Scoring System (mBESS)[5] testing

This balance testing is based on a modified version of the Balance Error Scoring System (BESS)[5]. A timing device is required for this testing.

Each of 20-second trial/stance is scored by counting the number of errors. The examiner will begin counting errors only after the athlete has assumed the proper start position. The modified BESS is calculated by adding one error point for each error during the three 20-second tests. The maximum number of errors for any single condition is 10. If the athlete commits multiple errors simultaneously, only one error is recorded but the athlete should quickly return to the testing position, and counting should resume once the athlete is set. Athletes that are unable to maintain the testing procedure for a minimum of five seconds at the start are assigned the highest possible score, ten, for that testing condition.

OPTION: For further assessment, the same 3 stances can be performed on a surface of medium density foam (e.g., approximately 50cm x 40cm x 6cm).

**Balance testing – types of errors**

| | | |
|---|---|---|
| 1. Hands lifted off iliac crest | 3. Step, stumble, or fall | 5. Lifting forefoot or heel |
| 2. Opening eyes | 4. Moving hip into > 30 degrees abduction | 6. Remaining out of test position > 5 sec |

*"I am now going to test your balance. Please take your shoes off (if applicable), roll up your pant legs above ankle (if applicable), and remove any ankle taping (if applicable). This test will consist of three twenty second tests with different stances."*

(a) Double leg stance:

*"The first stance is standing with your feet together with your hands on your hips and with your eyes closed. You should try to maintain stability in that position for 20 seconds. I will be counting the number of times you move out of this position. I will start timing when you are set and have closed your eyes."*

(b) Single leg stance:

*"If you were to kick a ball, which foot would you use?* [This will be the dominant foot] *Now stand on your non-dominant foot. The dominant leg should be held in approximately 30 degrees of hip flexion and 45 degrees of knee flexion. Again, you should try to maintain stability for 20 seconds with your hands on your hips and your eyes closed. I will be counting the number of times you move out of this position. If you stumble out of this position, open your eyes and return to the start position and continue balancing. I will start timing when you are set and have closed your eyes."*

(c) Tandem stance:

*"Now stand heel-to-toe with your non-dominant foot in back. Your weight should be evenly distributed across both feet. Again, you should try to maintain stability for 20 seconds with your hands on your hips and your eyes closed. I will be counting the number of times you move out of this position. If you stumble out of this position, open your eyes and return to the start position and continue balancing. I will start timing when you are set and have closed your eyes."*

### Tandem Gait

Participants are instructed to stand with their feet together behind a starting line (the test is best done with footwear removed). Then, they walk in a forward direction as quickly and as accurately as possible along a 38mm wide (sports tape), 3 metre line with an alternate foot heel-to-toe gait ensuring that they approximate their heel and toe on each step. Once they cross the end of the 3m line, they turn 180 degrees and return to the starting point using the same gait. Athletes fail the test if they step off the line, have a separation between their heel and toe, or if they touch or grab the examiner or an object.

### Finger to Nose

"I am going to test your coordination now. Please sit comfortably on the chair with your eyes open and your arm (either right or left) outstretched (shoulder flexed to 90 degrees and elbow and fingers extended), pointing in front of you. When I give a start signal, I would like you to perform five successive finger to nose repetitions using your index finger to touch the tip of the nose, and then return to the starting position, as quickly and as accurately as possible."

### References


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2. Maddocks, DL; Dicker, GD; Saling, MM. The assessment of orientation following concussion in athletes. Clinical Journal of Sport Medicine 1995; 5: 32-33
3. Jennett, B., Bond, M. Assessment of outcome after severe brain damage: a practical scale. Lancet 1975; i: 480-484
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## CONCUSSION INFORMATION

~~Any athlete suspected of having a concussion should be removed from~~ play and seek medical evaluation.

### Signs to watch for

Problems could arise over the first 24-48 hours. The athlete should not be left alone and must go to a hospital at once if they experience:

- Worsening headache
- Drowsiness or inability to be awakened
- Inability to recognize people or places
- Repeated vomiting
- Unusual behaviour or confusion or irritable
- Seizures (arms and legs jerk uncontrollably)
- Weakness or numbness in arms or legs
- Unsteadiness on their feet.
- Slurred speech

Consult your physician or licensed healthcare professional after a suspected concussion. **Remember, it is better to be safe.**

### Rest & Rehabilitation

After a concussion, the athlete should have physical rest and relative cognitive rest for a few days to allow their symptoms to improve. In most cases, after no more than a few days of rest, the athlete should gradually increase their daily activity level as long as their symptoms do not worsen. Once the athlete is able to complete their usual daily activities without concussion-related symptoms, the second step of the return to play/sport progression can be started. The athlete should not return to play/sport until their concussion-related symptoms have resolved and the athlete has successfully returned to full school/learning activities.

When returning to play/sport, the athlete should follow a stepwise, **medically managed exercise progression, with increasing amounts of exercise.** For example:

### Graduated Return to Sport Strategy

| Exercise step | Functional exercise at each step | 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, e.g., 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 play/sport | Normal game play. | |

In this example, it would be typical to have 24 hours (or longer) for each step of the progression. If any symptoms worsen while exercising, 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).

