Policy #:	Title: Head Injury Assessment and Management Protocol	Distribution: Athletics Department, PERD Department, All Clinical Staff
Effective date: 05/2010	Revision date: 06/2022	Planned Review: 05/2023
Approvals: Arturo Aguilar, MD	Last Reviewed: 05/2021	Reviewed by: Nick Pfeifer, ATC; Kristina Green, ATC

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 baseline concussion 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.
- To delineate role, responsibilities, and a framework for treatment of patients following a concussion.

Education

- Athletic Training Services will provide and discuss educational information to all varsity and club sports officers, patients, coaches, athletic administrators, pertinent faculty members, team physicians, athletic trainers and other personnel involved in student-athlete health and safety decision making on a yearly basis.
- The information provided will include, but is 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 in the form of National Collegiate Athletic Association (NCAA) Sports Science Institute (SSI) Concussion Safety-student athletes (Appendix I), the National Collegiate Athletic Association (NCAA) Sports Science Institute (SSI) Concussion Safety-coaches (Appendix II) and the National Collegiate Athletic Association (NCAA) Sports Science Institute (SSI) Concussion Safety-faculty (Appendix III).
- Each student-athlete will initial and sign the Student Athlete Injury and Illness Responsibility Statement (Appendix IV), which is disseminated, collected, and stored by the Department of Athletics.
- Varsity athletics administrators, coaches, and other pertinent associated personnel will sign the Stakeholder Concussion Education Statement (Appendix V), which is disseminated, collected, and stored by the Department of Athletics.

Reducing Exposure to Head Trauma

- Athletic Training Services will work with the Department of Athletics and the Department of Physical Education, Recreation & Dance to emphasize ways to minimize head trauma exposure. These efforts will be guided by conclusions drawn from literature that is consistent with *Interassociation Recommendations: Preventing Catastrophic Injury and Death in Collegiate Athletes* and injury trends at Boston University. Action steps to minimize head trauma exposure may include, but are not limited to: Ensuring all practices and competitions adhere to existing ethical standards
    - Prohibiting the use of playing or protective equipment (including the helmet) as a weapon during all practices and competitions
    - Prohibiting the deliberate intent to inflict injury on another player during all practices and competitions
    - Ensuring all playing and protective equipment (including helmets), as applicable, meets relevant equipment safety standards and related certification requirements
    - 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
    - Participating in quality improvement projects

Baseline Assessments

- All patients that are a member of a Boston University varsity sport will complete baseline assessments prior to their first physical activity (practice, game, or conditioning session) of their first season with the team. Additional high-risk club/non-varsity members will complete the same baseline process include: cheerleading, dance, ice hockey, rugby, and soccer.
- Patient assessments 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.
- Elements of the baseline process may include, but are not limited to:
    - A personal review of their history of concussion(s) and head injury including: concussion symptom evaluation, neurological disorders, history of concussion, mental health disorder
    - Sport Concussion Assessment Tool, 5th Edition (SCAT5$^{©}$) (Appendix VI) **designed and supported by the Consensus Statement on Concussion in Sport: the 5th International Conference on Concussion in Sport (Berlin 2016)*
    - Computerized neurocognitive assessment using the Immediate Post-Concussion Assessment and Cognitive Testing Program (ImPACT®)
    - Postural control using the Biodex Balance System™ SD
    - Computerized neurocognitive and postural control assessment applications using Sway Medical
    - Vestibulospinal and/or vestibular-ocular assessment

- Additionally, the following patients from all sports may receive baseline assessments 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
- All baseline assessments performed will be reviewed prior to medical compliance by a team physician to determine pre-participation clearance and/or the need for additional consult or assessments.
- Modification for baseline assessments may occur based upon the discretion of the Director of Sports Medicine, team physicians, Athletic Training Services, and/or patient request.

Recognition and Diagnosis of Head Injury

Sport and City Specific Healthcare Coverage Polices

- In accordance with the City of Boston legislation, “An Ordinance Creating a College Athlete Head Injury Gameday Safety Protocol," (Appendix VII) 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.
- The following sports will have a licensed athletic trainer or appropriate medical designee under the direction of the Director of Sports Medicine “present” at all competitions and “available” at all practices:
    - Basketball
    - Field hockey
    - Ice hockey
    - Lacrosse
    - Pole Vault
    - Rugby
    - Soccer
- To be *present* means to be on site at the campus or arena of competition.
- To be *available* means that, at a minimum, medical personnel can be contacted at any time during the practice via telephone, messaging, email, pager, or other immediate communication means to facilitate case discussion and arrangements for the patient to be evaluated.

Initial Assessment

- 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 5th International Conference on Concussion in Sport (Berlin 2016)* (Appendix VIII).
- 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 trainer or team physician.
    - This initial evaluation should encompass a symptom assessment, physical and neurological exam, cognitive assessment, balance exam, and clinical assessment for cervical spine trauma, skull fracture, intracranial bleed, and catastrophic injury.
    - If the result of that evaluation is the suspicion of concussion, the patient will be removed from sport/activity and a more comprehensive evaluation will be conducted if deemed appropriate.
    - Furthermore, a more comprehensive evaluation will be conducted for patients who, for any amount of time, become unconscious following a suspected head injury.
    - The results of all evaluations will be reported to the Director of Sports Medicine and the treating clinician will follow the Concussion Management Checklist (Appendix IX).

- The patient may only return to play the same day if concussion is no longer suspected.
    - The return to activity decision will be made by either a licensed athletic trainer or team physician.

- In certain circumstances a higher prioritization of care may need to occur. Should any of the following be identified upon examination the Emergency Action Plan will be activated for further immediate medical care:
    - Glasgow Coma Scale <13 on initial assessment
    - Glasgow Come Scale <15 at 2+ hours post-initial assessment
    - Prolonged loss of consciousness
    - Focal neurological deficit suggesting intracranial trauma
    - Repetitive emesis
    - Persistently diminishing/worsening mental status
    - Cervical Spine Injury (e.g., Canadian C-Spine Rules)
    - Other neurological signs/symptoms

Management of Concussion in Absence of an Athletic Trainer

- In the event that a team is off-campus without an athletic trainer and a student-athlete is suspected of having a concussion, the student-athlete should be withheld from activity until the team physician or athletic trainer has evaluated them.
- The above procedure will be utilized as well when a student-athlete sustains a concussion not related to sports participation.

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 X) about their injury with recommendations for them to review.
- During periods of academic responsibility, Cognitive Rest Letters (Appendix XI) will be provided and may be presented to their instructors. These letters outline the importance of cognitive rest including, but not limited to, classroom activity on the day of injury.
    - It is 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/television, video games, cell phone use, etc. until deemed fit to progress by Athletic Training Services.
- 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.
- Other relevant stakeholders (e.g., Director of Sports Medicine, athletics staff members, and the NCAA reporting structure) will be updated on the patient's diagnosis and injury status.
- 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 may include a graded symptom checklist as outlined in the SCAT5© (Appendix VI), the Buffalo Concussion Treadmill/Bike Test (Appendix XII), the Vestibular-Oculomotor Screening (Appendix XIII), and/or other clinically relevant assessment tools.
    - The exact timing of the implementation of these assessments will be determined on a case-by-case basis.
    - Information gathered from these assessment tools will aid in the development of individualized care plans targeted to each patient's specific clinical trajectory to introduce symptom limited physical activity and therapeutic exercise/intervention.
    - All treatment decisions will be rendered based on clinical discretion with approval from the Director of Sports Medicine and/or their appropriately licensed designee.
    - Athletic Training Services, the Director of Sports Medicine, and/or team physicians may at any time during the rehabilitation process refer the patient to a neuro-psychological specialist if deemed appropriate.

Management of Persistent Symptoms

- For patients with prolonged recovery, evaluation by a physician will be completed to consider additional diagnosis and best management options including but not limited to fatigue and/or sleep disorder, migraine or other headache disorders, mental health symptoms and disorders, ocular dysfunction, vestibular dysfunction, cognitive impairment, and autonomic dysfunction.

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 Student-Athlete Support Services following the diagnosis of a head injury (if occurring during periods of academic responsibility) to identify a point-person to navigate the return to learn process with all patients that are members of varsity teams.
- Specific recommendations and modifications regarding appropriate return to learn progressions (Graduated Return to School Strategy is located at the end of the section) will be made on an individual basis as tolerated for up to two weeks, as indicated by the identified point person through the collaboration between the patient, Athletic Training Services, the Director of Sports Medicine, and other appropriate members of the multidisciplinary care team as deemed necessary, including but not limited to, team physicians, psychologist, counselor, neuropsychologist, faculty athletics representative, academic counselor, course instructors, college administrators, Office of Disability Services representatives, and coaches.
- All recommendations will be made in compliance with Americans with Disabilities Act Amendments Act (ADAAA).
- Continued or worsening symptoms (especially for greater than 2 weeks) 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 7 days, patients will be referred to campus resources that are consistent with ADAAA and will include one or more of the following: the Office of Disability Services, learning specialists, or the ADAAA office.

Graduated Return to School Strategy

Stage	Aim	Activity	Goal of each step
1	Daily activities at home that do not give the student symptoms	Typical activities of the student during the day as long as they do not increase symptoms (e.g., 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

Return to Sport

- The timetable for a return-to-sport will be individualized and dependent on numerous factors.
- At minimum, it will be in accordance with the Graduated Return to Sport Strategy located at the end of this section.
- To advance from each stage of activity the patient must endorse no symptom provocation between each stage (e.g., minimum of 24 hours between each stage of activity).
- In the event that a patient reports provocation of symptoms during the Graduated Return to Sport Strategy, they will be regressed to the previous activity stage until they have been evaluated as non-symptomatic for a period of at least 24 hours.
- The final determination of unrestricted return to sport decision will be made by the Director of Sports Medicine, or their appropriately licensed designee, following consideration of the completion of the Graduated Return to Sport Strategy to the satisfaction of Athletic Training Services.
- At minimum, the following standards must be met:
    - The patient has returned to pre-injury symptom profile
    - The patient should meet or exceed their previous baseline assessment(s), if not available national normative data may be used as a reference point
    - The patient does not endorse any symptom provocation with cognitive and physical activity
    - The patient has tolerated the Graduated Return to Sport Strategy without symptom provocation or re-occurrence
- 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 Director of Sports Medicine, or their appropriately licensed designee, to be medically compliant to return to full and unrestricted athletic participation.

Graduated Return to Sport Strategy

Stage	Aim	Activity Examples	Goal of each step
1	Symptom Control and Impairment Reduction	Daily activities that do not provoke symptoms. Sub-symptom threshold activity.	Gradual introduction of work/school activities Symptom reduction and target impairments
2	Aerobic exercise	Light to Moderate Aerobic Activity. No resistance training.	Sustained aerobic activity
3	Sport-specific exercise	Sport Specific Conditioning. No head impact activities.	Add movement and variability
4	Non-contact training drills	Harder training drills. May start progressive resistance training.	Exercise, coordination, and increased thinking
Physician clearance for contact activity and concussion assessments (e.g., ImPACT, Biodex, Sway) must be performed/acknowledged by a team physician before continuing to next stage			
5	Unrestricted training	Following medical clearance, participate in normal training activities.	Restore confidence and assess functional skills
6	Unrestricted return to sport	Normal game play	Full return

This policy is intended to guide patient care. Medical conditions and specific medical situations are often complex and require health care providers to make independent judgments. These policies may be modified by practitioners to achieve maximal patient outcomes.

