Physiotherapy Alberta
College + Association

Concussion Management:
A Toolkit for Physiotherapists

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Introduction

Concussion is a complex injury that can have far-reaching consequences for an individual, his/her family, and society. Concussion has the potential to be a significant public health burden.

In light of this, concussion management is emerging as a growing practice area in many health-care professions, and research on concussion and its management is evolving rapidly. Research on concussion has primarily been focused on sport-related concussion in children and collegiate athletes. However, concussions can also occur as a result of falls, motor vehicle accidents, explosions and assault, and in conjunction with other injuries. The principles for management of sport-related concussions may be applied to non-sport injuries, and this document will provide guidance as appropriate.

Physiotherapy Alberta - College + Association developed the *Concussion Management: A Toolkit for Physiotherapists* (the Toolkit) to provide physiotherapists who do not routinely treat concussion with information and resources for evidence-based assessment and management of adult (18+) patients with persistent post-concussive symptoms. Management of pediatric concussion is not included in this Toolkit. Information on the management of pediatric concussion can be found in the ONF Guidelines for Diagnosing and Managing Pediatric Concussion.

Where articles within the Toolkit report research findings in these populations, it is referencing the evidence available to date. The Toolkit is a living document and will be reviewed and revised as knowledge advances.

The Toolkit is based on the recommendations in The 2013 Consensus Statement on Concussion in Sport[1] (Consensus Statement) and The 2013 Ontario Neurotrauma Foundation's Guidelines for Concussion/Mild Traumatic Brain Injury & Persistent Symptoms: Second Edition, for adults (age 18+ years of age)[2] (ONF Guidelines). The text has been supplemented with links to specific modules within the ONF Guidelines. Where possible, this document is aligned with the National Institute of Neurological Disorders and Stroke Common Data Element project (NINDS).[3]

The Toolkit is not a clinical manual; it is intended as a resource for physiotherapists for the provision of evidence-based assessment and treatment of concussion. It provides an overview of concussion (definition, prevalence and prognosis) a review of general concussion management and the physiotherapy role within the multidisciplinary team.
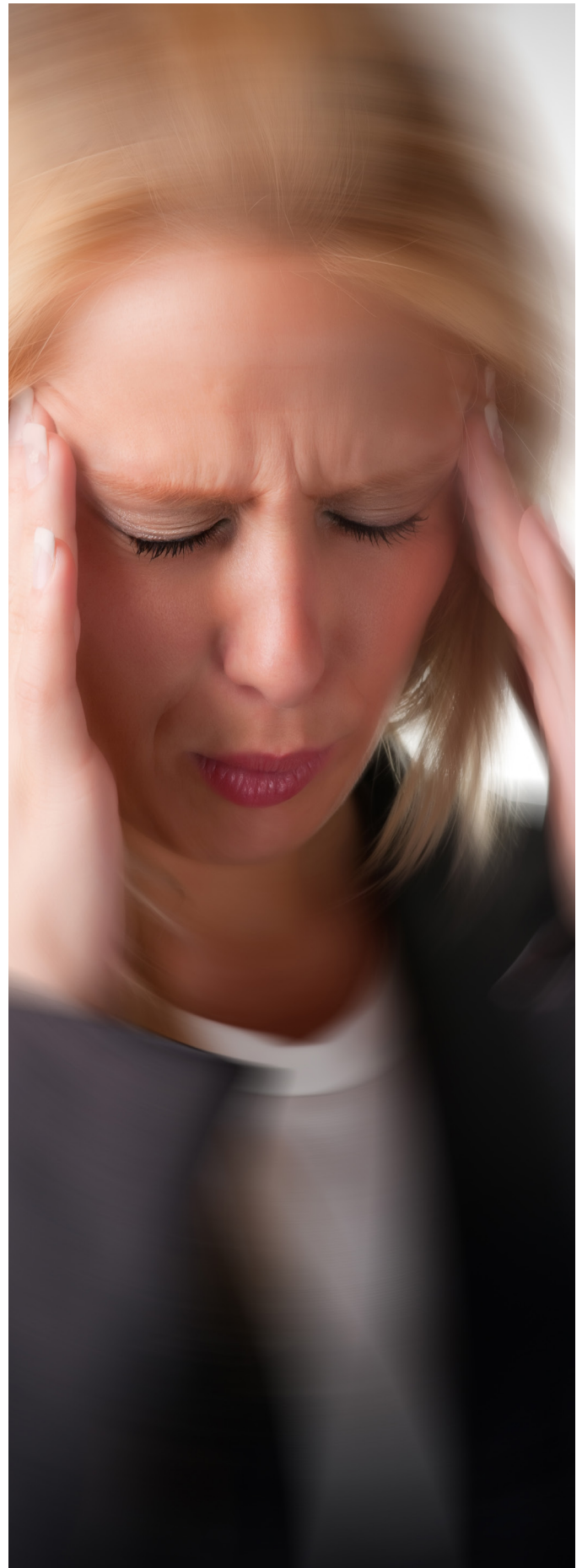
Concussion

Concussion is a complex pathophysiological process affecting the brain.[1] It is the result of an injury caused by a biomechanical force i.e., a direct blow to the head, neck or face or from a blow to another part the body with a mechanical force transmitted to the head. The individual may not experience a loss of consciousness (LOC) with the incident. In fact, only approximately 10% of concussions involve LOC.

Prevalence

Over 160,000 Canadians experience an acquired brain injury annually, with mild traumatic brain injury (mTBI) accounting for the largest proportion of traumatic brain injuries (TBIs).[4] Concussion is included in this category as a subset of mild traumatic brain injury. Although the exact incidence of concussion is not known, Statistics Canada reported that 94,000 Canadians aged 12 and over experienced an "activity limiting concussion" between 2009 to 2010.[5] The leading causes of concussion were sports, motor vehicle accidents (MVAs), falls, and assault. The majority of these concussions occurred in adolescents and older adults.[5]

A 2015 report from the Canadian Institute for Health Information found that 27% of brain injuries seen in Ontario and Alberta emergency rooms in the previous year were sport-related, with hockey, cycling and football/rugby leading to the largest numbers of hospital visits.[6]

In the non-sport population, falls are the leading cause of an mTBI resulting from an external force in adults 65 years and older.[7] A cross-sectional study of occupational TBIs in Ontario found that the majority were caused by being "struck by or against an inanimate object" (e.g., falling object, machinery or wall) or by falls, with 57% incurred by men at an average age of 38 years old.[8]

Signs and symptoms

Signs and symptoms of concussion are believed to be an alteration in brain function and not indicative of structural damage to the brain. Concussion is sometimes referred to as an "invisible injury" as the results of standard structural imaging tests such as MRI or CT scan are normal. However, newer imaging techniques are being developed that may provide further insight into any functional alterations that occur following injury. The Centres for Disease Control and Prevention has categorized the signs and symptoms of concussion into the following four domains:[9]

Thinking/Remembering	Physical	Emotional/Mood	Sleep disturbance
Difficulty thinking clearly	Headache	Irritability	Sleeping more than usual
Feeling "slowed down"	Nausea or vomiting	Sadness	Sleeping less than usual
Difficulty concentrating	Balance problems	More emotional	Trouble falling asleep
Difficulty remembering new information	Dizziness	Nervousness or anxiety	
	Fuzzy or blurry vision		
	Feeling tired, having no energy		
	Sensitivity to light, noise		

Concussion is suspected if the individual presents with one or more signs or symptoms in any of the above domains. Concussion is diagnosed based on the patient's symptoms and findings of a comprehensive clinical assessment.

The most commonly reported subjective physical complaints following concussion are headache and dizziness, followed by nausea and neck pain.[10] Physiotherapy can be effective in cases where symptoms of dizziness, neck pain and headache have a cervical spine and/or vestibular and balance origin.[11]

Risk of concussion

There are a number of factors, or modifiers, that influence both the risk of concussion and the potential for a prolonged recovery from sport-related concussion. Individuals with a previous history of concussion are at a greater risk of concussion, as are athletes who engage in contact and collision sports. There is also a greater risk of concussion during game play than in practice or training.[1]

The following factors are suggestive of an increased risk for prolonged recovery in sport-related concussion:

- Number, severity and duration of symptoms
- History of migraine headaches
- Pre-injury mood disorders, learning disorders and attention deficit disorders (ADD/ADHD)
- Younger age[12]

A recent systematic review of prolonged concussion in the non-sport population between the ages of 16 and 65 reported that older age and female gender are the two most significant factors in development of persistent symptoms post-concussion.[13]

Prognosis

In the majority of sport-related concussion cases, symptoms resolve within seven to ten days from onset. In the non-sport population, most experience full recovery within three months.[14]

For the remainder, however, signs and symptoms continue beyond this time frame and may persist for months or longer. A recent study found that up to 30% of children report ongoing symptoms one month following mTBI.[15] Similarly, symptoms may persist in up to 33% of non sport-related concussions.[16]

The International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD 10 defines this as post-concussion syndrome (Figure 1), with diagnostic criteria including presence of symptoms in three symptom categories four weeks after onset. However, in the literature, the condition is termed "post-concussion syndrome," "post-concussive syndrome," "chronic" or "persistent post-concussion syndrome" and "post-traumatic concussion syndrome." As there is no consensus on the term to date, the Toolkit uses the descriptor "persistent post-concussion symptoms" in reference to physiotherapy in concussion management.[1]

The clinical presentation is a set of non-specific symptoms that may be the continuation of symptoms resulting from the original incident, related to secondary injuries (e.g., cervical spine) or to a pre-existing condition such as a migraine headache.[14] The differential diagnosis for these symptoms includes depression, somatization, chronic fatigue, chronic pain, cervical injury, vestibular dysfunction, ocular dysfunction, or some combination of these conditions.[14] Patients whose symptoms persist may also be at risk to develop other co-morbidities such as aerobic de-conditioning, chronic pain, anxiety disorder, and depression. Academic or work performance may also be affected.

