“Finding a way through the Fog”
The Science of Concussion in Sport.

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PhD, MSc. PGDipManipTh, PGCertTerTch, DipPhty

School of Human Health and Social Sciences
Central Queensland University
### Concussion Symptoms

**How do you feel?**

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

<table>
<thead>
<tr>
<th>Symptom</th>
<th>none</th>
<th>mild</th>
<th>moderate</th>
<th>severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headache</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>&quot;Pressure in head&quot;</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Neck Pain</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Nausea or vomiting</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Dizziness</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Blurred vision</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Balance problems</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Sensitivity to light</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Sensitivity to noise</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Feeling slowed down</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Feeling like “in a fog”</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>“Don’t feel right”</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Difficulty concentrating</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Difficulty remembering</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Fatigue or low energy</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Confusion</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Drowsiness</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Trouble falling asleep</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>More emotional</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Irritability</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Sadness</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Nervous or Anxious</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>
Overview

• What is concussion?
• Why is it a problem?
• What are the potential consequences?
• How do we assess sports concussion?
• How can Sport Science inform assessment?
• How do we return athletes to sport?
• What if they don’t get better quickly?
• How do we deal with that?
Concussion: “The Silent Epidemic”

• Sports Related Concussion (SRC) is a common consequence of sport and recreation participation

• Concussions often go unrecognised

• Unconsciousness is not a requirement for the diagnosis of concussion

• Players under-report concussions - culture or deception?

• Continuing to play/participate while recovering, places the athlete at increased risk
Continuum of head injury (TBI)

Sport-Related Traumatic Brain Injury

Functional

concussion

Mild traumatic brain injury (mTBI)

Severe traumatic brain injury

Structural
Concussion is a functional injury

**Neurometabolic cascade**

- ↑ glutamate (cell toxicity)
- ↑ K+ ↑ Ca++ pump
- ↑ demand for glucose
- ↑ Hyperglycolysis
- ↑ lactate accumulation
- ↓ ATP production

Decrease in cerebral blood flow (CBF) = “Brain energy crisis”

K+, potassium; CMRglucose, cerebral metabolic rate of glucose utilization; Ca2+, calcium; CBF, cerebral blood flow. (Hovda et al., 1995)
Continuum of head injury (TBI)

Sport-Related Traumatic Brain Injury

Functional

Mild traumatic brain injury

concussion

Severe traumatic brain injury

Structural
Barack Obama

"I’m a big football fan, but I have to tell you if I had a son, I’d have to think long and hard before I let him play football."
Arachnoid Cyst?

- “Benign” congenital cyst
- More susceptible to subdural haemorrhage
- Affects 1-2% of population (3-6M in USA)
- 2:1/4:1 males:females
- Identifiable on MRI/CT
- Bridging veins torsioned/tear

- Should we screen athletes?
- Should they be allowed to play??
Signs of Subdural haemorrhage

- A history of recent head injury
- Loss of consciousness or fluctuating levels of consciousness
- Irritability, Seizures, Pain, Numbness
- Headache (either constant or fluctuating)
- Dizziness, Disorientation, Amnesia, Weakness or lethargy
- Nausea or vomiting, Loss of appetite
- Personality changes, Inability to speak or slurred speech
- Ataxia, or difficulty walking
- Altered breathing patterns
- Hearing loss or hearing ringing (tinnitus)
- Blurred Vision
- Deviated gaze, or abnormal movement of the eyes
Signs of Concussion......except...

- A history of recent head injury
- Loss of consciousness or **fluctuating levels of consciousness**
- Irritability, Seizures, Pain, Numbness
- Headache (either constant or fluctuating)
- Dizziness, Disorientation, Amnesia, Weakness or lethargy
- Nausea or vomiting, Loss of appetite
- Personality changes, Inability to speak or slurred speech
- Ataxia, or difficulty walking
- **Altered breathing patterns**
- Hearing loss or hearing ringing (tinnitus)
- Blurred Vision
- Deviated gaze, or **abnormal movement of the eyes**
Long term effects of repeated concussions?
The Five “R’s” of Concussion

• **Recognise and Remove** – Any player suspected or recognised with concussion **must** be removed from training and playing and **not** return to Rugby or other sport or physical activity on the same day.

• **Refer** – Any player suspected or recognised with concussion **must** see a medical doctor as soon as possible.

• **Rest** – Players diagnosed with concussion **must** rest completely until all signs and symptoms of concussion have disappeared.

• **Recover** – The concussed player **must** first recover from all signs and symptoms of concussion at rest and return to activities of normal daily living **before starting exercise**.

