



Evaluation of Concussion & Post Concussion Syndrome

Presented By:
John Leddy, MD FACSM FACP

Associate Professor of Clinical Orthopedics
Medical Director- UB Concussion Management Clinic
Program Director - University at Buffalo
Sports Medicine Fellowship

Barry Willer
John Baker
David Pendergast
Karl Kozlowski
Les Bisson
John Marzo
Jim Donnelly
Len Epstein...

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WNY Concussion Management and Research Interest Group

- UB Concussion Management Clinic
- UB Neurosurgery
- UB Neurology (adult and pediatric)
- Dent Neurologic Institute
- Excelsior Orthopedics
- Buffalo Orthopedics
- Buffalo Spine and Sports Medicine
- UB Department of Physiology and Biophysics
- UB Department of Physical Therapy, Exercise and Nutrition Sciences
- UB Department of Rehabilitation Sciences
- UB Department of Psychiatry
- UB Department of Nuclear Medicine
- UB Department of Orthopedics and Sports Medicine (Niagara Falls)
- Buffalo Neuroimaging and Analysis Center (BNAC)
- UB Speech and Hearing Center
- UB School of Nursing
- UB School of Health and Health Related Professions
- UB Department of Biostatistics
- **Buffalo Bills and Buffalo Sabres Alumni...**

Upstate NY “Thruway Concussion Consortium”

- University at Buffalo
- University of Rochester
- SUNY Upstate at Syracuse
- SUNY Albany
- Others?? Contact ledy@buffalo.edu

How often does a concussion occur?

- 1 in 4 young people will have at least one concussion before they finish/leave high school
- Twice as likely among boys
- Most often from sports (teenagers) or falls (children)
- 1.5-2 million/yr. in US.



ONE IN

4

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or falls (children)**

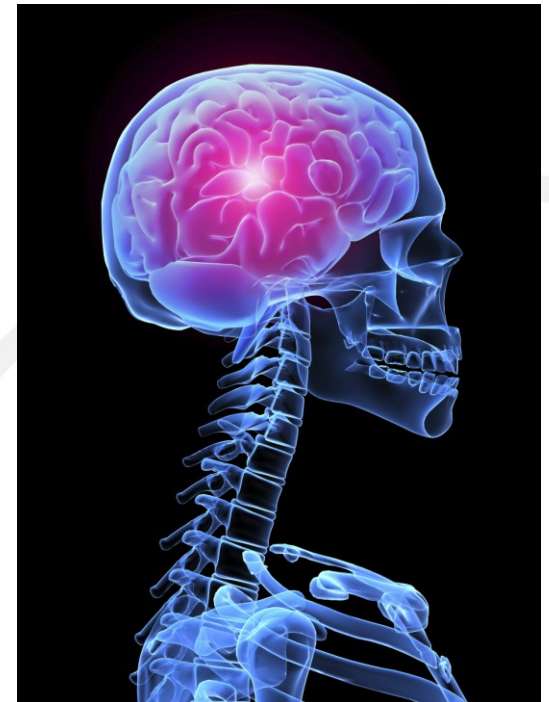
1.5-2

million each year in the US



What is a Concussion?

- A blow to the head that results in an “altered state of consciousness”
- Represented by **confusion**
- May or may not have **unconsciousness**
- Almost always some level of **amnesia** (memory loss)
 - Post traumatic amnesia
 - Retrograde amnesia



confusion
unconsciousness



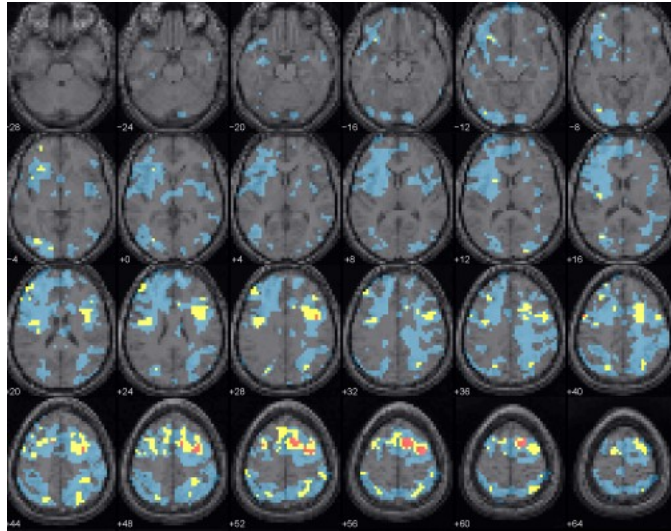
amnesia

Alternate Neuro Imaging

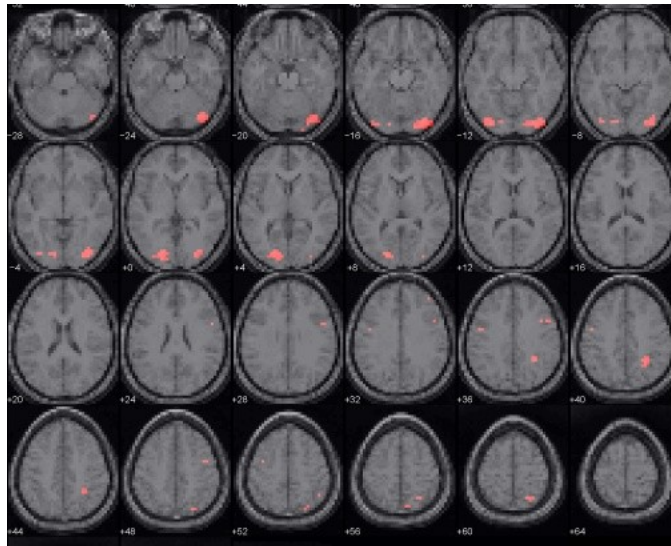
fMRI demonstrates activation patterns that correlate with symptom severity and recovery in concussion.

While not part of routine assessment at the present time, such methods provide additional insight to pathophysiological mechanisms.

Math-SRT PCS (N=3)



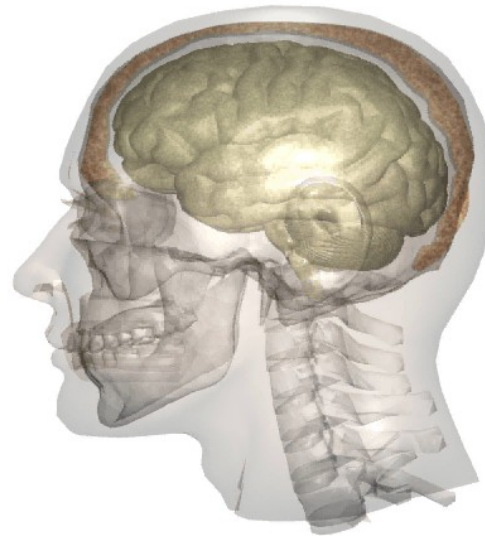
Composite of metabolic activity associated with simple math questions in PCS pre-Rx. Wide range of activity is unfocused and inefficient.