Written clearance should be provided by a healthcare professional before return to play/sport as directed by local laws and regulations.

### Graduated Return to School Strategy

Concussion may affect the ability to learn at school. The athlete may need to miss a few days of school after a concussion. When going back to school, some athletes may need to go back gradually and may need to have some changes made to their schedule so that concussion symptoms do not get worse. If a particular activity makes symptoms worse, then the athlete should stop that activity and rest until symptoms get better. To make sure that the athlete can get back to school without problems, it is important that the healthcare provider, parents, caregivers and teachers talk to each other so that everyone knows what the plan is for the athlete to go back to school.

**Note: If mental activity does not cause any symptoms, the athlete may be able to skip step 2 and return to school part-time before doing school activities at home first.**

| Mental Activity | Activity at each step | Goal of each step |
|---|---|---|
| 1. Daily activities that do not give the athlete symptoms | Typical activities that the athlete does during the day as long as they do not increase symptoms (e.g. reading, texting, screen time). Start with 5-15 minutes 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. |

If the athlete continues to have symptoms with mental activity, some other accomodations that can help with return to school may include:

- Starting school later, only going for half days, or going only to certain classes
- More time to finish assignments/tests
- Quiet room to finish assignments/tests
- Not going to noisy areas like the cafeteria, assembly halls, sporting events, music class, shop class, etc.
- Taking lots of breaks during class, homework, tests
- No more than one exam/day
- Shorter assignments
- Repetition/memory cues
- Use of a student helper/tutor
- Reassurance from teachers that the child will be supported while getting better

The athlete should not go back to sports until they are back to school/ learning, without symptoms getting significantly worse and no longer needing any changes to their schedule.

BJSM

# Sport concussion assessment tool - 5th edition

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# **Appendix VII:** Buffalo Concussion Treadmill Test (BCTT)

# Use of Graded Exercise Testing in Concussion and Return-to-Activity Management

**John J. Leddy, MD, FACSM FACP[1] and Barry Willer, PhD[2]**

**Abstract**

Concussion is a physiologic brain injury that produces systemic and cognitive symptoms. The metabolic and physiologic changes of concussion result in altered autonomic function and control of cerebral blood flow. Evaluation and treatment approaches based upon the physiology of concussion may therefore add a new dimension to concussion care. In this article, we discuss the use of a standard treadmill test, the Buffalo Concussion Treadmill Test (BCTT), in acute concussion and in postconcussion syndrome (PCS). The BCTT has been shown to diagnose physiologic dysfunction in concussion safely and reliably, differentiate it from other diagnoses (*e.g.*, cervical injury), and quantify the clinical severity and exercise capacity of concussed patients. It is used in PCS to establish a safe aerobic exercise treatment program to help speed recovery and return to activity. The use of a provocative exercise test is consistent with world expert consensus opinion on establishing physiologic recovery from concussion.

**Introduction**

Expert consensus holds that the best treatment during the immediate and early recovery period after concussion is rest from physical and cognitive exertion (41). The concept that rest is best is supported partially by animal and human evidence that excessive activity soon after concussion prolongs recovery (22,36). There is also some evidence of a vulnerable period early after concussion during which the brain is susceptible to repeat injury and/or worsening symptoms with cognitive or physical stress (19). The concept of using rest for recovery from the acute effects of concussion also has been extended generally to apply to those with postconcussion syndrome (PCS), *i.e.*, the persistence of symptoms beyond several weeks or months (25). The efficacy of rest in all phases of concussion recovery recently has been challenged (44). A study by Majerske *et al.* (36) demonstrated that cognitive recovery is best when the patient is involved in some limited exercise and cognitive activity after concussion but is worse when the activity is either too great or too little.

Concussion has been thought traditionally to represent primarily a disturbance of cognition, and there is a considerable body of research describing and promoting cognitive testing as the optimal approach to establish the degree of functional (read: cognitive) recovery. More recently, concussion is being described as a physiological insult to the brain (32). The metabolic and physiologic changes that accompany concussion result, among other things, in altered autonomic function and control of cerebral blood flow (CBF) (16,26). As such, evaluation and treatment approaches that are based upon the physiology of concussion may add a new dimension to concussion care. The purpose of this article is to review the use of exercise testing to evaluate physiologic recovery from the acute effects of concussion and to review the theory and evidence behind using individualized aerobic exercise treatment in the return-to-activity (RTA) management of those with concussion and PCS.

**Definitions of Concussion and PCS**

Concussion is a transient disturbance of neurologic function resulting from traumatic forces imparted to the brain (41). While sport concussion may be differentiated from non-sport-related mild traumatic brain injury (TBI) based upon mechanism of injury (41), the symptoms reported are the same. While there continues to be debate about the finer aspects of concussion diagnosis, there appears to be general consensus on the key elements and a host of measures available to assess symptoms (35), cognitive impairments (8), and balance (23). Most patients recover from the acute effects of concussion within days to weeks, but some take longer, up to several months or more (37). Those that take longer to recover are said to have PCS.