Concussion Management Team

- A multi-disciplinary team will be responsible for employing the protocols outlined in this document. Everyone on the team is assigned respective roles in mild traumatic brain injury/concussion management.
    - Director of Sports Medicine: Will serve as the final authority on patient's return to learn and return to sport
    - Team Physicians: Clearance for return to play and learn, as well as oversight surrounding care plans
    - Sport Neurologist: Consultation for persistence symptoms or patients with unique/pre-existing comorbidities
    - Athletic Training Neurology Fellow: Maintain quality improvement initiatives and mentorship around concussion cases
    - Neurology Trained Athletic Training Staff: Consult on complex and atypical presentation of concussions and other traumatic brain injury cases
    - Non-Neurology Trained Athletic Training Staff: Recognize and treat mild traumatic brain injury, will refer student athletes to team physician if they show symptoms of concussion, can provide final clearance for return to play if aligned with physician assessment
    - Student-Athlete Academic Services: Providence guidance and assistance with cognitive activity for varsity student-athletes
    - Office of Disability Services: Provide academic adjustments/accommodations for student classroom activities

Independent Medical Care

- It is the medical staff's decision regarding patient injury management and return to play. The decision may not be overridden by coach or other intercollegiate athletics staff.
- Medical staff will have unchallengeable authority to stop any athletic activity deemed unsafe for the patient.
- While patients may pursue additional or independent medical care at their own expense, and while any such input provided will be considered by medical staff, return to Boston University athletic participation decisions reside solely with the Boston University Director of Sports Medicine or their appropriately licensed designee.
- Athletic Training Services is an autonomous administrative unit, separate from the Department of Athletics and Department of Physical Education, Recreation, and Dance 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.*

Appendix I: NCAA SSI Concussion Safety – student-athletes
Appendix II: NCAA SSI Concussion Safety – coaches
Appendix III: NCAA SSI Concussion Safety – faculty/staff
Appendix IV: Student-Athlete Injury and Illness Responsibility Statement
Appendix V: Stakeholder Concussion Education Statement
Appendix VI: Sport Concussion Assessment Tool, 5th Edition (SCAT5)
Appendix VII: Ordinance Creating a College Athlete Head Injury Gameday Safety Protocol; City of Boston, Boston Public Health Commission
Appendix VIII: Consensus Statement on Concussion in Sport: the 5th International Conference on Concussion in Sport held in Berlin, October 2016
Appendix IX: Clinician Concussion Management Checklist
Appendix X: Informational Handout
Appendix XI: Cognitive Rest Letter
Appendix XII: Buffalo Concussion Treadmill Test (BCTT)
Appendix XIII: Vestibular Oculo-Motor Screening (VOMS)

Appendix I: NCAA SSI Concussion Safety – student-athletes

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CONCUSSION SAFETY

WHAT STUDENT-ATHLETES NEED TO KNOW

What is a concussion?

The Consensus Statement on Concussion in Sport, which resulted from the 5th international conference on concussion in sport, defines sport-related concussion as follows:

Sport-related concussion (SRC) is a traumatic brain injury induced by biomechanical forces. Several common features that may be utilized to clinically define the nature of a concussion head injury include… For complete definition click **here**:

How can I keep myself safe?

1. Know the symptoms.

You may experience …

- Headache or head pressure
- Nausea
- Balance problems or dizziness
- Double or blurry vision
- Sensitivity to light or noise
- Feeling sluggish, hazy or foggy
- Confusion, concentration or memory problems

2. Speak up.

- If you think you have a concussion, stop playing and talk to your coach, athletic trainer or team physician immediately.

3. Take time to recover.

- Follow your team physician and athletic trainer's directions during concussion recovery. If left unmanaged, there may be serious consequences.
- Once you've recovered from a concussion, talk with your physician about the risks and benefits of continuing to participate in your sport.

How can I be a good teammate?

1. Know the symptoms.

You may notice that a teammate …

- Appears dazed or stunned
- Forgets an instruction
- Is confused about an assignment or position
- Is unsure of the game, score or opponent
- Appears less coordinated
- Answers questions slowly
- Loses consciousness

2. Encourage teammates to be safe.

- If you think one of your teammates has a concussion, tell your coach, athletic trainer or team physician immediately.
- Help create a culture of safety by encouraging your teammates to report any concussion symptoms.

3. Support your injured teammates.

- If one of your teammates has a concussion, let him or her know you and the team support playing it safe and following medical advice during recovery.
- Being unable to practice or join team activities can be isolating. Make sure your teammates know they're not alone.

No two concussions are the same. New symptoms can appear hours or days after the initial impact.
If you are unsure if you have a concussion, talk to your athletic trainer or team physician immediately.

This policy is intended to guide patient care. Medical conditions and specific medical situations are often complex and require health care providers to make independent judgments. These policies may be modified by practitioners to achieve maximal patient outcomes.

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What happens if I get a concussion and keep practicing or competing?

- Due to brain vulnerability after a concussion, an athlete may be more likely to suffer another concussion while symptomatic from the first one.
- In rare cases, repeat head trauma can result in brain swelling, permanent brain damage or even death.
- Continuing to play after a concussion increases the chance of sustaining other injuries too, not just concussion.
- Athletes with concussion have reduced concentration and slowed reaction time. This means that you won't be performing at your best.
- Athletes who delay reporting concussion take longer to recover fully.

What are the long-term effects of a concussion?

- We don't fully understand the long-term effects of a concussion, but ongoing studies raise concerns.
- Athletes who have had multiple concussions may have an increased risk of degenerative brain disease and cognitive and emotional difficulties later in life.

What do I need to know about repetitive head impacts?

- Repetitive head impacts mean that an individual has been exposed to repeated impact forces to the head. These forces may or may not meet the threshold of a concussion.
- Research is ongoing but emerging data suggest that repetitive head impact also may be harmful and place a student-athlete at an increased risk of neurological complications later in life.

Did you know?

- NCAA rules require that team physicians and athletic trainers manage your concussion and injury recovery independent of coaching staff, or other non-medical, influence.
- We're learning more about concussion every day. To find out more about the largest concussion study ever conducted, which is being led by the NCAA and U.S. Department of Defense, visit **ncaa.org/concussion**.

CONCUSSION TIMELINE

Baseline Testing
Balance, cognitive and neurological tests that help medical staff manage and diagnose a concussion.

Concussion
If you show signs of a concussion, NCAA rules require that you be removed from play and medically evaluated.

Recovery
Your school has a concussion management plan, and team physicians and athletic trainers are required to follow that plan during your recovery.

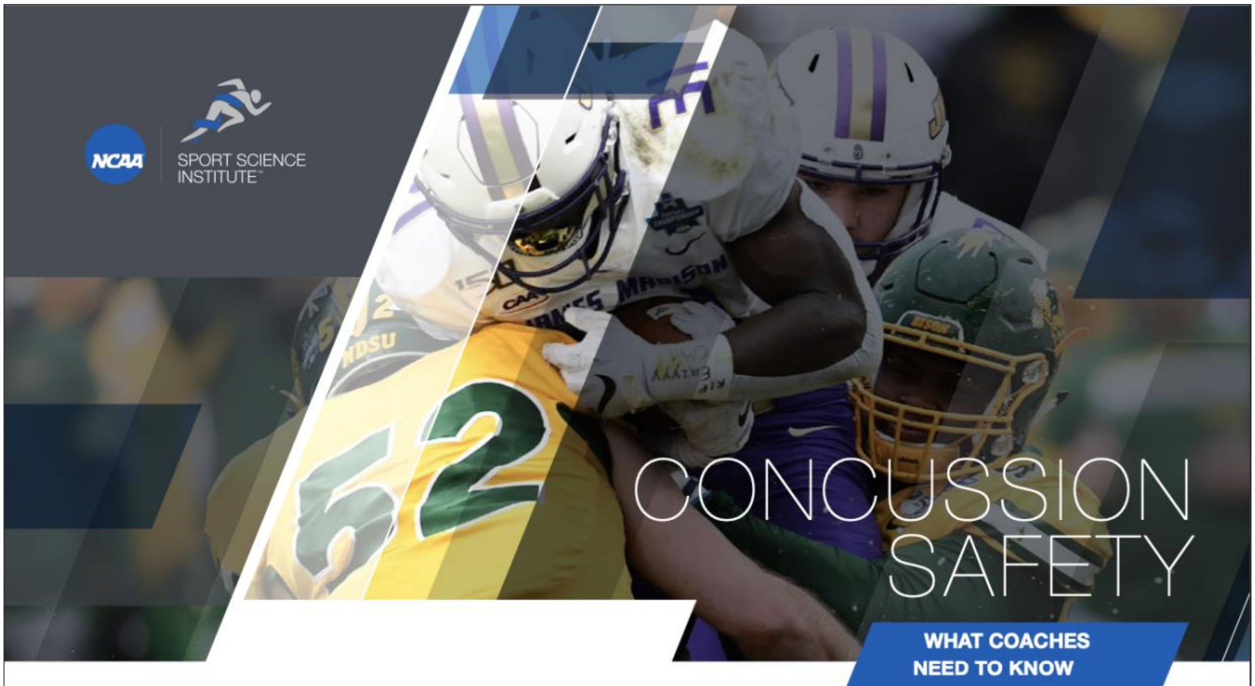
Return-to-Learn
Return-to-learn should be done in a step-by-step progression in which adjustments are made as needed to manage your symptoms.

Return-to-Play
Return-to-play only happens after you have returned to your preconcussion baseline and you've gone through a step-by-step progression of increasing activity.

For more information, visit ncaa.org/concussion.

This policy is intended to guide patient care. Medical conditions and specific medical situations are often complex and require health care providers to make independent judgments. These policies may be modified by practitioners to achieve maximal patient outcomes.

Appendix II: NCAA SSI Concussion Safety – coaches



What is a concussion?

The Consensus Statement on Concussion in Sport, which resulted from the 5th international conference on concussion in sport, defines sport-related concussion as follows:

Sport-related concussion (SRC) is a traumatic brain injury induced by biomechanical forces. Several common features that may be utilized to clinically define the nature of a concussion head injury include… For complete definition click **here**:

How can I tell if an athlete has a concussion?

You may notice the athlete …

- Appears dazed or stunned
- Forgets an instruction
- Is confused about an assignment or position
- Is unsure of the game, score or opponent
- Appears less coordinated
- Answers questions slowly
- Loses consciousness

The athlete may tell you he or she is experiencing …

- A headache, head pressure or that he or she doesn't feel right following a blow to the head
- Nausea
- Balance problems or dizziness
- Double or blurry vision
- Sensitivity to light or noise
- Feeling sluggish, hazy or foggy
- Confusion, concentration or memory problems

Note that no two concussions are the same. All possible concussions must be evaluated by an athletic trainer or team physician.

This policy is intended to guide patient care. Medical conditions and specific medical situations are often complex and require health care providers to make independent judgments. These policies may be modified by practitioners to achieve maximal patient outcomes.

What can I do to keep student-athletes safe?

	Preseason	In-Season	Time of Injury	Recovery
What can I do?	Create a culture in which concussion reporting is encouraged and promoted.	Know the signs and symptoms of concussions.	Remove athletes from play immediately if you think they have a concussion and refer them to the team physician or athletic trainer.	Follow the recovery and return-to-play protocol established by team physicians and athletic trainers.
Why does it matter?	Athletes who don't immediately seek care for a suspected concussion take longer to recover.	The more people who know what to look for in a concussed athlete, the more likely a concussion will be identified.	Early removal from play can mean a quicker recovery and help avoid serious consequences.	Team physicians and athletic trainers have the training to follow best practices related to the concussion recovery process.
Tips and strategies	Be present when your team physician or athletic trainer provides concussion education material to your team. Tell your team that this matters to you.	Check in with your team physician or athletic trainer if you want to learn more about concussion safety.	Provide positive reinforcement when an athlete reports a suspected concussion.	Tell athletes that decisions related to their return to play and health are entirely in the hands of the team physician and athletic trainer.

You play a powerful role in setting the tone for concussion safety on your team. Let your team know that you take concussion seriously and reporting the symptoms of a suspected concussion is an important part of your team's values.

What happens if an athlete gets a concussion and keeps practicing or competing?

- Due to brain vulnerability after a concussion, an athlete may be more likely to suffer another concussion while symptomatic from the first one.
- In rare cases, repeat head trauma can result in brain swelling, permanent brain damage or even death.
- Continuing to play after a concussion increases the chance of sustaining other injuries too, not just concussion.
- Athletes with a concussion have reduced concentration and slowed reaction time. This means they won't be performing at their best.
- Athletes who delay reporting concussion may take longer to recover fully.

What are the long-term effects of a concussion?

- We don't fully understand the long-term effects of a concussion, but ongoing studies raise concerns.
- Athletes who have had multiple concussions may have an increased risk of degenerative brain disease, and cognitive and emotional difficulties later in life.

What do I need to know about repetitive head impacts?

- Repetitive head impacts mean that an individual has been exposed to repeated impact forces to the head. These forces may or may not meet the threshold of a concussion.
- Research is ongoing but emerging data suggest that repetitive head impact also may be harmful and place a student-athlete at an increased risk of neurological complications later in life.

Did you know?

- Most contact or collision teams have at least one student-athlete diagnosed with a concussion every season.
- Your school has a concussion management plan, and team physicians and athletic trainers are expected to follow that plan during a student-athlete's recovery.
- NCAA rules require that team physicians and athletic trainers have the unchallengeable authority to make all medical management and return-to-play decisions for student-athletes.
- We're learning more about concussion every day. To find out more about the largest concussion study ever conducted, which is being led by the NCAA and U.S. Department of Defense, visit **ncaa.org/concussion.**

For more information, visit **ncaa.org/concussion**.

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Appendix III: NCAA SSI Concussion Safety – faculty/staff

What is a concussion?

