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

- 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).

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.
Boston University Athletic Training Services
Head Injury Assessment and Management Protocol

- 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 Coma 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 SCATS© (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 neuropsychological 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.
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 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

<table>
<thead>
<tr>
<th>Stage</th>
<th>Aim</th>
<th>Activity Examples</th>
<th>Goal of each step</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Symptom Control and Impairment Reduction</td>
<td>Daily activities that do not provoke symptoms.</td>
<td>Gradual introduction of work/school activities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sub-symptom threshold activity.</td>
<td>Symptom reduction and target impairments</td>
</tr>
<tr>
<td>2</td>
<td>Aerobic exercise</td>
<td>Light to Moderate Aerobic Activity. No resistance training.</td>
<td>Sustained aerobic activity</td>
</tr>
<tr>
<td>3</td>
<td>Sport-specific exercise</td>
<td>Sport Specific Conditioning. No head impact activities.</td>
<td>Add movement and variability</td>
</tr>
<tr>
<td>4</td>
<td>Non-contact training drills</td>
<td>Harder training drills. May start progressive resistance training.</td>
<td>Exercise, coordination, and increased thinking</td>
</tr>
<tr>
<td>5</td>
<td>Unrestricted training</td>
<td>Following medical clearance, participate in normal training activities.</td>
<td>Restore confidence and assess functional skills</td>
</tr>
<tr>
<td>6</td>
<td>Unrestricted return to sport</td>
<td>Normal game play</td>
<td>Full return</td>
</tr>
</tbody>
</table>

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.
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.
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 I: NCAA SSI Concussion Safety – student-athletes

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.

   - 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.
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.
### What can I do to keep student-athletes safe?

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

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.
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.
Appendix IV: Student-Athlete Injury and Illness Responsibility Statement

Boston University
Student-Athlete Injury and Illness Responsibility Statement

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.

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.

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:

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

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

- 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.

- 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.

- 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.

- 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

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 V: Stakeholder Concussion Education Statement

Boston University

Stakeholder Injury and Illness Responsibility Statement

___

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.

___

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.

___

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:

___

A concussion is a brain injury and it is my responsibility to report all suspected concussions to an athletic trainer and/or team physician.

___

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

___

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.

___

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.

___

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.
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INSTRUCTIONS

Words in italics throughout the SCAT5 are the instructions given to the athlete by the clinician

Symptom Scale

The timeframe 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 scores, 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 maximum of 30.

Choose one of the word lists (either S 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 say 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 “T” 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 backwards. 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)® testing

This balance testing is based on a modified version of the Balance Error Scoring System (BESS). 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 within any given condition, 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 crests
2. Stepping, stumble, or fall
3. Lifting forefoot or heel from ground
4. Moving hip into >30 degrees abduction
5. 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 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. 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.”

(b) Single leg stance

“If you were to kick a ball, which foot would you use? [This will be the dominant foot] How 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-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 38cm 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 another 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 fixed to 90 degrees and elbow and fingers extended), pointing in front of you. When I give a start signal, I would like you to perform five successive finger to nose repetitions using your index finger to touch the tip of the nose, and then return to the starting position, as quickly and as accurately as possible.”

References


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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
- Repeated vomiting
- Drowsiness or inability to be awakened
- Seizures (arms and legs jerk uncontrollably)
- Inability to recognize people or places
- 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

<table>
<thead>
<tr>
<th>Exercise step</th>
<th>Functional exercise at each step</th>
<th>Goal of each step</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Symptom-limited activity</td>
<td>Daily activities that do not provoke symptoms.</td>
<td>Gradual reintroduction of work/school activities.</td>
</tr>
<tr>
<td>2. Light aerobic exercise</td>
<td>Walking or stationary cycling at slow to medium pace.</td>
<td>No resistance training.</td>
</tr>
<tr>
<td>4. Non-contact training drills</td>
<td>Harder training drills, e.g., passing drills. May start progressive resistance training.</td>
<td>Exercise, coordination, and increased thinking.</td>
</tr>
<tr>
<td>5. Full-contact practice</td>
<td>Following medical clearance, participate in normal training activities.</td>
<td>Restore confidence and assess functional skills by coaching staff.</td>
</tr>
<tr>
<td>6. Return to play/sport</td>
<td>Normal game play.</td>
<td>Gradual return to typical activities.</td>
</tr>
</tbody>
</table>

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 steps 2 and return to school part-time before doing school activities at home first.