The definition of PCS is much less specific than that of acute concussion. The symptom checklists still apply, but in many instances patients believed to have PCS have no more

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symptoms than those who have never been concussed (37). Neuropsychological testing of those with PCS does not appear to have much value for confirming the diagnosis (9). The timeframe for recovery is influenced by factors such as athlete status (31), age (34), sex (42), and history of prior concussions (24). Research so far, however, has been unsuccessful at identifying factors that consistently predict PCS, largely because PCS is not one syndrome but is a heterogeneous disorder without reliable diagnostic criteria.

The diagnosis of PCS among nonathletes generally includes persistent symptoms for at least 3 months. Athletes (defined as those individuals competing in sport who sustain a concussion during sport) have delayed recovery when symptoms persist for a time frame longer than normally would be expected for that athlete, *i.e.*, from 3 to 6 wk (25). For example, younger adolescent and children athletes may require 4 to 6 wk to recover from the acute effects of concussion (38) whereas collegiate and professional athletes are outside the typical recovery period after 3 wk or more of persistent symptoms (25,48). These time-to-diagnosis differences and other symptom-based criteria are arbitrary, so one of the objectives of this article is to provide a more scientific definition of PCS based on some of the physiologic changes that are precipitated by concussion.

### Pathophysiology of Concussion and PCS

It is intellectually useful (although perhaps not necessarily accurate) to try to differentiate the pathophysiology and clinical presentation of the acute effects of concussion from those of PCS. Linear, rotational, and blast-delivered forces to the brain induce rapid dynamic changes in neurotransmitters, intracellular and extracellular ions, glucose metabolism, and CBF (19). Recent evidence from studies using diffusion tensor imaging shows that this traumatic metabolic cascade also may be accompanied by microstructural injury to neurons, especially in the white matter of the brain (7). The acute pathophysiology of concussion produces a constellation of evolving signs and symptoms that reflect cognitive, emotional, and somatic dysfunction. Animal and human data suggest that this typically resolves, assuming no recurrent insult, within days to weeks after the injury (19,40). The etiology of the persistent symptoms in PCS patients is, however, controversial because until recently, the lack of findings on standard neuroimaging has led some to conclude that PCS, rather than being a direct consequence of brain injury, represents either an unmasking of a subclinical psychological illness, a reactive depression, a form of post traumatic stress disorder, a consequence of pain, or a form of malingering (25).

Recent physiological and advanced neuroimaging studies reveal, however, that some PCS patients have objective evidence of brain dysfunction that may explain their symptoms and limitations. For example, concussed athletes with prolonged depressive symptoms showed reduced functional magnetic resonance imaging (fMRI) activation in the dorsolateral prefrontal cortex and striatum and attenuated activation in medial frontal and temporal regions accompanied by gray matter loss in these areas (11). Some PCS patients have persistent abnormalities of brain blood flow on single-photon emission computerized tomography scan (1), neurochemical imbalances (*e.g.*, serum S100B) (45), and electrophysiological indices of impairment (5). Postural instability is much more likely to be present when the other signs and symptoms are the result of organic-based PCS (23). In magnetic resonance spectroscopy studies, athletes who reported being symptom free at 3 to 15 d did not demonstrate complete metabolic recovery until a mean of 30 d postinjury, and mitochondrial metabolism took an additional 15 d to recover if a second concussion occurred before full metabolic recovery after a first concussion (47). There is fMRI evidence of abnormal CBF volume and distribution in humans both acutely after concussion (39) and in those with PCS (10) that may explain why concussed patients become fatigued easily with cognitive activity.

Concussion-induced mechanical changes coupled with the neurometabolic alterations described above can affect functional cerebral circulation (19). This, in conjunction with post-TBI autonomic dysfunction, has been proposed as a possible etiology for prolonged symptoms of PCS (32). Cerebral autoregulation — the capacity to maintain CBF at appropriate levels during changes in systemic blood pressure (BP) — and CBF itself are disturbed after concussion (26), which may explain why symptoms reappear or worsen with excessive physical exertion or other stressors. This appears to be a particularly important issue in adolescents, where abnormal CBF has been reported up to 4 wk after injury despite reported resolution of resting symptoms (38). Abnormal regulation of CBF may be due to altered autonomic nervous system (ANS) function and/or altered carbon dioxide ($CO_2$) regulation after concussion. $CO_2$ tension in the blood is the primary regulator of CBF (32). Concussed athletes have altered ANS balance (16), which is reflected by higher heart rates (HR) during steady-state exercise versus controls (17). The primary ANS control center, located in the brainstem, may be damaged in concussion, particularly if there is a rotational force applied to the upper cervical spine (18). Altered autonomic regulation after TBI is believed to be due to changes in the autonomic centers in the brain and/or an uncoupling of the connections between the central ANS, the arterial baroreceptors, and the heart. It is proportional to TBI severity and improves during TBI recovery (20).

### Concussion and Exercise

Emerging data suggest that exercise improves brain function via favorable effects on brain neuroplasticity (2) as early as after 6 to 8 wk of exercise (46). The rapidity of the effect of exercise on the brain suggests that the mechanism may not involve exercise influence on cerebrovascular disease risk but rather improved neuronal function. Aerobic exercise has been shown to improve significantly fMRI cortical connectivity and activation (12). Moderate aerobic exercise (60% of maximum HR performed for 150 $min \cdot wk^{-1}$) is cognitively protective (28) and is associated with greater levels of brain-derived neurotrophic factor (BDNF), which is involved in neuron repair after injury, as well as greater hippocampal volume and improved spatial memory (14). Another salutary effect of regular exercise is improved regulation of CBF (3).