Composite reveals efficient and focused attention to math questions in PCS post-Rx. This is similar to non-injured controls.

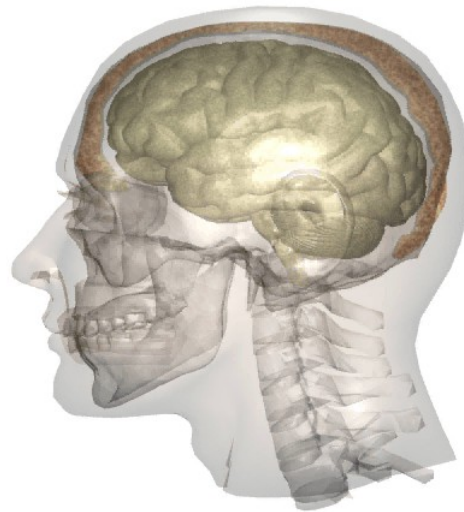
How does a concussion happen?

- #1- Head is the moving object and comes to an abrupt stop
- Does not have to hit an object, whiplash alone is sufficient
- Less common: Head is hit by a moving object

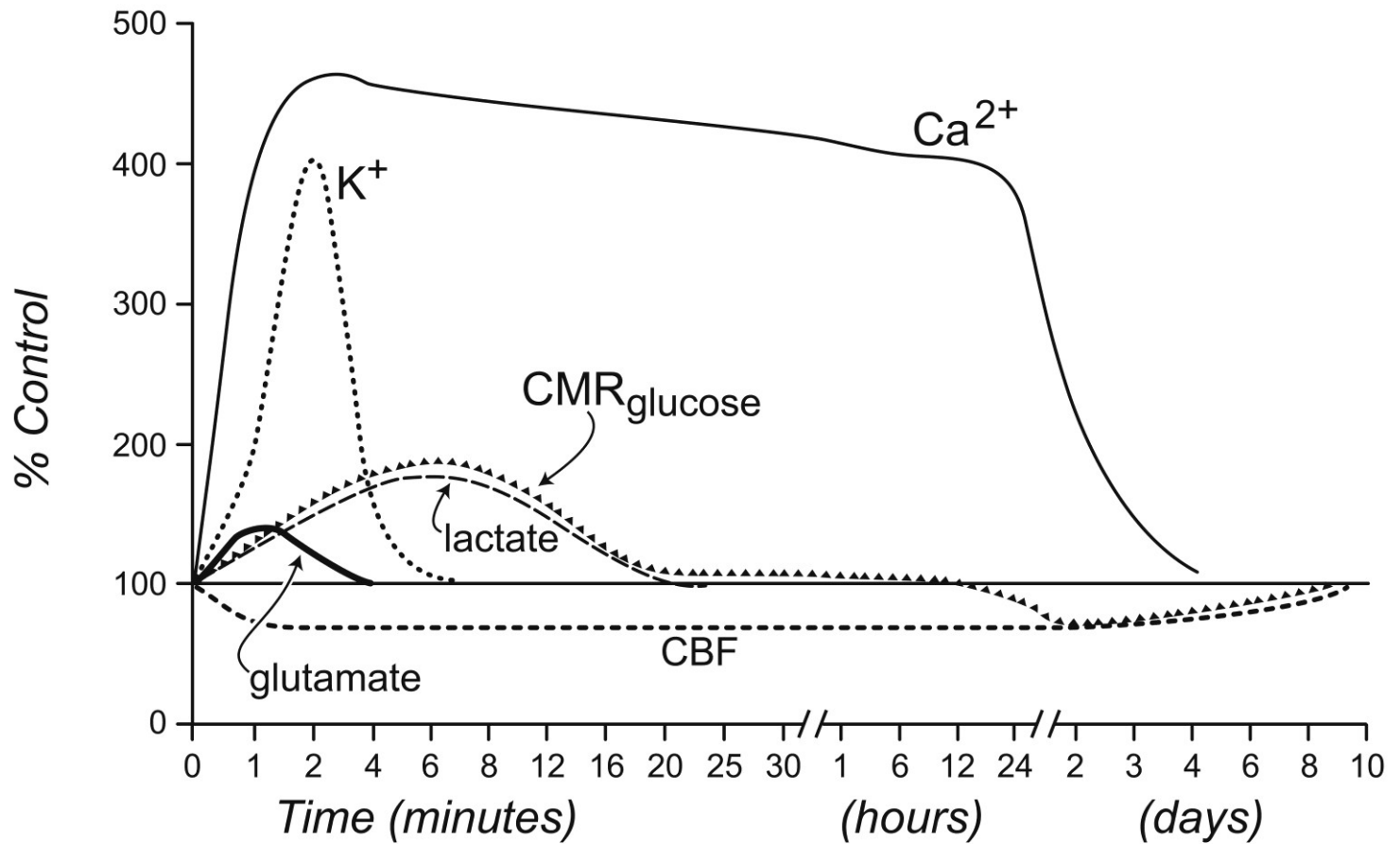


What happens to your brain?

- It is the movement of the brain inside the skull that causes the damage
- Damaged neurons (**Diffuse axonal injury**) produce neurotoxins and a cascade of metabolic changes



Metabolic Cascade after Concussion



History

History of trauma causing “significant cerebral concussion”

1. Is there acceleration deceleration of the head? Is there a possible whiplash effect on the neck?
2. Is there evidence of amnesia/confusion?
3. Is there a history of concussion? When, how many and how long to recover from each?

History

Establishing a pre-morbid history of migraine headaches, depression, anxiety, ADHD, or learning disability is also crucial since TBI can exacerbate these conditions and they in turn can be responsible, if only partially, for ongoing symptoms.

Common Acute Symptoms of Cerebral Concussion

Somatic	Neurobehavioral	Cognitive
Headache	Drowsiness	Feeling “slowed down”
Nausea	Fatigue/lethargy	Feeling “in a fog” or “dazed”
Vomiting	Sadness/depressed	Difficulty concentrating
Balance problems/dizziness	Nervousness/irritability	Difficulty remembering
Sensitivity to light/noise	Sleeping more than usual	
Numbness/Tingling	Trouble falling asleep	
Blurred vision/diplopia/ flashing lights		
Tinnitus		

On-field or Sideline Evaluation of Acute Concussion

Once first aid issues are addressed, then an assessment of cognition should be made.