These signs and symptoms are specific to the individual and treatment should address the clinical assessment findings. The risk for persistent symptoms occurring does not appear to be correlated to the severity of the initial injury.[2] Pre-existing conditions may also be factors in the development of ongoing symptoms.[14] While the recovery rate for sport-related concussion is high, the incidence of persistent symptoms is higher in those who experience concussions due to other causes.[2]

International Classification of Diseases[7] (ICD-10) diagnostic criteria for post-concussion syndrome

A. History of head trauma with loss of consciousness preceding symptom onset by a maximum of four weeks.*

B. Symptoms in three or more of the following symptom categories:
- Headache, dizziness, malaise, fatigue, noise intolerance
- Irritability, depression, anxiety, emotional lability
- Subjective concentration, memory, or intellectual difficulties without neuropsychological evidence of marked impairment
- Insomnia
- Reduced alcohol tolerance
- Preoccupation with above symptoms and fear of brain damage with hypochondriacal concern and adoption of sick role

* LOC is not a diagnostic requirement in current literature on concussion

FN World Health Organization *International statistical classification of disease and relation health problems. 10th ed. Geneva, Switz: World Health Organization; 1992.*

Figure 1

Second Impact Syndrome (SIS) is believed to represent an injury sustained over two or more separate events, in which an individual who has had one concussion has a subsequent injury within several weeks of the first, before healing from the initial injury has occurred. This can cause diffuse cerebral swelling, brain herniation, and sudden death.[17]

Although there are many anecdotal narratives about SIS, it is a controversial diagnosis. Current research suggests that it is a rare occurrence.[17] However, it is critical that clinicians reinforce the importance of caution in return to play as a preventive strategy.

Concussion as a co-morbidity

Concussion may occur in conjunction with other injuries. The following are examples of conditions or injuries in which the clinician should consider conducting a scan for concussion:

- Older adults following a fall
- Clients presenting with Whiplash Associated Disorder (WAD)
- Spinal cord injury[18]
- Victims of assault
- Blast injuries (explosions)

If a concussion is a suspected co-morbidity, the physiotherapy assessment for these presenting conditions includes a multidimensional screening tool such as the Sport Concussion Assessment Tool 3 (SCAT3).[1] Additional clinical assessment to evaluate the cervical spine and vestibular system as well as a thorough neurological scan should be performed where indicated. If the patient's clinical history, symptoms and physical exam demonstrate findings consistent with concussion, the physiotherapist has a professional obligation to report these findings to the appropriate health-care providers (e.g., physician, psychologist).

Concussion Management

Concussion is a functional injury with complex and heterogenous symptoms that may be somatic, cognitive and/or affective in origin. Management optimally involves a team of health-care professionals who collaborate to provide integrated care (physician, physiotherapist, occupational therapist, speech language pathologist, SLP, psychologist, optometrist, etc.). This can be achieved in many ways: from practice co-location to development of a multidisciplinary network.

Initial management

The Consensus Guidelines recommend referral to multidisciplinary management if the athlete's symptoms persist beyond the accepted timeframe of 7-10 days.[1] Module 2 of the ONF Guidelines recommends symptom management if symptoms persist more than a few days and referral for comprehensive evaluation and management if symptoms persist greater than four to six weeks.[2] Both concur in recommending an initial period of rest to allow the individual's symptoms to resolve before initiating treatment.

Module 2 of the 2013 ONF Guidelines provides recommendations and an algorhythm for initial management of concussion along with guidance on education and printable information sheets for patients and their families. It includes guidance for the patient on the care for the first 24-48 hours post-concussion diagnosis, as well as education on signs and symptoms that may occur in the following month.[2]

Education and reassurance are effective in lowering the risk of prolonged recovery.[2] Patients are advised that the prognosis for the majority of individuals is positive. For most individuals, the symptoms are transient and recovery is anticipated within three weeks. Both the patient and his/her family benefit from education about concussion and the importance of appropriate physical and cognitive rest.[1]

Physical rest means avoidance of strenuous exercise and/or removal from play. Patients are encouraged to keep a regular routine that does not provoke their symptoms and to balance daily activity with periods of rest.

Cognitive rest means limiting activities that require focus, concentration and attention and/or provoke symptoms. Examples of activities include reading, studying, texting, video game play, television, or movies and use of the computer.[19]

As concussion is a constellation of heterogenous symptoms, interventions are based on the presenting symptoms and assessment findings for each person and follow a program of gradual increase in both cognitive and physical activity. It is generally accepted that return to school/occupational activities precedes returning to sport.[1] Gradual increases in both cognitive and physical activity can be planned specific to the occupation/lifestyle of the individual.

For children and youth, the return to learn (full cognitive activity) is managed with a stepwise program, as illustrated in Table 1. Once the student is symptom free for 24 hours, cognitive activity is increased gradually in both complexity and length of time engaged at home and at school. While there is no requirement for medical clearance, once the student returns to school communication with teachers and educators is recommended.

Return to Learn Protocol

This tool is a guideline for managing a student's return to school following a concussion. Timelines and activities may vary by direction of a health care professional.

AT HOME			AT SCHOOL			
STAGE 1:	**STAGE 2:**		**STAGE 3:**	**STAGE 4:**	**STAGE 5:**	**STAGE 6:**
Physical & cognitive rest • Basic board games, crafts, talk on phone, photography • Physical activities that do not increase heart rate or break a sweat **Avoid:** • Computer, TV, texting, video games, reading **No:** • School work • Sports • Work • Driving until cleared by a health care professional	**Start with light cognitive activity:** Gradually increase cognitive activity up to 30 min. **Prior activities plus:** • Reading, TV, drawing, Lego • Limited peer contact and social networking • Take frequent breaks **Contact school to create return to learn plan.**	**When light cognitive activity is tolerated:** Introduce school work. **Prior activities plus:** • School work as per return to learn plan **Communicate with school on student's progression.**	**Back to school part-time** Part-time school with maximum accommodations. **Prior activities plus:** • School work at school as per return to learn plan **No:** • P.E. • physical activity at lunch/recess • homework • testing • sports • assemblies • field trips **Communicate with school on student's progression.**	**Part-time school** Increase school time with moderate accommodations. **Prior activities plus:** • Increase time at school • Decrease accommodations • Homework – up to 30 min./day • Classroom testing with adaptations **No:** • P.E. • physical activity at lunch/recess • sports • standardized testing **Communicate with school on student's progression.**	**Full-time school** Full days at school, minimal accommodations. **Prior activities plus:** • Start to eliminate accommodations • Increase homework to 60 min./day • Limit routine testing to one test per day with adaptations **No:** • P.E. • physical activity at lunch/recess • sports • standardized testing	**Full-time school** Full days at school, no learning accommodations. • Attend all classes • All homework • Full extracurricular involvement • All testing **No:** • full participation in P.E. or sports until *Return to Play* protocol completed and written medical clearance provided
	No: • School attendance • Sports • Work				**Work up to full days at school, minimal learning accommodations**	**Full academic load**
Rest	**Gradually add cognitive activity including school work at home**	**School work only at school**		**Increase school work, introduce homework, decrease learning accommodations**		
When symptom-free for 24 hours, **BEGIN STAGE 2**	Tolerates 30 min. of cognitive activity, introduce **school work at home**	Tolerates 60 min. of school work in two 30 min. intervals, **BEGIN STAGE 3**	Tolerates 120 min. of cognitive activity in 30-45 min. intervals, **BEGIN STAGE 4**	Tolerates 240 min. of cognitive activity in 45-60 min. intervals, **BEGIN STAGE 5**	Tolerates school full-time with no learning accommodations **BEGIN STAGE 6**	Return to Learn protocol completed, focus on **RETURN TO PLAY**

Note: A student is tolerating an activity if symptoms are not exacerbated.

Adapted from the Return to Learn protocol by G.F. Strong School Program (Vancouver School Board), Adolescent and Young Adult Program, G.F. Strong Rehabilitation Centre

www.cattonline.com

Table 1

Athletes follow a staged or progressive exercise protocol. Following a period of rest until the athlete is asymptomatic at rest for 24-48 hours, they follow a gradual, or stepwise, return to activity and sport which is described in Table 2. If the athlete remains asymptomatic for 24 hours at a stage, they progress to the next stage. If symptoms do recur, they are instructed to rest for 24 hours before resuming activity at the level at which they were symptom free. The athlete progresses through the stages, only returning to actual (contact or game) play when they have received medical clearance to do so.

Module 12 of the ONF Guidelines provides recommendations for return to work, school and activity for adults following concussion. It includes considerations for post- secondary return to school as well as algorithms for both return to school and return-to-work timelines.

Similar to the return to learn principles, physical and cognitive activity is gradually increased in focus requirement and complexity while maintaining the sub-symptom threshold. For example, increasing time on activity, adding external stimuli (sound, busy visual environments) to task, and resuming computer use, etc.

Return to Play Communication Tool

Return to Learn should be completed before Return to Play.