It is reasonable to infer that, if introduced at the right time, exercise might improve neuronal function after TBI. Experimental animal data show that premature voluntary exercise within the first week after concussion delays recovery and is associated with impaired cognitive memory task performance by interfering with the postconcussion rise of neuroplasticity molecules including BDNF (21). Aerobic exercise performed 14 to 21 d after concussion, however, upregulates BDNF in association with improved cognitive performance (22). Nonexperimental human data support that too much activity too soon after concussion is detrimental to recovery, but that too little activity is also detrimental (36). Individuals with TBI who exercise are less depressed and report better health status when compared with those who do not exercise (49). Thus exercise treatment after concussion may be beneficial if administered at the appropriate time and as long as the exercise is of appropriate type (*i.e.*, aerobic), intensity, and duration.

Physical deconditioning of the cardiovascular system due to prolonged rest is common in TBI (48). Deconditioning has been associated with reduced CBF (50) whereas exercise training has beneficial effects on CBF control (3), which may relate to restoration of autonomic balance and/or sensitization of the autoregulatory system to gradual increases in systemic BP with controlled exercise (32). With respect to acute concussion, there is no evidence that complete rest beyond 3 d in adults is beneficial, whereas gradual reintroduction of activity appears to be (44). We have shown recently that it is safe for adult PCS patients to exercise up to 74% of maximum predicted capacity (27), which provides an evidence base for stage 2 (light aerobic exercise) of the Zurich Conference Guidelines' graduated return to play (RTP) protocol (41). We have shown also that aerobic exercise treatment improves symptoms and outcome in PCS subjects in association with improved fitness and autonomic function (*i.e.*, better HR and BP control) during exercise (31). The precise mechanisms for the effect, however, have yet to be elucidated.

### The Buffalo Concussion Treadmill Test

We have developed a standard treadmill test, the Buffalo Concussion Treadmill Test (BCTT), that is the only functional test thus far shown to diagnose safely (31) and reliably (29) physiologic dysfunction in concussion, differentiate it from other diagnoses (*e.g.*, cervical injury, depression, migraines) (6), and quantify the clinical severity and exercise capacity of concussed patients (31). The BCTT is based upon the Balke cardiac treadmill test, which requires a very gradual increase in workload that has been shown to be safe in patients with cardiac and orthopedic problems. The HR and BP recorded at the threshold of symptom exacerbation become the basis for the individualized exercise prescription for patients with PCS. The contraindications to performing the BCTT are those that typically would contraindicate the performance of a cardiac stress test. The absolute and relative contraindications to performing the BCTT are presented in Table 1.

**Table 1.**
**Absolute and relative contraindications to performing the Buffalo Concussion Treadmill Test.**

| | |
|---|---|
| *Absolute Contraindications to Performing the BCTT* | |
| History | Unwilling to exercise. |
| | Increased risk for cardiopulmonary disease as defined by the American College of Sports Medicine.[a] |
| Physical examination | Focal neurologic deficit. |
| | Significant balance deficit, visual deficit, or orthopedic injury that would represent a significant risk for walking/running on a treadmill. |
| *Relative Contraindications to Performing the BCTT* | |
| History | Beta-blocker use. |
| | Major depression (may not comply with directions or prescription). |
| | Does not understand English. |
| Physical examination | Minor balance deficit, visual deficit, or orthopedic injury that increases risk for walking/running on a treadmill. |
| | SBP >140 mm Hg or DBP > 90 mm Hg. |
| | Obesity: body mass index ≥30 kg·m$^{-2}$. |

[a] Individuals with known cardiovascular, pulmonary, or metabolic disease; signs and symptoms suggestive of cardiovascular or pulmonary disease; or individuals aged ≥45 years who have more than one risk factor to include: 1) family history of myocardial infarction, coronary revascularization, or sudden death before 55 yr of age; 2) cigarette smoking; 3) hypertension; 4) hypercholesterolemia; 5) impaired fasting glucose; or 6) obesity (body mass index ≥30 kg·m$^{-2}$).

SBP, systolic blood pressure; DBP, diastolic blood pressure.

### BCTT protocol (31)

The test is a modification of the cardiac Balke protocol. The starting speed is 3.6 mph at 0% incline but can be altered

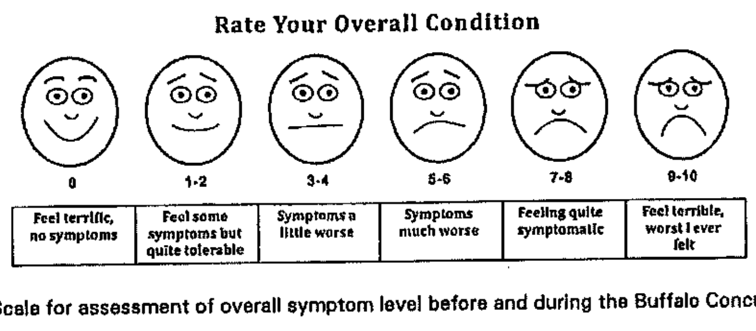


**Figure 1:** Visual Analog Scale for assessment of overall symptom level before and during the Buffalo Concussion Treadmill Test.