Focused neuro exam:

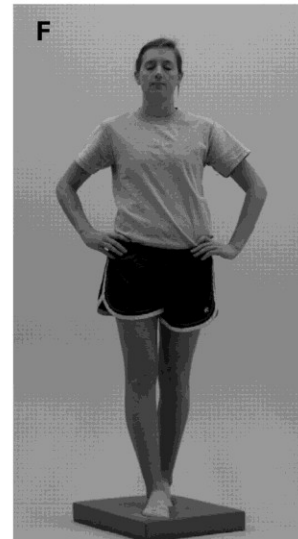
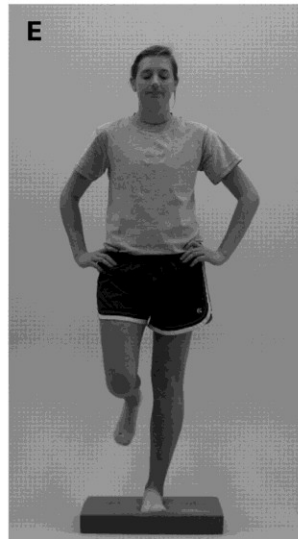
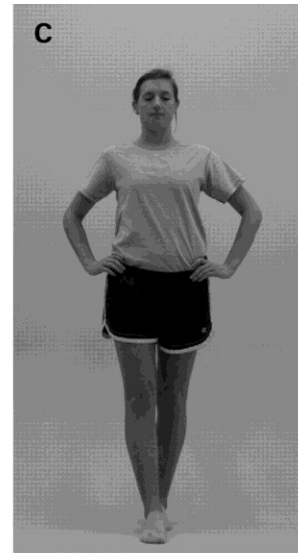
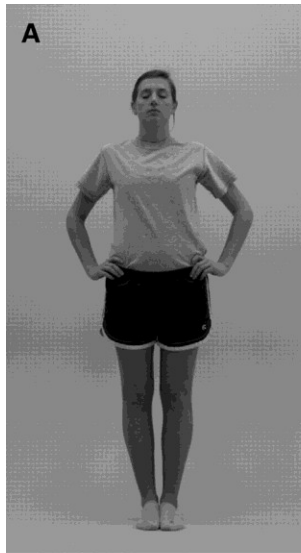
- Check the eyes and balance.
- Assess at rest and, if athlete says symptoms have resolved, after **exertion**.



Physical Examination

- Assessment of concentration (drills of stating the months of the year in reverse and a series of digits backwards tests) and memory (recall of 3 words at 5 minutes) and examination of the cranial nerves.
- The Romberg test, tandem gait, and oculomotor testing (smooth pursuits, saccades, accommodation) should also be performed because vestibular deficits may persist for up to 10 days after concussion.
- After the neurologic examination, the cervical spine should be carefully assessed for tenderness, spasm and range of motion.

Balance



Published studies have identified postural stability deficits lasting approximately 72 hours following sport-related concussion.

Vital Signs

Classic Cushing response occurs with intracranial hypertension.

- systemic hypertension, bradycardia, and respiratory depression.

On Field: persistence of high BP and high pulse pressure (systolic – diastolic > 60 mmHg) combined with bradycardia. May signal a cerebral bleed.

Consensus Statement on Concussion in Support 3rd International Conference on Concussion in Sport Zurich, November 2008.

McCrory P, Meeuwisse W, Johnston K, Dvorak J, Aubry M, Molloy M, and Cantu R. Consensus Statement on Concussion in Sport 3rd International Conference on Concussion in Sport held in Zurich, November 2008.

Clinical Journal of Sport Medicine. 2009;19(3):185-200.

SCAT2



Sport Concussion Assessment Tool 2

Name _____

Sport/team _____

Date/time of injury _____

Date/time of assessment _____

Age _____ Gender M F

Years of education completed _____

Examiner _____

What is the SCAT2?¹

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 2005². This tool also enables the calculation of the Standardized Assessment of Concussion (SAC)³,⁴ score and the Maddocks questions⁵ for sideline concussion assessment.

Instructions for using the SCAT2

The SCAT2 is designed for the use of medical and health 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 (like those listed below) and often does not involve loss of consciousness. Concussion should be suspected in the presence of **any one or more** of the following:

- Symptoms (such as headache), or
- Physical signs (such as unsteadiness), or
- Impaired brain function (e.g. confusion) or
- Abnormal behaviour.

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.

Symptom Evaluation

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 (if applicable)	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 _____

(Add all scores in table, maximum possible: 22 x 6 = 132)

Do the symptoms get worse with physical activity? Y N

Do the symptoms get worse with mental activity? Y N

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

Pocket SCAT2



FIFA®



Concussion should be suspected in the presence of **any one or more** of the following: symptoms (such as headache), or physical signs (such as unsteadiness), or impaired brain function (e.g. confusion) or abnormal behaviour.

1. Symptoms

Presence of any of the following signs & symptoms may suggest a concussion.

- Loss of consciousness
- Seizure or convulsion
- Amnesia
- Headache
- "Pressure in head"
- Neck Pain
- Nausea or vomiting
- Dizziness
- Blurred vision
- Balance problems
- Sensitivity to light
- Sensitivity to noise
- Feeling slowed down
- Feeling like "in a fog"
- "Don't feel right"
- Difficulty concentrating
- Difficulty remembering
- Fatigue or low energy
- Confusion
- Drowsiness
- More emotional
- Irritability
- Sadness
- Nervous or anxious

2. Memory function

Failure to answer all questions correctly may suggest a concussion.

"At 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?"

3. Balance testing

Instructions for tandem stance

*"Now stand heel-to-toe with your **non-dominant** foot in back. Your weight should be evenly distributed across both feet. 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."*

Observe the athlete for 20 seconds. If they make more than 5 errors (such as lift their hands off their hips; open their eyes; lift their forefoot or heel; step, stumble, or fall; or remain out of the start position for more than 5 seconds) then this may suggest a concussion.

Any athlete with a suspected concussion should be IMMEDIATELY REMOVED FROM PLAY, urgently assessed medically, should not be left alone and should not drive a motor vehicle.

On-field or Sideline Evaluation of Acute Concussion

- The player should not be left alone following the injury, and serial monitoring for deterioration is essential over the initial few hours following injury.
- A player with diagnosed concussion should not be allowed to return to play on the day of injury. Formerly, NFL allowed adult athletes to return to play on the same day as the injury but not any more.