STAGE 1: No sporting activity	STAGE 2: Light aerobic exercise	STAGE 3: Sport-specific exercise	STAGE 4: Non-contact drills	STAGE 5: Full-contact practice	STAGE 6: BACK IN THE GAME
Symptom-limited physical and cognitive rest	Walking, swimming, stationary cycling. No resistance training. Heart rate <70%	Skating drills (ice hockey), running drills (soccer). No head-impact activities	Progress to complex training drills (e.g., passing drills). May start resistance training	Following medical clearance participate in normal training activities	Normal game play
Recovery	Increase heart rate	Add movement	Exercise, coordination, cognitive load	Restore confidence; assess functional skills	
Symptom-free for 24 hours? **Yes:** Begin Stage 2 **No:** Continue resting Time & date completed:	Symptom-free for 24 hours? **Yes:** Move to Stage 3 **No:** Return to Stage 1 Time & date completed:	Symptom-free for 24 hours? **Yes:** Move to Stage 4 **No:** Return to Stage 2 Time & date completed:	Symptom-free for 24 hours? **Yes:** Move to Stage 5 **No:** Return to Stage 3 Time & date completed:	Symptom-free for 24 hours? **Yes:** Return to play **No:** Return to Stage 4 Time & date completed:	

If symptoms reappear at any stage, go back to the previous stage until symptom-free for 24 hours. You may need to move back a stage more than once during the recovery process.

Medical clearance required before moving to Stage 5

CATT — Concussion Awareness Training Tool

BC INJURY research and prevention unit

Table 2

The effect of the following factors on the individual's symptoms is included in return-to-work planning:

- Type of work (physical labour, office work, combination of both)
- Work environment (open office, driving, home office, amount of interaction with staff or public)
- Level of stress
- Mode of transportation (bus, subway, driving a car)

Management of persistent signs and symptoms

Individuals whose symptoms persist are referred for further assessment and treatment in a multidisciplinary setting, which may include physiotherapy, depending on the clinical presentation of the individual.

Currently there are no established, specific protocols for the management of persistent post-concussion symptoms. This is in part due to the range of contributing factors, such as the mechanism of injury (e.g. a non-sport event, a fall, or a motor vehicle collision), pre-existing conditions such as a history of migraine, and the potential for symptom overlap. Concussion is a heterogeneous injury and thus can present with a variety of signs and symptoms. Module 4 of the ONF Guidelines recommends taking a symptom-based approach as the cluster of symptoms varies considerably between patients.

This means that each person's management is based on his/her individual clinical presentation.

Similarly, physiotherapy interventions in the management of persistent post-concussion symptoms are based on the physiotherapy differential diagnostic process - a careful assessment of the patient's history, signs and symptoms.

The Physiotherapy Role

Physiotherapists are one of the health-care professionals in the multidisciplinary concussion management team, and collaborate with other providers (e.g., physicians, psychologists, occupational therapists) and professionals (educators, employers) in the delivery of optimal care.

Overview

As with other practice areas or techniques (pelvic floor, spinal manipulation), physiotherapists are responsible to develop competence in concussion management and build a network of competent providers for consultation and collaboration as appropriate.

Physiotherapists may screen for concussion, conduct a physiotherapy differential diagnosis of presenting signs and symptoms, and treat those impairments which are responsive to physiotherapy management as well as other presenting co-morbidities. Treatment planning and exercise prescription support the individual's return-to-play/return-to-activity progression. A comprehensive physiotherapy assessment will also screen for signs of more serious pathology or conditions that may require referral to colleagues with specific expertise or to other disciplines.

Recent research suggests that physiologic (autonomic) cervical and vestibular impairments are potential clinical sub-types or disorders within the concussion diagnosis.[20,21,22] As dizziness and headaches may be reported in a physiologic disorder following concussion, as well as in cervical and vestibular disorders, physiotherapy assessment can help differentiate the origin of these symptoms and determine the appropriate management strategy.[23]

The following sections provide information on:

- Screening tools used to assist in the assessment of concussion
- The approach to assessment of an individual with concussion or persistent symptoms, with links to tools referenced
- Current evidence for physiotherapy management of concussion

The Toolkit is not a clinical manual; it is intended as a resource for physiotherapists in the provision of evidence-based assessment and treatment of concussion. Physiotherapy assessment will include documentation of signs and symptoms of mood disorder, cognitive symptoms and sleep disturbance, although the Toolkit does not include management strategies. Physiotherapists are advised to be aware of these aspects, consider the implications to their practice, and, when appropriate, refer to the appropriate clinician.

Modules 8 and Module 9 of the ONF Guidelines review management of persistent mental health and cognitive disorders.

There is evidence that neuropsychological testing can be a useful aid in management of concussion in conjunction with other assessment tools and clinical judgment. The tests are best administered and interpreted by a neuropsychologist and will contribute to the medical decision regarding return to play. However, there is insufficient evidence to support the routine use of baseline neuropsychological testing.[1]

Concussion screening tools

Two currently available screening tools help guide the clinician in determining whether the patient has sustained a concussion: the Sport Concussion Assessment Tool – 3 (SCAT3)[1] and the Vestibular/Ocular Motor Screening Assessment (VOMS).[24] The two tools are complementary and help determine the best course of treatment. SCAT3 documents signs and symptoms, while the VOMS assesses vestibular and ocular impairment.

SCAT3

The SCAT3 (Appendix 1) is a standardized tool designed for use by multiple different health-care professionals in the assessment of concussion in individuals 13 years of age and older. It includes validated assessment tools for both signs and symptoms of concussion and can be used as a screening tool to rapidly evaluate domains such as symptoms, immediate and delayed memory, concentration, coordination and standing balance. It takes approximately 10-15 minutes to complete. This tool was developed in the area of sport-related concussion but may also be used in the area of non-sport concussion, although this has not yet been evaluated in the literature. The SCAT3 and its components may also be used throughout treatment to monitor the patient/client's progress, and provide a consistent reporting mechanism for use across disciplines.

While it is understood that the SCAT3 has limitations, it is a concise tool that covers multiple domains and is used by several professions. This facilitates communication between professionals and supports quality care.

The SCAT3 symptom scale may be completed by the patient or with assistance (i.e. with family member or through a clinician interview). In either case, the process used to complete the symptom scale should be recorded as this can affect the scoring.

Note: The Maddox score in SCAT3 is used in the on field assessment only.

The SCAT3 includes a modified Balance Error Scoring System (mBESS). However, the BESS itself has not yet been validated for use with non-sport concussions, and performance has been shown to decrease when the subjects are over 50 years of age.[25]

The Single Limb Stance Test (SLS) or Unipedal Stance Test is part of the BESS and has been tested for use with a range of conditions, including concussion for individuals from ages 18-99. Normative values for test results for each 10-year age grouping have been reported.[26]

VOMS

The VOMS (Appendix 2) was first published in 2014 and has been proposed as a brief clinical screen for detection of concussion in adults with sport-related concussion under the age of 49. It has been reported to identify change in symptoms related to oculomotor and vestibulo-ocular stimuli. The mBESS and the VOMS are complementary screening tools. The mBESS assesses standing balance in different stances on a firm surface, and the VOMS includes a series of vestibular and oculomotor tests that are completed by the patient. The VOMS is not used to evaluate the patient's ability to complete the tests, but rather examines the effect each test has on his/her symptoms.

A video produced by the University of Pittsburgh Medical Centre demonstrates its application here: https://www.youtube.com/watch?v=E2uF0lcyNps.

While the SCAT3 and VOMS screen for signs and symptoms related to concussion, they are not stand-alone assessments. Incorporating multiple tools helps ensure a comprehensive assessment. The two screening tools are used to provide relevant information in the differential diagnosis process. A thoughtful history and clinical examination as well as engagement of the physician and other health-care professionals based on the patient presentation is imperative for management of persistent post-concussion symptoms.

Physiotherapy assessment

When it has been verified that the clinical presentation is consistent with concussion, a detailed assessment is conducted to determine whether physiotherapy is indicated for the individual.

Physiotherapy is indicated and can be effective in concussion management when dizziness, neck pain, headache and impaired balance have cervical spine and/or vestibular involvement. Treatment is based on the physiotherapy differential diagnosis made through patient history and clinical assessment of presenting signs and symptoms.

A Differential Diagnosis Checklist has been included as Appendix 3.

The history, screening tools and initial physical scan are the first step in differentiating potential symptom origins.

A. History

- Mechanism of injury
- Current symptom intensity/frequency in comparison to pre-injury status
- General medical history: determine any pre-existing conditions that may affect symptoms and recovery. Include:
  - Age and gender
  - Prior concussion history
  - History of migraines, sleep disorders, depression, ADHD, etc.
- Occupation/employment: determine normal level of physical/cognitive activity in planning return to sport/work/school/play
- Other activities: determine levels of activity to monitor during rehab process such as driving, sports, writing, music, social media, etc.
- Mood: the symptom severity questionnaire in SCAT3 includes four questions on mood
  - Consider use of additional screening tools such as: the Depression, Anxiety and Stress Scale (DASS -21), the Patient Health Questionnaire-9 (PHQ-9), or the Hospital Anxiety and Depression Scale (HADS)
- Sleep pattern: any indication of disruption to normal sleep pattern (drowsiness, falling asleep or difficulty waking)

Identify the other members of the interprofessional health-care team. Refer the patient to his/her physician, a clinical psychologist or neuropsychologist if there are any indications that either mood or sleep has been affected since the injury occurred. Occupational therapy may also be indicated in management of fatigue.

