Scientific Advances in Sport-Related Concussion:

Taking the Guess Work Out of Clinical Management

Michael McCrea, PhD, ABPP
Professor and Director of Brain Injury Research
Departments of Neurosurgery and Neurology

New Frontiers in the Assessment and Management of Sport-Related Concussion
Medical College of Wisconsin
July 30, 2013

Froedtert & Medical College of Wisconsin

Children's Hospital of Wisconsin

SRC: What's All The Fuss About?

- Up to 3.8 million concussions due to sport and recreation per year
- Among most frequent injuries in contact and collision sports
- More than just "bell rung"
- Serious acute effects that effect function
- Urgency to "get back out there"
- Concern about lasting effects
- **Not just in the Pros…**

Not Just on Sundays…

Never Underestimate the Stupidity of Adults!

Sport Concussion: *Clinical Challenges*

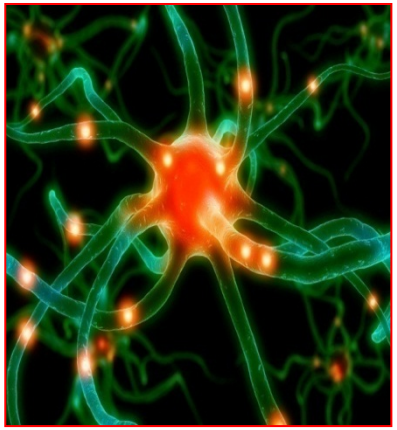
UNKNOWN	CLINICAL APPLICATION
Injury Biomechanics	How much is enough to cause concussion?
Diagnosis & Assessment	What are the most effective methods to diagnose and evaluate athletes with SRC?
Recovery Time	How long does it typically take to recover after SRC?
Injury Management	When is it safe for an athlete to return to play?
Long-term Effects	Are there potential long-term risks associated with repetitive concussion?

What Does the Science Tell Us?

Scientific Advances in SRC:

Acute Effects & Recovery

DEFINITION | **MECHANISM** | **TRUE NATURAL HISTORY**



Pathophysiology:
What *is* a concussion?
What are the signs & symptoms?

Minimum Threshold:
How much is enough to cause brain injury?

Acute Effects and Recovery Time Following Concussion in Collegiate Football Players
The NCAA Concussion Study

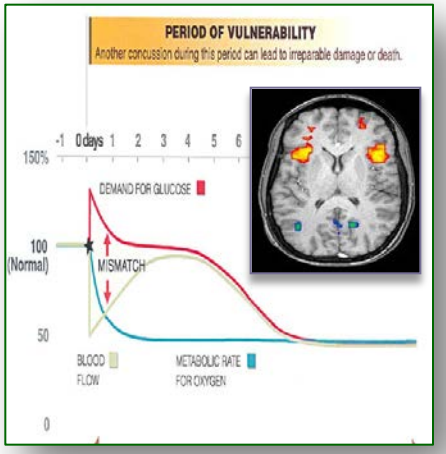
Michael McCrea, PhD
Kevin M. Guskiewicz, PhD, ATC
Stephen W. Marshall, PhD
William Barr, PhD
Christopher Randolph, PhD
Robert C. Cantu, MD
James A. Onate, PhD, ATC
Jingzhen Yang, MPH
James P. Kelly, MD

Context Lack of empirical data on recovery time following sport-related concussion hampers clinical decision making about return to play after injury.

Objective To prospectively measure immediate effects and natural recovery course relating to symptoms, cognitive functioning, and postural stability following sport-related concussion.

Design, Setting, and Participants Prospective cohort study of 1631 football players from 15 US colleges. All players underwent preseason baseline testing on concussion assessment measures in 1999, 2000, and 2001. Ninety-four players with concussion (based on American Academy of Neurology criteria) and 56 noninjured controls underwent assessment of symptoms, cognitive functioning, and postural stability immediately, 3 hours, and 1, 2, 3, 5, 7, and 90 days after injury.

Clinical Recovery:
How long does it take for sign & symptoms to recover?