RTP Same Day?

NO

There are data demonstrating that, at the collegiate and high school level, athletes allowed to RTP on the same day may demonstrate NP deficits post-injury that may not be evident on the sidelines and are more likely to have delayed onset of symptoms and prolonged recovery.

Neuro Imaging

- Brain CT (or, where available, MRI) contributes little to concussion evaluation but should be employed whenever suspicion of an intra-cerebral structural lesion exists.
- Examples of such situations may include prolonged disturbance of conscious state, focal neurological deficit or worsening symptoms.

Who should go to the ER?

Prolonged LOC (seconds-minutes, not “one second”)

Seizure or focal neurologic deficit

- Unilateral dilated pupil

Deteriorating Clinical Status

- Declining level of consciousness
- Worsening headache, emesis

Concussion Management

Cornerstone of concussion management as of 2012 is **physical and cognitive rest** until symptoms resolve, and then a graded program of exertion prior to medical clearance and return to play.

Concussion Management

Physical AND cognitive rest is required. Activities that require concentration and attention (e.g., scholastic work, videogames, text messaging, etc.) may exacerbate symptoms and possibly delay recovery

Best Treatment for Concussion in the Early Stages (14 days)

Avoid contact sports or any activity where there is a risk of a subsequent head injury.

“Second Impact Syndrome”

Consensus Statement on Concussion in Sport 3rd International Conference on Concussion in Sport Zurich, November 2008

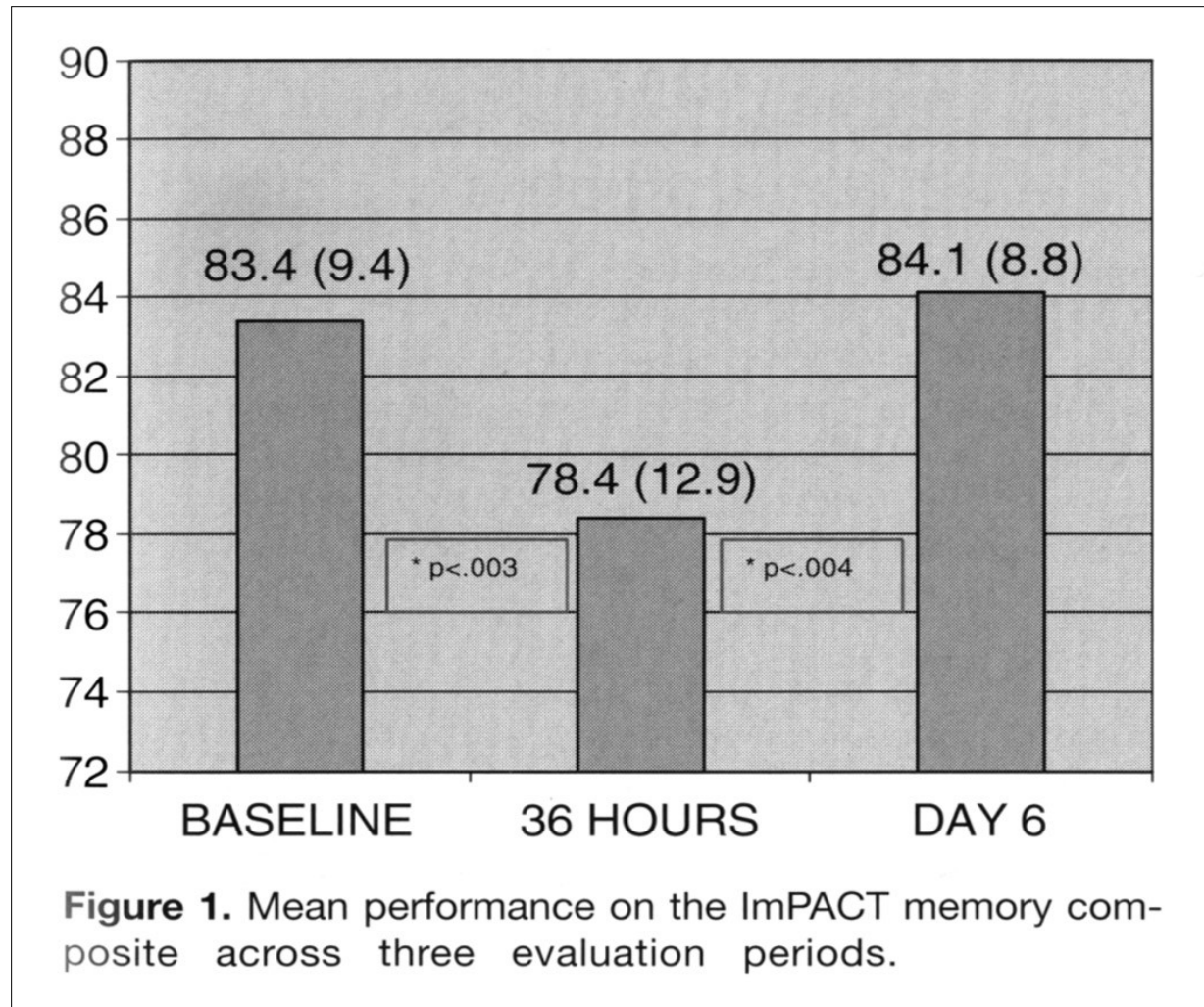
Majority(80%-90%) of concussions resolve in a short (7-10 day) period, although the recovery time frame may be longer in children and adolescents.

Zurich: Computerized Neurophysiological Assessment ImPact, ANAM, etc.

Although in most cases cognitive recovery largely overlaps with the time course of symptom recovery, sometimes cognitive recovery may occasionally precede or more commonly follow clinical symptom resolution.

Assessment of cognitive function is important but not the sole basis for making the RTP decision after concussion.

Grade 1 or “Ding” Concussion



The Value of Treadmill Exercise Testing and Computerized Neuropsychological Testing for Return to Sport in Adolescents with Concussion

2012 AMSSM Annual Meeting, Atlanta, GA

- Concussed athletes (n=59, 46 M, age range 13-19y, mean age 15.7y) who reported symptom resolution 3 weeks after injury completed Automated Neuropsychological Assessment Metrics (ANAM) computerized testing followed by the BCTT on the same day.
- ANAM sub-test performance (according to age normative data) was evaluated. *Athletes did not have a pre-injury baseline NP test.
- Athletes who were able to exercise to voluntary exhaustion without exacerbation of symptoms on the BCTT were returned to sport following the step-wise progression recommended by the Zurich consensus conference.