B. Medical tests and results

Physiotherapy assessment includes documentation of the following:

- Physician/medical investigation, including any record of tests ordered in the diagnostic process
- Radiological/diagnostic imaging results, where indicated (see below)
- All medications including the type (prescription or OTC) and frequency /pattern of use to determine compliance or overuse.

Red/Yellow flags

The following signs and symptoms may be indicators of cervical spine fracture, subdural hematoma, or cerebral bleed. Refer the patient for immediate medical evaluation if there is evidence of the following:

- Diplopia, dysarthria, dysphagia, quadrilateral paresthesia/numbness
- Significant mid-line cervical spine tenderness
- Fainting or loss of consciousness
- Progressively worsening headache
- Confusion
- Repetitive vomiting

In some patients, evaluation with the Canadian c-spine rule[27] may be appropriate. It is a useful screening procedure that assists the clinician in determining the need for diagnostic imaging in the alert patient who has neck pain following blunt trauma. Therapists may apply it as part of their assessment of patients demonstrating red/yellow flags.

These two videos illustrate how the C-spine rule is used in hospitals and how it can be used in a PT practice:

- University of Ottawa: https://www.youtube.com/watch?v=k0cqlYvpv1o
- BC Physio: https://www.youtube.com/watch?v=muD1fVpVnoc

C. Physical scan

Clinical assessment begins with tools that are least likely to provoke symptoms and progress to those more likely to do so.

Initial scan:

- Observation of posture in:
  - Standing, sitting and walking, including head position in all three postures
- Neurologic scan, which includes:
  - Cranial nerves
  - Dermatomes and myotomes (key muscles)
  - Deep tendon reflexes (upper and lower extremities)
  - Cerebellar function
  - Upper motor neuron (e.g., clonus, Babinski, Oppenheimer and Hoffman's)
- Resting heart rate, blood pressure.

A useful review of the neurological clinical assessment can be found at Neuroexam.com.

Based on the initial findings, a detailed assessment is performed to gather and incorporate new information and to further clarify the most likely cause of presenting signs and symptoms,

> **CLINICAL TIP:** The findings of the neurological scan will help determine sequence and direction of assessment.

whether cervicogenic, vestibular, or other. Assessment findings will help determine the priorities in treatment planning and implementation.

Cervical Spine

Cervicogenic signs and symptoms may include neck pain, dizziness, headache and difficulty with balance or unsteadiness. Several of these symptoms are similar to, or overlap with, vestibular signs and symptoms in concussion or persistent post-concussive symptoms.[2]

A neurological scan and assessment of the cervical spine are conducted prior to vestibular assessment. This will ensure that the individual's cervical spine can tolerate the positions and movements required for vestibular testing (e.g., extension and rotation). Assessment begins with active range of motion and soft tissue palpation of entire cervical spine. In the case of cervical spine involvement, positional tests for the vestibular system can be performed with the cervical spine in neutral.

Cervical assessment includes levels C0-C4, as symptoms of headache and neck pain may originate from impairments at these levels.[28,29] In the event of positive findings, such as symptom provocation or alleviation, a more detailed assessment of the appropriate level(s), including biomechanical assessment, is carried out. Physiotherapists who do not routinely use manual therapy in their practice may consult a manual therapy colleague.

The assessment includes a test for vertebrobasilar insufficiency (VBI). VBI is a medical condition caused by a disruption in the vertebrobasilar arterial system. It is not common, but is a serious condition that causes dizziness, and requires the physiotherapist to rule it out in assessment. If any alerting factors in the neurological scan or history suggest VBI, the patient should be referred to his/her physician. Current best practice is to perform the modified Vertebral Artery Test (mVAT), an active test carried out in sitting, prior to treating the cervical spine.

There is some debate on the validity of the mVAT as a test for VBI.[30] In the event of a positive finding or suspected VBI, refer the patient to his/her physician for further assessment or for urgent medical care as indicated.

> **CLINICAL TIP:** Begin VBI testing in least provocative position and progress. As part of the differential diagnosis process, consider the possibility of vestibular involvement, and rule this out using the approach detailed in the APA Clinical Guidelines for Assessing Vetebrobasilar Insufficiency in the Management of Cervical Spine Disorders 2006.[31]

The Cervical Joint Position Error Test (JPET) is believed to assess cervico-cephalic proprioception and neck reposition sense.[32] It is easy to administer and test the patient's ability to relocate his/her head back to center after maximal or submaximal rotation in the transverse and sagittal planes.

Physiopedia's Cervical Scan and the International Federation of Orthopaedic Manipulative Therapists' Cervical Framework Document provide useful reviews for physiotherapy assessment of the cervical spine. Links to these websites can be found in the Resources section.

Assessment - specific symptoms

Based on history and findings, the assessment will focus on specific symptoms.

The following assessment tools do not represent all testing procedures, but were selected based on evidence for their use in each symptom presentation.

Headaches

Headaches are consistently the most common symptom reported following concussion. For the patient with persistent post-concussion symptoms, however, there may be other causes. Headaches are differentiated as primary (diagnoses such as migraine, tension or cluster) and secondary (headaches arising from other causes, such as sinus, cervicogenic, trauma or meningitis).[33]

Research supports physiotherapy as an intervention for the assessment and management of primary chronic tension-type headaches[34] and secondary headaches of musculoskeletal origin, such as the cervicogenic headache.[35,36]

There is no evidence that physiotherapy is effective in the management of other headaches, such as migraine. If signs and symptoms are indicative of migraine, the patient is referred to his/her physician.

Module 6 of the ONF Guidelines provides an overview for management of post-traumatic headaches.

The Headache Impact Test (HIT-6TM)[37] is a self-report questionnaire that can be used on initial assessment and to monitor change or progress during treatment. The six questions measure the impact of headaches on the individual's normal function at work, school, home and in social situations. It uses a five-point scale and scores over 50 indicate the need for medical attention.

The Cervical Flexion Rotation Test has been validated as an assessment tool for cervicogenic headaches (CGH).[38] The diagnostic criteria for CGH include headache with neck pain and stiffness and with dysfunction in the upper cervical spine.[39] Rotation is significantly reduced in patients with CGH compared to other headaches and the asymptomatic population.[38]

The Cranio Cervical Flexion Test is used to test the ability to recruit the deep cervical muscles. Impairment or delayed action of the deep cervical muscles may be a factor in headaches.[40]

Dizziness

Prolonged dizziness following concussion may occur for a variety of reasons. The cervical spine and the vestibular system are two potential sources, although a range of other systems may be involved (e.g., postural hypotension, infections, or vertebrobasilar insufficiency, etc.).[30] Assessment of dizziness integrates all clinical findings (e.g., cranial nerves, cervical spine assessment) with the history to differentiate the most likely source of symptoms and determine if physiotherapy interventions are appropriate, or if further medical evaluation is warranted.

The Dizziness Handicap Inventory (DHI) is a 25-item self-assessment inventory used to evaluate the perceived handicapping effects imposed by dizziness and can be used to monitor treatment effectiveness.[41] Each item is scored as: 0 (representing none), 2 (somewhat) or 4 (yes).

> **CLINICAL TIP:** Record the nature, duration, aggravating and easing factors. Clarify whether the patient has been or currently experiences vertigo, which will help differentiate the source and assist in the assessment and treatment planning.

Vestibular System

Vestibular dysfunction may affect balance, posture or vestibulo-ocular function. The BESS, described earlier, assesses standing balance. The vestibulo-ocular reflex (VOR) is responsible for maintaining focus on a target while the head is in motion. Depending on assessment findings, a more detailed vestibular assessment may be indicated. In the case of suspected central vestibular dysfunction, therapists who do not have that skill set should refer their patients to their physician for further medical evaluation or a physiotherapist with expertise in vestibular rehabilitation.

Benign Paroxysmal Positional Vertigo (BPPV) is a mechanical problem with the inner ear that results in episodes of vertigo with changes in position. There is evidence that five of the items included in the Dizziness Handicap Inventory (numbers 1, 5, 11, 13 and 25) form a subset helpful in determining if the patient has BPPV. Positive responses to all five, along with history and assessment findings, help guide the direction of the assessment and may indicate referral to a vestibular therapist for management of BPPV.[42]

In the senior population, there is evidence that a DHI score greater than 50 may be a predictor of BPPV, again informing the assessment process and/or indicating referral to a vestibular therapist.[43]

Balance

Observe the individual's response to static and dynamic tests, dynamic functional activities (such as sit to stand), and a range of gait patterns (e.g., tandem gait, heel/toe, forwards/backwards). Although generalized balance testing is not specific to vestibular dysfunction, in the case of vestibular dysfunction, individuals may have difficulty when testing requires them to rely on vestibular input to maintain balance (e.g., standing with eyes closed, turning head while walking).

Module 10 of the ONF Guidelines provides an overview of the assessment and management of persistent vestibular (balance and dizziness) and vision dysfunction in mTBI.

Further information on balance, dizziness and vestibular disorders is available from the Vestibular Disorders Association.

Additional tests

The following tests may be useful in the assessment of dynamic balance, depending on the patient's age, medical condition or other factors (e.g., activity level):

The Functional Gait Assessment[44] was developed based on the Dynamic Gait Index, and has been validated for community dwelling adults between the ages or 40-89 and for those with neurological conditions including TBI and vestibular disorders. Along with the BESS, it may be useful in assessing balance and postural control in concussion management in all populations.[45]

The Dynamic Gait Index[44] is used among older adults with functional limitations due to chronic conditions. It is designed to allow for use of an assistive device.