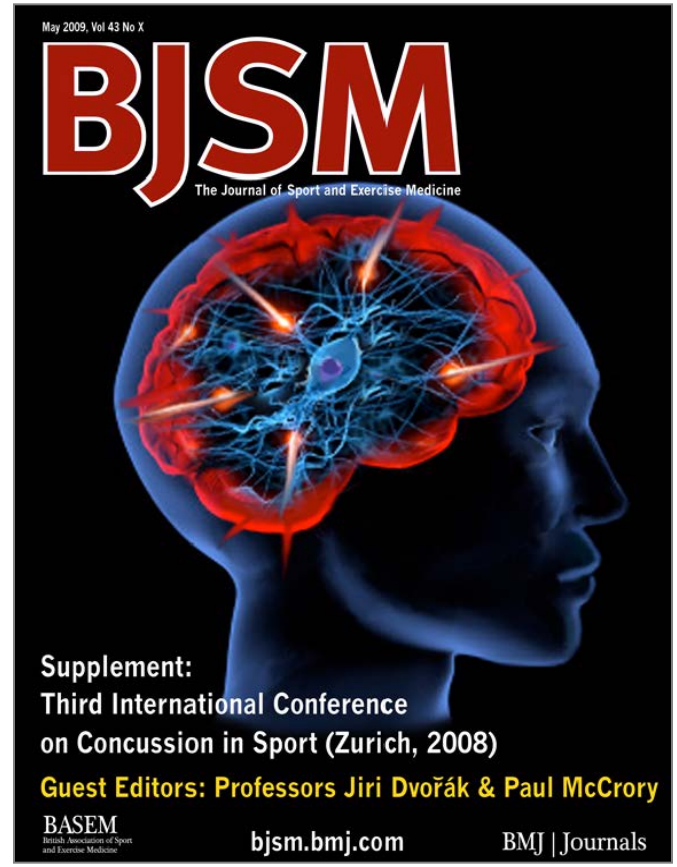
Window of Vulnerability:
How long does the *brain* take to recover?

Driving Evidence Based Diagnosis, Assessment and Management

What *is* a Concussion?

After blow to head, disruption of normal brain cellular activity ("***Neurometabolic Cascade***") commonly causes rapid onset of neurologic dysfunction:

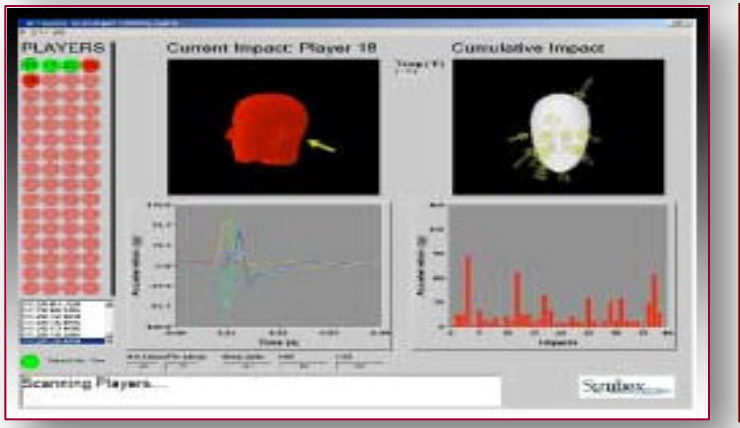
- Clinical Symptoms: headache, dizziness, dazed/confused, poor concentration, feeling in a fog, nausea, etc.
- Physical Signs/Acute Injury Characteristics: LOC, PTA
- Neurobehavioral Changes: irritability, mood changes, etc.
- Cognitive Impairment: memory, attention, reaction time, processing speed
- Sleep Disturbance: drowsiness, insomnia, hypersomnia

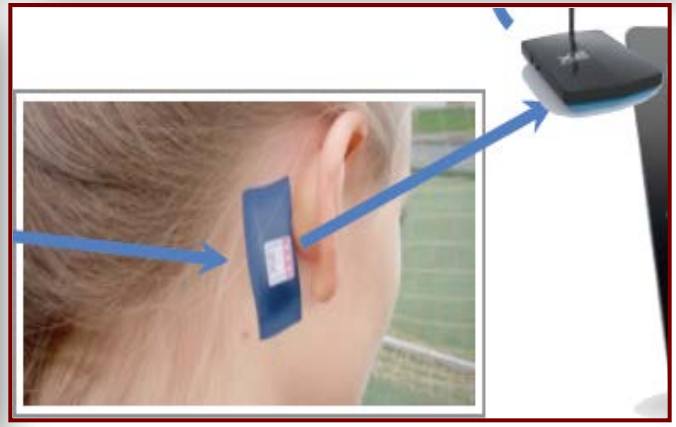


Only about 10% of athletes are "knocked out"

How Much is Enough to Cause Brain Injury?