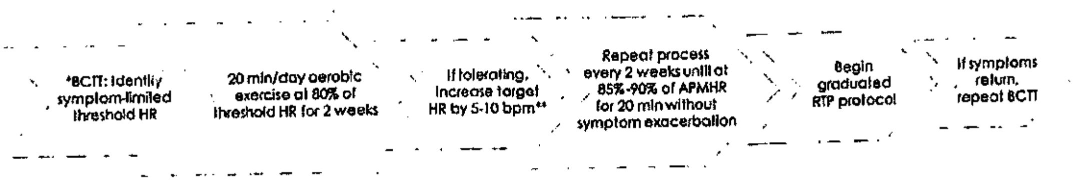


**Figure 2:** Use of the BCTT and exercise prescription for RTA in physiologic PCD. APMHR, age-predicted maximum HR. *After 3 wk of symptoms. **5 bpm for nonathletes; 10 bpm for athletes. To obtain a more precise target HR, consider repeating the BCTT every 2 wk.

if needed (increase speed a little to comfort for taller or athletic persons and reduce the speed for shorter or sedentary persons). During the first minute, the patient walks at 0% incline. The incline is increased by 1% at minute 2 and by 1% each minute thereafter while maintaining the same speed until the maximum incline is reached or the patient cannot continue. Rating of perceived exertion (RPE, Borg scale) and symptoms are assessed every minute. HR (by HR monitor) and BP (by automated cuff if available; if not, HR alone is sufficient) are measured every 2 min, and the test is stopped at a significant exacerbation of symptoms (defined as ≥3 points from that day's pretreadmill test resting overall symptom score on a 1- to 10-point visual analog scale (VAS), Fig. 1) or at exhaustion (RPE of 19 to 20). If the patient reaches maximum incline and can still continue (not yet at RPE of 19 to 20 or exacerbation of symptoms), the speed is increased by 0.4 mph for each subsequent minute until stopping criteria are fulfilled. The test is deferred in those with significant pretest resting symptoms (*i.e.*, ≥7 on the pretest VAS).

It is more accurate to classify patients experiencing prolonged symptoms after concussion as having one of several 'postconcussion disorders' (PCD) rather than a single 'PCS' because there is more than one cause of prolonged symptoms after concussion (6). The patient's performance and symptom pattern during the BCTT, combined with a pretest physical examination, can help with the differential diagnosis of PCD (Table 2). Concussion symptoms, for example, typically are exacerbated by exercise, whereas exercise usually rapidly improves symptoms of depression (13). If patients can exercise to exhaustion without reproduction or exacerbation of headache or other concussion symptoms, and they demonstrate a normal physiological response to exercise, then we conclude that the symptoms are not due to the physiologic concussion but to another problem, most commonly, a cervical injury, vestibular/ocular dysfunction, or a posttraumatic headache syndrome such as migraine (6). A careful physical examination of the cervical spine and a neurologic examination focusing on the vestibular system and oculomotor responses (Table 2) can help identify sources other than concussion that produce similar symptoms such as dizziness, headache, trouble concentrating, and blurred vision (33). In general, an isolated posttraumatic vestibular injury presents with symptoms of true positional vertigo (*i.e.*, a sensation of motion and nausea precipitated by head motion) with a positive Dix-Hallpike maneuver (sustained nystagmus and vertigo with sudden head rotation) but typically without other associated postconcussion symptoms. Vestibular symptoms caused primarily by concussion/PCS, while they may be exacerbated temporarily by head position changes, are typically not as position dependent, do not demonstrate nystagmus with the Dix-Hallpike maneuver, are almost always present at rest (with or without head motion), and are associated usually with multiple other PCS complaints such as lightheadedness and cognitive problems. Furthermore it must be recognized that exercise itself can produce symptoms such as fatigue, headache, and dizziness as the patient approaches voluntary exhaustion. Exercise symptoms, however, can be differentiated from those of physiologic concussion since they typically occur at peak exertion near exhaustion or immediately following intense exercise, whereas concussed patients develop symptoms earlier on in exercise that prevents them from continuing (31). The other common response observed during exercise is a cervical headache, which often improves as the muscles warm up only to return at the end of the test when patients may be straining to finish. The key differentiating point is that those with a cervicogenic headache or dizziness are able to exercise to exhaustion, despite some symptoms, whereas patients who have not recovered from the physiologic disturbance of concussion stop at a submaximal level because of significant symptom exacerbation. It is important to realize that many patients with prolonged symptoms after concussion no longer have concussion as the source of their symptoms; rather, they have symptoms from other sources, most commonly a cervical injury, a vestibular injury, or a posttraumatic migraine (6), which can benefit from therapy specifically tailored to these etiologies (4).Thus the BCTT combined with a careful physical examination can help the practitioner narrow the differential diagnosis of persistent postconcussion symptoms and so direct therapy to the specific cause, enhancing the RTA process.