• **Return** – Players return to contact training and games following the ‘Graduated Return to Play’ protocol.
Identification of SRC

“There has previously been a multitude of assessment tools used for SRC”

- Standardized Assessment of Concussion (SAC)
- Balance Error Scoring System (BESS)
- Sideline evaluation of concussion
- AAN & BIA management of concussion
- Sideline concussion check UPMC, SMNZ, ACC, BIA
- McGill abbreviated concussion evaluation (ACE)
- NHL Physician evaluation form
- The UK Jockey Club assessment of concussion
- Canadian Academy of Sports Medicine guidelines
- Maddocks questions
- etc........................
Identification of SRC

“Need for a universally, clinically acceptable assessment tool”
• Revised definition of SRC
• CISG recognized limitations in current systems grading concussion and subsequent RTP
• Duration or clinical severity could not be reliably predicted from initial presentation
• Athletes diagnosed with a concussion should not RTP that day
Prague Consensus

Summary and agreement statement of the 2nd International Conference on Concussion in Sport, Prague 2004

P McCrory, K Johnston, W Meeuwisse, M Aubry, R Cantu, J Dvorak, T Graf-Baumann, J Kelly, M Lovell and P Schamasch

doi:10.1136/bjsm.2005.018614
Sports Concussion Assessment Tool

The SCAT Card
(Sport Concussion Assessment Tool)

Athlete Information

What is a concussion? A concussion is a disturbance in the function of the brain caused by a direct or indirect force to the head. It results in a variety of symptoms (like those listed below) and may, or may not, involve memory problems or loss of consciousness.

How do you feel? You should score yourself on the following symptoms, based on how you feel now.

<table>
<thead>
<tr>
<th>Symptom</th>
<th>None</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headache</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
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<td>2</td>
</tr>
<tr>
<td>Nausea or vomiting</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Vision problems</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Hearing problems / ringing</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>&quot;Don't feel right&quot;</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Feeling &quot;dazed&quot; or &quot;dazed&quot;</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Confusion</td>
<td>0</td>
<td>1</td>
<td>2</td>
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<td>0</td>
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<td>2</td>
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<tr>
<td>Feeling like &quot;in a fog&quot;</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Drowsiness</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Fatigue or low energy</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>More emotional than usual</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Irritability</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Difficulty concentrating</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Difficulty remembering</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

(follow up symptoms only)

<table>
<thead>
<tr>
<th>Symptom</th>
<th>None</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sadness</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Nervous or anxious</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Trouble falling asleep</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Sleeping more than usual</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Sensitivity to light</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Sensitivity to noise</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

What should I do?
Any athlete suspected of having a concussion should be removed from play, and then seek medical assessment.

Signs to watch for:
Problems could arise over the first 24-48 hours. You should not be left alone and must go to a hospital at once if you:
- Have a headache that gets worse
- Are very drowsy or can’t be awakened (woken up) easily
- 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 unstable on your feet; have slurred speech

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

What can I expect?
Concussion typically results in the rapid onset of short-lived impairment that resolves spontaneously over time. You can expect that you will be told to rest until you are fully recovered (that means resting your body and your mind). Then, your doctor will likely advise that you go through a gradual increase in exercise over several days (or longer) before returning to sport.

Medical Evaluation

Name: __________________________ Date: __________
Sport/Team: ____________________ Mouth guard? Y N

1) SIGNS
Was there loss of consciousness or unresponsiveness? Y N
Was there seizure or convulsive activity? Y N
Was there a balance problem / unsteadiness? Y N

2) MEMORY
Modified Maddocks questions (check correct)

At what venue are we? __________ Which half is it? __________ Who scored last? __________
What team did we play last? __________ Did we win last game? __________

3) SYMPTOM SCORE
Total number of positive symptoms (from reverse side of the card) = __________

4) COGNITIVE ASSESSMENT
5 word recall (Examples) Immediate Delayed (after concentration task)

Word 1 | cat | _ | _
Word 2 | _ | _ | _
Word 3 | _ | shoe | _
Word 4 | _ | _ | book
Word 5 | _ | _ | car

(moments in reverse order:
Jun-May-Apr-Mar-Feb-Jan-Dec-Nov-Oct-Sep-Aug-Jul (cycle incorrect)

or
Digits backwards (check correct)
3-2-1-3-4-5-6-5-4-3-2-1-

5 word recall now

Ask delayed 5-word recall now

5) NEUROLOGIC SCREENING
Pass | Fail
Speech | _ | _
Eye Motion and Pupils | _ | _
Pronator Drift | _ | _
Gait Assessment | _ | _

Any neurologic screening abnormality necessitates formal neurologic or hospital assessment