Correlating Head Impact Exposure with Clinical Effects & Outcome





MORE THAN A "DING"

- Controlling for rotational acceleration, location of impact on the head
  - Concussion 17x more likely if linear acceleration ≥100g
  - 15x more likely if rotation > 5000m/sec2

Is it About "How Many" or "How Much"?

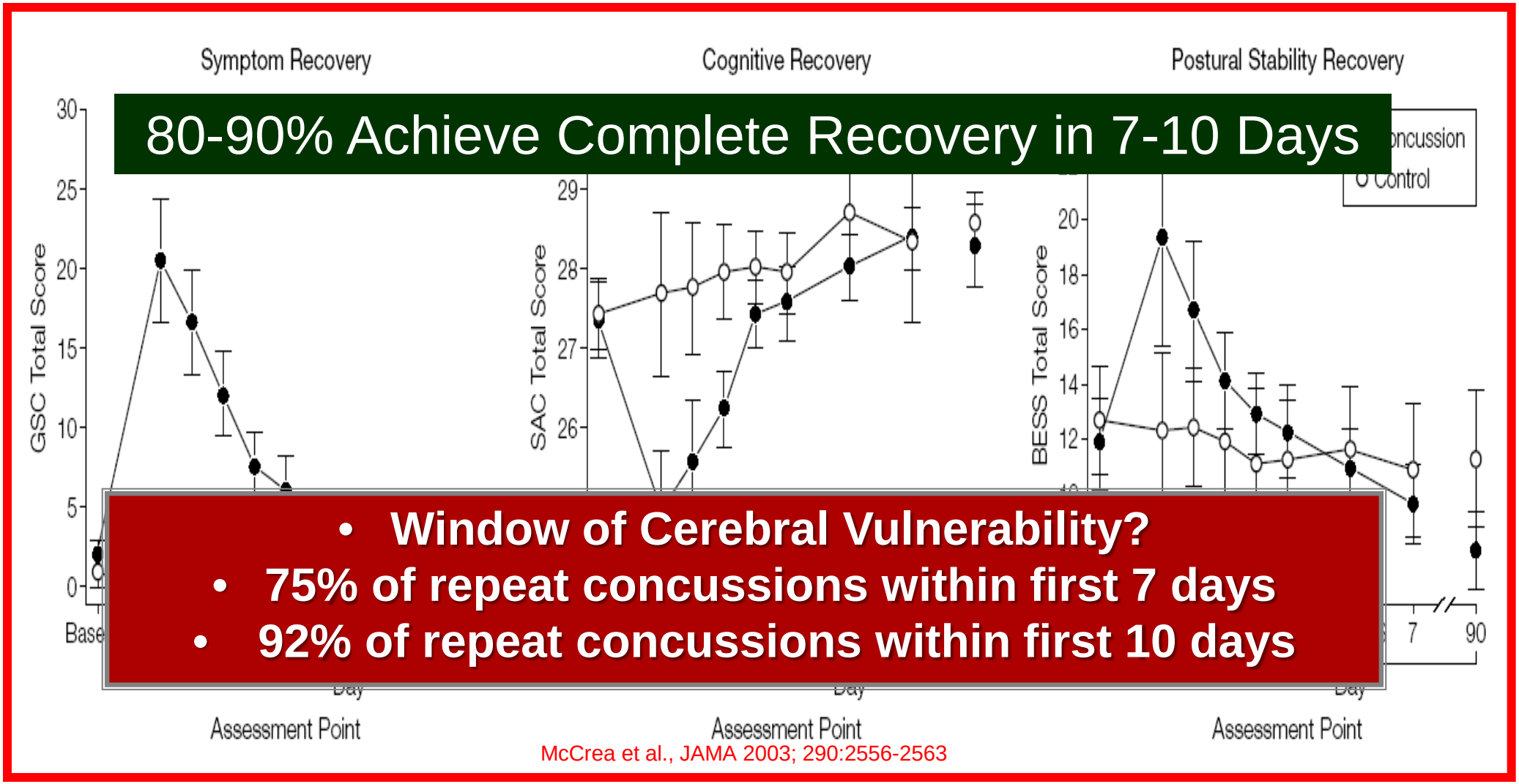
HS/College FB Players: ~ 950 impacts/season (average 25g) without clinically injury

How Long Does it Take to Recover?