The Consensus Statement on Concussion in Sport, which resulted from the 5th international conference on concussion in sport, defines sport-related concussion as follows:

Sport-related concussion (SRC) is a traumatic brain injury induced by biomechanical forces. Several common features that may be utilized to clinically define the nature of a concussion head injury include… For complete definition click **here**:

What is your role in Concussion Recovery?

- Each athletics department should have a concussion management plan that outlines the steps to be taken by team physicians and athletic trainers following a sport-related concussion diagnosis and during a student-athlete's recovery.
- The concussion management plan should provide for the identification of an academic point person who will navigate return-to-learn activities with a student-athlete who has been diagnosed with a sport-related concussion.
- The return-to-learn pathway is considered part of the suggested medical management plan and, in more complex cases of return-to-learn, the academic point person will be part of a broader interdisciplinary team.
- Return-to-learn should be done in a step-by-step progression that fits the needs of the individual, with adjustments to be made as needed to manage the student-athlete's unique symptoms and recovery response.
- As an academic point person or other member of academic staff, it is beneficial to understand the science underlying concussion management and the rationale behind related return-to-learn considerations.

Specific Return-to-Learn Considerations

Return-to-learn guidelines assume that both physical and cognitive activities require brain energy utilization, and that after a sport-related concussion, brain energy may not be available for physical and cognitive exertion because of the brain energy crisis. The student-athlete may appear physically normal but may be unable to perform as expected due to concussion symptoms.

The unique nature of concussion symptoms and recovery make it difficult to provide prescriptive recommendations for return-to-learn. Importantly, unrestricted return-to-sport should not occur before unrestricted return-to-learn for injuries occurring while the athlete is enrolled in classes. The broad return-to-learn recommendations outlined on the next page are based on available data and related expert consensus, and portions of the content have been previously published by the NCAA as part of its **Concussion Safety Protocol Checklist** and corresponding **Concussion Safety Protocol Template**.

This policy is intended to guide patient care. Medical conditions and specific medical situations are often complex and require health care providers to make independent judgments. These policies may be modified by practitioners to achieve maximal patient outcomes.

Return-to-Learn Recommendations

Stepwise Progression

The first step of return-to-learn is relative physical and cognitive rest. Relative cognitive rest involves minimizing potential cognitive stressors, such as reading and schoolwork. The necessary period of time that a concussed student-athlete waits before resuming class or homework should be individualized with a return to classroom/studying as tolerated. Return-to-learn should be gradual with specific attention to any worsening of concussion symptoms following cognitive exposure or symptoms lasting longer than two weeks. According to currently available expert consensus:

- If the student-athlete cannot tolerate light cognitive activity, he or she should remain at home or in the residence hall.
- Once the student-athlete can tolerate light cognitive activity, he/she should return to the classroom as tolerated, often in graduated increments.
- At any point, if the student-athlete experiences a worsening of symptoms with academic challenge (i.e., more symptomatic than baseline), or scores on clinical/cognitive measures decline, the team physician should be notified, and the student-athlete's return-to-learn activity reassessed.

Common Academic Adjustments

For the student-athlete whose academic schedule requires a minor modification in the first one to two weeks following a sport-related concussion, adjustments can often be accomplished through consultation between the student-athlete and the academic point person without material changes to schedules, curriculum or testing environments. Recovery and return-to-learn schedules will vary on a case-by-case basis but the majority of student-athletes who are concussed fully recover within two weeks.

Atypical or Persistent Symptoms

- In the case of complex return-to-learn scenarios (e.g., atypical cases or cases in which symptoms persist beyond two weeks), the extent of necessary academic adjustments/accommodations should be decided in consultation with a broader multi-disciplinary team that may include, among others, the team physician, athletic trainer, faculty athletics representative, coach, teachers, office of disability representatives, neuropsychologist or psychologist/counselor.
- Cases that cannot be managed through schedule or academic accommodations may require the engagement of other campus resources. These resources should be engaged in a manner consistent with the Americans with Disabilities Act Amendments Act and should include learning specialists and/or representatives from the campus office of disability services or ADAAA.

Implementation of Return-to-Learn

The successful implementation of return-to-learn depends on several variables, including the following:

- Recognition that concussion symptoms vary widely among student-athletes, and even within the same individual who may be suffering a repeat concussion.
- Identification of an academic point person who can work with the recovering student-athlete to navigate the challenges that may occur in the academic space.
- Identification of symptoms that may warrant additional medical attention or impair cognitive recovery, such as headache conditions, difficulty maintaining attention, hyperactivity, anxiety and mood swings.
- Identification of additional campus resources that can help assure that the rights of the recovering student-athlete are adequately considered during this transition period.

Available Campus Resources

Campus resources vary, and may include the following:

- **Learning specialists**. Many college campuses have certified learning specialists who have specialized knowledge of medical conditions such as concussion and post-concussion syndrome.
- **Office of disability services**. Most campuses have a disability office that is responsible for verifying each student's impairment under the Americans with Disabilities Act Amendments Act and some institutions also offer a separate ADAAA office.

For more information, visit ncaa.org/concussion.

Appendix IV: Student-Athlete Injury and Illness Responsibility Statement

BOSTON UNIVERSITY

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.

_______ Initial — I have been provided an opportunity to discuss the above referenced information and have any relevant questions I have answered.

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

Modified 05/2020

Appendix V: Stakeholder Concussion Education Statement

BOSTON UNIVERSITY

Boston University
Stakeholder Injury and Illness Responsibility Statement

_______ Initial — As a representative of the Department of Athletics at Boston University, I understand that it is my responsibility to report all known and suspected injuries and illnesses 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 suspected concussions to an athletic trainer and/or team physician.

_______ Initial — I have been provided an opportunity to discuss the above referenced information and have any relevant questions I have answered.

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 suspected concussions to an athletic trainer and/or team physician.

_______ Initial — A concussion can affect one's ability to perform everyday activities, and affects reaction, time, balance, sleep, and classroom performance.

_______ Initial — I will not allow a student-athlete to return to play in a game or practice if I suspect they have received a blow to the head or body that results in concussion-related symptoms.

_______ Initial — If a student-athlete acquires an injury that results in concussion-related symptoms I will support all instructions related to the treatment of the injury given to the student-athlete by a member or Athletic Training Services and team physicians.

_______ 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 Stakeholder — Date

________________________________ ________________________
Printed Name of Stakeholder — Position/Role

Modified 5/2020

This policy is intended to guide patient care. Medical conditions and specific medical situations are often complex and require health care providers to make independent judgments. These policies may be modified by practitioners to achieve maximal patient outcomes.

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

BJSM Online First, published on April 26, 2017 as 10.1136/bjsports-2017-097506SCAT5

To download a clean version of the SCAT tools please visit the journal online (http://dx.doi.org/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

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.

This policy is intended to guide patient care. Medical conditions and specific medical situations are often complex and require health care providers to make independent judgments. These policies may be modified by practitioners to achieve maximal patient outcomes.

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.

Davis GA, *et al. Br J Sports Med* 2017;**0**:1–8. doi:10.1136/bjsports-2017-097506SCAT5

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

Davis GA, *et al. Br J Sports Med* 2017;**0**:1–8. doi:10.1136/bjsports-2017-097506SCAT5 3

3

STEP 3: COGNITIVE SCREENING

Standardised Assessment of Concussion (SAC)[4]

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			

Name: ______________________

DOB: ______________________

Address: ______________________

ID number: ______________________

Examiner: ______________________

Date: ______________________

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

Davis GA, *et al. Br J Sports Med* 2017;**0**:1–8. doi:10.1136/bjsports-2017-097506SCAT5

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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 of 30	of 15 of 30	of 15 of 30
Concentration (of 5)			
Neuro exam	Normal Abnormal	Normal Abnormal	Normal Abnormal
Balance errors (of 30)			
Delayed Recall	of 5 of 10	of 5 of 10	of 5 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.

Davis GA, *et al. Br J Sports Med* 2017;**0**:1–8. doi:10.1136/bjsports-2017-097506SCAT5

This policy is intended to guide patient care. Medical conditions and specific medical situations are often complex and require health care providers to make independent judgments. These policies may be modified by practitioners to achieve maximal patient outcomes.

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

Davis GA, *et al. Br J Sports Med* 2017;**0**:1–8. doi:10.1136/bjsports-2017-097506SCAT5

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

1. McCrory et al. Consensus Statement On Concussion In Sport – The 5th International Conference On Concussion In Sport Held In Berlin, October 2016. British Journal of Sports Medicine 2017 (available at www.bjsm.bmj.com)

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

4. McCrea M. Standardized mental status testing of acute concussion. Clinical Journal of Sport Medicine. 2001; 11: 176-181

5. Guskiewicz KM. Assessment of postural stability following sport-related concussion. Current Sports Medicine Reports. 2003; 2: 24-30

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.

Davis GA, *et al. Br J Sports Med* 2017;**0**:1–8. doi:10.1136/bjsports-2017-097506SCAT5

Appendix VII: Ordinance Creating a College Athlete Head Injury Gameday Safety Protocol

Offered by Councilor Josh Zakim

CITY OF BOSTON

IN THE YEAR TWO THOUSAND FOURTEEN

AN ORDINANCE CREATING A COLLEGE ATHLETE HEAD INJURY GAMEDAY SAFETY PROTOCOL

WHEREAS, Basic principles of human and civil rights guarantee the right to physical health and personal safety; and

WHEREAS, The City of Boston has a particular responsibility to safeguard these human and civil rights for both residents of and visitors to the City; and

WHEREAS, The City of Boston commonly hosts intercollegiate athletic events; and

WHEREAS, Colleges and universities participating in intercollegiate athletic events avail themselves of numerous city services, including police, fire, and emergency medical response; and

WHEREAS, Injuries of the head, neck, and spine in athletic competition are a serious public health concern in Boston and throughout the United States; and

WHEREAS, Sports leagues such as the National Football League and National Hockey League, as well as the Massachusetts Interscholastic Athletic Association, have instituted comprehensive head injury safety protocols for the protection of professional and high school athletes alike; and

WHEREAS, The National Collegiate Athletic Association ("NCAA") has failed to establish any such protocols or guidelines for its member institutions; and

WHEREAS, The NCAA's continued failure to do so endangers college athletes everywhere.

NOW THEREFORE,

Be it ordained by the City Council of Boston, as follows:

Section 1.
Definitions.
(a) "Athletic program" means an intercollegiate athletic program at any institution of higher education within the meaning of subdivision (b).

(b) "Institution of higher education" means any four-year college or university that maintains an intercollegiate athletic program.
(c) "College athlete" means any college student who participates in an intercollegiate athletic program of an institution of higher education.
(d) "Athletic scholarship" means financial aid provided to a college athlete by an institution of higher education that is provided in exchange for, but not exclusively in exchange for, that college athlete's participation in that institution of higher education's athletic program.
(e) "Intercollegiate athletic event" means any game, match, meet, race, or other event during which college athletes from athletic programs of more than one institution of higher education compete against each other.

Section 2.
Concussion Defined.
(a) For purposes of these sections, "concussion" means a complex pathophysiological process affecting the brain induced by biomechanical forces. Several common features that incorporate clinical, pathologic and biomechanical injury constructs that may be utilized in defining the nature of a concussive head injury include:

(1) Concussion 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.
(2) Concussion typically results in the rapid onset of transient impairment of neurologic function that resolves spontaneously. However, in some cases, symptoms and signs may evolve over a number of minutes to hours.
(3) Concussion may result in neuropathological changes, but the acute clinical symptoms largely reflect a functional disturbance rather than a structural injury and, as such, no abnormality is seen on standard structural neuroimaging studies.
(4) Concussion results in a graded set of clinical symptoms that may or may not involve loss of consciousness. Resolution of the clinical and cognitive symptoms typically follows a sequential course; however, it is important to note that, in some percentage of cases, postconcussive symptoms may be prolonged.

(b) Potential concussion signs (observable):

(1) Any loss of consciousness;
(2) Slow to get up following a hit to the head ("hit to the head" may include secondary contact with the playing surface);
(3) Motor coordination/balance problems (stumbles, trips/falls, slow/labored movement);
(4) Blank or vacant look;
(5) Disorientation (e.g., unsure of where he is on the field or location of bench);
(6) Clutching of head after contact;
(7) Visible facial injury in combination with any of the above.

(c) Potential Concussion Symptoms (athlete reported, following direct or indirect contact):

(1) Headache;
(2) Dizziness;
(3) Balance or coordination difficulties;
(4) Nausea;
(5) Amnesia for the circumstances surrounding the injury (i.e., retrograde/anterograde amnesia);
(6) Cognitive slowness;

(7) Light/sound sensitivity;
(8) Disorientation;
(9) Visual disturbance;
(10) Tinnitus.