6) RETURN TO PLAY
Athletes may return to play the same day of injury.
When returning athletes to play, they should follow a stepwise symptom-limited program, with stages of progression. For example:
1. Return until asymptomatic (physical and mental rest)
2. Light aerobic exercise (e.g. stationary cycle) or
3. Sport-specific exercise
4. Non-contact training drills (start light resistance training)
5. Full contact training after medical clearance
6. Return to competition (game play)

There should be approximately 24 hours (or longer) for each stage and the athlete should not return to stage 1 if symptoms recur.
Resistance training should only be added in the later stages. Medical clearance should be given before return to play.
## 5. Neurological screening

<table>
<thead>
<tr>
<th></th>
<th>Pass</th>
<th>Fail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speech</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Eye motion and pupils</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Pronator drift</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Gait assessment</td>
<td>?</td>
<td></td>
</tr>
</tbody>
</table>
Motor Performance Tasks

Commonly reported physical signs of SRC include impaired coordination, unsteady gait, and poor balance

(Kelly & Rosenberg 1998; McCrory et al., 2004 )
Timed motor performance tasks

- Finger-to-Nose (FTN)
- Tandem Gait (TG)
- Single Leg Stance (SLS) on floor (EC)
Sports Concussion Assessment Tool 2

SCAT2: Sport Concussion Assessment Tool 2

Symptom Evaluation

How do you feel?
You should score yourself on the following symptoms, based on how you feel now.

- Headache
- Pressure in head
- Neck pain
- Sensation of dizziness
- Blurred vision
- Balance problems
- Sensitivity to light
- Sensitivity to noise
- Feeling dizzy/drifted
- Feeling like you’re on a ship
- Start feeling tired
- Start feeling weaker

Scores:

- 1: No symptoms
- 2: Slightly
- 3: Moderately
- 4: Severely
- 5: Unable to evaluate

- Total score: Maximum possible 20

Balance testing

The balance testing involves a modified version of the Star Excursion Battery test, which is performed for the scoring.

Tests:

- Finger-to-nose test
- Foot-to-floor test
- Knee-to-floor test
- Heel-to-knee test

Scores:

- 1: No error
- 2: Minimal error
- 3: Moderate error
- 4: Severe error
- 5: Unable to perform

- Total score: Maximum possible 40

Coordination examination

Upper limb coordination

- Finger-to-nose test
- Foot-to-floor test
- Knee-to-floor test
- Heel-to-knee test

Scores:

- 1: No error
- 2: Minimal error
- 3: Moderate error
- 4: Severe error
- 5: Unable to perform

- Total score: Maximum possible 40

Overall score

- Total score: Maximum possible 100

Recommendations

- Immediate medical attention
- Follow-up medical examination
- Contact your healthcare provider
- Follow-up with a physical therapist

2008
# Sports Concussion Assessment Tool 2

**SCAT2**

**Sport Concussion Assessment Tool 2**

### Name

### Sport

### Date/time of injury

### Date/time of assessment

### Age

<table>
<thead>
<tr>
<th></th>
<th>M</th>
<th>F</th>
<th>R</th>
</tr>
</thead>
</table>

### Years of education completed

### Experience

### What is the SCAT2?

This tool represents a standardized method of evaluating injured athletes for concussion and can be used in athletes aged from 10 years and older. It supersedes the original SCAT published in 2005. This tool also enables the calculation of the Standardized Assessment of Concussion (SAC) score and the standard deviation of the SCAT score.

The SCAT2 is designed for the use of medical and non-medical professionals. Preseason baseline testing with the SCAT2 can be helpful for interpreting post-injury test scores. Words in italics throughout the SCAT2 are the instructions given to the athlete by the tester.

This tool may be freely copied for distribution to individuals, teams, groups, and organizations.

### 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 symptoms (as listed below) and often does not involve loss of consciousness. Concussion should be suspected in the presence of any or more of the following:

- Physical signs (e.g., headache), or
- Impaired brain function (e.g., confusion) or
- Abnormal behavior.

Any athlete with a suspected concussion should be removed from play (RCPA) immediately assessed, reevaluated for deterioration (i.e., should not be left alone) and should not drive a motor vehicle.

### Symptom Evaluation

#### How do you feel?

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

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
</table>

#### Headache

- "Pain in head?"