Rate of Postinjury Recovery in HS and College Athletes	Total (%)	Cumulative Total (%)
Rapid (< 1 day)	21.1	21.1
Gradual (> 1 day, < 7 days)	64.3	85.4
Prolonged (1 week – 1 month)	11.9	97.3
Persistent (> 1 month)	2.7	100.0

Pellman et al., (2004): PPCS 1.6% of pro football players

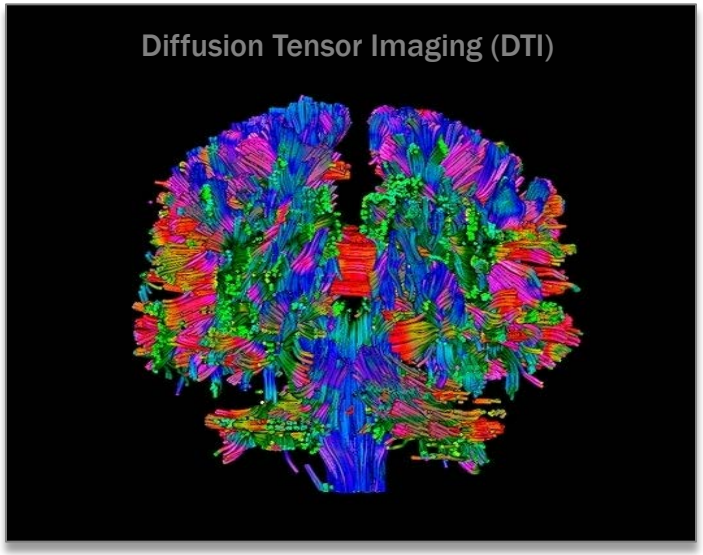
Recovery and Risk Related

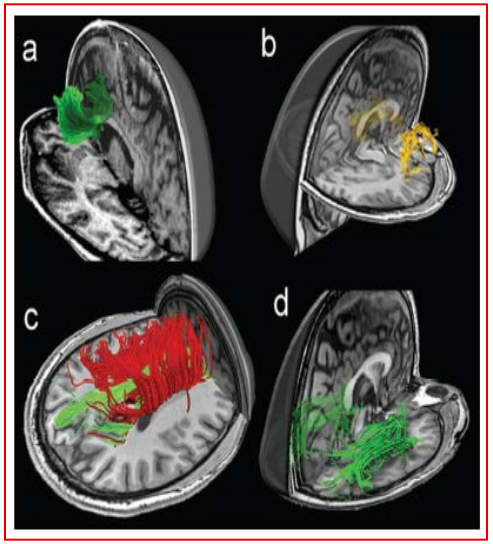


McCrea et al., JAMA 2003; 290:2556-2563

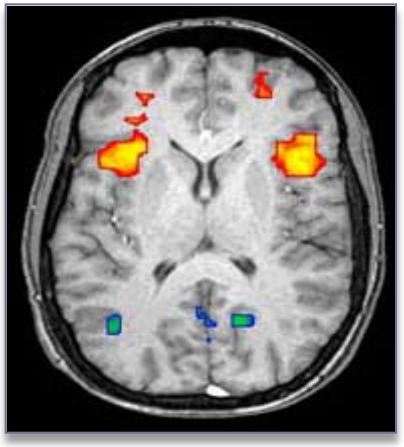
RTP: How Long is Long Enough?

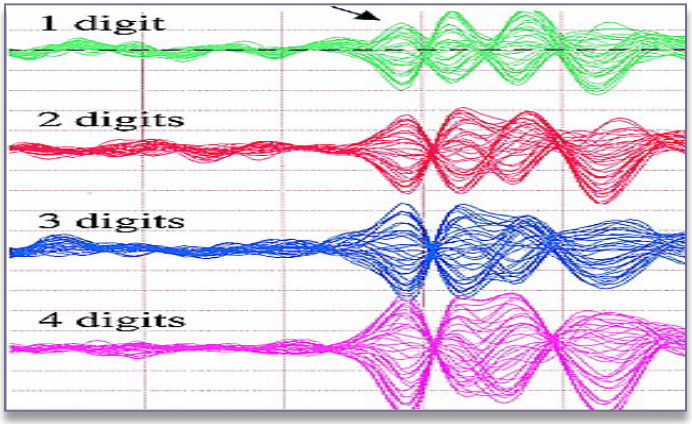
Window of Vulnerability:
When is the Brain Recovered?