Section 3.
Scope.
These sections shall apply to any athletic program, regardless of domicile, participating in any intercollegiate athletic event that is:
(a) Sanctioned by the NCAA; and
(b) Located in any part of the City of Boston.

Section 4.
Gameday Safety Protocol.
(a) An athletic program shall develop and write an Emergency Medical Action Plan (the "Plan") for all practice, training, and game venues. The medical staff of the athletic program shall discuss, practice, and review the Plan regularly.
(b)(1) The designated host athletic program of any intercollegiate athletic event shall provide an on-call 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 any primary care CAQ sports medicine certified physician that has documented competence and experience in the treatment of acute head injuries. In the event a college athlete suffers or is suspected to have suffered an injury to the head, neck, or spine, the host athletic program shall ensure that the Neurotrauma Consultant is present at the event venue within 30 minutes. The Neurotrauma Consultant shall work with the host or visiting athletic program's medical staff in the diagnosis and care of any college athlete's injury to the head, neck or spine.
(2) If the injured college athlete's athletic program has medical staff present at the event venue, ultimate injury diagnosis remains exclusively within the professional judgment of the medical staff of the athletic program of the injured college athlete.
(3) In the event there is no designated host athletic program for an intercollegiate athletic event, the participating athletic programs shall jointly provide the on-call Neurotrauma Consultant.
(c) If a college athlete participating in an intercollegiate athletic event becomes unconscious, the college athlete shall not return to the event during which the college athlete became unconscious. The college athlete shall not participate in any future practices, training sessions, or intercollegiate athletic events in Boston until the college athlete receives written authorization for such participation from a licensed physician or other appropriately trained or licensed health care professional, as determined by the Boston Public Health Commissioner. The college athlete must provide such authorization to his or her athletic program's athletic director.
(d) If a college athlete participating in an intercollegiate athletic event suffers a concussion as diagnosed by a medical professional, or is suspected to have suffered a concussion, the college athlete shall not return to the event during which the concussion or suspected concussion occurred. The college athlete shall not participate in any future practices, training sessions, or intercollegiate athletic events in Boston until the college athlete receives written authorization for such participation from a licensed physician or other appropriately trained or licensed health care

professional, as determined by the Boston Public Health Commissioner. The college athlete must provide such authorization to his or her athletic program's athletic director.

Section 5.
Additional Requirement for Football, Ice Hockey, and Men's Lacrosse.
(a) This section shall apply exclusively to institutions of higher education that grant athletic scholarships.
(b) For an intercollegiate athletic event involving the sports of football, ice hockey, and men's lacrosse:
(1) The designated host athletic program shall provide an on-site Neurotrauma Consultant at the event venue. 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 any primary care CAQ sports medicine certified physician that has documented competence and experience in the treatment of acute head injuries. 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. The Neurotrauma Consultant shall be focused on identifying symptoms of concussion and mechanisms of injury that warrant concussion evaluation, working in consultation with medical staff of the athletic programs to implement concussion evaluations, and observing exams of the head, neck, and spine performed by medical staff. In the event a college athlete suffers or is suspected to have suffered an injury to the head, neck, or spine, the Neurotrauma Consultant shall work with the athletic program's medical staff in the diagnosis and care of the injury.
(2) If the injured college athlete's athletic program has medical staff present at the event venue, ultimate injury diagnosis remains exclusively within the professional judgment of the medical staff of the athletic program of the injured college athlete.
(3) In the event there is no designated host athletic program for an intercollegiate athletic event, the participating athletic programs shall jointly provide the on-site Neurotrauma Consultant.
(c) For athletic programs to which this section applies, the provisions of this section shall replace Section 4, subsection (b).

Section 6.
Enforcement.
The Boston Public Health Commission and the Boston Human Rights Commission, or their designee(s), shall have the authority to enforce these sections. Anyone who desires to register a complaint of noncompliance under these sections may do so by contacting the Boston Public Health Commission, the Boston Human Rights Commission, or their designee(s).

Section 7.
The provisions of this ordinance shall take effect immediately upon passage.

Filed in Council: May 16, 2014

Appendix VIII: Consensus Statement on Concussion in Sport – 5th International Conference

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

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.

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.

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).

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

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.

This policy is intended to guide patient care. Medical conditions and specific medical situations are often complex and require health care providers to make independent judgments. These policies may be modified by practitioners to achieve maximal patient outcomes.

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

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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

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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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REFERENCES

1 Aubry M, Cantu R, Dvorak J, *et al*; Concussion in Sport (CIS) Group. Summary and agreement statement of the 1st international symposium on concussion in sport, Vienna 2001. *Clin J Sport Med* 2002;12:6–11.
2 McCrory P Johnston K, Meeuwisse W, *et al*. Summary and agreement statement of the 2nd international conference on concussion in sport, Prague 2004. *Br J Sports Med* 2005;39:i78–i86.
3 McCrory P, Meeuwisse W, Johnston K, *et al*. Consensus statement on concussion in sport - the third international conference on concussion in sport held in Zurich, November 2008. *Phys Sportsmed* 2009;37:141–59.
4 McCrory P, Meeuwisse WH, Aubry M, *et al*. Consensus statement on concussion in sport: the 4th international conference on concussion in sport held in Zurich, november 2012. *Br J Sports Med* 2013;47:250–8.
5 Meeuwisse WH, Schneider KJ, Dvořák J, *et al*. The Berlin 2016 process: a summary of methodology for the 5th International Consensus Conference on Concussion in Sport. *Br J Sports Med* 2017;51:873–876.
6 Maddocks D, Dicker G. An objective measure of recovery from concussion in Australian rules footballers. *Sport Health* 1989;7:6–7.
7 Maddocks DL, Dicker GD, Saling MM. The assessment of orientation following concussion in athletes. *Clin J Sport Med* 1995;5:32–5.
8 McCrea M. Standardized mental status assessment of sports concussion. *Clin J Sport Med* 2001;11:176–81.
9 McCrea M, Kelly JP, Randolph C, *et al*. Standardized assessment of concussion (SAC): on-site mental status evaluation of the athlete. *J Head Trauma Rehabil* 1998;13:27–35.
10 McCrea M, Randolph C, Kelly J. *The Standardized Assessment of Concussion (SAC): Manual for Administration, Scoring and Interpretation*. 2nd ed. Waukesha: WI, 2000.
11 McCrea M, Kelly JP, Kluge J, *et al*. Standardized assessment of concussion in football players. *Neurology* 1997;48:586–8.
12 Collie A, Darby D, Maruff P. Computerised cognitive assessment of athletes with sports related head injury. *Br J Sports Med* 2001;35:297–302.
13 Collie A, Maruff P. Computerised neuropsychological testing. *Br J Sports Med* 2003;37:2–3.
14 Collie A, Maruff P, McStephen M, *et al*. Psychometric issues associated with computerised neuropsychological assessment of concussed athletes. *Br J Sports Med* 2003;37:556–9.
15 Collins MW, Grindel SH, Lovell MR, *et al*. Relationship between concussion and neuropsychological performance in college football players. *Jama* 1999;282:964–70.
16 Lovell MR. The relevance of neuropsychologic testing for sports-related head injuries. *Curr Sports Med Rep* 2002;1:7–11.
17 Lovell MR, Collins MW. Neuropsychological assessment of the college football player. *J Head Trauma Rehabil* 1998;13:9–26.
18 Bleiberg J, Cernich AN, Cameron K, *et al*. Duration of cognitive impairment after sports concussion. *Neurosurgery* 2004;54:1073–78–78–80.
19 Bleiberg J, Warden D. Duration of cognitive impairment after sports concussion. *Neurosurgery* 2005;56:E1166.
20 Broglio SP, Macciocchi SN, Ferrara MS. Neurocognitive performance of concussed athletes when symptom free. *J Athl Train* 2007;42:504–8.
21 Broglio SP, Macciocchi SN, Ferrara MS. Sensitivity of the concussion assessment battery. *Neurosurgery* 2007;60:1050–7–7–8.
22 Gioia G, Janusz J, Gilstein K, *et al*. Neueopsychological management of consussion in children and adolescents: effects of age and gender on ImPact. abstract). *Br J Sp Med* 2004;38:657.
23 McCrory P, Collie A, Anderson V, *et al*. Can we manage sport related concussion in children the same as in adults? *Br J Sports Med* 2004;38:516–9.
24 Makdissi M, Schneider KJ, Feddermann-Demont N, *et al*. Approach to investigation and treatment of persistent symptoms following sport-related concussion: a systematic review. *Br J Sports Med* 2017;51:958–68.
25 Manley G, Gardner AJ, Schneider KJ, *et al*. A systematic review of potential long-term effects of sport-related concussion. *Br J Sports Med* 2017;51:969–77.
26 McCrory P. Preparticipation assessment for head injury. *Clin J Sport Med* 2004;14:139–44.

27 Johnston KM, Lassonde M, Ptito A. A contemporary neurosurgical approach to sport-related head injury: the McGill concussion protocol. *J Am Coll Surg* 2001;192:515–24.
28 Delaney J, Lacroix V, Leclerc S, *et al*. Canadian football league season.. *Clin J Sport Med* 1997;2000:9–14.
29 Delaney JS, Lacroix VJ, Leclerc S, *et al*. Concussions among university football and soccer players. *Clin J Sport Med* 2002;12:331–8.
30 Johnston KM, Bloom GA, Ramsay J, *et al*. Current concepts in concussion rehabilitation. *Curr Sports Med Rep* 2004;3:316–23.
31 Denke NJ. Brain injury in sports. *J Emerg Nurs* 2008;34:363–4.
32 Gianotti S, Hume PA. Concussion sideline management intervention for rugby union leads to reduced concussion claims. *NeuroRehabilitation* 2007;22:181–9.
33 Guilmette TJ, Malia LA, McQuiggan MD. Concussion understanding and management among new England high school football coaches. *Brain Inj* 2007;21:1039–47.
34 Hootman JM, Dick R, Agel J. Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives. *J Athl Train* 2007;42:311–9.
35 Valovich McLeod TC, Schwartz C, Bay RC. Sport-related concussion misunderstandings among youth coaches. *Clin J Sport Med* 2007;17:140–2.
36 Sye G, Sullivan SJ, McCrory P. High school rugby players' understanding of concussion and return to play guidelines. *Br J Sports Med* 2006;40:1003–5.
37 Theye F, Mueller KA. "Heads up": concussions in high school sports. *Clin Med Res* 2004;2:165–71.
38 Kashluba S, Paniak C, Blake T, *et al*. A longitudinal, controlled study of patient complaints following treated mild traumatic brain injury. *Arch Clin Neuropsychol* 2004;19:805–16.
39 Gabbe B, Finch CF, Wajswelner H, *et al*. Does community-level Australian football support injury prevention research? *J Sci Med Sport* 2003;6:231–6.
40 Kaut KP, DePompei R, Kerr J, *et al*. Reports of head injury and symptom knowledge among college athletes: implications for assessment and educational intervention. *Clin J Sport Med* 2003;13:213–21.
41 Davidhizar R, Cramer C. "The best thing about the hospitalization was that the nurses kept me well informed" Issues and strategies of client education. *Accid Emerg Nurs* 2002;10:149–54.
42 McCrory P. What advice should we give to athletes postconcussion? *Br J Sports Med* 2002;36:316–8.
43 Bazarian JJ, Veenema T, Brayer AF, *et al*. Knowledge of concussion guidelines among practitioners caring for children. *Clin Pediatr* 2001;40:207–12.
44 Langlois JA, Rutland-Brown W, Wald MM. The epidemiology and impact of traumatic brain injury: a brief overview. *J Head Trauma Rehabil* 2006;21:375–8.
45 Langlois JA, Sattin RW. Traumatic brain injury in the United States: research and programs of the centers for disease control and prevention (CDC). *J Head Trauma Rehabil* 2005;20:187–8.
46 Kelly JP, Rosenberg JH. The development of guidelines for the management of concussion in sports. *J Head Trauma Rehabil* 1998;13:53–65.

This policy is intended to guide patient care. Medical conditions and specific medical situations are often complex and require health care providers to make independent judgments. These policies may be modified by practitioners to achieve maximal patient outcomes.