<table>
<thead>
<tr>
<th>Mental Activity</th>
<th>Activity at each step</th>
<th>Goal of each step</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Daily activities that do not give the athlete symptoms</td>
<td>Typical activities that the athlete does during the day as long as they do not increase symptoms (e.g., reading, testing, screen time). Start with 5-15 minutes at a time and gradually build up.</td>
<td>Gradual return to typical activities.</td>
</tr>
<tr>
<td>2. School activities</td>
<td>Homework, reading or other cognitive activities outside of the classroom.</td>
<td>Increase tolerance to cognitive work.</td>
</tr>
<tr>
<td>3. Return to school part-time</td>
<td>Gradual introduction of schoolwork. May need to start with a partial school day or with increased breaks during the day.</td>
<td>Increase academic activities.</td>
</tr>
<tr>
<td>4. Return to school full-time</td>
<td>Gradually progress school activities until a full day can be tolerated.</td>
<td>Return to full academic activities and catch up on missed work.</td>
</tr>
</tbody>
</table>

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

- Starting school later, only going for half days, or going only to certain classes
- Taking lots of breaks during class, homework, tests
- More time to finish assignments/tests
- Longer assignments
- Quiet room to finish assignments/tests
- Repetition/memory cues
- Not going to noisy areas like the cafeteria, assembly halls, sporting events, music class, shop class, etc.

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.

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

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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.
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).
Boston University Athletic Training Services
Head Injury Assessment and Management Protocol

(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/labor 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.
(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


PREAMBLE

The 2017 Concussion in Sport Group (CISG) consensus statement is designed to build on the principles outlined in the previous statements 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 what needs 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. A full list of scientific committee members, expert panellists, authors, observers and those who were invited but could not attend are detailed 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 ‘K’s of SRC management to provide a logical flow of
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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Boston University Athletic Training Services
Head Injury Assessment and Management Protocol

Consensus statement

The assessment of novel and selective fluid (e.g., 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-injury 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-concussive symptoms and/or that rest may promote recovery by minimizing 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 (i.e., 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 (i.e., >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 neurological injury to the brain. A detailed multimodal clinical assessment is required to identify specific primary and secondary pathologies that may be contributing to persistent post-traumatic symptoms. At a minimum, the assessment should include a comprehensive history, focused physical examination, and special tests where indicated (e.g., 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:

- an individualised symptom-limited aerobic exercise programme in patients with persistent post-concussive symptoms associated with autonomic instability or physical deconditioning, and
- a targeted physical therapy programme in patients with cervical spine or vestibular dysfunction,
- 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 steady 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 CSG 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 SRS 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 SRS 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 diziness, 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 categorized 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.
Consensus statement

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 (e.g., 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 individualized.

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 neuropathology 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.26–28 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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Consensus statement

document (British Journal of Sports Medicine, issues 11 and 12, 2017). This document is first and foremost intended to inform clinical practice; however, it must be remembered that, while agreement exists on the principal messages conveyed by this document, the authors acknowledge that the science of concussion is incomplete and therefore management and return-to-play decisions lie largely in the realm of clinical judgement on an individualised basis.

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Appendix IX: Clinician Concussion Management Checklist

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
- 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.

