Sport related concussion (SRC) evaluation and diagnosis

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Learning Objectives

- Epidemiology
- Pathophysiology
- Diagnosis

- Disclosures: I have no financial relationships or conflicts of interest
- I am funded by the NIH to study inflammation in TBI: NEI K08 EY029362

Epidemiology of Sport Related Concussion (SRC)

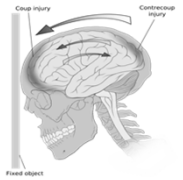
- Approximately 38-40 million children and adolescents participate in sports and activities each year.
- More than 100 million adults engage in physical activity and sport each year
- Centers for Disease Control estimates that 1.6 to 3.8 million concussions occur in sports and recreational activities annually

- Risk of SRC is associated with the amount of contact in a sport or activity
- Collision sports: football, wrestling, rugby, combat sports
- Contact sports: soccer, basketball, lacrosse
- Noncontact sports: running, swimming, biking

Daneshvar et al. 2012.
CDC TBI in the US; epidemiology and rehabilitation Congressional Report 2015
Van Pelt et al. 2019

Concussion Pathophysiology

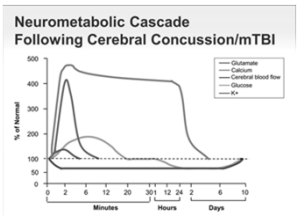
- Mechanism of injury:
- Coup-Counter coup mechanism
- SRC: acute neurophysiological change due to mechanical energy applied to the head, neck or body with transmitting forces to the brain



Bazarian et al. 2018
CDC TBI in the US; epidemiology and rehabilitation Congressional Report 2015

Concussion Pathophysiology

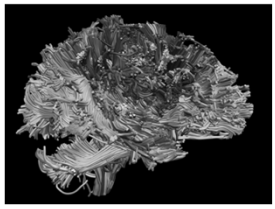
- Biomechanical force transitions to cause a metabolic injury
- Metabolic cascade that starts with electrolyte abnormalities (K+ and Ca2+).
- Depletion of glucose in an attempt to re-establish cell homeostasis.
- The rapid use of glucose leads to a prolonged hypo-metabolic state.



Giza and Kutcher, 2014

SRC leads to a network injury

- 100 billion+ neurons in the central nervous system (CNS)
- Each region must communicate efficiently and synchronously
- Metabolic disequilibrium leads to dys-synchronous neuronal communication



Concussion Symptoms

Somatic:
Headache
Dizziness
Balance problems
Visual disturbances
Photo/Phonophobia

Cognitive:
Confusion/Disorientation/Fatigue
Amnesia
Foggy thinking
Inattention
Delayed verbal response
Slurred speech
LOC

Sleep:
Trouble falling asleep
Sleeping more
Sleeping less

Affective:
Emotional Lability
Anxiety
Irritability
Sadness

Uncommon:
Seizure
Posturing

Post Concussion Symptom Score

	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

Standardized symptom checklist can rate the severity of these symptoms

http://www.cdc.gov/TraumaticBrainInjury/

SRC Evaluation

- The "in sport" or "sideline" assessment and then the clinical assessment
- Sideline assessment: Athletic trainers, physicians, coaches, parents.
- Remove the player from the field and find a non-distracting location to evaluate.

"When in doubt, sit them out"

CDC.gov/headsup

Sideline Assessment for SRC

- First step is to consider and evaluate for more severe injuries
  - Focal neurologic deficit
  - Prolonged LOC
  - Potential concurrent spinal cord injury
  - GCS < 15
  - Worsening exam
- Consider more severe diagnoses: Does the patient need emergent medical attention

- Evaluate for concussion:
- Use a standardized assessment tool

Concussion Diagnosis:

- There is no biomarker test
- There are no characteristic imaging finding on conventional imaging
- **Concussion is a clinical diagnosis**

Clinic Concussion Evaluation

- History of event
  - Consistent with TBI
- Symptoms checklist
- Past medical history
  - Confounding factors:
    - Migraine
    - ADHD
    - Anxiety or depression
    - Learning disability
- Social history
  - Stressors, substance abuse
- Physical exam