#### Nausea or vomiting

#### Soreness or tenderness

#### Balance problems

#### Difficulty concentrating

#### Difficulty remembering

#### Inattention or hyperactivity

#### Drowsiness

#### Trouble falling asleep (impaired sleep)

#### Mood/emotional changes

#### Irritability

#### Nervous or Antisocial

#### Total/number of symptoms (Maximum possible 20)

#### Symptom severity score

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
</table>

#### Do the symptoms get worse with physical activity?

#### Do the symptoms get worse with mental activity?

#### Overall rating

- 0 - No change
- 1 - Very different
- 2 - Different
- 3 - Very similar
- 4 - Similar
- 5 - Very different

### Balance testing

**Balance testing**

The balance testing is based on a modified version of the Balance Error Scoring System (BESS)

**Balance testing:**

- "I am now going to test your balance. Please take your shoes off, remove all hats, remove any eyeglasses (if applicable). This test will consist of three varying conditions with different effects.

- **Wobble leg stance:**
  - The first stance is standing with your feet together with your hands on your hips and with your eyes closed. They should try to maintain balance for 10 seconds without any wobble, locking in the middle of the stance.

- **Triple leg stance:**
  - If you were to fall off a cliff which tool would you use? This will be the dominant foot.

- **Stance:**
  - Stand on your non-dominant foot with your eyes open, keeping your head horizontal. If your foot slips towards the side, count the number of times you lose your balance. If you fall, you should try to maintain balance for 10 seconds with your hands on your hips and your eyes closed. They should try to maintain balance for 10 seconds without any wobble, locking in the middle of the stance.

### Cognitive assessment

**Standardized Assessment of Concussion (SAC) manikin test**

#### Delays in recall

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

#### Overall score

- 0 - Normal
- 1 - Mild
- 2 - Moderate
- 3 - Severe

#### SAC total

- 0 - Normal
- 1 - Mild
- 2 - Moderate
- 3 - Severe

### Motor Skills

- 0 - Normal
- 1 - Mild
- 2 - Moderate
- 3 - Severe

### Score calculation

**Balance testing score:**

**Cognitive assessment score:**

**Overall score:**

**SAC total:**

**Motor Skills:**

**Definition:**

Data for a SAC test can be used only if the test is administered during a diagnostic evaluation. The test can be used to help determine if the athlete has recovered from a concussion. The test should be administered at least 24 hours after the injury and should be repeated at least 7 days after the injury. The test should be administered by a qualified professional.

**Situations:**

- If the athlete has a history of concussion, the test should be administered at least 24 hours after the injury.
- If the athlete has a history of concussion, the test should be administered at least 7 days after the injury.
- If the athlete has a history of concussion, the test should be administered at least 30 days after the injury.
- If the athlete has a history of concussion, the test should be administered at least 90 days after the injury.

**Administration:**

- The test should be administered at least 24 hours after the injury.
- The test should be administered at least 7 days after the injury.
- The test should be administered at least 30 days after the injury.
- The test should be administered at least 90 days after the injury.

**Data:**

Data for a SAC test can be used only if the test is administered during a diagnostic evaluation. The test can be used to help determine if the athlete has recovered from a concussion. The test should be administered at least 24 hours after the injury and should be repeated at least 7 days after the injury. The test should be administered by a qualified professional.

**Scoring:**

- The test scores should be used only if the test is administered during a diagnostic evaluation.
- The test scores should be used only if the test is administered at least 24 hours after the injury.
- The test scores should be used only if the test is administered at least 7 days after the injury.
- The test scores should be used only if the test is administered at least 30 days after the injury.
- The test scores should be used only if the test is administered at least 90 days after the injury.

**Conclusions:**

- If the athlete has a history of concussion, the test scores should be used only if the test is administered at least 24 hours after the injury.
- If the athlete has a history of concussion, the test scores should be used only if the test is administered at least 7 days after the injury.
- If the athlete has a history of concussion, the test scores should be used only if the test is administered at least 30 days after the injury.
- If the athlete has a history of concussion, the test scores should be used only if the test is administered at least 90 days after the injury.

**Interim conclusion:**

If the athlete has a history of concussion, the test scores should be used only if the test is administered at least 24 hours after the injury.

**Final conclusion:**

If the athlete has a history of concussion, the test scores should be used only if the test is administered at least 7 days after the injury.

**Recovery:**

If the athlete has a history of concussion, the test scores should be used only if the test is administered at least 30 days after the injury.

**Recovery:**

If the athlete has a history of concussion, the test scores should be used only if the test is administered at least 90 days after the injury.

**Recovery:**

If the athlete has a history of concussion, the test scores should be used only if the test is administered during a diagnostic evaluation.
Balance examination

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

Balance 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 total number of errors for any single condition is 10. If a 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.