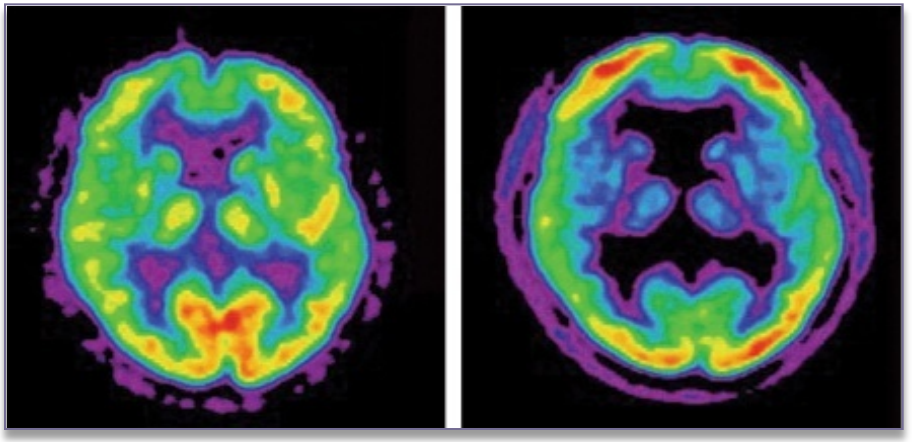


MRI (3-T) / Functional MRI

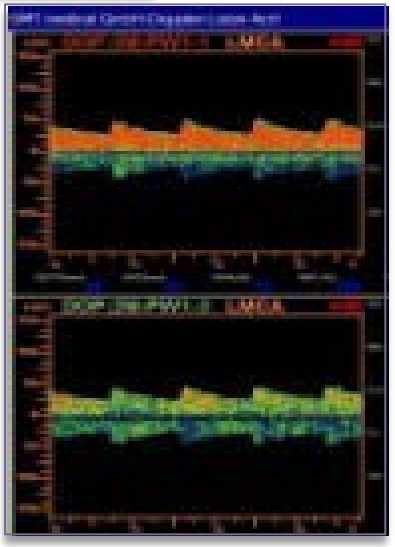




Magneto Encephalography (MEG) Scanner

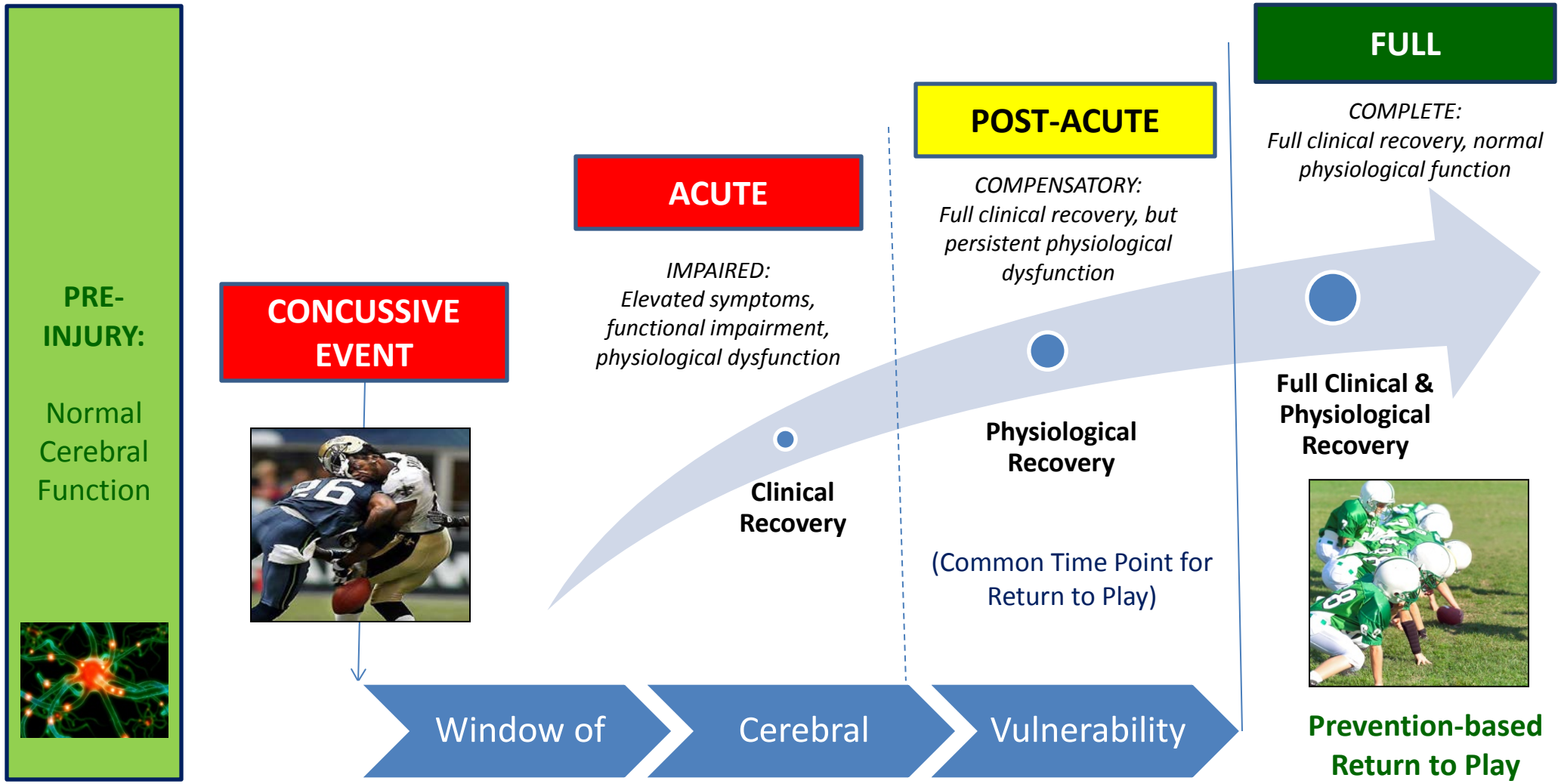


Positron Emission Tomography with Computed Tomography (PET/CT)



Trans-Cranial Doppler Ultrasound

Integrated Recovery Model



Science Driving Injury Management & Prevention

Toward International Consensus

Evidence-based Injury Assessment, Management and Return to Play:

CONSENSUS STATEMENT

Consensus Statement on Concussion in Sport—the 4th International Conference on Concussion in Sport Held in Zurich, November 2012

Paul McCrory, MBBS, PhD, Willem Meeuwisse, MD, PhD, Mark Aubry, MD, Bob Cantu, MD, Jiri Dvorak, MD, Ruben J. Echemendia, PhD, Lars Engebretsen, MD, PhD, Karen Johnston, MD, PhD, Jeffrey S. Kutcher, MD, Martin Raftery, MBBS, Allen Sills, MD, and Coauthors: Brian W. Benson, MD, PhD, Gavin A. Davis, MBBS, Richard G. Ellenbogen, MD, Kevin M. Guskiewicz, PhD, ATC, Stanley