Results

- All athletes exercised to exhaustion without exacerbation of concussion symptoms on the BCTT.
- Despite being deemed ready to return to sport, **54%** of athletes had 1 or more (range 1-6) ANAM subtests below average (9th percentile or below) and **22%** had 1 or more (range 1-4) ANAM subtests clearly below average (2nd percentile or below).
- All athletes returned to sport without recurrent symptoms during sport.
- Phone contact follow up with 30 athletes collected 3-41 months (mean 18.2 ± 11.4 months) revealed that none had experienced recurrence of symptoms during sport although 15/30 (50%) reported some symptoms with school activities.
- ANAM test performance did not predict symptoms reported on the day of the treadmill test or symptoms reported upon return to school.

Significance

- The data suggest that a standardized exercise stress test may be a useful indicator of readiness to return to sport after concussion.
- NP testing performed at rest, at least in athletes who do not have a pre-injury “baseline” test, does not appear to be useful in the return to sport decision process.

Zurich Conference RTP

- Recovery to normal or baseline performance on a computerized NP test is one measure of recovery and readiness to RTP.
- Cornerstone of management and RTP is rest until symptoms resolve followed by a graded program of exertion till the athlete can exercise to the full capacity of his/her sport without recurrence of symptoms.

2009 Zurich Guidelines

TABLE 1. Graduated Return to Play Protocol

Rehabilitation Stage	Functional Exercise at Each Stage of Rehabilitation	Objective of Each Stage
1. No activity	Complete physical and cognitive rest	Recovery
2. Light aerobic exercise	Walking, swimming or stationary cycling keeping intensity <70% MPPHR; 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	

No scientific evidence to support this protocol.

Zurich Conference

- Is provocative exercise testing useful in guiding RTP?
- What is the best RTP strategy for elite athletes?
- What is the best RTP strategy for non-elite athletes?

Buffalo Concussion Treadmill Test (BCTT) to evaluate physiological readiness to RTP after concussion

BCTT is **safe** in concussed patients with prolonged symptoms

(Clinical Journal of Sport Medicine 20(1):21-27, 2010)

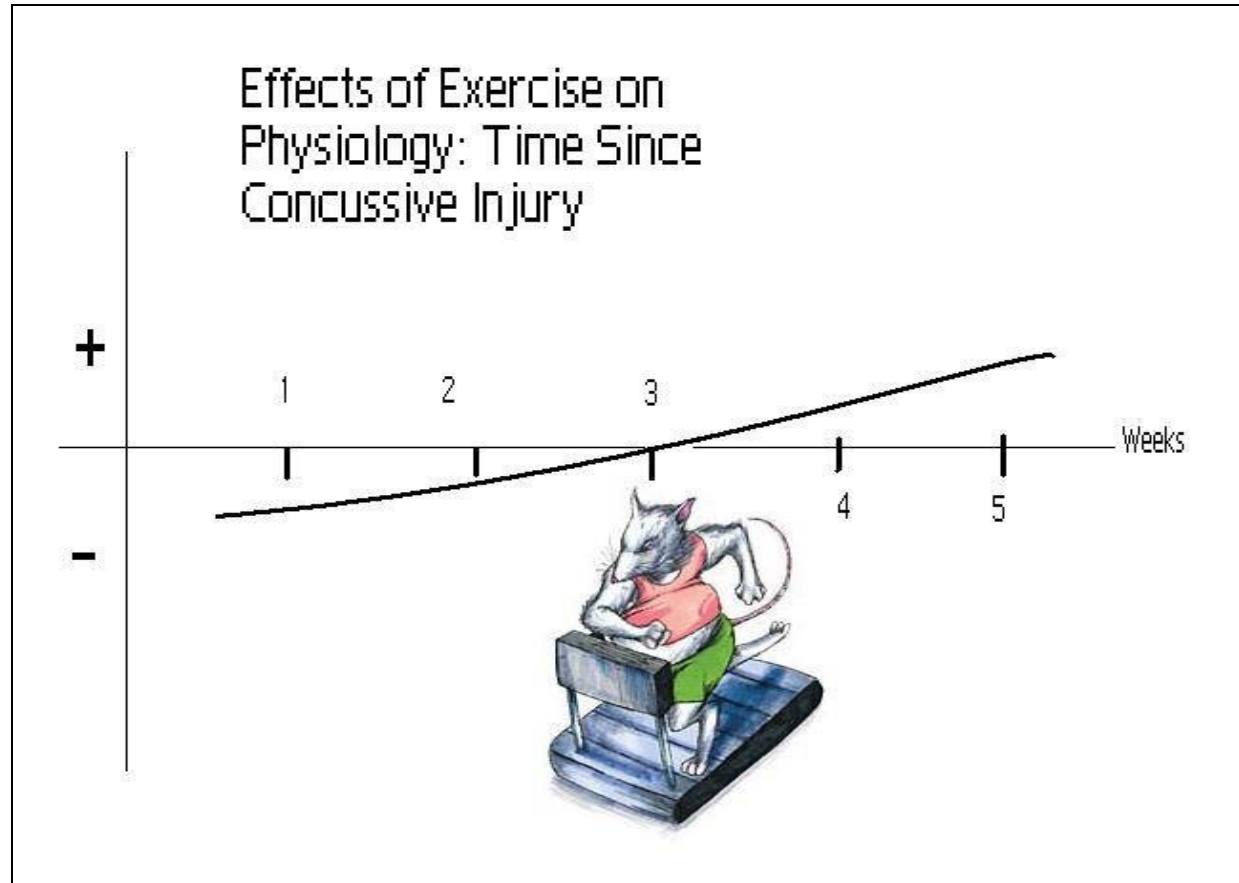
BCTT is **reliable** in evaluation of concussed patients.

- High IRR
- Good RTR

(Clinical Journal of Sport Medicine 21:89-94, 2011.)