Appendix IX: Clinician Concussion Management Checklist

Boston University
Athletic Training Services

285 Babcock Street
Boston, Massachusetts 02215
T 617-353-2746 F 617-353-3579

Clinician Concussion Management Checklist

Initial Diagnosis Concussion Checklist

- ☐ Patient educated on pathology, acute management strategies, and red flags
- ☐ Handouts on concussion given to patient
- ☐ If patient is in academic semester, cognitive rest letters provided to patient
- ☐ Patient given AT contact information to communicate with and for follow-up
- ☐ Concussion added to patient's PNC problem list, with onset date and status as "Active"
- ☐ Symptom sheet and/or SCAT-5 uploaded to patient's chart
- ☐ Director of Sports Medicine cc'd on patient's note
- ☐ AT Neurology Fellow cc'd on patient's note
- ☐ If varsity athlete and in academic semester, Student-Athlete Academic Support Services alerted of patient's injury

Discharge Concussion Checklist

- ☐ RTP completed
- ☐ Neurocognitive assessment completed and reviewed by team physician
- ☐ Postural control assessment completed and reviewed by team physician
- ☐ In patient's chart, concussion problem list has been changed to "Resolved"
- ☐ If varsity athlete, email sent to buathdir@bu.edu

Modified 6/2022

Appendix X: 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

CONCUSSION TIMELINE

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.

Appendix XI: Cognitive Rest Letter

Boston University
Athletic Training Services

285 Babcock Street
Boston, Massachusetts 02215
T: 617-353-2746 F: 617-353-3579
athtrn@bu.edu

(date of creation)

Dear Professor,

This letter is to inform you that *(patient's full name, BUID#)* sustained a concussion on *(date of injury)*. 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 *(patient's first name)* 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 requirements, 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, playing video games 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 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. Additionally, for more information about our department and services provided, please refer to our website at: https://www.bu.edu/shs/athletic-training/

Sincerely,

Arturo Aguilar, MD	*(AT's full name)*
Director of Sports Medicine	Athletic Trainer
aguilar@bu.edu	*(AT's email)*
617-353-2746	617-353-2746

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Appendix XII: 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 $kg \cdot m^{-2}$.

[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 $kg \cdot m^{-2}$).

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

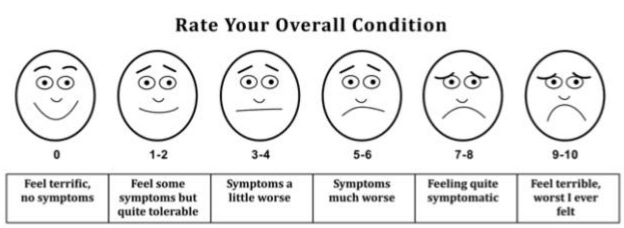

Figure 1: Visual Analog Scale for assessment of overall symptom level before and during the Buffalo Concussion Treadmill Test.

This policy is intended to guide patient care. Medical conditions and specific medical situations are often complex and require health care providers to make independent judgments. These policies may be modified by practitioners to achieve maximal patient outcomes.

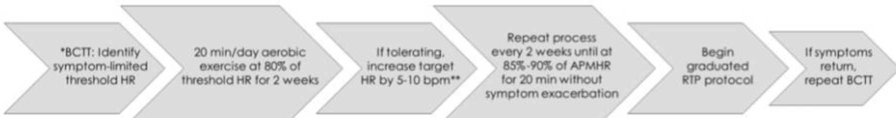

Figure 2: Use of the BCTT and exercise prescription for RTA in physiologic PCD. APMHR, age-predicted maximum HR. *After 3 wk of symptoms. **5 bpm for nonathletes; 10 bpm for athletes. To obtain a more precise target HR, consider repeating the BCTT every 2 wk.

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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References

1. Agrawal D, Gowda NK, Bal CS, *et al.* Is medial temporal injury responsible for pediatric postconcussion syndrome? A prospective controlled study with single-photon emission computerized tomography. *J. Neurosurg.* 2005;102:167–71.
2. Ahlskog JE, Geda YE, Graff-Radford NR, Petersen RC. Physical exercise as a preventive or disease-modifying treatment of dementia and brain aging. *Mayo Clin. Proc.* 2011;86:876–84.
3. Alderman BL, Arent SM, Landers DM, Rogers TJ. Aerobic exercise intensity and time of stressor administration influence cardiovascular responses to psychological stress. *Psychophysiology* 2007;44:759–66.
4. Alsalaheen BA, Mucha A, Morris LO, *et al.* Vestibular rehabilitation for dizziness and balance disorders after concussion. *J. Neurol. Phys. Ther.* 2010;34:87–93.

5. Arciniegas DB, Topkoff JL. Applications of the P50 evoked response to the evaluation of cognitive impairments after traumatic brain injury. *Phys. Med. Rehabil. Clin. N. Am.* 2004;15:177–203, viii.

6. Baker JG, Freitas MS, Leddy JJ, *et al.* Return to full functioning after graded exercise assessment and progressive exercise treatment of postconcussion syndrome. *Rehabil. Res. Pract.* 2012;2012:705309.

7. Bazarian JJ. Diagnosing mild traumatic brain injury after a concussion. *J. Head Trauma Rehabil.* 2010;25:225–7.

8. Bleiberg J, Cernich AN, Cameron K, *et al.* Duration of cognitive impairment after sports concussion. *Neurosurgery* 2004;54:1073–8; discussion 8–80.

9. Boake C, McCauley SR, Levin HS, *et al.* Diagnostic criteria for postconcussional syndrome after mild to moderate traumatic brain injury. *J. Neuropsychiatry Clin. Neurosci.* 2005;17:350–6.

10. Chen JK, Johnston KM, Frey S, *et al.* Functional abnormalities in symptomatic concussed athletes: an fMRI study. *Neuroimage* 2004;22:68–82.

11. Chen JK, Johnston KM, Petrides M, Ptito A. Neural substrates of symptoms of depression following concussion in male athletes with persisting postconcussion symptoms. *Arch. Gen. Psychiatry* 2008;65:81–9.

12. Colcombe SJ, Kramer AF, Erickson KI, *et al.* Cardiovascular fitness, cortical plasticity, and aging. *Proc. Natl. Acad. Sci. U. S. A.* 2004;101:3316–21.

13. Dimeo F, Bauer M, Varahram I, *et al.* Benefits from aerobic exercise in patients with major depression: a pilot study. *Br. J. Sports Med.* 2001;35:114–7.

14. Erickson KI, Voss MW, Prakash RS, *et al.* Exercise training increases size of hippocampus and improves memory. *Proc. Natl. Acad. Sci. U. S. A.* 2011; 108:3017–22.

15. Gagnon I, Galli C, Friedman D, *et al.* Active rehabilitation for children who are slow to recover following sport-related concussion. *Brain Inj.* 2009;23: 956–64.

16. Gall B, Parkhouse W, Goodman D. Heart rate variability of recently concussed athletes at rest and exercise. *Med. Sci. Sports Exerc.* 2004;36: 1269–74.

17. Gall B, Parkhouse WS, Goodman D. Exercise following a sport induced concussion. *Br. J. Sports Med.* 2004;38:773–7.

18. Geets W, de Zegher F. EEG and brainstem abnormalities after cerebral concussion. Short term observations. *Acta Neurol. Belg.* 1985;85:277–83.

19. Giza CC, Hovda DA. The neurometabolic cascade of concussion. *J. Athl. Train.* 2001;36:228–35.

20. Goldstein B, Toweill D, Lai S, *et al.* Uncoupling of the autonomic and cardiovascular systems in acute brain injury. *Am. J. Physiol.* 1998;275(4 Pt 2): R1287–92.

21. Griesbach GS, Gomez-Pinilla F, Hovda DA. The upregulation of plasticity-related proteins following TBI is disrupted with acute voluntary exercise. *Brain Res.* 2004;1016:154–62.

22. Griesbach GS, Hovda DA, Molteni R, *et al.* Voluntary exercise following traumatic brain injury: brain-derived neurotrophic factor upregulation and recovery of function. *Neuroscience.* 2004;125:129–39.

23. Guskiewicz KM. Assessment of postural stability following sport-related concussion. *Curr. Sports Med. Rep.* 2003;2:24–30.

24. Guskiewicz KM, Marshall SW, Bailes J, *et al.* Recurrent concussion and risk of depression in retired professional football players. *Med. Sci. Sports Exerc.* 2007;39:903–9.

25. Jotwani V, Harmon KG. Postconcussion syndrome in athletes. *Curr. Sports Med. Rep.* 2010;9:21–6.

26. Junger EC, Newell DW, Grant GA, *et al.* Cerebral autoregulation following minor head injury. *J. Neurosurg.* 1997;86:425–32.

27. Kozlowski KF, Graham J, Leddy JJ, *et al.* Exercise intolerance in individuals with postconcussion syndrome. *J. Athl. Train.* 2013;48:627–35.

28. Lautenschlager NT, Cox KL, Flicker L, *et al.* Effect of physical activity on cognitive function in older adults at risk for Alzheimer disease: a randomized trial. *JAMA* 2008;300:1027–37.

29. Leddy JJ, Baker JG, Kozlowski K, *et al.* Reliability of a graded exercise test for assessing recovery from concussion. *Clin. J. Sport Med.* 2011;21:89–94.

30. Leddy JJ, Cox JL, Baker JG, *et al.* Exercise treatment for postconcussion syndrome: a pilot study of changes in functional magnetic resonance imaging activation, physiology, and symptoms. *J. Head Trauma Rehabil.* 2013; 28:241–9.

31. Leddy JJ, Kozlowski K, Donnelly JP, *et al.* A preliminary study of subsymptom threshold exercise training for refractory post-concussion syndrome. *Clin. J. Sport Med.* 2010;20:21–7.

32. Leddy JJ, Kozlowski K, Fung M, *et al.* Regulatory and autoregulatory physiological dysfunction as a primary characteristic of post concussion syndrome: implications for treatment. *NeuroRehabilitation* 2007;22: 199–205.

33. Leddy JJ, Sandhu H, Sodhi V, *et al.* Rehabilitation of concussion and post-concussion syndrome. *Sports Health* 2012;4:147–54.

34. Lovell MR, Collins MW, Iverson GL, *et al.* Recovery from mild concussion in high school athletes. *J. Neurosurg.* 2003;98:296–301.

35. Lovell MR, Iverson GL, Collins MW, *et al.* Measurement of symptoms following sports-related concussion: reliability and normative data for the post-concussion scale. *Appl. Neuropsychol.* 2006;13:166–74.

36. Majerske CW, Mihalik JP, Ren D, *et al.* Concussion in sports: postconcussive activity levels, symptoms, and neurocognitive performance. *J. Athl. Train.* 2008;43:265–74.

37. Makdissi M, Cantu RC, Johnston KM, *et al.* The difficult concussion patient: what is the best approach to investigation and management of persistent (>10 days) postconcussive symptoms? *Br. J. Sports Med.* 2013;47:308–13.

38. Maugans TA, Farley C, Altaye M, *et al.* Pediatric sports-related concussion produces cerebral blood flow alterations. *Pediatrics* 2012;129:28–37.

39. McAllister TW, Sparling MB, Flashman LA, *et al.* Differential working memory load effects after mild traumatic brain injury. *Neuroimage* 2001;14: 1004–12.

40. McCrea M, Guskiewicz KM, Marshall SW, *et al.* Acute effects and recovery time following concussion in collegiate football players: the NCAA Concussion Study. *JAMA* 2003;290:2556–63.

41. McCrory P, Meeuwisse W, Aubry M, *et al.* Consensus statement on concussion in sport — the 4th International Conference on Concussion in Sport held in Zurich, November 2012. *Clin. J. Sport Med.* 2013;23:89–117.

42. Preiss-Farzanegan SJ, Chapman B, Wong TM, *et al.* The relationship between gender and postconcussion symptoms after sport-related mild traumatic brain injury. *PM R.* 2009;1:245–53.

43. Randolph C, McCrea M, Barr WB. Is neuropsychological testing useful in the management of sport-related concussion? *J. Athl. Train.* 2005;40: 139–52.

44. Silverberg ND, Iverson GL. Is rest after concussion 'the best medicine?': recommendations for activity resumption following concussion in athletes, civilians, and military service members. *J. Head Trauma Rehabil.* 2013; 28:250–9.

45. Stalnacke BM, Bjornstig U, Karlsson K, Sojka P. One-year follow-up of mild traumatic brain injury: post-concussion symptoms, disabilities and life satisfaction in relation to serum levels of S-100B and neurone-specific enolase in acute phase. *J. Rehabil. Med.* 2005;37:300–5.

46. Stroth S, Hille K, Spitzer M, Reinhardt R. Aerobic endurance exercise benefits memory and affect in young adults. *Neuropsychol. Rehabil.* 2009;19: 223–43.

47. Vagnozzi R, Signoretti S, Tavazzi B, *et al.* Temporal window of metabolic brain vulnerability to concussion: a pilot 1H-magnetic resonance spectroscopic study in concussed athletes — part III. *Neurosurgery* 2008;62: 1286–95; discussion 95–6.