A. Herring, MD, Grant Iverson, PhD, Barry D. Jordan, MD, MPH, James Kissick MD, CCFP, Dip Sport Med, Michael McCrea, PhD, ABPP, Andrew S McIntosh, MBiomedE, PhD, David L. Maddocks, LLB, PhD, Michael Makdissi, MBBS, PhD, Laura Purcell, MD, FRCPC, Margot Putukian, MD, Michael Turner MBBS, Kathryn Schneider, PT, PhD, Charles H. Tator, MD, PHD

Published Ahead of Print on March 18, 2013 as 10.1212/WNL.0b013e31828d57dd

SPECIAL ARTICLE

AMERICAN ACADEMY OF NEUROLOGY

Summary of evidence-based guideline update: Evaluation and management of concussion in sports

Report of the Guideline Development Subcommittee of the American Academy of Neurology

Christopher C. Giza, MD*
Jeffrey S. Kutcher, MD*
Stephen Ashwal, MD, FAAN
Jeffrey Barth, PhD
Thomas S.D. Getchius
Gerard A. Gioia, PhD
Gary S. Gronseth, MD, FAAN
Kevin Guskiewicz, PhD, ATC
Steven Mandel, MD, FAAN
Geoffrey Manley, MD, PhD
Douglas B. McKeag, MD, MS
David J. Thurman, MD, FAAN
Ross Zafonte, DO

Correspondence to American Academy of Neurology:

ABSTRACT

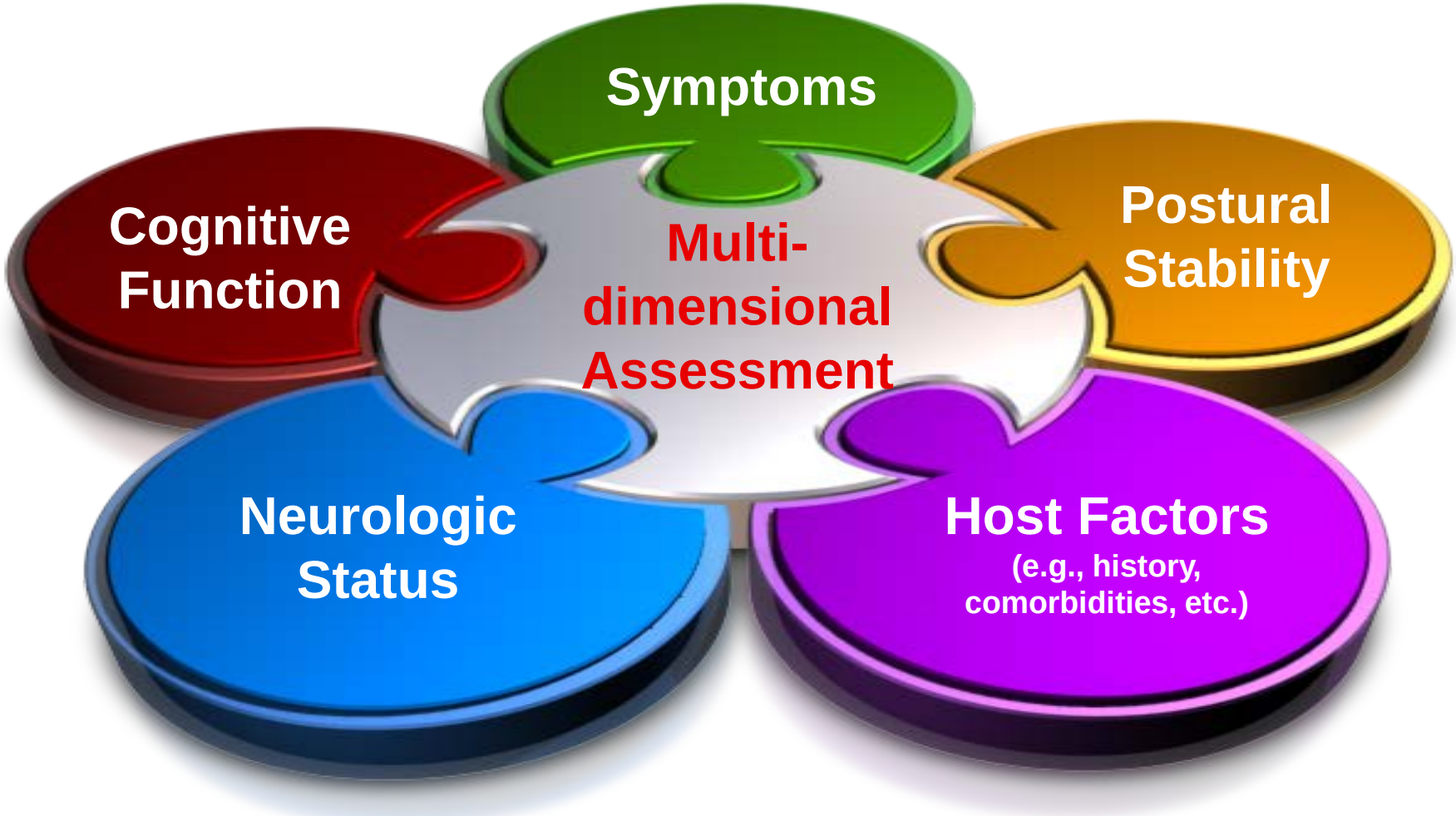
Objective: To update the 1997 American Academy of Neurology (AAN) practice parameter regarding sports concussion, focusing on 4 questions: 1) What factors increase/decrease concussion risk? 2) What diagnostic tools identify those with concussion and those at increased risk for severe/prolonged early impairments, neurologic catastrophe, or chronic neurobehavioral impairment? 3) What clinical factors identify those at increased risk for severe/prolonged early postconcussion impairments, neurologic catastrophe, recurrent concussions, or chronic neurobehavioral impairment? 4) What interventions enhance recovery, reduce recurrent concussion risk, or diminish long-term sequelae? The complete guideline on which this summary is based is available as an online data supplement to this article.

Methods: We systematically reviewed the literature from 1955 to June 2012 for pertinent evidence. We assessed evidence for quality and synthesized into conclusions using a modified Grading of Recommendations Assessment, Development and Evaluation process. We used a modified Delphi process to develop recommendations.