Exercise Post-Rat Concussion, Timing is Key



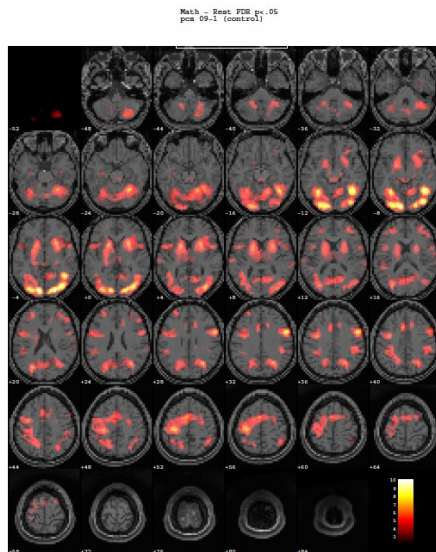
Griesbach et al Brain Res 2004
Greisbach et al Neuroscience 2004

fMRI Study of PCS

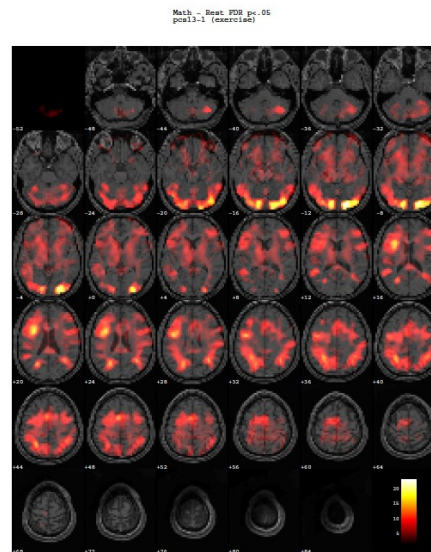
Leddy JJ, Cox JL, Baker JG, Wack DS, Pendergast DR, Zivadinov R, and Willer B. Exercise Treatment for Post Concussion Syndrome: A Pilot Study of Changes in fMRI Activation, Physiology and Symptoms. *Journal of Head Trauma Rehabilitation (in press)*.

Time 1 fMRI Results – Individual Scans

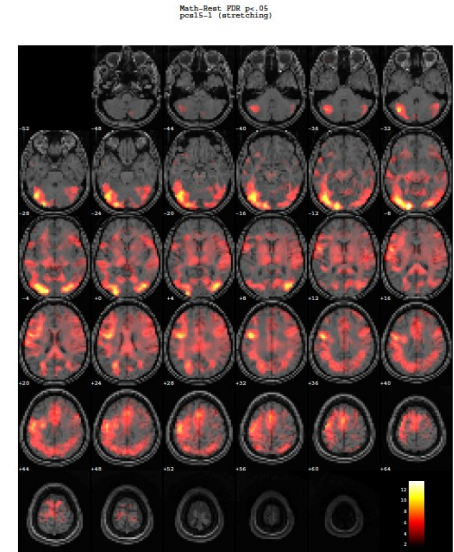
Controls



PCS Exercise

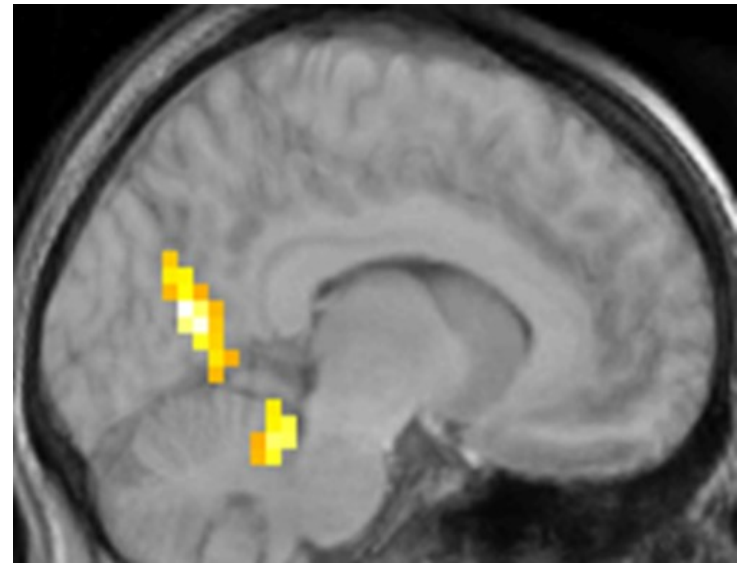


PCS Stretch



Time 1 fMRI Results – Pooled Data

Healthy controls (n=4) had significantly greater activation in the posterior cingulate gyrus and cerebellum than in all PCS subjects (n=8)

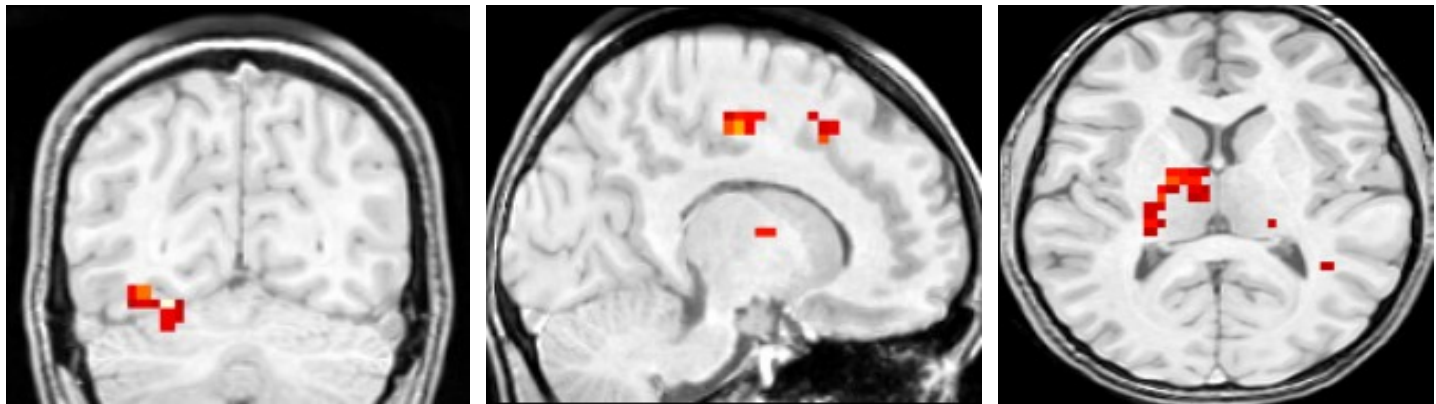


Region	BA ^a	x	y	z	T
Left Posterior Cingulate	30	-9	-66	9	8.01
Right Cuneus	31	2	-62	6	6.76
Left Cerebellum	*	-10	-41	-18	7.6
Right Cerebellum	*	10	-41	-18	6.9

All $p < .05$ FDR, corrected; ^a Brodmann Area; xyz are Talairach coordinates

Time 2 fMRI Results – Pooled Data

Healthy controls did not differ from the PCS EXERCISE group **but** they had significantly greater activity in the left cerebellum ($p < 0.05$, corrected), left cingulate gyrus and thalamus ($p < .001$, uncorrected) versus PCS STRETCH group.