48. Willer B, Leddy JJ. Management of concussion and post-concussion syndrome. *Curr. Treat. Options Neurol.* 2006;8:415–26.

49. Wise EK, Hoffman JM, Powell JM, *et al.* Benefits of exercise maintenance after traumatic brain injury. *Arch. Phys. Med. Rehabil.* 2012;93:1319–23.

50. Zhang R, Zuckerman JH, Pawelczyk JA, Levine BD. Effects of head-down-tilt bed rest on cerebral hemodynamics during orthostatic stress. *J. Appl. Physiol.* 1997;83:2139–45.

Appendix XIII: Vestibular Oculo-Motor Screening (VOMS)

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A Brief Vestibular/Ocular Motor Screening (VOMS) Assessment to Evaluate Concussions:

Preliminary Findings

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Abstract

Background—Vestibular and ocular motor impairments and symptoms have been documented in patients with sport-related concussions. However, there is no current brief clinical screen to assess and monitor these issues.

Purpose—To describe and provide initial data for the internal consistency and validity of a brief clinical screening tool for vestibular and ocular motor impairments and symptoms after sport-related concussions.

Study Design—Cross-sectional study; Level of evidence, 2.

Methods—Sixty-four patients, aged 13.9 ± 2.5 years and seen approximately 5.5 ± 4.0 days after a sport-related concussion, and 78 controls were administered the Vestibular/Ocular Motor Screening (VOMS) assessment, which included 5 domains: (1) smooth pursuit, (2) horizontal and vertical saccades, (3) near point of convergence (NPC) distance, (4) horizontal vestibular ocular reflex (VOR), and (5) visual motion sensitivity (VMS). Participants were also administered the Post-Concussion Symptom Scale (PCSS).

Results—Sixty-one percent of patients reported symptom provocation after at least 1 VOMS item. All VOMS items were positively correlated to the PCSS total symptom score. The VOR (odds ratio [OR], 3.89; $P<.001$) and VMS (OR, 3.37; $P<.01$) components of the VOMS were most predictive of being in the concussed group. An NPC distance ≥5 cm and any VOMS item symptom score ≥2 resulted in an increase in the probability of correctly identifying concussed

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patients of 38% and 50%, respectively. Receiver operating characteristic curves supported a model including the VOR, VMS, NPC distance, and ln(age) that resulted in a high predicted probability (area under the curve = 0.89) for identifying concussed patients.

Conclusion—The VOMS demonstrated internal consistency as well as sensitivity in identifying patients with concussions. The current findings provide preliminary support for the utility of the VOMS as a brief vestibular/ocular motor screen after sport-related concussions. The VOMS may augment current assessment tools and may serve as a single component of a comprehensive approach to the assessment of concussions.

Keywords

concussion; vestibular; ocular motor; symptoms

A sport-related concussion is an individualized injury that presents with a myriad of cognitive, physical, emotional, somatic, and sleep-related symptoms and impairments that should require a multifaceted approach to assessment and management.[14,26] Among the recommended assessments are physical examinations, clinical interviews, symptom reports, and neurocognitive and balance tests. Recently, researchers have reported that vestibular impairments are common after a concussion and may delay recovery from this injury.[20,27] Dizziness, which may represent an underlying impairment of the vestibular and/or ocular motor systems, is reported by 50% of concussed athletes[23] and is associated with a 6.4-times greater risk, relative to any other on-field symptom, in predicting protracted (>21 days) recovery.[24] Despite the emerging evidence that vestibular-related impairments and symptoms are important to assess after concussions, there are currently no brief but comprehensive clinical tools to do so. Additional measures are needed to help clinicians identify vestibular impairments and symptoms after concussions.

The vestibular system is a complex network that includes small sensory organs of the inner ear (utricle, saccule, and semicircular canals) and connections to the brain stem, cerebellum, cerebral cortex, ocular system, and postural muscles. This system provides information regarding head movements and positions to maintain visual and balance control. The vestibular system is organized into 2 distinct functional units. The vestibulo-ocular system maintains visual stability during head movements, whereas the vestibulospinal system is responsible for postural control.[12] Because of the organization and neurophysiology of the vestibular system, impairments in the vestibulo-ocular system commonly manifest as symptoms of dizziness and visual instability. Conversely, vestibulo-spinal system dysfunction commonly results in disrupted balance.[21] Because these 2 functional vestibular networks do not share identical neuronal circuitry, it is possible to have impairments of the vestibulo-ocular system without impairments of the vestibulospinal system.[1]

It is known that vestibulospinal (ie, balance) impairments are common within the first few days after a concussion.[11,17] Subjectively, nearly 40% of athletes report balance disruption in the first week after a sport-related concussion.[23] However, the utility of balance impairments alone as a measure of a vestibular system injury may be limited because objective clinical balance impairments recover for the majority of athletes within 3 to 5 days after the injury.[17,30] It is likely that balance impairments are distinct from other vestibular-related impairments and symptoms, as most athletes who experience dizziness after a concussion do not report concomitant balance impairments.[24] In neuro-otology clinics, vestibulo-ocular and vestibulospinal functions are assessed separately, as their constructs are unique.[33] Until recently, all vestibular impairments after concussions were commonly assessed using the Balance Error Scoring System (BESS)[16] or the Sensory Organization Test (SOT).[28] However, these measures are static assessments and only represent the vestibulospinal aspect of the vestibular system. These tests do not address dynamic aspects of the vestibular system or vestibulo-ocular control. Thus, dysfunction resulting from vestibulo-ocular impairments and symptoms may be overlooked when using only vestibulospinal assessments. As such, additional clinical vestibular assessments are warranted that go beyond the current vestibulospinal measures to include vestibulo-ocular and ocular motor aspects.

In addition to vestibular impairments, ocular motor impairments are also common after concussions. Nearly 30% of concussed athletes report visual problems during the first week after the injury.[23] Ocular motor impairments and symptoms may manifest as blurred vision, diplopia, impaired eye movements, difficulty in reading, dizziness, headaches, ocular pain, and poor visual-based concentration.[7] A recent study of rugby players illustrated the value of assessing saccadic eye movements to better identify concussions without reported signs/ symptoms using the King-Devick test.[22] However, the King-Devick test does not evaluate other areas of ocular motor function such as pursuit, convergence, or accommodation, all of which have been implicated in mild traumatic brain injury (mTBI) studies as important indicators of dysfunction.[5,6] Current concussion evaluation tools such as the Sideline Assessment of Concussion (SAC), Sport Concussion Assessment Tool–3 (SCAT-3), BESS, and SOT do not include assessments of vestibulo-ocular and ocular motor function. The frequency of reported dizziness and visual problems in athletes with sport-related concussions suggests that a more comprehensive assessment of vestibular and ocular motor impairments and symptoms is needed. The identification of these vestibular and visual-related impairments and symptoms represents an emerging component of assessment that may positively augment current approaches to the evaluation and management of concussions.

The purpose of this article was to describe and provide initial data for the internal consistency of a new brief clinical screening tool of vestibular and ocular motor impairments and symptoms after sport-related concussions. We also examined the screening tool's predictive validity in correctly identifying concussed athletes from healthy controls.

MATERIALS AND METHODS

Research Design

A cross-sectional research design was used to examine vestibular and ocular motor, balance, and symptom assessments of patients with a diagnosed sport-related concussion compared with healthy controls.

Participants

A total of 100 consecutive patients with a diagnosed sport-related concussion met study criteria and were enrolled in the study. Thirty-six of these patients were excluded because of ≥1 exclusion criteria (see below). Complete data were available for 64 of the concussed patients with time since injury of ≤21 days. A control group consisting of 78 healthy participants aged ≤18 years was selected from a total of 106 eligible athletes who participated in a baseline concussion testing and education program. Any concussed or control participant older than 18 years with a history of more than 1 concussion, brain surgery, neurological disorder, treatment for substance abuse, and/ or psychiatric disorder was excluded from the study.

Instrumentation

The Vestibular/Ocular Motor Screening (VOMS) Assessment—The VOMS was developed to assess vestibular and ocular motor impairments via patient-reported symptom provocation after each assessment. The VOMS employed in this study consisted of brief assessments in the following 5 domains: (1) smooth pursuit, (2) horizontal and vertical saccades, (3) convergence, (4) horizontal vestibular ocular reflex (VOR), and (5) visual motion sensitivity (VMS). A copy of the VOMS form and standardized instructions for each test are provided in Appendix 1 (available in the online version of this article at http://ajsm.sagepub.com/supplemental). A visual depiction representing each test is provided in Appendix 2 (available online). Patients verbally rate changes in headache, dizziness, nausea, and fogginess symptoms compared with their immediate preassessment state on a scale of 0 (none) to 10 (severe) after each VOMS assessment to determine if each assessment provokes symptoms. Convergence was assessed by both symptom report and objective measurement of the near point of convergence (NPC; see description in Appendix 1). The NPC values were averaged across 3 trials, and normal NPC values are within 5 cm.[32] It is important to note that only horizontal VOR data are reported in this article; however, the VOMS has since been modified to incorporate the assessment of VOR in both the horizontal and vertical planes. The VOMS takes approximately 5 to 10 minutes to administer.

The Post-Concussion Symptom Scale (PCSS)—The PCSS was used to measure concussion-related symptoms. The scale consists of 22 self-reported symptom items (eg, dizziness, headache) rated on a scale from 0 (none) to 6 (severe). Total symptom scores on the PCSS range from 0 to 132. The PCSS takes approximately 5 minutes to complete.

Procedures

This study was approved under an exempt medical records review protocol by the University of Pittsburgh Human Subjects Institutional Review Board. All concussed patients completed the VOMS and PCSS assessments during their initial clinical visit after a sport-related concussion. Physical therapists trained in screening vestibular and ocular motor function administered the 3 measures in private examination rooms. The order of administration of these measures was (1) the PCSS, (2) a computerized neurocognitive test whose data were not analyzed for the purposes of this study, and (3) the VOMS. All healthy controls completed the VOMS and PCSS as part of a standard baseline testing and education program. The VOMS was administered individually in a clinic setting to the control group by vestibular physical therapists and athletic trainers educated in vestibular and ocular motor screening. The PCSS was administered to the controls in small groups (with ≤3 participants) in supervised examination rooms.

Data Analysis

Patient and control differences on group demographic characteristics and VOMS domain measures were tested using a nonparametric Mann-Whitney *U* test for continuous variables and contingency table analyses, with the χ^2 test for categorical variables. Age was tested against the hypothesis of a normal distribution with the Kolmogorov-Smirnov test. Transformations were evaluated for use as covariates in multivariate analyses. A significance level of $P < .05$ was set for the preceding analyses.

To examine the internal consistency of the VOMS, a Cronbach α analysis was conducted to assess internal consistency. A series of Spearman rank-order correlations between VOMS and PCSS scores among the concussed patients were conducted to examine the convergent validity of the VOMS.

Logistic regression sensitivity and specificity analyses were performed to examine the predictive validity of the VOMS to discriminate between concussed patients and controls. Univariate associations with odds ratios (ORs) between the likelihood of concussions and all demographic and VOMS test outcomes were first assessed. Variables demonstrating a significant association at a $P < .10$ threshold were then retained for the multivariate estimation of the best subset of predictors of the likelihood of concussions. A step forward likelihood ratio process was used with a $P < .05$ criterion to select predictors for a final multivariate model. Receiver operating characteristic (ROC) curves with area under the curve (AUC) analyses, cutoff scores, and likelihood ratios (LRs) were used to describe the accuracy of individual VOMS item scores and the predictive probabilities from the final best subset model to identify concussed patients.

RESULTS

Demographic Data

The sample of concussed patients consisted of 64 patients (36 male, 28 female) aged 13.9 ± 2.5 years (range, 9–18 years) who were seen approximately 5.5 ± 4.0 days (range, 1–21 days) after the injury. The majority of the sample (93.8%; n = 60) was enrolled in the study within 14 days of the injury. The control sample consisted of 78 participants (57 male, 21 female) aged 12.9 ± 1.6 years (range, 10–17 years). Patients in the concussed group were significantly ($P < .01$) older, and this group had a greater proportion of female patients (44%; $P = .04$) than the control group (27%). With regard to previous concussions, the patients and controls were not significantly different ($P = .10$). There was a history of concussions in 14 (22%) of the patients and 9 (12%) of the controls. The mean NPC distance was obtained from 62 of the concussed patients. The data for age demonstrated a nonnormal distribution. This variable demonstrated a normal distribution after natural logarithmic transformation.