## BCTT versus Computerized Neurocognitive Testing in RTP

Since the BCTT has good reliability for identifying patients with symptom exacerbation from concussion, it can help to establish physiologic recovery from concussion and readiness for RTA (29). In a sample of 117 high school athletes, the BCTT, when used in combination with the Zurich Guidelines' recommendations for graduated RTP, was 100% successful for returning concussed athletes to sport (Darling *et al.*, accepted for publication). All athletes exercised to exhaustion without exacerbation of concussion symptoms on the BCTT, and all returned to sport without recurrent symptoms. Meanwhile almost half (48%) of the athletes had one or more computerized neuropsychological (cNP) subtest or composite scores (on ANAM or ImPACT) 'below average' on the same day that they successfully completed the BCTT. Thus the ability of concussed athletes to exercise to exhaustion on the BCTT without

**Table 2.**
Differential diagnosis of PCD using the BCTT and the physical examination.

| Diagnosis | Physiologic PCD | Cervicogenic PCD | Migraine PCD | Affective PCD | Vestibular/Ocular PCD |
|---|---|---|---|---|---|
| BCTT response | Distinct submaximal symptom-limited threshold characterized by complaints of sudden increase in lightheadedness, headache, head pressure, or "fullness" of the head. | No distinct symptom-limited threshold. Able to exercise to exhaustion. Posterior headache that improves early in exercise but often returns near exhaustion. | BCTT not performed if migraine present. If migraine not present, there is no distinct symptom-limited threshold. Able to exercise to exhaustion. | No distinct symptom-limited threshold. Able to exercise to exhaustion. Mood usually improves with exercise testing. | No distinct symptom-limited threshold. Able to exercise to exhaustion. Symptoms are usually visual (blurred vision, difficulty with focusing) or mild lightheadedness. Vertigo typically is not reported during the test. |
| Physical exam | May have orthostatic drop in BP and or rise in HR. | Cervical muscle tenderness and/or spasm, reduced motion, altered cervical proprioception, suboccipital tenderness | Exam usually normal when not symptomatic. May have photosensitivity. | May have flat or depressed affect. | Discomfort (and sometimes nystagmus) with ocular smooth pursuits and saccades, abnormal ocular convergence (>6 cm), abnormal VOR,[a] positive Romberg and abnormal tandem gait. |

[a] VOR, vestibulo-ocular reflex; BCTT, Buffalo Concussion Treadmill Test; PCD, post concussion disorders.

symptom exacerbation better predicted readiness to begin the RTP process than did same-day cNP test performance. cNP test performance did not relate to RTP and was not associated statistically with symptoms reported upon return to school. These data support expert consensus opinion that the ability of concussed athletes to perform provocative exercise without symptom exacerbation establishes readiness to RTP (41).

### Exercise Treatment of Concussion and PCS

The primary forms of concussion and PCS treatment traditionally have included rest, education, coping techniques, support and reassurance, neurocognitive rehabilitation, and antidepressants (48). There is some evidence that education, coping techniques, and neurocognitive rehabilitation have modest benefit in PCS patients (33). With respect to acute concussion, while it is accepted generally that children and adolescents require more cognitive and physical rest in the beginning to avoid delaying recovery, there is no evidence that complete rest beyond 3 d in adults is beneficial, whereas gradual reintroduction of activity appears to be most effective (44). Prolonged rest, especially in athletes, can lead to physical deconditioning and secondary symptoms such as fatigue and reactive depression (48).

The Zurich Consensus Statement recognizes the important physiologic component of testing and recovery after concussion. It advises that when asymptomatic at rest, concussed patients should progress stepwise from light aerobic activity such as walking or stationary cycling up to sport or work-specific activities (41). Recurrence of symptoms mandates return to the previously tolerated level of activity before advancing again. We have applied this principle to those with persistent symptoms. Our non-randomized pilot study showed that individualized aerobic exercise treatment improved symptoms in PCS subjects in association with improved fitness and autonomic function (*i.e.*, better HR and BP control) during exercise (31) and, when compared with a period of no intervention, safely sped rate of recovery and restored function (sport and work) (31). A similar rehabilitation program has been established for children with PCS after sport-related concussion that combines gradual, closely monitored physical conditioning, general coordination exercises, visualization, education, and motivation activities (15). The efficacy of exercise treatment in patients with persistent concussion symptoms awaits confirmation in larger randomized trials, and the mechanisms for the effect of exercise on concussion have yet to be elucidated, but in a recent small controlled study in PCS we showed that exercise treatment restored normal local CBF regulation, as indicated by fMRI activation, versus a placebo stretching intervention in association with improved aerobic capacity and resolution of symptoms (30). Some concussion symptoms may therefore be related to abnormal local CBF regulation that is amenable to individualized aerobic exercise treatment.