**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

**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

**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

**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.

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Appendix XI: Cognitive Rest Letter

Boston University
Athletic Training Services
285 Babcock Street
Boston, Massachusetts 02215
T: 617-353-2746 F: 617-353-3579
athtm@bu.edu

(date of creation)

Dear Professor,

This letter is to inform you that (patient’s full name, BUILD#) 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
Director of Sports Medicine
aguilar@bu.edu
617-353-2746

(AT’s full name)

Athletic Trainer
(AT’s email)

617-353-2746

Modified 06/2022

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

John J. Leddy, MD, FACSM FACP1 and Barry Willer, PhD2

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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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.
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.**

<table>
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<tr>
<th>Absolute Contraindications to Performing the BCTT</th>
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<td>History</td>
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<td>Physical examination</td>
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<th>Relative Contraindications to Performing the BCTT</th>
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<td>History</td>
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<td>Physical examination</td>
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<tr>
<td>Obesity: body mass index ( \geq 30 \text{ kg m}^{-2} ).</td>
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*Individuals with known cardiovascular, pulmonary, or metabolic disease; signs and symptoms suggestive of cardiovascular or pulmonary disease; or individuals aged \( \geq 45 \) 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 \( \geq 30 \text{ kg m}^{-2} \)).

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

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

*Figure 2:* Visual Analog Scale for assessment of overall symptom level before and during the Buffalo Concussion Treadmill Test.

*Figure 3:* 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.
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.
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 dwk 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 safety 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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The authors declare no conflicts of interest.

References

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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 XIII: Vestibular Oculo-Motor Screening (VOMS)

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

Preliminary Findings

Anne Mucha, DPT†, Michael W. Collins, PhD†, R.J. Elbin, PhD†, Joseph M. Furman, MD, PhD§, Cara Troutman-Enseki, DPT‡, Ryan M. DeWolf, MS, ATC‡, Greg Marchetti, PhD‡, and Anthony P. Kontos, PhD†‡

Investigation performed at the University of Pittsburgh, Pittsburgh, Pennsylvania, USA

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 patients.

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‖‖Rangos School of Health Sciences, Duquesne University, Pittsburgh, Pennsylvania, USA.

One or more of the authors has declared the following potential conflict of interest: M.W.C. is a cofounder and 10% shareholder of ImpACT Applications Inc.

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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. 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. Dizziness, which may represent an underlying impairment of the vestibular and/or ocular motor systems, is reported by 50% of concussed athletes and is associated with a 6.4-times greater risk, relative to any other on-field symptom, in predicting protracted (>21 days) recovery. 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 (utricles, sacculles, 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. 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. 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.

It is known that vestibulospinal (ie, balance) impairments are common within the first few days after a concussion. Subjectively, nearly 40% of athletes report balance disruption in the first week after a sport-related concussion. 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. 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. In neuro-otology clinics, vestibulo-ocular and vestibulospinal functions are assessed separately, as their constructs are unique. Until recently, all vestibular impairments after concussions were commonly assessed using the Balance Error Scoring System (BESS) or the Sensory Organization Test (SOT). 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. 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. 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. 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. 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.

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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 $\chi^2$ 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 $\alpha$ 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.

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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 (in 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 nonconcussed 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 (i.e., 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. Although ocular motor impairments after an mTBI have been reported by researchers, 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. 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 SAC23 and BESS, which are components of the SCAT-3, do not include measures of vestibular or ocular motor function. The King-Devick test, a test that includes saccadic eye movements, has recently been used for assessments after concussions. 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. 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 others.
and central vestibular disorders. The emerging literature also supports vestibular rehabilitation for dizziness, balance, and vestibulo-ocular impairments after concussions. Many ocular motor problems can also be managed with vision training or a modification to lenses. Research has shown that convergence insufficiency, in particular, is responsive to targeted vision therapy. Additionally, there is evidence to support the use of vision therapy for accommodative deficits, impaired version movements, and minor ocular misalignments. 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. 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

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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.