This policy is intended to guide patient care. Medical conditions and specific medical situations are often complex and require health care providers to make independent judgments. These policies may be modified by practitioners to achieve maximal patient outcomes.

Internal Consistency of the VOMS

The internal consistency of the VOMS total symptom score and the NPC distance was high, with Cronbach α = .92. All of the items contributed positively to the overall internal consistency. The lowest interitem correlations were seen between the NPC distance and the VOMS symptom scores, ranging from 0.44 (vertical saccade) to 0.53 (smooth pursuit) (Table 1).

Symptom Provocation After VOMS Assessments

The VOR item was associated with the highest percentage of concussed patients reporting symptom provocation after administration (61%; n = 39) and the highest mean total symptom score (3.7 ± 5.1). The smooth pursuit and vertical saccade items evoked symptoms in the minimum percentage of concussed patients (33%; n = 21), with mean total symptom scores of 2.1 ± 4.8 and 2.1 ± 4.6, respectively. The maximum percentage of controls reporting symptom provocation on any VOMS test item was 9% (n = 7) and was found for the VOR, horizontal saccade, and smooth pursuit items. No controls reported a total symptom score greater than 2 after any VOMS individual item test. The mean total symptom scores for all VOMS tests were significantly (all $P<.001$) greater in the concussed patients compared with controls (Table 2).

NPC Distance

The mean NPC distance was significantly greater in the concussed group compared with the control group ($P< .001$), with a mean difference between groups of 4.0 cm (95% CI, 1.9–6.1 cm). The mean NPC distance across the 3 trials for the concussed patient sample was 5.9 ± 7.7 cm (range, 0–41.3 cm), whereas the NPC distance for the control group averaged 1.9 ± 3.2 cm (Table 2).

Relationship Between the VOMS and PCSS Among Concussed Patients

In the concussed group, results from Spearman rank-order correlations yielded several significant relationships between the VOMS items and PCSS scores (Table 2). The VOMS total symptom scores were moderately positively correlated (all $P< .05$) to the PCSS, ranging from 0.28 (NPC distance) to 0.65 (convergence symptom score).

Predicting Concussions and Healthy Controls

Age (ln transformed) (OR, 17.65; $P= .01$) and male sex (OR, 0.49; $P= .05$) were independently associated with the likelihood of concussions and were included as potential confounding variables in the assessment of each VOMS item. All VOMS symptom scores and the NPC distance demonstrated a significant relationship with the likelihood of concussions. Age, and not sex, was a significant covariate with each VOMS item in the association with the likelihood of concussions. With an adjustment for ln(age), individual VOMS scores predicted between 23% (NPC distance) and 53% (VOR) of the variance in the likelihood of concussions. The strongest individual score associations were supported for VOR (OR, 3.89; $P< .001$), VMS (OR, 3.37; $P< .01$), and NPC distance (OR, 1.21 for each 1-cm increase; $P<.001$) (Table 3).

The ROC AUC analyses demonstrated that all unadjusted VOMS scores accurately identified patients with concussions, with a maximum AUC of 0.78 (VOR) (Table 4). A cutoff of ≥2 total symptoms on any VOMS item demonstrated positive LRs between 23.9 (smooth pursuit, vertical saccade) and 42.8 (VOR). An NPC distance of ≥5 cm demonstrated a positive LR of 5.8 (Table 4). These results implied a minimum increase in the posttest probability of correctly identifying a concussed patient of approximately 50% for any VOMS symptom score of ≥2 and 38% for an NPC distance of ≥5 cm based on a pretest probability of 44% in the study sample.

Multivariate logistic regression using a forward entry method identified the best subset of independent predictors of concussions as VMS (OR, 2.84; $P < .02$), VOR (OR, 2.80; $P < .01$), and convergence distance (OR, 1.15; $P < .05$), with ln(age) as a significant covariate ($P = .03$). This 4-factor model predicted 61% of the variance in the likelihood of concussions. The ROC analysis for the accuracy of the predicted probability from this model to identify patients with concussions demonstrated an AUC of 0.89 (95% CI, 0.84–0.95; $P < .001$) (Figure 1).

DISCUSSION

The results of this initial study suggest that the VOMS, a brief (5–10 minute) screen for vestibular and ocular motor impairments and symptoms, possesses internal consistency and demonstrates basic validity compared with the PCSS and may serve to augment current assessments used after sport-related concussions. Our findings also provide preliminary evidence for the use of the VOMS to identify patients with sport-related concussions from healthy controls.

The VOMS demonstrated excellent internal consistency ($\alpha = .92$) in the current sample. The highest interitem correlations were between the individual symptom scores, with lower correlations between the symptom scores and NPC distance measures. This finding suggests that the VOMS items measure related, but not identical, components of the vestibular and ocular motor systems. The VOMS was able to distinguish concussed from noncon-cussed athletes. Patients in the concussed group scored significantly higher on all of the VOMS items than did the controls. In fact, it was clear from the data that the controls exhibited very few symptoms after each VOMS component. In addition, the mean NPC distance for the concussed group was more than 3 times greater than that for the control group. Moreover, the variability in symptoms and NPC distance was very low for the controls. Together, these findings indicate that the VOMS provides a measure that may be useful in differentiating concussed patients from controls.

To examine the concurrent validity of the VOMS, we compared it to an established measure of concussions, namely, the PCSS total score. Each of the VOMS items was positively correlated with the PCSS total score. These correlations were moderate and provide partial initial support for the concurrent validity of the VOMS but suggest that the VOMS and PCSS may not measure the same construct. In addition, the NPC distance was correlated at a lower level ($r = 0.28$). Ideally, 2 measures should be moderately ($r = 0.30$–0.60) to highly ($r > 0.70$) correlated to indicate concurrent validity.

The findings indicate that the VOR, VMS, and NPC distance components of the VOMS in combination are clinically useful in identifying concussions. The current study's results also provide clinically practical cutoff values for the VOMS item symptom scores and the NPC distance to accurately identify patients with concussions. Assuming an initial 50% probability (ie, chance) of a concussion, any individual VOMS item with a total symptom score of ≥2 increases the probability of being concussed by at least 46%. Similarly, an NPC distance of ≥5 cm increases the probability of a concussion by at least 34%. The nature of these cutoff values is both intuitive and useful to clinicians for identifying patients with concussions.

The current study's findings highlight the importance of the ocular motor components of the VOMS, particularly NPC distance. Clinically, convergence insufficiency can mimic many of the signs/symptoms attributed to concussions such as headache, difficulty in reading, difficulty in focusing, and blurred vision.[32] Although ocular motor impairments after an mTBI have been reported by researchers,[5,6] this study is the first to examine ocular motor impairments and symptoms after sport-related concussions. Ocular motor components (smooth pursuit, vertical/ horizontal saccades, convergence) of the VOMS provoked symptoms in 33% to 42% of patients in the current sample. Additionally, NPC distance measures were, on average, 4.0 cm greater in concussed patients than in controls. According to the literature, NPC values up to 5 cm are considered normal in the general population.[32] Our findings also support using a cutoff value of ≥5 cm for the NPC distance after sport-related concussions, which resulted in a 34% increase in accurately diagnosing a concussion.

Common concussion assessment tools such as the SAC[25] and BESS, which are components of the SCAT-3,[3,26] do not include measures of vestibular or ocular motor function. The King-Devick test,[29] a test that includes saccadic eye movements, has recently been used for assessments after concussions.[13,22] According to the present study's results, pursuit eye movements and NPC distance, in addition to saccades, should be included in any ocular motor assessment of concussions.

Clinical Implications

The VOMS demonstrated high sensitivity, indicating that a positive test result was highly accurate in identifying athletes who experienced a sport-related concussion. As such, it may have additional utility in providing information to guide clinical management. A concussion has typically been conceptualized as a uniform condition, which has limited the assessment and management approach to this injury. However, researchers and clinicians have begun to conceptualize concussions using more individualized methods in which each injury has a predominant clinical presentation and trajectory that should inform both the assessment and treatment.[10] The current findings suggest that through the VOMS, patients with impairments and symptoms in vestibular and ocular motor function after sport-related concussions can be identified. As such, the VOMS may assist in prompting referrals for more targeted vestibular and vision assessments and rehabilitation when any item is positive.

The concept of rehabilitation in concussion management is evolving. Vestibular rehabilitation is known to be effective in the management of specific conditions such as vestibular hypofunction, benign paroxysmal positional vertigo, migraine-related dizziness, and central vestibular disorders.[4,18] The emerging literature also supports vestibular rehabilitation for dizziness, balance, and vestibulo-ocular impairments after concussions.[2,19,27] Many ocular motor problems can also be managed with vision training or a modification to lenses.[8] Research has shown that convergence insufficiency, in particular, is responsive to targeted vision therapy.[31] Additionally, there is evidence to support the use of vision therapy for accommodative deficits, impaired version movements, and minor ocular misalignments.[8] The value of incorporating vestibular and visual rehabilitation into the management of post-concussive patients with vestibular and ocular motor impairments, as identified by the VOMS, warrants further study.

Future Directions and Research

To our knowledge, there are no clinical tools that provide a brief but comprehensive assessment of vestibular and ocular motor functioning and symptoms after concussions. The results of the current study suggest that the VOMS has the potential to fill this void in the clinical assessment of this injury. Our preliminary study provides initial evidence for the use of the VOMS to assess vestibular and ocular motor screening as part of a comprehensive approach that also includes clinical examination, symptom evaluation, neuro-cognitive testing, and balance assessment components.

Researchers have indicated that the utility of many tools used for the identification of deficits after a concussion is limited to the acute stage of the injury.[9,15,16,30] As such, researchers should examine the ability of the VOMS to detect impairments after concussions across time with serial administration in the acute (sideline), subacute, and chronic phases as an adjunct to other concussion management tools. Additional research on whether the VOMS can help predict recovery time from this injury is also warranted. Moreover, the use of the VOMS as a screening tool to trigger immediate referral for vestibular and ocular motor therapy and its effect on recovery time is warranted. Such a study would allow researchers to determine the clinical utility of the VOMS for identifying patients for early intervention.

Limitations

The data from the current study are cross-sectional, and complete data were not available for all participants. The VOMS was not administered in a standardized order to all participants. The use of subjective patient reporting of symptoms after VOMS testing may lead to recall bias. The lack of baseline measures in this study precludes us from knowing whether scores on the VOMS are representative of the effects of concussions per se. The concussed patients may have had pre-existing vestibular and ocular motor symptoms before their injuries. However, the very low VOMS symptom and NPC distance scores for the healthy controls in the current study suggest that this a priori group difference was unlikely. Participants in the control group were significantly younger than those in the concussed group. However, age differences between the groups were controlled for using statistical procedures. The sample represents only patients presenting to a concussion clinic, which may have biased the sample toward a selection effect for a specific type of patient with pronounced impairments and symptoms after a concussion. Finally, it is important to note that the VOMS is a screening tool that is primarily symptom based and is not intended to serve as a comprehensive measure of vestibular and ocular motor impairments. The VOMS is designed to elicit symptoms that can be used to identify and refer patients with possible vestibular and ocular motor involvement after concussions for additional evaluation.