### RTP and RTA

Symptom reports and, despite its widespread use, cNP testing may not be the most reliable indicators of concussion recovery (43). The following is an illustration of how the BCTT can be used to gauge recovery after the symptoms seen acutely after concussion are reported to have resolved at rest. Using the BCTT, the athlete is able to exercise to exhaustion without symptom exacerbation. You conclude that s/he is recovered physiologically and can begin the graduated RTP process safely. Conversely if the athlete developed symptoms that stopped the test before peak exertion, you have objective information that s/he is not physiologically ready and will need more recovery time. The most commonly reported symptoms indicating that the concussion is not resolved are worsening headache, dizziness (*i.e.*, lightheadedness), and/or a sensation that the head feels "full." A comparison of the HR at the point of symptom exacerbation to the athlete's theoretical maximum HR gives you a good indication of how close the athlete is to full physiologic recovery. If close to full recovery, the test can be repeated in a few days to a week. The test can be performed in a physician's office, an athletic training or physical therapy facility, hospital clinic, or a health club, provided that the staff has been trained in treadmill test administration and that there is medical supervision in proximity.

With respect to RTA in patients with physiologic PCD, the BCTT can be performed safely in those who remain symptomatic for more than 3 wk (Fig. 2). If a submaximal symptom exacerbation threshold is identified, patients are given a prescription to perform aerobic exercise (on a stationary cycle, treadmill or elliptical) for 20 min per day at a subthreshold intensity, *i.e.*, at 80% of the threshold HR achieved on the BCTT, once per day for 5 to 6 $d \cdot wk^{-1}$ using an HR monitor. They are required to have someone present during exercise for safety monitoring and should terminate exercise at the first sign of symptom exacerbation or after 20 min, whichever comes first. The BCTT can be repeated every 2 to 3 wk to establish a new symptom-limited threshold HR until symptoms are no longer exacerbated on the treadmill (Fig. 2). A more reasonable and cost-effective approach that avoids repeated testing, however, is to establish the threshold HR on the initial test and increase the exercise HR target by 5 to 10 bpm every 2 wk (via phone call or email), provided the patient is responding favorably (6). More fit patients and athletes generally respond faster (31) and can increase by 10 bpm every 2 wk, whereas nonathletes typically respond better to 5 bpm increments every 2 to 3 wk. Rate of exercise intensity progression varies, and some patients may have to stay at a particular HR for more than 2 wk, which is fine as the idea is to give patients specific goals to achieve without focusing on how fast it takes to realize full physiologic recovery. Physiologic resolution of PCD is defined as the ability to exercise to voluntary exhaustion at 85% to 90% of age-predicted maximum HR for 20 min without exacerbation of symptoms (31). Patients can then begin the Zurich graduated RTP program. Exercise testing should be considered only for patients without orthopedic or vestibular problems that increase the risk of falling off the treadmill and only in those patients who are at low risk for cardiac disease (31). In those patients who have a nonphysiologic cause of persistent symptoms (*e.g.*, cervicogenic PCD or vestibular PCD), or a combination of disorders (patients with physiologic PCD also can have a neck injury), we have found that including regular aerobic exercise at a subthreshold level (80% of the maximum HR achieved on the BCTT) along with specific treatment for the nonphysiologic disorder is not only not detrimental but in fact appears to enhance recovery (6).

## Conclusion

Growing literature suggests that concussion is a physiologic brain injury that produces systemic symptoms and cognitive dysfunction. Most patients who rest acutely recover from concussion within days to weeks but an important minority does not. Treadmill testing as a method to establish physiologic recovery from concussion makes sense since it better replicates what athletes and active persons (such as soldiers) do. For those with PCD, rest beyond 3 wk appears to be detrimental to recovery whereas regular aerobic exercise appears to have beneficial effects on symptoms and cognition, perhaps because aerobic exercise promotes neuroplasticity and improves control of CBF. Treadmill testing in those with PCD can help with the differential diagnosis of persistent symptoms to guide appropriate therapy. Treadmill test performance can establish the degree of physiologic recovery and give patients information on their prognosis. The symptom threshold HR can be used to prescribe an *individualized* subthreshold progressive aerobic exercise program that can improve symptoms safely, speed RTA, and restore function in many patients with PCD. Individualized exercise is a nonpharmaceutical intervention that challenges the current paradigm of prolonged rest, has minimal adverse effects, can be implemented with standard equipment, and could be used at many physician offices and health facilities, including military facilities and in the field, with relative ease. Further study of exercise testing and treatment in concussion and PCD should include randomized trials to evaluate its potential for safely and more rapidly returning acutely concussed patients and those with PCD to activity and to elucidate the underlying mechanisms of the beneficial effects of exercise evaluation and treatment in those experiencing concussion and PCD.


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# **Appendix VIII:** Vestibular Oculo-Motor Screening (VOMS)

# Vestibular/Ocular-Motor Screening (VOMS) for Concussion

| Vestibular/Ocular Motor Test: | Not Tested | Headache 0-10 | Dizziness 0-10 | Nausea 0-10 | Fogginess 0-10 | Comments |
|---|---|---|---|---|---|---|
| **BASELINE SYMPTOMS:** | N/A | | | | | |
| Smooth Pursuits | | | | | | |
| Saccades – Horizontal | | | | | | |
| Saccades – Vertical | | | | | | |
| Convergence (Near Point) | | | | | | **(Near Point in cm):**<br>Measure 1: ______<br>Measure 2: ______<br>Measure 3: ______ |
| VOR – Horizontal | | | | | | |
| VOR – Vertical | | | | | | |
| Visual Motion Sensitivity Test | | | | | | |

## Instructions:

**Interpretation:** This test is designed for use with subjects ages 9-40. When used with patients outside this age range, interpretation may vary. Abnormal findings or provocation of symptoms with any test may indicate dysfunction – and should trigger a referral to the appropriate health care professional for more detailed assessment and management.
**Equipment:** Tape measure (cm); Metronome; Target w/ 14 point font print.