Region	BA	x	y	z	T
Left Cerebellum	*	-23	-64	-17	18.51**
Left Cingulate Gyrus	31, 32, 24	-13	-21	42	11.8#
Left Thalamus	*	-16	-10	10	9.65#
Right thalamus	*	17	-36	5	8.6#

All $p < .05$ FDR, corrected; ^a Brodmann Area; xyz are Talairach coordinates

The Significance of Loss of Consciousness (LOC)

- In moderate to severe brain injury, LOC duration predicts outcome but in sport concussion it has not correlated with injury severity.
- Consensus discussion in Zurich determined that prolonged (>1 minute duration) LOC would be considered as a factor that may modify management.

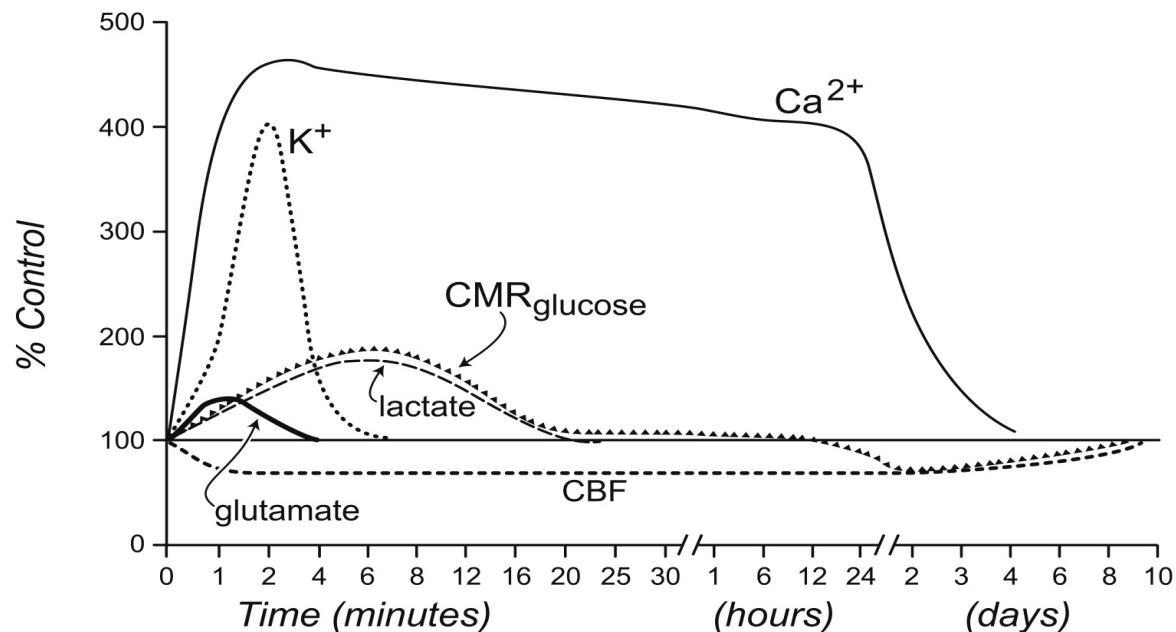
TABLE 2. Concussion Modifiers

Factors	Modifier
Symptoms	Number Duration (>10 days) Severity
Signs	Prolonged LOC (>1 min), amnesia
Sequelae	Concussive convulsions
Temporal	Frequency - repeated concussions over time Timing - injuries close together in time “Recency” - recent concussion or TBI
Threshold	Repeated concussions occurring with progressively less impact force or slower recovery after each successive concussion
Age	Child and adolescent (<18 years old)
Co- and Pre-morbidities	Migraine, depression or other mental health disorders, attention deficit hyperactivity disorder (ADHD), learning disabilities (LD), sleep disorders
Medication	Psychoactive drugs, anticoagulants
Behaviour	Dangerous style of play
Sport	High-risk activity, contact and collision sport, high sporting level

Risks of Repeated Concussions

Animal research

- The concussed brain is in a vulnerable state that places it at increased risk of more debilitating injury should it sustain more trauma before metabolic homeostasis has been restored.



Risks of Repeated Concussions

1. Second Impact Syndrome (controversial).
2. Concussion risk increases after having had one or more concussions.
3. Previous concussions may be associated with slower recovery of neurological function.
4. Repeated concussions may result in permanent neurocognitive impairment (**CTE**: chronic traumatic encephalopathy) and an increased incidence of suicide and depression.
5. Post Concussion Syndrome.

How many Concussions are too many?

Athletes with a history of ≥ 3 concussions are 9 times more likely to have severe symptoms than those without a history of concussion.
What about more than one concussion in a sport season?

Risk Factors for Delayed Recovery

- History of three or more prior concussions
- Female gender
- Younger age
- Prior history of cognitive dysfunction
- Affective disorders such as depression
- Migraine Headaches
- Too much physical and/or cognitive activity within first week after concussion.