CONCLUSION

The current findings indicate that the VOMS possessed internal consistency and was able to differentiate between concussed athletes and healthy unmatched controls. The results supported moderate correlations between the VOMS items and total concussion symptom scores, providing initial evidence for the concurrent validity of the measure. Cutoff scores of ≥2 total symptoms after any VOMS item or an NPC distance of ≥5 cm resulted in high rates (96% and 84%, respectively) of identifying concussions. Moreover, a combination of VOR, VMS, and NPC distance scores (controlling for age) resulted in a positive prediction rate of 0.89 for identifying this injury. The VOMS appears to assess distinct vestibular and ocular motor symptoms, which are unrelated to current clinical balance measures. The VOMS may help clinicians to identify patients for vestibular and ocular referrals and more targeted treatment, thereby enhancing recovery from this injury.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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References

1. Allum JH. Recovery of vestibular ocular reflex function and balance control after a unilateral peripheral vestibular deficit. Front Neurol. 2012; 3:83. [PubMed: 22623921]
2. Alsalaheen BA, Mucha A, Morris LO, et al. Vestibular rehabilitation for dizziness and balance disorders after concussion. J Neurol Phys Ther. 2010; 34(2):87–93. [PubMed: 20588094]
3. Baillargeon A, Lassonde M, Leclerc S, Ellemberg D. Neuropsychological and neurophysiological assessment of sport concussion in children, adolescents and adults. Brain Inj. 2012; 26(3):211–220. [PubMed: 22372409]
4. Brown KE, Whitney SL, Marchetti GF, Wrisley DM, Furman JM. Physical therapy for central vestibular dysfunction. Arch Phys Med Rehabil. 2006; 87(1):76–81. [PubMed: 16401442]
5. Capo-Aponte JE, Urosevich TG, Temme LA, Tarbett AK, Sanghera NK. Visual dysfunctions and symptoms during the subacute stage of blast-induced mild traumatic brain injury. Mil Med. 2012; 177(7):804–813. [PubMed: 22808887]
6. Ciuffreda KJ, Kapoor N, Rutner D, Suchoff IB, Han ME, Craig S. Occurrence of oculomotor dysfunctions in acquired brain injury: a retrospective analysis. Optometry. 2007; 78(4):155–161. [PubMed: 17400136]
7. Ciuffreda KJ, Ludlam D, Thiagarajan P. Oculomotor diagnostic protocol for the mTBI population. Optometry. 2011; 82(2):61–63. [PubMed: 21276567]

8. Ciuffreda KJ, Rutner D, Kapoor N, Suchoff IB, Craig S, Han ME. Vision therapy for oculomotor dysfunctions in acquired brain injury: a retrospective analysis. Optometry. 2008; 79(1):18–22. [PubMed: 18156092]
9. Coldren RL, Kelly MP, Parish RV, Dretsch M, Russell ML. Evaluation of the Military Acute Concussion Evaluation for use in combat operations more than 12 hours after injury. Mil Med. 2010; 175(7):477–481. [PubMed: 20684450]
10. Collins MW, Kontos AP, Reynolds E, Murawski CD, Fu FH. A comprehensive, targeted approach to the clinical care of athletes following sport-related concussion. Knee Surg Sports Traumatol Arthrosc. 2014; 22(2):235–246. [PubMed: 24337463]
11. Covassin T, Elbin RJ, Harris W, Parker T, Kontos A. The role of age and sex in symptoms, neurocognitive performance, and postural stability in athletes after concussion. Am J Sports Med. 2012; 40(6):1303–1312. [PubMed: 22539534]
12. Cullen KE. The vestibular system: multimodal integration and encoding of self-motion for motor control. Trends Neurosci. 2012; 35(3):185–196. [PubMed: 22245372]
13. Galetta KM, Brandes LE, Maki K, et al. The King-Devick test and sports-related concussion: study of a rapid visual screening tool in a collegiate cohort. J Neurol Sci. 2011; 309(1–2):34–39. [PubMed: 21849171]
14. Giza CC, Kutcher JS, Ashwal S, et al. Summary of evidence-based guideline update: evaluation and management of concussion in sports. Report of the Guideline Development Subcommittee of the American Academy of Neurology. Neurology. 2013; 80(24):2250–2257. [PubMed: 23508730]
15. Grubenhoff JA, Kirkwood M, Gao D, Deakyne S, Wathen J. Evaluation of the standardized assessment of concussion in a pediatric emergency department. Pediatrics. 2010; 126(4):688–695. [PubMed: 20819901]
16. Guskiewicz KM. Postural stability assessment following concussion: one piece of the puzzle. Clin J Sport Med. 2001; 11(3):182–189. [PubMed: 11495323]
17. Guskiewicz KM, Ross SE, Marshall SW. Postural stability and neuro-psychological deficits after concussion in collegiate athletes. J Athl Train. 2001; 36(3):263–273. [PubMed: 12937495]
18. Hillier SL, Hollohan V. Vestibular rehabilitation for unilateral peripheral vestibular dysfunction. Cochrane Database Syst Rev. 2007; (4):CD005397. [PubMed: 17943853]
19. Hoffer ME, Balaban C, Gottshall K, Balough BJ, Maddox MR, Penta JR. Blast exposure: vestibular consequences and associated characteristics. Otol Neurotol. 2010; 31(2):232–236. [PubMed: 20009782]
20. Hoffer ME, Gottshall KR, Moore R, Balough BJ, Wester D. Characterizing and treating dizziness after mild head trauma. Otol Neurotol. 2004; 25(2):135–138. [PubMed: 15021772]
21. Khan S, Chang R. Anatomy of the vestibular system: a review. Neuro-Rehabilitation. 2013; 32(3): 437–443. [PubMed: 23648598]
22. King D, Brughelli M, Hume P, Gissane C. Concussions in amateur rugby union identified with the use of a rapid visual screening tool. J Neurol Sci. 2013; 326(1–2):59–63. [PubMed: 23374885]
23. Kontos AP, Elbin RJ, Schatz P, et al. A revised factor structure for the Post-Concussion Symptom Scale: baseline and postconcussion factors. Am J Sports Med. 2012; 40(10):2375–2384. [PubMed: 22904209]
24. Lau BC, Kontos AP, Collins MW, Mucha A, Lovell MR. Which on-field signs/symptoms predict protracted recovery from sport-related concussion among high school football players? Am J Sports Med. 2011; 39(11):2311–2318. [PubMed: 21712482]
25. McCrea M, Kelly JP, Kluge J, Ackley B, Randolph C. Standardized assessment of concussion in football players. Neurology. 1997; 48(3):586–588. [PubMed: 9065531]
26. McCrory P, Meeuwisse WH, Aubry M, et al. Consensus statement on concussion in sport: the 4th International Conference on Concussion in Sport held in Zurich, November 2012. Br J Sports Med. 2013; 47(5):250–258. [PubMed: 23479479]
27. Naguib MB, Madian Y, Refaat M, Mohsen O, El Tabakh M, Abo-Setta A. Characterisation and objective monitoring of balance disorders following head trauma, using videonystagmography. J Laryngol Otol. 2012; 126(1):26–33. [PubMed: 22035505]
28. Nashner LM, Black FO, Wall C 3rd. Adaptation to altered support and visual conditions during stance: patients with vestibular deficits. J Neurosci. 1982; 2(5):536–544. [PubMed: 6978930]

29. Oride MK, Marutani JK, Rouse MW, DeLand PN. Reliability study of the Pierce and King-Devick saccade tests. Am J Optom Physiol Opt. 1986; 63(6):419–424. [PubMed: 3728637]

30. Riemann BL, Guskiewicz KM. Effects of mild head injury on postural stability as measured through clinical balance testing. J Athl Train. 2000; 35(1):19–25. [PubMed: 16558603]

31. Scheiman M, Cotter S, Kulp MT, et al. Treatment of accommodative dysfunction in children: results from a randomized clinical trial. Optom Vis Sci. 2011; 88(11):1343–1352. [PubMed: 21873922]

32. Scheiman M, Gallaway M, Frantz KA, et al. Nearpoint of convergence: test procedure, target selection, and normative data. Optom Vis Sci. 2003; 80(3):214–225. [PubMed: 12637833]

33. Slattery EL, Sinks BC, Goebel JA. Vestibular tests for rehabilitation: applications and interpretation. NeuroRehabilitation. 2011; 29(2):143–151. [PubMed: 22027075]

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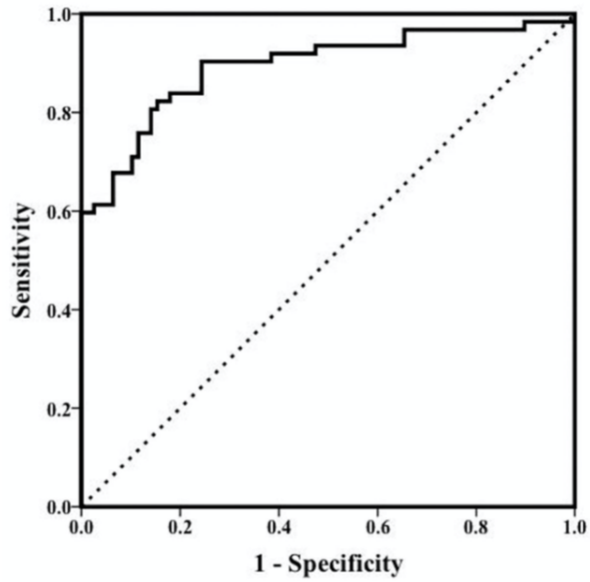

Figure 1.
Receiver operating characteristic curve describing the area under the curve (AUC) for identifying patients with concussions versus healthy controls using vestibular ocular reflex and visual motion sensitivity symptom scores and near point of convergence distance. *Adjusted for ln(age): AUC = 0.89. Dotted line indicates AUC = 0.50 (P<.001).

This policy is intended to guide patient care. Medical conditions and specific medical situations are often complex and require health care providers to make independent judgments. These policies may be modified by practitioners to achieve maximal patient outcomes.

TABLE 1

Interitem Correlations for VOMS Assessment Domain Scores and Convergence Distance in Concussed Patients[a]

VOMS Domain	Smooth Pursuit	Horizontal Saccade	Vertical Saccade	Convergence	Horizontal Vestibular Ocular Reflex	Visual Motion Sensitivity
Smooth pursuit	—	—	—	—	—	—
Horizontal saccade	0.88	—	—	—	—	—
Vertical saccade	0.85	0.85	—	—	—	—
Convergence	0.83	0.82	0.81	—	—	—
Horizontal vestibular ocular reflex	0.62	0.72	0.63	0.71	—	—
Visual motion sensitivity	0.82	0.84	0.82	0.77	0.71	—
Near point of convergence distance, cm	0.53	0.52	0.44	0.49	0.52	0.50

[a]VOMS, Vestibular/Ocular Motor Screening.

This policy is intended to guide patient care. Medical conditions and specific medical situations are often complex and require health care providers to make independent judgments. These policies may be modified by practitioners to achieve maximal patient outcomes.

TABLE 2

VOMS Assessment Domains for Symptom Provocation and Total Symptom Scores in Concussed Patients and Healthy Controls[a]

VOMS Domain	Concussed Patients (n = 64[b])	Controls (n = 78)	*P* Value, Group Difference[c]	Correlation to PCSS[d]
Smooth pursuit	2.1 ± 4.8 (0–31)	0.1 ± 0.3 (0–2)	<.001	0.38
Horizontal saccade	2.5 ± 4.8 (0–29)	0.1 ± 0.3 (0–2)	<.001	0.59
Vertical saccade	2.1 ± 4.6 (0–29)	0.1 ± 0.3 (0–2)	<.001	0.47
Convergence	2.2 ± 4.0 (0–20)	0.1 ± 0.3 (0–2)	<.001	0.65
Horizontal vestibular ocular reflex	3.7 ± 5.1 (0–22)	0.1 ± 0.3 (0–2)	<.001	0.54
Visual motion sensitivity	3.1 ± 5.7 (0–35)	0.1 ± 0.3 (0–2)	<.001	0.44
Near point of convergence distance, cm	5.9 ± 7.7 (0–41.3)	1.9 ± 3.2 (0–15.3)	<.001	0.28

[a]Values are expressed as mean ± SD (range). PCSS, Post-Concussion Symptom Scale; VOMS, Vestibular/Ocular Motor Screening.

[b]n = 62 concussed patients for near point of convergence distance.

[c]Mann-Whitney *U* nonparametric test.

[d]All $P < .01$ except near point of convergence distance ($P < .03$, Spearman nonparametric correlation).

TABLE 3

VOMS Assessment Domain Scores: Individual Item Associations With the Likelihood of Concussions[a]

VOMS Domain	β	Wald χ^2	*P* Value	Odds Ratio	$R^{2\,b}$
Smooth pursuit	.83	7.89	<.01	2.29	0.28
Horizontal saccade	1.01	10.31	<.01	2.75	0.34
Vertical saccade	.98	8.96	<.01	2.65	0.31
Convergence	.78	7.98	<.01	2.18	0.30
Horizontal vestibular ocular reflex	1.36	16.97	<.001	3.89	0.53
Visual motion sensitivity	1.21	10.35	<.01	3.37	0.40
Near point of convergence distance, cm	.19	13.33	<.001	1.21	0.23

[a]Logistic regression (maximum likelihood estimation), adjusted for ln(age). VOMS, Vestibular/Ocular Motor Screening.

[b]Nagelkerke R^2.

TABLE 4

AUC Analysis, Cutoff Score, and LR of Positive Results for VOMS Domain Scores[a]

VOMS Domain	AUC	*P* Value	Cutoff Score for Positive Test Result (≥)	LR for Positive Test Result
Smooth pursuit	0.64	<.01	2	23.9
Horizontal saccade	0.68	<.001	2	28.9
Vertical saccade	0.65	<.01	2	23.9
Convergence	0.64	<.01	2	26.4
Horizontal vestibular ocular reflex	0.78	<.001	2	42.8
Visual motion sensitivity	0.73	<.001	2	32.7
Near point of convergence distance, cm	0.73	<.001	5	5.8

[a]AUC, area under the curve; LR, likelihood ratio; VOMS, Vestibular/Ocular Motor Screening.