The Community Balance and Mobility Scale was developed for use with adults with mild to moderate neurological deficits, including traumatic brain injury in a variety of settings from acute care to the community.[46]

Management

The Consensus Guidelines recommend referral to multidisciplinary management if the athlete's symptoms persist beyond the accepted timeframe. Module 2 of the ONF Guidelines recommends symptom management if symptoms persist for more than a few days and referral for comprehensive evaluation and management if symptoms persist longer than four to six weeks. Both concur in recommending an initial period of rest to allow the individual's symptoms to resolve before initiating treatment.

Active rehabilitation is recommended to minimize risk of adverse physical or psychological consequences or prolonging symptoms.[47]

Module 5 of the ONF Guidelines describes general management of persistent symptoms following concussion.

At time of writing, there are no evidence-based guidelines for physiotherapy specific to management of persistent post-concussion symptoms. Physiotherapy treatment is therefore based on clinical assessment of signs and symptoms and implementation of existing evidence-informed interventions for the identified impairments.[48]

The research on rehabilitation for persistent post-concussion symptoms is primarily in the context of sport-related concussions and for children and collegiate athletes. While these research findings have not been evaluated for adults with non-sport related concussion, the principles may be applied to their treatment within the context of the individual's age, goals and function.

Physiotherapy management includes education and support, treatment of signs and symptoms responsive to physiotherapy such as impairments of the cervical spine and/or vestibular system and sub-symptom threshold aerobic exercise.

Cervicogenic and vestibular management

A recent RCT showed that adolescents and young adults with persistent symptoms following concussion who were treated with physiotherapy interventions (including treatment for cervical and vestibular findings such as neuromotor retraining, sensorimotor retraining, manual therapy and vestibular rehabilitation) were nearly four times more likely to be medically cleared to return to sport in an eight-week time period when compared to rest and the standard return-to-play protocol.[11]

Cervical spine rehabilitation

Physiotherapy interventions for cervicogenic impairments may include neuromotor retraining (for the cranovertebral and cervical and scapulothoracic regions), sensorimotor retraining, manual therapy and soft tissue techniques.

Vestibular rehabilitation

Vestibular rehabilitation has been shown to be effective in the management of dizziness and gait and balance dysfunction following concussion in both children and adults.[49] Techniques may include adaptation, substitution, habituation, standing and dynamic balance retraining, and canalith repositioning maneouvers. A retrospective chart review of home programs prescribed by vestibular therapists to patients following concussion showed that the most frequent home program exercises prescribed were eye/head co-ordination, followed by standing static balance exercises and ambulation exercises.[50]

Aerobic exercise

Exercise intolerance may be a physiologic sign of concussion. However, the current evidence is limited to uncontrolled studies and the improvements seen may be due to time or other factors.[51] Recent studies have demonstrated that sub-threshold aerobic exercise is safe and may improve symptoms and outcomes in patients with persistent symptoms, as well as improve fitness and autonomic function (i.e., better heart rate and blood pressure control) during exercise in both the sport and non-sport concussion populations.[52,52,54] Symptom threshold may be established with exercise bicycle or treadmill testing. Similar protocols have demonstrated functional improvements in children.[55]

Activity pacing

Many clinicians include pacing and planning daily activity within the multidisciplinary plan of care for individuals with persistent post-concussive symptoms.[2] Learning to use strategies (e.g., using a daily planner, a timer to limit participation, and planned rest times) to keep symptoms sub-threshold in daily activities is thought to support a gradual increase in tolerance and rehabilitation goals. Where possible, an occupational therapist should be consulted to provide guidance on planning and pacing daily activities.

The Pain Health website* provides individuals who have chronic musculoskeletal pain with evidence-informed information and resources for management of their pain. It describes strategies and provides worksheets to help establish their symptom sub-threshold target and remain symptom free while gradually increasing activity levels.

Oculomotor dysfunction

There is evidence that up to 30% of athletes experience visual disturbances in the first week following injury.[56] If these symptoms persist (e.g., blurred vision, reading problems, diplopia, vestibular symptoms in crowded environment, light sensitivity) there may be a detrimental effect on the individual's recovery.[57] Based on clinical exam findings, a referral to a vestibular therapist, a neurologist, a neuro-optometrist, or to their physician for management may be warranted.

Physical modalities

Physiotherapists use many passive modalities (electrotherapy, heat, etc.) within their practice to manage the signs and symptoms of concussion. However, as there is currently no evidence to support their use for this patient population, they have not been included at this time. Clinicians are encouraged to use their professional judgment and clinical skill in treatment implementation.

Approach to Treatment

The physiotherapy treatment plan is multifaceted and based on assessment findings and symptom presentation. For example, the timing and intensity of physiotherapy sessions is an integral component of treatment planning for the patient sensitive to external stimuli. Consider scheduling initial appointments when the clinic is quieter/less busy for those with noise sensitivity. If the patient is sensitive to light, the treatment could occur in a room with curtains drawn or with the patient wearing dark glasses. Increasing exposure to external stimuli and introduction of dual tasking exercises may be incorporated as part of their treatment progression as tolerated.

Interventions specific to the patient are prioritized and introduced sequentially to assess response to and confirm direction of care. For example, depending on the individual patient's presentation, pain management may be the initial treatment. If assessment findings support a vestibular component, vestibular rehabilitation may be the treatment of choice, but may need to be deferred until the patient's headaches have been addressed.[23]

WHAT WE KNOW: Concussion is a functional brain injury with complex and heterogeneous symptom presentation. It should be managed based on the individual presentation. In the case of ongoing symptoms of dizziness, neck pain and headaches for greater than 10 days, multimodal physiotherapy (including treatment for the cervical spine and vestibular systems) may be of benefit.

EMERGING EVIDENCE: Sub-symptom aerobic exercise and treatment of oculomotor impairments may be of benefit in the treatment of concussion, however the current evidence is limited.

WHAT WE DON'T KNOW: The optimal duration of rest as well as the timing to initiate treatment following injury is not yet fully understood.[56]

TAKE AWAY MESSAGE: Concussion is a functional injury with complex and heterogenous symptoms that may be somatic, cognitive and/or affective in origin. Treatment is based on individual presentation. Physiotherapy may be of benefit but should be in the context of an interdisciplinary team approach.

These individuals benefit from careful assessment in a multidisciplinary setting. Physiotherapy is indicated and can be effective in concussion management where the origin of the symptoms of dizziness, neck pain, headache and impaired balance have a cervical spine and/or vestibular origin.

* A Government of Western Australia Department of Health initiative

Conclusion

Although the majority of individuals who experience a concussion have a full recovery, as many as one third will report persistent symptoms for an extended amount of time.

Physiotherapy Alberta developed this Toolkit to provide physiotherapists with information and resources for a consistent approach to management of adults who have sustained a concussion. It is critical that physiotherapists recognize the complex and multifaceted nature of concussion, and understand their role and context within a multidisciplinary management approach. Physiotherapists have the knowledge and skill to assess and treat the relevant impairments (cervical and vestibular) related to concussion and persistent symptoms, and to provide insight into the potential origin of symptoms that can help determine the appropriate course of treatment.
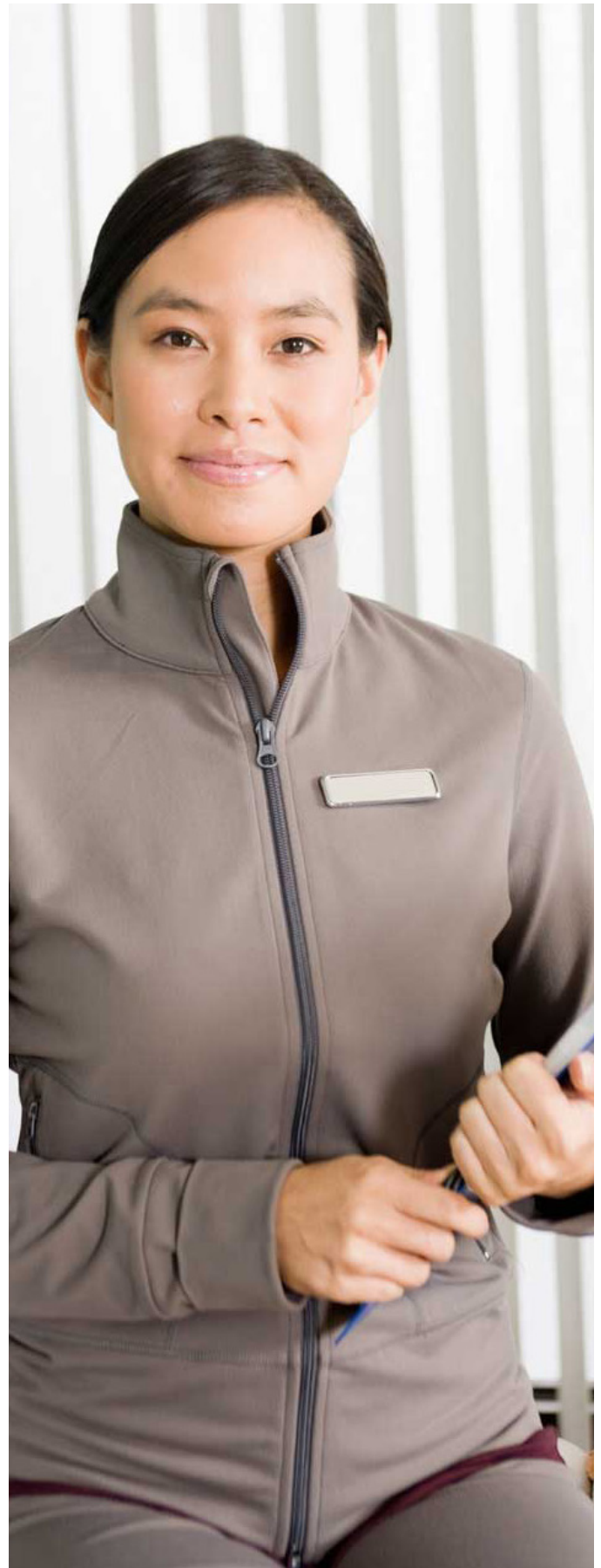
Appendix 1:
SCAT3