- Mental Status
  - level of consciousness
  - orientation
  - concentration
  - memory
- Cranial Nerves
  - eyes: pupils, EOMs, smooth pursuit, saccades, nystagmus, convergence
- Motor and motor control
  - Strength
  - coordination
- Balance and coordination
  - complex balance maneuvers
- Vestibular system
- MSK/Neck

Matusak et al. 2016

History and symptoms

- Is there a history consistent with a concussive event?
- How long ago was the injury
- Symptoms and progression

- Symptom checklist:
- Standardized tools with a symptom checklist
  - Sport concussion assessment tool (SCAT5)
  - Acute concussion evaluation (ACE)
  - Post concussion symptom scale

	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
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Sadness	0	1	2	3	4	5	6
Nervous or anxious	0	1	2	3	4	5	6

Past Medical History

- Past Concussions: how many, how long was the recovery, problems with the recovery.
- Migraines: increased risk of prolonged recovery, hard to differentiate headaches from concussion symptoms
- ADD/ADHD and Mood disorders: increased risk of prolonged recovery
- Learning disabilities: hard to return to classroom
- Strabismus or vision problems: increased risk of prolonged symptoms

Scopaz and Hatzenbuehler; 2013
Swanson et al. 2017

Social History

- The social history gives you an opportunity to gain insight into your athlete.
  - Sports played
  - Level of competition
  - Athlete perspective of when they want to get back on the field
    - Big game
    - Try outs for next sport
- Substance abuse:
  - Alcohol
  - Drugs
  - Cigarettes
- Stressors
  - Tests/papers
  - Significant others
  - family

Concussion Neurologic Exam

- Mental Status
  - level of consciousness
  - orientation
  - concentration
  - memory
- Cranial Nerves
  - eyes: pupils, EOMs, smooth pursuit, saccades, nystagmus, convergence
- Motor and motor control
  - Strength
  - coordination
- Balance and coordination
  - complex balance maneuvers
- Vestibular system
  - Vestibular ocular reflex (VOR)
  - Visual Motion Sensitivity (VOMS)
- Neck exam:
  - Range of motion (ROM)
  - Paraspinal muscles – tone, pain
  - Spinous process
  - Suboccipital notch

Diagnosis of Certainty

Classification	Definition	Management
Definite	Concussion is the ONLY explanation for the clinical presentation.	As concussed
Probable	Concussion is the most likely cause of the clinical presentation. While other possible explanations exist, they are deemed less likely. The traumatic insult was clearly defined by witnesses or identifiable on video.	As concussed
Possible	Other possible explanations are identified, such as migraine headache, dehydration, or viral illness. The presumed traumatic insult was not witnessed or difficult to describe. Concussion may not be the most likely cause of the clinical presentation	Situational*

Where you see your patient and how far removed they are from the injury is as important

Giza et al 2014

Plan

- Concussion recovery is influenced by:
  - Gender, concussion history, medical co-morbidies, and age
- Individualized recovery plans and expectations is important

Giza CC and Kutcher JS. Sports Concussion Diagnosis and Management Continuum.2014 Dec;20(6 **Sports** Neurology):1552-69..

The future of mTBI diagnosis

There are many gaps in the diagnosis management and treatment of mTBI:

- How do I know the patient was injured
  - conventional imaging is normal
  - symptom score
- Biomarkers of injury and recovery
  - Blood
  - Imaging
- A way to correlate therapies with recovery and patient subjectiveness

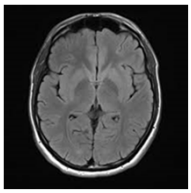
Biomarkers:

- What makes a good biomarker: present when the condition occurs, correlates with symptoms or severity of disease, and disappears when the condition is gone.
- Concussion biomarkers are difficult
  - heterogeneity in mechanisms of injury
  - age
  - sex
  - time post injury
  - Marker is unique to mTBI
- Blood tests :CNS injury markers:
  - Neurofilament light chain (NF-L)
  - Glial Fibrillary Associated Protein (GFAP)
  - S100 calcium binding protein B (S100b)
  - ubiquitin C-terminal hydrolase-L1 (UCH-L1)
  - microtubule associated protein 2 (MAP-2)
  - β-amyloid peptide 42 ($A\beta_{42}$)
  - Neuron Specific Enolase (NSE)
- Cheek swabs
  - microRNAs