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

<table>
<thead>
<tr>
<th>Condition</th>
<th>Total errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double Leg Stance (feet together)</td>
<td>of 10</td>
</tr>
<tr>
<td>Single leg stance (non-dominant foot)</td>
<td>of 10</td>
</tr>
<tr>
<td>Tandem stance (non-dominant foot at back)</td>
<td>of 10</td>
</tr>
</tbody>
</table>

Balance examination score (30 minus total errors) of 30
Timed motor performance tasks

- Finger-to-Nose (FTN)
- Tandem Gait (TG)
- Single Leg Stance (SLS) on floor (EC)
Validating Tandem Gait for the SCAT
### Diagnostic accuracy

<table>
<thead>
<tr>
<th>Test</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>PPV</th>
<th>NPV</th>
<th>Odds Ratio</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tandem gait</td>
<td>0.55</td>
<td>0.95</td>
<td>0.91</td>
<td>0.70</td>
<td>23.2</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Measure</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tandem gait</td>
<td>11.54</td>
<td>11.45</td>
<td>11.25</td>
<td>11.41 ± 2.30</td>
</tr>
</tbody>
</table>

### Effect of Exercise / Activity

<table>
<thead>
<tr>
<th>Time</th>
<th>Mean ± SD</th>
<th>Comparisons</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>T-1</td>
<td>13.61 ± 2.71</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T-2</td>
<td>13.08 ± 2.84</td>
<td>T-1 vs. T-2</td>
<td>0.0216</td>
</tr>
<tr>
<td>T-3</td>
<td>12.23 ± 2.22</td>
<td>T-2 vs. T-3</td>
<td>0.0009</td>
</tr>
<tr>
<td>T-4</td>
<td>12.09 ± 2.10</td>
<td>T-3 vs. T-4</td>
<td>0.6109</td>
</tr>
</tbody>
</table>

Schneiders et al., British Journal of Sports Medicine 2008; 42(12): 1011-1013
Schneiders et al., Scandinavian Journal of Medicine & Science in Sports, 2012
Thirty-six participants were recruited from each of three sporting environments/surface (total = 108) - Grass, Hardwood court, Artificial turf.

Three conditions were tested - Boots/shoes on surface, Barefoot on surface, Barefoot on firm surface/asphalt.

There was a significant main effect by condition ($F_{2,138} = 26.31, p = 0.001$) with all 3 groups faster with footwear than barefoot.

The results demonstrated that performance on the timed TG task varied significantly with the nature of the sporting group or surface and whether participants were barefoot or shod.

Footwear resulted in a faster performance than when the TG task was performed barefoot. Likewise, times varied between each sporting environment which might suggest that the sporting surface or the type of athletes played a role in TG performance.
Assessment of a concussive population

<table>
<thead>
<tr>
<th>Neurological tasks</th>
<th>Concussed players (n=18)</th>
<th>Normal controls (n=18)</th>
<th>T(DF), P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>FTN (s)</td>
<td>4.1 ± 1.3 2.3-6.9</td>
<td>3.1 ± 0.5 2.3-3.8</td>
<td>2.897(34), 0.007</td>
</tr>
<tr>
<td>TG (s)</td>
<td>14.7 ± 3.8 8.5-22.4</td>
<td>10.5 ± 1.9 8.4-14.2</td>
<td>4.140(34), 0.000</td>
</tr>
<tr>
<td>SLS (s)</td>
<td>12.3 ± 8.3 4.0-30.0</td>
<td>15.5 ± 11.2 1.9-30.0</td>
<td>-0.961(34), 0.343</td>
</tr>
</tbody>
</table>

Schneiders et al., TBS PTiS
Consensus statement on concussion in sport: the 4th International Conference on Concussion in Sport held in Zurich, November 2012

Paul McCrory,¹ Willem H Meeuwisse,²,³ Mark Aubry,⁴,⁵,⁶ Bob Cantu,⁷,⁸ Jiří Dvořák,⁹,¹⁰,¹¹ Ruben J Echemendia,¹²,¹³ Lars Engebretsen,¹⁴,¹⁵,¹⁶ Karen Johnston,¹⁷,¹⁸ Jeffrey S Kutcher,¹⁹ Martin Raftery,²⁰ Allen Sills,²¹ Brian W Benson,²²,²³,²⁴ Gavin A Davis,²⁵ Richard G Ellenbogen,²⁶,²⁷ Kevin Guskeiwicz,²⁸ Stanley A Herring,²⁹,³⁰ Grant L Iverson,³¹ Barry D Jordan,³²,³³,³⁴ James Kissick,³⁵,³⁶,³⁷ Michael McCrea,³⁸ Andrew S McIntosh,³⁹,⁴⁰,⁴¹ David Maddocks,⁴² Michael Makdissi,⁴³,⁴⁴ Laura Purcell,⁴⁵,⁴⁶ Margaret Putukian,⁴⁷,⁴⁸ Kathryn Schneider,⁴⁹ Charles H Tator,⁵⁰,⁵¹,⁵²,⁵³ Michael Turner⁵⁴
1. Glasgow coma scale (GCS)

   - Best eye opening
     - None
     - Eye opening to sound
     - Eye opening spontaneously
   - Best verbal response
     - None
     - Incomprehensible
     - Inappropriate words
     - Confused
     - Oriented
   - Best motor response
     - No motor response
     - Extension to pain
     - Abnormal flexion to pain
     - Localizes to pain
     - Obey commands
   - Glasgow coma score (E + V + M)
   - GCS should be recorded for all athletes in case of subsequent deterioration.