SCAT3™

FIFA · IIHF · OLYMPIC RINGS · IRB · FEI

Sport Concussion Assessment Tool – 3rd Edition
For use by medical professionals only

Name: _____   Date/Time of Injury: _____   Examiner: _____
Date of Assessment: _____

What is the SCAT3?[1]

The SCAT3 is a standardized tool for evaluating injured athletes for concussion and can be used in athletes aged from 13 years and older. It supersedes the original SCAT and the SCAT2 published in 2005 and 2009, respectively[2]. For younger persons, ages 12 and under, please use the Child SCAT3. The SCAT3 is designed for use by medical professionals. If you are not qualified, please use the Sport Concussion Recognition Tool[1]. Preseason baseline testing with the SCAT3 can be helpful for interpreting post-injury test scores.

Specific instructions for use of the SCAT3 are provided on page 3. If you are not familiar with the SCAT3, please read through these instructions carefully. This tool may be freely copied in its current form for distribution to individuals, teams, groups and organizations. Any revision or any reproduction in a digital form requires approval by the Concussion in Sport Group.
NOTE: The diagnosis of a concussion is a clinical judgment, ideally made by a medical professional. The SCAT3 should not be used solely to make, or exclude, the diagnosis of concussion in the absence of clinical judgement. An athlete may have a concussion even if their SCAT3 is "normal".

What is a concussion?

A concussion is a disturbance in brain function caused by a direct or indirect force to the head. It results in a variety of non-specific signs and/or symptoms (some examples listed below) and most often does not involve loss of consciousness. Concussion should be suspected in the presence of **any one or more** of the following:

- Symptoms (e.g., headache), or
- Physical signs (e.g., unsteadiness), or
- Impaired brain function (e.g. confusion) or
- Abnormal behaviour (e.g., change in personality).

SIDELINE ASSESSMENT

Indications for Emergency Management

NOTE: A hit to the head can sometimes be associated with a more serious brain injury. Any of the following warrants consideration of activating emergency procedures and urgent transportation to the nearest hospital:

- Glasgow Coma score less than 15
- Deteriorating mental status
- Potential spinal injury
- Progressive, worsening symptoms or new neurologic signs

Potential signs of concussion?

If any of the following signs are observed after a direct or indirect blow to the head, the athlete should stop participation, be evaluated by a medical professional and **should not be permitted to return to sport the same day** if a concussion is suspected.

Any loss of consciousness?	Y	N
"If so, how long?" _____		
Balance or motor incoordination (stumbles, slow/laboured movements, etc.)?	Y	N
Disorientation or confusion (inability to respond appropriately to questions)?	Y	N
Loss of memory:	Y	N
"If so, how long?" _____		
"Before or after the injury?" _____		
Blank or vacant look:	Y	N
Visible facial injury in combination with any of the above:	Y	N

1 Glasgow coma scale (GCS)

Best eye response (E)	
No eye opening	1
Eye opening in response to pain	2
Eye opening to speech	3
Eyes opening spontaneously	4

Best verbal response (V)	
No verbal response	1
Incomprehensible sounds	2
Inappropriate words	3
Confused	4
Oriented	5

Best motor response (M)	
No motor response	1
Extension to pain	2
Abnormal flexion to pain	3
Flexion/Withdrawal to pain	4
Localizes to pain	5
Obeys commands	6

Glasgow Coma score (E + V + M)	of 15

GCS should be recorded for all athletes in case of subsequent deterioration.

2 Maddocks Score[3]

"I am going to ask you a few questions, please listen carefully and give your best effort."
Modified Maddocks questions (1 point for each correct answer)

What venue are we at today?	0	1
Which half is it now?	0	1
Who scored last in this match?	0	1
What team did you play last week/game?	0	1
Did your team win the last game?	0	1
Maddocks score		of 5

Maddocks score is validated for sideline diagnosis of concussion only and is not used for serial testing.

Notes: Mechanism of Injury ("tell me what happened"?):

_____
_____
_____
_____
_____

Any athlete with a suspected concussion should be REMOVED FROM PLAY, medically assessed, monitored for deterioration (i.e., should not be left alone) and should not drive a motor vehicle until cleared to do so by a medical professional. No athlete diagnosed with concussion should be returned to sports participation on the day of Injury.

BACKGROUND

Name: _____ Date: _____

Examiner: _____

Sport/team/school: _____ Date/time of injury: _____

Age: _____ Gender: ☐ M ☐ F

Years of education completed: _____

Dominant hand: ☐ right ☐ left ☐ neither

How many concussions do you think you have had in the past? _____

When was the most recent concussion? _____

How long was your recovery from the most recent concussion? _____

Have you ever been hospitalized or had medical imaging done for a head injury? ☐ Y ☐ N

Have you ever been diagnosed with headaches or migraines? ☐ Y ☐ N

Do you have a learning disability, dyslexia, ADD/ADHD? ☐ Y ☐ N

Have you ever been diagnosed with depression, anxiety or other psychiatric disorder? ☐ Y ☐ N

Has anyone in your family ever been diagnosed with any of these problems? ☐ Y ☐ N

Are you on any medications? If yes, please list: ☐ Y ☐ N

SCAT3 to be done in resting state. Best done 10 or more minutes post excercise.

SYMPTOM EVALUATION

3 How do you feel?

"You should score yourself on the following symptoms, based on how you feel now".

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

Total number of symptoms (Maximum possible 22) ☐

Symptom severity score (Maximum possible 132) ☐

Do the symptoms get worse with physical activity? ☐ Y ☐ N

Do the symptoms get worse with mental activity? ☐ Y ☐ N

☐ self rated ☐ self rated and clinician monitored
☐ clinician interview ☐ self rated with parent input

Overall rating: If you know the athlete well prior to the injury, how different is the athlete acting compared to his/her usual self?
Please circle one response:

no different	very different	unsure	N/A

Scoring on the SCAT3 should not be used as a stand-alone method to diagnose concussion, measure recovery or make decisions about an athlete's readiness to return to competition after concussion. Since signs and symptoms may evolve over time, it is important to consider repeat evaluation in the acute assessment of concussion.

COGNITIVE & PHYSICAL EVALUATION

4 Cognitive assessment
Standardized Assessment of Concussion (SAC)[4]

Orientation (1 point for each correct answer)

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

Immediate memory

List	Trial 1		Trial 2		Trial 3		Alternative word list		
elbow	0	1	0	1	0	1	candle	baby	finger
apple	0	1	0	1	0	1	paper	monkey	penny
carpet	0	1	0	1	0	1	sugar	perfume	blanket
saddle	0	1	0	1	0	1	sandwich	sunset	lemon
bubble	0	1	0	1	0	1	wagon	iron	insect
Total									

Immediate memory score total ☐ of 15

Concentration: Digits Backward

List	Trial 1		Alternative digit list		
4-9-3	0	1	6-2-9	5-2-6	4-1-5
3-8-1-4	0	1	3-2-7-9	1-7-9-5	4-9-6-8
6-2-9-7-1	0	1	1-5-2-8-6	3-8-5-2-7	6-1-8-4-3
7-1-8-4-6-2	0	1	5-3-9-1-4-8	8-3-1-9-6-4	7-2-4-8-5-6
Total of 4					

Concentration: Month in Reverse Order (1 pt. for entire sequence correct)

Dec-Nov-Oct-Sept-Aug-Jul-Jun-May-Apr-Mar-Feb-Jan	0	1
Concentration score		of 5

5 Neck Examination:
Range of motion   Tenderness   Upper and lower limb sensation & strength
Findings: _____

6 Balance examination
Do one or both of the following tests.
Footwear (shoes, barefoot, braces, tape, etc.) _____

Modified Balance Error Scoring System (BESS) testing[5]
Which foot was tested (i.e. which is the **non-dominant** foot) ☐ Left ☐ Right
Testing surface (hard floor, field, etc.) _____
Condition

Double leg stance:	Errors
Single leg stance (non-dominant foot):	Errors
Tandem stance (non-dominant foot at back):	Errors

And/Or

Tandem gait[6,7]
Time (best of 4 trials): _____ seconds

7 Coordination examination
Upper limb coordination
Which arm was tested: ☐ Left ☐ Right
Coordination score of 1

8 SAC Delayed Recall[4]
Delayed recall score of 5

INSTRUCTIONS

Words in *Italics* throughout the SCAT3 are the instructions given to the athlete by the tester.

Symptom Scale

"You should score yourself on the following symptoms, based on how you feel now".

To be completed by the athlete. In situations where the symptom scale is being completed after exercise, it should still be done in a resting state, at least 10 minutes post exercise.
For total number of symptoms, maximum possible is 22.
For Symptom severity score, add all scores in table, maximum possible is $22 \times 6 = 132$.