Results: Specific risk factors can increase or decrease concussion risk. Diagnostic tools to help identify individuals with concussion include graded symptom checklists, the Standardized Assessment of Concussion, neuropsychological assessments, and the Balance Error Scoring System. Ongoing clinical symptoms, concussion history, and younger age identify those at risk for postconcussion impairments. Risk factors for recurrent concussion include history of multiple concussions, particularly within 10 days after initial concussion. Risk factors for chronic neurobehavioral impairment include concussion exposure and *APOE* ε4 genotype. Data are insufficient to show that any intervention enhances recovery or diminishes long-term sequelae postconcussion. Practice recommendations are presented for preparticipation counseling, management of suspected concussion, and management of diagnosed concussion. *Neurology*® 2013;••:••

Science Driving Best Practice!

Multi-Dimensional Concussion Assessment:
Maximizing Clinical Confidence



There is no single or one size fits all solution!

SCAT3™

Sport Concussion Assessment Tool – 3rd Edition

For use by medical professionals only

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

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

4th International Consensus Conference on Concussion in Sport

2013 Evidence-Based Injury Management and Return to Play:

Rest and Graded Exertion are the cornerstones

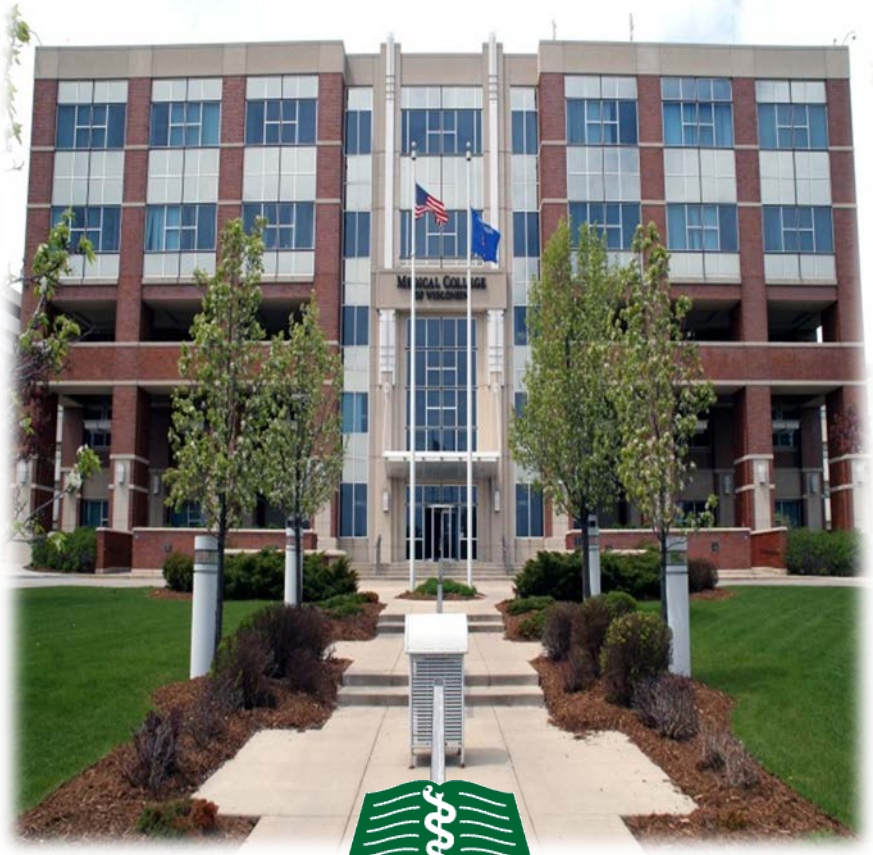
Table 1 Graduated return to play protocol

Rehabilitation stage	Functional exercise at each stage of rehabilitation	Objective of each stage
1. No activity	Symptom limited physical and cognitive rest	Recovery
2. Light aerobic exercise	Walking, swimming or stationary cycling keeping intensity <70% maximum permitted heart rate No resistance training	Increase HR
3. Sport-specific exercise	Skating drills in ice hockey, running drills in soccer. No head impact activities	Add movement
4. 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
5. Full-contact practice	Following medical clearance participate in normal training activities	Restore confidence and assess functional skills by coaching staff
6. Return to play	Normal game play	

Same Day RTP is Prohibited

Concussion Exchange Rate:
Straight Talk for the Athlete

- Give me one game now and I'll give you several back
- Steal a game from me right now and there's a strong chance it'll cost you the season.



MEDICAL COLLEGE OF WISCONSIN

Thank You

Michael McCrea, PhD, ABPP
Professor of Neurosurgery and Neurology
Director of Brain Injury Research
Medical College of Wisconsin

Office: 414-955-7302
Email: mmccrea@mcw.edu