2. Maddocks Score

   - "Your symptoms are not a big deal, please listen carefully and give your best effort." Modified Maddocks questions (I point for each correct answer)
   - What sense are we at today?
     - Visual
     - Auditory
     - Tactile
   - Who is the last to win?
     - Who scored last in the match?
     - Who scored the last goal (team)?
   - Did you win the last game?
   - Maddocks score

   - Maddocks score in noted patients undergoing concussion may not be used for serial testing.

3. How do you feel?

   - You should score yourself on the following symptoms, based on how you feel today:

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headache</td>
<td>0-4</td>
</tr>
<tr>
<td>Pressure in head</td>
<td>0-2</td>
</tr>
<tr>
<td>Neck pain</td>
<td>0-2</td>
</tr>
<tr>
<td>Nausea/vomiting</td>
<td>0-2</td>
</tr>
<tr>
<td>Dizziness</td>
<td>0-2</td>
</tr>
<tr>
<td>Blurred vision</td>
<td>0-2</td>
</tr>
<tr>
<td>Balance problems</td>
<td>0-4</td>
</tr>
<tr>
<td>Sensitivity light</td>
<td>0-4</td>
</tr>
<tr>
<td>Sensitivity noise</td>
<td>0-4</td>
</tr>
<tr>
<td>Feeling slowed down</td>
<td>0-4</td>
</tr>
<tr>
<td>Feeling like &quot;a fog&quot;</td>
<td>0-4</td>
</tr>
<tr>
<td>&quot;Don't feel right&quot;</td>
<td>0-4</td>
</tr>
<tr>
<td>Difficulty concentrating</td>
<td>0-4</td>
</tr>
<tr>
<td>Difficulty remembering</td>
<td>0-4</td>
</tr>
<tr>
<td>Fatigue or low energy</td>
<td>0-4</td>
</tr>
<tr>
<td>Confusion</td>
<td>0-4</td>
</tr>
<tr>
<td>Drowsiness</td>
<td>0-4</td>
</tr>
<tr>
<td>Trouble sleeping</td>
<td>0-4</td>
</tr>
<tr>
<td>More emotional</td>
<td>0-4</td>
</tr>
<tr>
<td>Irritability</td>
<td>0-4</td>
</tr>
<tr>
<td>Sadness</td>
<td>0-4</td>
</tr>
<tr>
<td>Nervous or Anxious</td>
<td>0-4</td>
</tr>
</tbody>
</table>

   - Total number of symptoms (Maximum possible 20)

4. COGNITIVE & PHYSICAL EVALUATION

   - Cognitive assessment
     - Standardized Assessment of Concussion (SACC)
       - Orientation (0 point for each correct answer)
         - What month is it? 0-2
         - What is the date today? 0-2
         - What is the day of the week? 0-2
         - What time is it? 0-2
         - What time is it right now? (within 1 hour) 0-1

   - Immediate memory
     - Letter span 0-2
     - Word span 0-2
     - Rhyme span 0-2

   - Total Immediate memory score total

   - Concentration
     - Digits Backward
       - Left 0-2
       - Right 0-2

   - Balance examination
     - Tandem gait test

   - Coordination examination
     - Upper limb coordination

   - SAC Delayed Recall
     - Delayed recall score

5. Neck Examination:

   - Range of motion
   - Tenderness
   - Upper and lower limb sensations and strength findings:
Balance examination

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

Modified Balance Error Scoring System (BESS) testing
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
Time (best of 4 trials) seconds

Coordination examination

Upper limb coordination
Which arm was tested Left Right
Coordination score of 1
Pocket CONCUSSION RECOGNITION TOOL™
To help identify concussion in children, youth and adults

RECOGNIZE & REMOVE
Concussion should be suspected if one or more of the following visible clues, signs, symptoms or errors in memory questions are present.