Acknowledgments

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References

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<table>
<thead>
<tr>
<th>VOMS Domain</th>
<th>Smooth Pursuit</th>
<th>Horizontal Saccade</th>
<th>Vertical Saccade</th>
<th>Convergence</th>
<th>Horizontal Vestibular Ocular Reflex</th>
<th>Visual Motion Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smooth pursuit</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Horizontal saccade</td>
<td>0.88</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Vertical saccade</td>
<td>0.85</td>
<td>0.85</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Convergence</td>
<td>0.83</td>
<td>0.82</td>
<td>0.81</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Horizontal vestibular oculx reflex</td>
<td>0.62</td>
<td>0.72</td>
<td>0.60</td>
<td>0.71</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Visual motion sensitivity</td>
<td>0.82</td>
<td>0.84</td>
<td>0.82</td>
<td>0.77</td>
<td>0.71</td>
<td>0.50</td>
</tr>
<tr>
<td>Near point of convergence distance, cm</td>
<td>0.53</td>
<td>0.52</td>
<td>0.44</td>
<td>0.49</td>
<td>0.52</td>
<td>0.50</td>
</tr>
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</table>

*VOMS, Vestibular/Ocular Motor Screening.*
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### TABLE 2

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

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

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).
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### TABLE 3

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

<table>
<thead>
<tr>
<th>VOMS Domain</th>
<th>β</th>
<th>Wald χ²</th>
<th>P Value</th>
<th>Odds Ratio</th>
<th>χ² LR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smooth pursuit</td>
<td>.83</td>
<td>7.89</td>
<td>&lt;.01</td>
<td>2.29</td>
<td>0.28</td>
</tr>
<tr>
<td>Horizontal saccade</td>
<td>1.01</td>
<td>10.31</td>
<td>&lt;.01</td>
<td>2.75</td>
<td>0.34</td>
</tr>
<tr>
<td>Vertical saccade</td>
<td>.98</td>
<td>8.96</td>
<td>&lt;.01</td>
<td>2.65</td>
<td>0.31</td>
</tr>
<tr>
<td>Convergence</td>
<td>.78</td>
<td>7.98</td>
<td>&lt;.01</td>
<td>2.18</td>
<td>0.30</td>
</tr>
<tr>
<td>Horizontal vestibular ocular reflex</td>
<td>1.36</td>
<td>16.97</td>
<td>&lt;.001</td>
<td>3.89</td>
<td>0.53</td>
</tr>
<tr>
<td>Visual motion sensitivity</td>
<td>1.21</td>
<td>10.35</td>
<td>&lt;.01</td>
<td>3.37</td>
<td>0.40</td>
</tr>
<tr>
<td>Near point of convergence distance, cm</td>
<td>.19</td>
<td>13.33</td>
<td>&lt;.001</td>
<td>1.21</td>
<td>0.23</td>
</tr>
</tbody>
</table>


*Nagelkerke R².
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 4
AUC Analysis, Cutoff Score, and LR of Positive Results for VOMS Domain Scores*

<table>
<thead>
<tr>
<th>VOMS Domain</th>
<th>AUC</th>
<th>P Value</th>
<th>Cutoff Score for Positive Test Result (cm)</th>
<th>LR for Positive Test Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smooth pursuit</td>
<td>0.64</td>
<td>&lt;.01</td>
<td>2</td>
<td>23.9</td>
</tr>
<tr>
<td>Horizontal saccade</td>
<td>0.68</td>
<td>&lt;.001</td>
<td>2</td>
<td>28.9</td>
</tr>
<tr>
<td>Vertical saccade</td>
<td>0.65</td>
<td>&lt;.01</td>
<td>2</td>
<td>23.9</td>
</tr>
<tr>
<td>Convergence</td>
<td>0.64</td>
<td>&lt;.01</td>
<td>2</td>
<td>28.4</td>
</tr>
<tr>
<td>Horizontal vestibular ocular reflex</td>
<td>0.78</td>
<td>&lt;.001</td>
<td>2</td>
<td>42.8</td>
</tr>
<tr>
<td>Visual motion sensitivity</td>
<td>0.73</td>
<td>&lt;.001</td>
<td>2</td>
<td>32.7</td>
</tr>
<tr>
<td>Near point of convergence distance, cm</td>
<td>0.73</td>
<td>&lt;.001</td>
<td>2</td>
<td>5.8</td>
</tr>
</tbody>
</table>

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