SAC[4]

Immediate Memory

"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."

Trials 2 & 3:

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

Complete all 3 trials regardless of score on trial 1 & 2. Read the words at a rate of one per second. **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

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

If correct, go to next string length. If incorrect, read trial 2. **One point possible for each string length**. Stop after incorrect on both trials. The digits should be read at the rate of one per second.

Months in reverse order

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

1 pt. for entire sequence correct

Delayed Recall

The delayed recall should be performed after completion of the Balance and Coordination Examination.

"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

Balance Examination

Modified Balance Error Scoring System (BESS) testing[5]

This balance testing is based on a modified version of the Balance Error Scoring System (BESS)[5]. A stopwatch or watch with a second hand is required for this testing.

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

(a) Double leg stance:

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

(b) Single leg stance:

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

(c) Tandem stance:

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

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

Each of the 20-second trials is scored by counting the errors, or deviations from the proper stance, accumulated by the athlete. The examiner will begin counting errors only after the individual 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 an athlete commits multiple errors simultaneously, only one error is recorded but the athlete should quickly return to the testing position, and counting should resume once subject is set. Subjects 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 50 cm x 40 cm x 6 cm).

Tandem Gait[6,7]

Participants are instructed to stand with their feet together behind a starting line (the test is best done with footwear removed). Then, they walk in a forward direction as quickly and as accurately as possible along a 38mm wide (sports tape), 3 meter 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. A total of 4 trials are done and the best time is retained. Athletes should complete the test in 14 seconds. Athletes fail the test if they step off the line, have a separation between their heel and toe, or if they touch or grab the examiner or an object. In this case, the time is not recorded and the trial repeated, if appropriate.

Coordination Examination

Upper limb coordination
Finger-to-nose (FTN) task:

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

Scoring: 5 correct repetitions in < 4 seconds = 1
Note for testers: Athletes fail the test if they do not touch their nose, do not fully extend their elbow or do not perform five repetitions. **Failure should be scored as 0.**

References & Footnotes

1. This tool has been developed by a group of international experts at the 4th International Consensus meeting on Concussion in Sport held in Zurich, Switzerland in November 2012. The full details of the conference outcomes and the authors of the tool are published in The BJSM Injury Prevention and Health Protection, 2013, Volume 47, Issue 5. The outcome paper will also be simultaneously co-published in other leading biomedical journals with the copyright held by the Concussion in Sport Group, to allow unrestricted distribution, providing no alterations are made.

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ATHLETE INFORMATION

Any athlete suspected of having a concussion should be removed from play, and then 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:

- Have a headache that gets worse
- Are very drowsy or can't be awakened
- Can't recognize people or places
- Have repeated vomiting
- Behave unusually or seem confused; are very irritable
- Have seizures (arms and legs jerk uncontrollably)
- Have weak or numb arms or legs
- Are unsteady on their feet; have slurred speech

Remember, it is better to be safe.
Consult your doctor after a suspected concussion.

Return to play

Athletes should not be returned to play the same day of injury.
When returning athletes to play, they should be **medically cleared and then follow a stepwise supervised program,** with stages of progression.

For example:

Rehabilitation stage	Functional exercise at each stage of rehabilitation	Objective of each stage
No activity	Physical and cognitive rest	Recovery
Light aerobic exercise	Walking, swimming or stationary cycling keeping intensity, 70% maximum predicted heart rate. No resistance training	Increase heart rate
Sport-specific exercise	Skating drills in ice hockey, running drills in soccer. No head impact activities	Add movement
Non-contact training drills	Progression to more complex training drills, eg passing drills in football and ice hockey. May start progressive resistance training	Exercise, coordination, and cognitive load
Full contact practice	Following medical clearance participate in normal training activities	Restore confidence and assess functional skills by coaching staff
Return to play	Normal game play	

There should be at least 24 hours (or longer) for each stage and if symptoms recur the athlete should rest until they resolve once again and then resume the program at the previous asymptomatic stage. Resistance training should only be added in the later stages.

If the athlete is symptomatic for more than 10 days, then consultation by a medical practitioner who is expert in the management of concussion, is recommended.

Medical clearance should be given before return to play.

Scoring Summary:

Test Domain	Score		
	Date: _____	Date: _____	Date: _____
Number of Symptoms of 22			
Symptom Severity Score of 132			
Orientation of 5			
Immediate Memory of 15			
Concentration of 5			
Delayed Recall of 5			
SAC Total			
BESS (total errors)			
Tandem Gait (seconds)			
Coordination of 1			

Notes:

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CONCUSSION INJURY ADVICE

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

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

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

Other important points:

- Rest (physically and mentally), including training or playing sports until symptoms resolve and you are medically cleared
- No alcohol
- No prescription or non-prescription drugs without medical supervision. Specifically:
  · No sleeping tablets
  · Do not use aspirin, anti-inflammatory medication or sedating pain killers
- Do not drive until medically cleared
- Do not train or play sport until medically cleared

Clinic phone number _____

Patient's name _____

Date/time of injury _____

Date/time of medical review _____

Treating physician _____

Contact details or stamp

SCAT3 SPORT CONCUSSION ASSESMENT TOOL 3 | **PAGE 4**   © 2013 Concussion in Sport Group

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Notes

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

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

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

Keywords

concussion; vestibular; ocular motor; symptoms

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

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

It is known that vestibulospinal (ie, balance) impairments are common within the first few days after a concussion.[11,17] Subjectively, nearly 40% of athletes report balance disruption in the first week after a sport-related concussion.[23] However, the utility of balance impairments alone as a measure of a vestibular system injury may be limited because objective clinical balance impairments recover for the majority of athletes within 3 to 5 days after the injury.[17,30] It is likely that balance impairments are distinct from other vestibular-

related impairments and symptoms, as most athletes who experience dizziness after a concussion do not report concomitant balance impairments.[24] In neuro-otology clinics, vestibulo-ocular and vestibulospinal functions are assessed separately, as their constructs are unique.[33] Until recently, all vestibular impairments after concussions were commonly assessed using the Balance Error Scoring System (BESS)[16] or the Sensory Organization Test (SOT).[28] However, these measures are static assessments and only represent the vestibulospinal aspect of the vestibular system. These tests do not address dynamic aspects of the vestibular system or vestibulo-ocular control. Thus, dysfunction resulting from vestibulo-ocular impairments and symptoms may be overlooked when using only vestibulospinal assessments. As such, additional clinical vestibular assessments are warranted that go beyond the current vestibulospinal measures to include vestibulo-ocular and ocular motor aspects.

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

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

MATERIALS AND METHODS

Research Design

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

Participants

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

Instrumentation

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

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

Procedures

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

program. The VOMS was administered individually in a clinic setting to the control group by vestibular physical therapists and athletic trainers educated in vestibular and ocular motor screening. The PCSS was administered to the controls in small groups (with ≤3 participants) in supervised examination rooms.

Data Analysis

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

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

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

RESULTS

Demographic Data

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

Internal Consistency of the VOMS

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

Symptom Provocation After VOMS Assessments

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

NPC Distance

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

Relationship Between the VOMS and PCSS Among Concussed Patients

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

Predicting Concussions and Healthy Controls

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

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

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

DISCUSSION

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

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

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

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

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

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

Clinical Implications

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

The concept of rehabilitation in concussion management is evolving. Vestibular rehabilitation is known to be effective in the management of specific conditions such as vestibular hypofunction, benign paroxysmal positional vertigo, migraine-related dizziness,

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

Future Directions and Research

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

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

Limitations

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

measure of vestibular and ocular motor impairments. The VOMS is designed to elicit symptoms that can be used to identify and refer patients with possible vestibular and ocular motor involvement after concussions for additional evaluation.

CONCLUSION

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

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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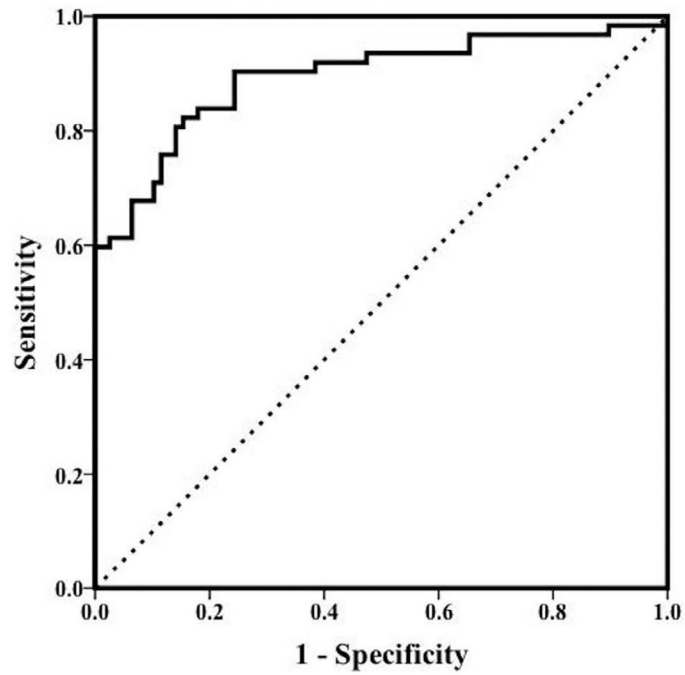
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Figure 1.
Receiver operating characteristic curve describing the area under the curve (AUC) for identifying patients with concussions versus healthy controls using vestibular ocular reflex and visual motion sensitivity symptom scores and near point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

TABLE 1

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

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

[a]VOMS, Vestibular/Ocular Motor Screening.