1. Visible clues of suspected concussion
Any one or more of the following visual clues can indicate a possible concussion:
- Loss of consciousness or responsiveness
- Lying motionless on ground / Slow to get up
- Unsteadily on feet / Balance problems or falling over / Incoordination
- Dazed, blank or vacant look
- Confused / Not aware of plays or events

2. Signs and symptoms of suspected concussion
Presence of any one or more of the following signs & symptoms may suggest a concussion:
- Loss of consciousness
- Seizure or convulsion
- Balance problems
- Nausea or vomiting
- Drowsiness
- More emotional
- Irritability
- Sadness
- Fatigue or low energy
- Nervous or anxious
- “Don’t feel right”
- Difficulty remembering
- Headache
- Dizziness
- Confusion
- Feeling slowed down
- “Pressure in head”
- Blurred vision
- Sensitivity to light
- Amnesia
- Feeling like “in a fog”
- Neck pain
- Sensitivity to noise
- Difficulty concentrating

3. Memory function
Failure to answer any of these questions correctly may suggest a concussion.
- “What venue are we at today?”
- “Which half is it now?”
- “Who scored last in this game?”
- “What team did you play last week / game?”
- “Did your team win the last game?”

Any athlete with a suspected concussion should be IMMEDIATELY REMOVED FROM PLAY, and should not be returned to activity until they are assessed medically. Athletes with a suspected concussion should not be left alone and should not drive a motor vehicle.

It is recommended that, in all cases of suspected concussion, the player is referred to a medical professional for diagnosis and guidance as well as return to play decisions, even if the symptoms resolve.

RED FLAGS
If ANY of the following are reported then the player should be safely and immediately removed from the field. If no qualified medical professional is available, consider transporting by ambulance for urgent medical assessment:
- Athlete complains of neck pain
- Increasing confusion or irritability
- Repeated vomiting
- Seizure or convulsion
- Weakness or tingling / burning in arms or legs
- Deteriorating conscious state
- Severe or increasing headache
- Unusual behaviour change
- Double vision

Remember:
- In all cases, the basic principles of first aid (danger, response, airway, breathing, circulation) should be followed.
- Do not attempt to move the player (other than required for airway support) unless trained to do so.
- Do not remove helmet (if present) unless trained to do so.

The Five “R’s” of Concussion

• **Recognise and Remove** – Any player suspected or recognised with concussion **must** be removed from training and playing and **not** return to Rugby or other sport or physical activity on the same day.

• **Refer** – Any player suspected or recognised with concussion **must** see a medical doctor as soon as possible.

• **Rest** – Players diagnosed with concussion **must** rest completely until all signs and symptoms of concussion have disappeared.

• **Recover** – The concussed player **must** first recover from all signs and symptoms of concussion at rest and return to activities of normal daily living **before starting exercise**.

• **Return** – Players return to contact training and games following the ‘Graduated Return to Play’ protocol.
Each step takes 24hrs so that an athlete would take at minimum 6 days to proceed through the full protocol.

Return to play (RTP) protocol: SCAT³

<table>
<thead>
<tr>
<th>Rehabilitation stage</th>
<th>Functional exercise at each stage of rehabilitation</th>
<th>Objective of each stage</th>
</tr>
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<tr>
<td>1. No activity</td>
<td>Symptom limited physical and cognitive rest</td>
<td>Recovery</td>
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<tr>
<td>2. Light aerobic exercise</td>
<td>Walking, swimming or stationary cycling keeping intensity &lt;70% maximum permitted heart rate No resistance training</td>
<td>Increase HR</td>
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<td>3. Sport-specific exercise</td>
<td>Skating drills in ice hockey, running drills in soccer. No head impact activities</td>
<td>Add movement</td>
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<td>Progression to more complex training drills, eg, passing drills in football and ice hockey May start progressive resistance training</td>
<td>Exercise, coordination and cognitive load</td>
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<tr>
<td>5. Full-contact practice</td>
<td>Following medical clearance participate in normal training activities</td>
<td>Restore confidence and assess functional skills by coaching staff</td>
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<td>6. Return to play</td>
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</table>
Neurometabolic cascade following concussion

$K^+$, potassium; $\text{CMR}_{\text{glucose}}$, cerebral metabolic rate of glucose utilization; $\text{Ca}^{2+}$, calcium; CBF, cerebral blood flow. With permission (Hovda et al., 1995)
RTP is based on symptomology