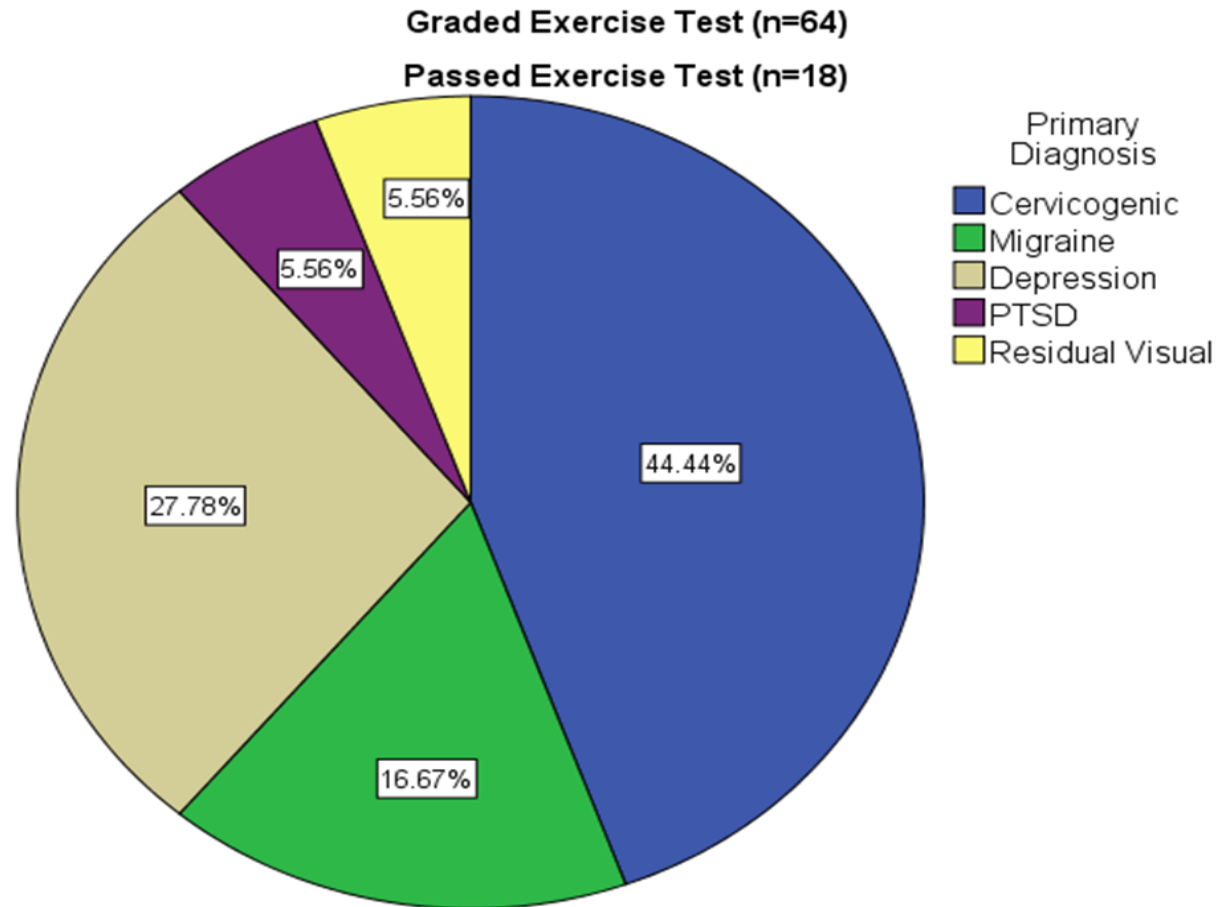
Football



Buffalo Concussion Treadmill Test and Differential Diagnosis of PCS

- Physiologic PCS is represented by symptoms + symptom exacerbation (with exertion), early on.
- Cervical strain usually produces headache and/or dizziness later during exercise testing.
 - Headache usually gets **better** during the exercise
 - Confirm with neck exam
- If not PCS or cervical strain then:
 - Anxiety reaction; Migraine; Vestibular issues; Ocular issues
 - Refer for assessment

Diagnoses for Patients who Passed the Exercise Test



Features incorporated to improve energy attenuation when blows are delivered to the side of the head or face.



Examining concussion rates and return to play in high school football players wearing newer helmet technology: a three-year prospective cohort study.

(Collins M; Lovell MR; Iverson GL; Ide T; Maroon J)
(Neurosurgery. 58(2):275-86; discussion 275-86, 2006 Feb).

Concussion Management

Fung M, Willer B, Moreland D, and Leddy JJ. Brain Injury 2006.

- Remove from sport or high risk activity
- Grading concussion – not useful acutely
- See a physician
- Advise others (parents) to observe and tell them why they should observe (hemorrhage)
 - Worsening symptoms (particularly headache)
 - Vomiting, Confusion, Increasing drowsiness

NYS Concussion Awareness and Management Act

- Remove from sport or high risk activity.
- No RTP till Sx free 24 hours and cleared by physician.
- All coaches, PE teachers, nurses and ATs complete biennial course on recognition.
- Effective July 1, 2012.
- School districts *may* establish a Concussion Management Team.

**Guidelines for Trainers and Coaches on
Return to Play for Student Athletes after Concussion**
Based upon the 2008 Zurich 3rd International Conference on Concussion in Sport
(*Clin J Sport Med* 2009;19:185–200)

Graduated Return to Play Protocol

Rehabilitation Stage	Functional Exercise at Each Stage of Rehabilitation	Objective of Each Stage
1. No activity	Complete physical and cognitive rest	Recovery
2. Light aerobic exercise	Walking, swimming or stationary cycling keeping intensity <70% MPPHR; 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	

Return to play following a concussion follows a stepwise process as outlined above. With this stepwise progression, the athlete should continue to proceed to the next level if asymptomatic at the current level.

Generally, each step should take 24 hours, so that the athlete would take approximately one week to proceed through the full rehabilitation protocol once asymptomatic at rest and with provocative exercise.

If any post-concussion symptoms occur while in the stepwise program, then the athlete should drop back to the previous asymptomatic level and try to progress again after a further 24-hour period of rest has passed.

John Leddy, M.D. operates the Concussion Clinic at the University at Buffalo.

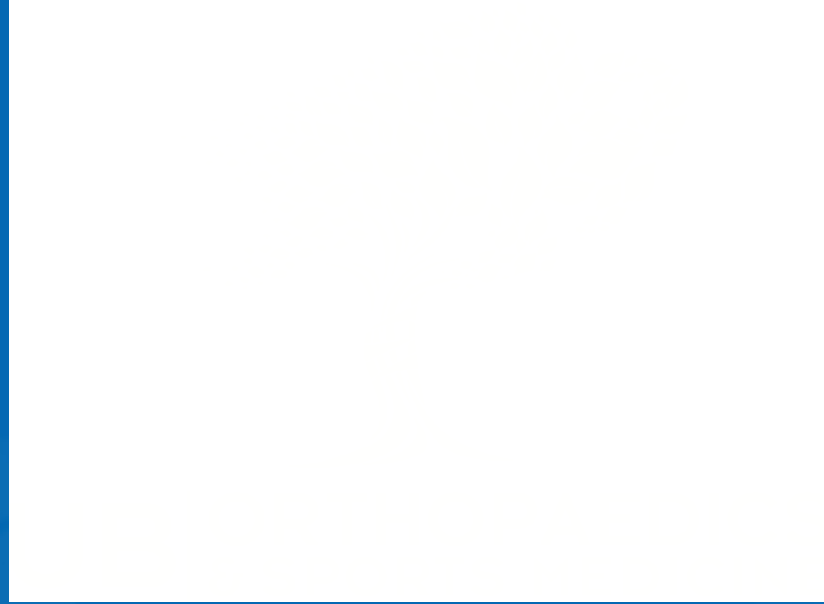
The Concussion Clinic provides evaluation and treatment for individuals suffering from a recent concussion and from post-concussion syndrome.

The school's internationally recognized experts are the most experienced in Western New York for evaluating patients with concussion and developing a safe return-to-activity (sport or work) program.

For more information, email trp2@buffalo.edu or call (716) 204-3200

www.concussion.buffalo.edu

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Thank you for your attention

Please wake up from LC (lecture concussion)

Questions?