**Baseline Symptoms** – Record: Headache, Dizziness, Nausea & Fogginess on 0-10 scale prior to beginning screening

- **Smooth Pursuits -** Test the ability to follow a slowly moving target. The patient and the examiner are seated. The examiner holds a fingertip at a distance of 3 ft. from the patient. The patient is instructed to maintain focus on the target as the examiner moves the target smoothly in the horizontal direction 1.5 ft. to the right and 1.5 ft. to the left of midline. One repetition is complete when the target moves back and forth to the starting position, and 2 repetitions are performed. The target should be moved at a rate requiring approximately 2 seconds to go fully from left to right and 2 seconds to go fully from right to left. The test is repeated with the examiner moving the target smoothly and slowly in the vertical direction 1.5 ft. above and 1.5 ft. below midline for 2 complete repetitions up and down. Again, the target should be moved at a rate requiring approximately 2 seconds to move the eyes fully upward and 2 seconds to move fully downward. Record: Headache, Dizziness, Nausea & Fogginess ratings after the test. (Figure 1)

- **Saccades** – Test the ability of the eyes to move quickly between targets. The patient and the examiner are seated.
  - **Horizontal Saccades**: The examiner holds two single points (fingertips) horizontally at a distance of 3 ft. from the patient, and 1.5 ft. to the right and 1.5 ft. to the left of midline so that the patient must gaze 30 degrees to left and 30 degrees to the right. Instruct the patient to move their eyes as quickly as possible from point to point. One repetition is complete when the eyes move back and forth to the starting position, and 10 repetitions are performed. Record: Headache, Dizziness, Nausea & Fogginess ratings after the test. (Figure 2)

- **Vertical Saccades**: Repeat the test with 2 points held vertically at a distance of 3 ft. from the patient, and 1.5 feet above and 1.5 feet below midline so that the patient must gaze 30 degrees upward and 30 degrees downward. Instruct the patient to move their eyes as quickly as possible from point to point. One repetition is complete when the eyes move up and down to the starting position, and 10 repetitions are performed. Record: Headache, Dizziness, Nausea & Fogginess ratings after the test. (Figure 3)

- **Convergence** – Measure the ability to view a near target without double vision. The patient is seated and wearing corrective lenses (if needed). The examiner is seated front of the patient and observes their eye movement during this test. The patient focuses on a small target (approximately 14 point font size) at arm's length and slowly brings it toward the tip of their nose. The patient is instructed to stop moving the target when they see two distinct images or when the examiner observes an outward deviation of one eye. Blurring of the image is ignored. The distance in cm. between target and the tip of nose is measured and recorded. This is repeated a total of 3 times with measures recorded each time. Record: Headache, Dizziness, Nausea & Fogginess ratings after the test. Abnormal: Near Point of convergence ≥ 6 cm from the tip of the nose. (Figure 4)

- **Vestibular-Ocular Reflex (VOR) Test** – Assess the ability to stabilize vision as the head moves. The patient and the examiner are seated. The examiner holds a target of approximately 14 point font size in front of the patient in midline at a distance of 3 ft.
    - **Horizontal VOR Test**: The patient is asked to rotate their head horizontally while maintaining focus on the target. The head is moved at an amplitude of 20 degrees to each side and a metronome is used to ensure the speed of rotation is maintained at 180 beats/minute (one beat in each direction). One repetition is complete when the head moves back and forth to the starting position, and 10 repetitions are performed. Record: Headache, Dizziness, Nausea and Fogginess ratings 10 sec after the test is completed. (Figure 5)
    - **Vertical VOR Test**: The test is repeated with the patient moving their head vertically. The head is moved in an amplitude of 20 degrees up and 20 degrees down and a metronome is used to ensure the speed of movement is maintained at 180 beats/minute (one beat in each direction). One repetition is complete when the head moves up and down to the starting position, and 10 repetitions are performed. Record: Headache, Dizziness, Nausea and Fogginess ratings after the test. (Figure 6)

- **Visual Motion Sensitivity (VMS) Test** – Test visual motion sensitivity and the ability to inhibit vestibular-induced eye movements using vision. The patient stands with feet shoulder width apart, facing a busy area of the clinic. The examiner stands next to and slightly behind the patient, so that the patient is guarded but the movement can be performed freely. The patient holds arm outstretched and focuses on their thumb. Maintaining focus on their thumb, the patient rotates, together as a unit, their head, eyes and trunk at an amplitude of 80 degrees to the right and 80 degrees to the left. A metronome is used to ensure the speed of rotation is maintained at 50 beats/min (one beat in each direction). One repetition is complete when the trunk rotates back and forth to the starting position, and 5 repetitions are performed. Record: Headache, Dizziness, Nausea & Fogginess ratings after the test. (Figure 7)