<table>
<thead>
<tr>
<th></th>
<th>none</th>
<th>mild</th>
<th>moderate</th>
<th>severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headache</td>
<td>0</td>
<td>X</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>“Pressure in head”</td>
<td>0</td>
<td>1</td>
<td>X</td>
<td>2</td>
</tr>
<tr>
<td>Neck Pain</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Nausea or vomiting</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Dizziness</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Blurred vision</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Balance problems</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Sensitivity to light</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Sensitivity to noise</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Feeling slowed down</td>
<td>0</td>
<td>X</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Feeling like “in a fog”</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>“Don’t feel right”</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Difficulty concentrating</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Trouble falling asleep</td>
<td>0</td>
<td>1</td>
<td>X</td>
<td>2</td>
</tr>
<tr>
<td>More emotional</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Irritability</td>
<td>0</td>
<td>1</td>
<td>X</td>
<td>2</td>
</tr>
<tr>
<td>Sadness</td>
<td>0</td>
<td>X</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Nervous or Anxious</td>
<td>0</td>
<td>1</td>
<td>X</td>
<td>2</td>
</tr>
</tbody>
</table>
Lifestyle factors affect symptom scores

- Studies in University/College students
  - Significant interaction between trouble sleeping and alcohol consumption.
  - Diurnal variation, physical and mental fatigue from studying (stress-anxiety) etc.

Post Concussion Syndrome & RTP

• The majority of athletes who sustain a concussion will reach full neurological recovery within 1–2 weeks,
• However approx. 10–20% will demonstrate persistent signs and symptoms lasting greater than 3 weeks
• The cornerstone of management, physical and cognitive rest, is often not effective in resolving these symptoms
Post Concussion Syndrome & RTP

The management of athletes with sub-acute concussion and Post-Concussion syndrome remains controversial and poorly established

Forward
Brain Injury special edition on Sports concussion
Post Concussion Disorder (PCD)

Characterized by persistent pathophysiological alterations in specific neurological sub-systems or global brain metabolism

(Ellis et al, 2015)

- Physiologic (global)
- Vestibulo-ocular (sub-system)
- Cervicogenic (sub-system)

While overlap between PCDs may exist the presence of each PCD has implications for patient prognosis and RTP decision-making
Physiologic PCD

- Characterized by persistent concussion symptoms and impairments caused by continued alterations in global cerebral metabolism.
  - Cell membrane permeability,
  - Ion transport regulation,
  - Neurotransmitter release
  - Cellular metabolism
  - Cerebral blood flow

- Athletes may report mild persistent symptoms (similar to initial assessment) or be asymptomatic at rest but continue to have exacerbation of symptoms during cognitive activity and/or physical exercise

- The role of autonomic nervous system (ANS) regulation in concussion recovery is not clear but may be involved and mediated by effects on cerebrovascular reactivity.
Management of Physiologic PCD

- Exercise is emerging as strategy to promote ANS and concussion recovery
  - Increase parasympathetic nervous system activity
  - Decrease sympathetic nervous system activity
  - Increase Cerebral Blood Flow (CBF)
- Animal models suggest aerobic exercise 14-21 days post injury is most beneficial
- Sub-symptom threshold exercise training may hasten recovery and improve functional outcomes in adolescents and adults with concussion
- 80% HRmax of threshold, once daily, 5-6 days/week
  - the rate of symptom improvement was highly correlated with the exercise intensity achieved

(Leddy et al., 2010)
Vestibulo-ocular PCD

• Characterized by persistent concussion symptoms and impairments caused by dysfunction of the vestibulo-ocular system.
  o vestibular, oculomotor and somatosensory systems
• Vestibulo-ocular reflex (VOR)
  o regulates gaze stabilization during head acceleration
• Vestibulo-spinal reflex (VSR)
  o co-ordinates head, neck and trunk positioning during dynamic body movements
• Symptoms of dizziness, gait instability, fogginess, blurred vision and difficulty focusing are common
• Vertigo and dizziness can be due to post-traumatic benign paroxysmal positional vertigo (BPPV)
Cervicogenic PCD

- Cervicogenic PCD is characterized by persistent concussion symptoms and impairments caused by dysfunction of the cervical spine somatosensory system.
- Athletes often describe impact mechanisms that involve rapid acceleration–deceleration forces to the head and cervical spine.
- Athletes complain of neck pain, stiffness, fatigue, dizziness, headaches and postural instability.
- On examination the cervical spine is implicated by hypomobile intervertebral segments, muscle spasm and tenderness of paraspinal structures.
Cervicogenic Management

• Cervical spine mobilisation
• Strengthening/stabilization
• Proprioceptive exercises
• Stretching soft-tissue
• Postural alignment/awareness/control
• Cervical retraction
• Gaze stabilisation
Summary

• Sports-related concussion (SRC) is currently an inevitable consequence of sport and physical activity participation
• SRC may (or may not) be associated with more severe head-injury or long term consequences
• It is vital that SRC (and severe head injury) is able to be quickly identified and appropriately managed
• The Global SCAT and CRT are evolving as a valuable tool that provides a best-practice approach to the evaluation of SRC
• Recognition of post-concussion syndrome and its management in athletes can be valuable