TABLE 2

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

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

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

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

[c] Mann-Whitney U nonparametric test.

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

TABLE 3

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

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

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

[b]Nagelkerke R^2.

TABLE 4

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

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

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

Vestibular/Ocular-Motor Screening (VOMS) for Concussion

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

Instructions:

Interpretation: This test is designed for use with subjects ages 9-40. When used with patients outside this age range, interpretation may vary. Abnormal findings or provocation of symptoms with any test may indicate dysfunction – and should trigger a referral to the appropriate health care professional for more detailed assessment and management.

Equipment: Tape measure (cm); Metronome; Target w/ 14 point font print.

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

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

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

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

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

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

- **Visual Motion Sensitivity (VMS) Test** – Test visual motion sensitivity and the ability to inhibit vestibular-induced eye movements using vision. The patient stands with feet shoulder width apart, facing a busy area of the clinic. The examiner stands next to and slightly behind the patient, so that the patient is guarded but the movement can be performed freely. The patient holds arm outstretched and focuses on their thumb. Maintaining focus on their thumb, the patient rotates, together as a unit, their head, eyes and trunk at an amplitude of 80 degrees to the right and 80 degrees to the left. A metronome is used to ensure the speed of rotation is maintained at 50 beats/min (one beat in each direction). One repetition is complete when the trunk rotates back and forth to the starting position, and 5 repetitions are performed. Record: Headache, Dizziness, Nausea & Fogginess ratings after the test. (Figure 7)
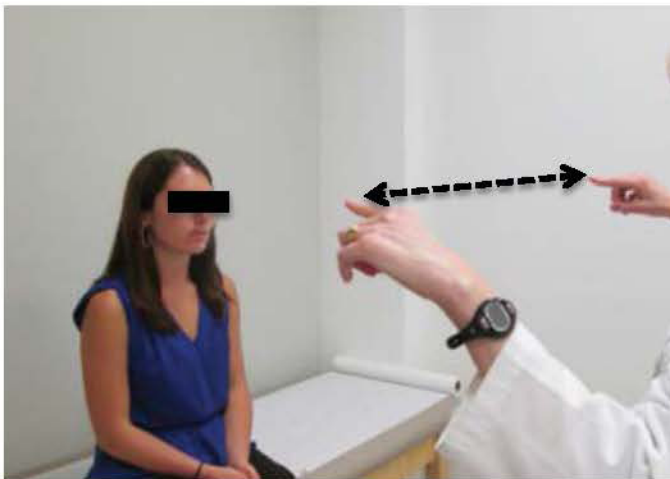
Figure 1. Smooth pursuits.
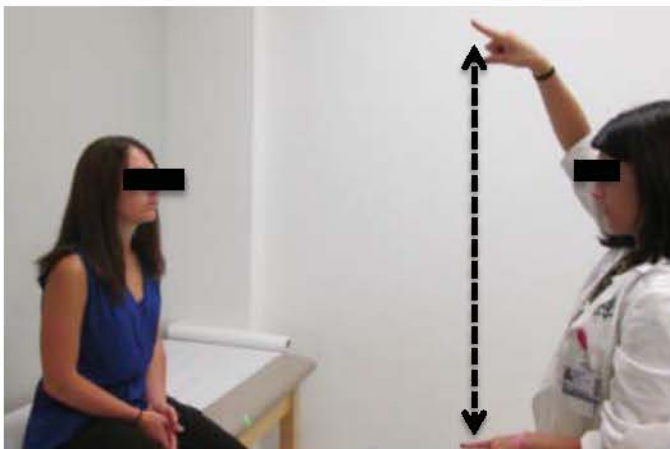

Figure 2. Horizontal saccades.

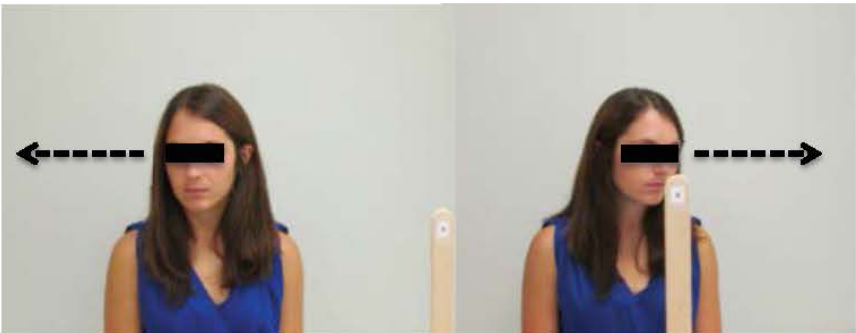**Figure 3. Vertical saccades.**

Figure 4. Convergence

Figure 5. Horizontal VOR.

Figure 6. Vertical VOR.

Figure 7. VMS.

Appendix 3:
Differential Diagnosis Concussion Assessment Checklist

Concussion is a functional brain injury with complex and heterogeneous symptom presentation. Physiotherapy is indicated and can be effective in concussion management where the symptoms of dizziness, neck pain, headache and impaired balance have cervical spine and/or vestibular involvement. Treatment is based on the physiotherapy differential diagnosis made through patient history and clinical assessment of presenting signs and symptoms.

Red/Yellow Flags

The following signs and symptoms may be indicators of serious pathology, such as cervical spine fracture, subdural hematoma, cerebral bleed or brainstem ischemia. Refer the patient for immediate medical evaluation if there is evidence of the following:

- Diplopia, dysarthria, dysphagia, quadrilateral paresthesia/numbness
- Significant mid-line cervical spine tenderness
- Fainting or loss of consciousness
- Progressively worsening headache
- Confusion
- Repeated vomiting

 * Adapted from Centres for Disease Control and Prevention four domains of concussion.

Symptom	Potential cause/PT differential diagnosis	Assessment tools/screens to consider if indicated	Conclusion/PT differential diagnosis	Treat/Monitor	Consult	Refer

Dizziness	• Blood pressure
	• Vestibular
	• Cervical Artery Dysfunction, including Vertebrobasilar Insufficiency
	• Cervicogenic
	• Migraine
	• Medications
		• History
		• Blood pressure
		• Neuro scan
		  · Cranial nerves
		  · Vestibular/Ocular Motor Screening (VOMS)
		• Modified vertebral Artery Test (mVAT)
		• Dix-Hallpike
		• C-spine, including
		  · C0-C4
		  · Joint position error test (JPET)
		• Head thrust test (if indicated)				

Headache	• Cervicogenic • Tension-type • Cluster • Migraine • Vestibular (if patient also c/o dizziness) • Medications, including overuse • Other (illness, sinus)	• History • Headache Impact Test (HIT – 6) • C-spine –articular C0-C4, myofascial, nerve root) • Vestibular • VOMS				
Balance	• Vestibular, including Oculomotor S & S • Cervicogenic • Medications • Central	• History • Posture, Gait · Standing and dynamic testing • Sport Concussion Assessment Tool (SCAT 3)* • C-spine • Neuro scan • JPET				
Neck Pain	• Whiplash • C-spine instability, undiagnosed fracture • Chronic (DDD, OA) • Posture	• History • Observation • Posture • Palpation • C-spine biomechanical examination • Neuromotor control				
Fatigue	• Sleep disturbance • Medications • Blood Pressure • Incomplete recovery – early RTP/RTW (physical/cognitive) • Other medical dx (e.g., diabetes, COPD)	• History • Blood Pressure				
Mood disorder (e.g., anxiety, depression, irritability, sadness)		• History • SCAT3 • Screens: DASS-21, PHQ –9, HADS**	N/A	N/A	N/A	
Cognitive Symptoms (e.g., feeling slowed down, difficulty thinking/remembering, feeling "foggy")		• History • SCAT3	N/A	N/A	N/A	
Sensitivity to light and/or noise	• Oculomotor • Migraine	• History (including migraine history – see IHS classification) • Cranial nerves				
Nausea	• Cervicogenic • Vestibular • BPPV (correlate with dizziness) • Migraine • Medication • Central	• History • C-spine • Cranial nerves • VOMS				
Visual Disturbance	• Cervicogenic • Vestibular, including Oculomotor • Central	• History • Cervical spine • Cranial nerves • VOMS				

* SCAT 3 has not been validated for non-sport concussion and sensitivity decreases over time. It is not intended as stand-alone tool; use in conjunction with other assessment tools and clinical judgment.

** Depression Anxiety and Stress Scale (DASS-21), the Patient Health Questionnaire (PHQ-9) and the Hospital Anxiety and Stress Scale (HADS).

Appendix 4:
Online Resources and Additional Reading

Online Resources Concussion Management

Awareness, Education, Management

- Parachute Canada: Active and Safe Concussion Toolkit. Parachute also released an app, Concussion Ed that is available for download on a number of platforms.
- The British Columbia Injury Research and Prevention Unit: Concussion Awareness Training Tool.
- The Centres for Disease Control and Injury Prevention: Heads Up

Pediatric Concussion Management

- Ontario Neurotrauma Foundation: Guidelines for Diagnosing and Managing Pediatric Concussion (2014)

Cervical Spine Assessment

- Physiopedia: Cervical Scan
- The International Federation of Manipulative Therapists Cervical Framework Document

Vestibular Disorders

- Vestibular Disorders Association

Managing Chronic Pain

- painHEALTH
- Pacing and goal setting from painHEALTH

Additional Reading

Concussion Management

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