Atif and Hicks 2019
Bazarian et al. 2018
Aiken et al. 2018

Imaging

- Brain CT or conventional MRI contribute little to concussion evaluation and diagnosis.
- Should be considered
  - whenever suspicion of an intracerebral or structural lesion (eg: skull fracture) exists.
  - prolonged LOC (>1 min), or deterioration of consciousness after being assessed
  - focal neurological deficit
  - worsening symptoms that are not improving



McCrory et al. 2013
Torres et al. 2019

Conclusions

- Sport related concussion is common and likely goes under reported in the community
- All athletes should have access to a qualified individual (ATC, coach, physician, trained parent) that can remove athletes from play if they suspect a concussion
- A concussion is a clinical diagnosis after more severe injuries have been excluded.
- Assessment and diagnosis of a concussion requires a trained physician with a detailed history and examination of the patient
- In the future, blood testing or imaging may be capable of diagnosing sport related concussion.

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Sports Concussion Management and Treatment

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- We receive fellowship funding from Allergan and Amgen
- There are off-label treatments discussed in this talk.

Objectives

- What are symptoms after a concussion? How are they managed?
- What is post-traumatic headache?
- How can you tell the difference between post-traumatic headache and migraine or other primary headache syndrome?

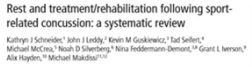
After removing the athlete…

- The player should NOT return to play that day
- The player should not be left alone after injury. The player should be serially checked for several hours after the injury to evaluate for deterioration.
- If no health care provider immediately available, player needs urgent referral

Common symptoms after concussion

- Headaches, fogginess, emotional lability
- Amnesia, focal deficits
- Unsteady gait
- Irritability or other behavior changes
- Cognitive changes (concentration deficit, slowed reaction times)
- Sleep/wake disturbance (trouble sleeping, drowsiness)
- Ocular symptoms (convergence insufficiency, trouble with saccades, abnormalities of the vestibulo-ocular reflex)

Rest


Rest and treatment/rehabilitation following sport-related concussion: a systematic review

Kathryn J Schneider,[1] John J Leddy,[2] Kevin M Guskiewicz,[3] Tad Seifert,[4] Michael McCrea,[5] Noah D Silverberg,[6] Nina Feddermann-Demont,[7,8] Grant L Iverson,[9] Alix Hayden,[10] Michael Makdissi[11,12]

- 24-48 hours of cognitive and physical rest
- After that, a gradual return to activities/exercise is recommended and encouraged.
- No evidence that keeping an athlete in a dark room and out of school and all exercise until symptoms completely resolve is beneficial. In fact, the opposite is true.

Screens

Original Investigation ONLINE FIRST

September 7, 2021

Effect of Screen Time on Recovery From Concussion

A Randomized Clinical Trial

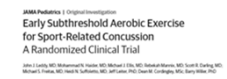
Theodore Macnow, MD[1,2]; Tess Curran, MD, MPH[1]; Courtney Tolliday, MD[1]; et al

Author Affiliations

JAMA Pediatr. Published online September 7, 2021. doi:10.1001/jamapediatrics.2021.2782

- Supports no screens 48 hours after injury.

Early Exercise



JAMA Pediatrics | Original Investigation

Early Subthreshold Aerobic Exercise for Sport-Related Concussion

A Randomized Clinical Trial

- There is evidence that early exercise improves outcomes in concussion.
- We use a Buffalo Concussion Treadmill Test to determine threshold for exercise rehabilitation

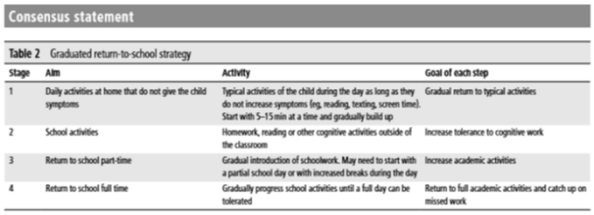
Buffalo Concussion Treadmill Test (BCTT)

- The heart rate at which concussion symptoms increase is considered the patient's heart rate threshold. Aerobic exercise is prescribed at 80% of the patient's heart rate threshold.
- The test can be used periodically to increase exercise prescription, and also later to clear the patient for return to play.

Source: Leddy, John J. MD, FACSM FACP1; Willer, Barry PhD2 Use of Graded Exercise Testing in Concussion and Return-to-Activity Management, Current Sports Medicine Reports: November/December 2013 - Volume 12 - Issue 6 - p 370-376 doi: 10.1249/JSR.0000000000000008

Return to School

- Most important!



Consensus statement

Table 2 Graduated return-to-school strategy

Stage	Aim	Activity	Goal of each step
1	Daily activities at home that do not give the child symptoms	Typical activities of the child during the day as long as they do not increase symptoms (eg, reading, texting, screen time). Start with 5–15 min at a time and gradually build up	Gradual return to typical activities
2	School activities	Homework, reading or other cognitive activities outside of the classroom	Increase tolerance to cognitive work
3	Return to school part-time	Gradual introduction of schoolwork. May need to start with a partial school day or with increased breaks during the day	Increase academic activities
4	Return to school full time	Gradually progress school activities until a full day can be tolerated	Return to full academic activities and catch up on missed work

McCrory P, Meeuwisse W, Dvorak J, et al. Br J Sports Med 2018;51:838–847.

Concussion and Migraine

- Personal or family history of migraine observed in 80+% of symptomatic mild TBI
- Why is there so much comorbidity?
  - Thought that hyperexcitability of the brain in migraineurs can lead to increased risk of sustaining concussion
  - We know a pre-existing headache disorder like migraine is associated with an increased risk of worsened and prolonged symptoms after a concussion.
  - Peripheral activation of the trigeminocervical complex?

- Source: Kuczynski A et al (2013). "Characteristics of post-traumatic headaches in children following mild traumatic brain injury and their response to treatment: a prospective cohort." *Dev Med Child Neurol*;55(7): 638-41.
- Source: Gordon et al (2006). "Is migraine a risk factor for the development of concussion?" *Br J Sports Med*; 40(2): 184–185.
- Source: Piovesan EJ, Kowacs PA, Oshinsky ML. (2003). "Convergence of cervical and trigeminal sensory afferents." *Curr Pain Headache Rep*;7(5): 377–83.

Acute Post-traumatic headache

- Most common symptom after minor head injury
- 94% of athletes with sports-related concussion have headache

- Source: Marar M et al. (2012). "Epidemiology of concussions among United States high school athletes in 20 sports." *Am J Sports Med*; 40: 747–755.

Acute Post-traumatic headache

- A. Any headache fulfilling criteria C and D
- B. Traumatic injury to the head has occurred
- C. Headache is reported to have developed within 7 days of one of the following:
  1. the injury to the head
  2. regaining consciousness following injury to the head
  3. Discontinuation of medication (s) that impair the ability to sense or report headache following the injury to the head
- D. Either of the following:
  1. headache has resolved within 3 months after the injury to the head
  2. headache has not yet resolved but 3 months have not yet passed since the injury to the head

- Persistent post-traumatic headache = the above criteria but greater than 3 months.
- Similar criteria for "whiplash" headaches

Source: ichd-3.org

Taking a Headache History

- Family history of migraine?
- Personal history of migraine?
- Detailed previous concussion history. Did they have headaches afterwards? How long? Were they like these?
- Location, length, character (Dull? Throbbing?), radiation, severity, time to build up, time of day when pain is worst or when headache starts, onset
- Associated symptoms: dizzy, nausea, vomiting, aura, photophobia, phonophobia, neck pain
- What is the patient taking for the pain?
- Triggers?
- Missing school/work due to headaches?
- Worsening with activity?

How to treat?

- No randomized controlled clinical trials in PTH treatment
- Standard of care is treating the headache like the primary headache type it most resembles (usually migraine)
- Early treatment: NSAIDs, oral steroids
- For prolonged headache: amitriptyline, gabapentin, Valproic acid, propranolol, or topiramate. All off-label.

CGRP?


Ashina et al. The Journal of Headache and Pain (2020) 21:42

The Journal of Headache and Pain

RESEARCH ARTICLE Open Access

Efficacy, tolerability, and safety of erenumab for the preventive treatment of persistent post-traumatic headache attributed to mild traumatic brain injury: an open-label study

Sleep


Efficacy of Melatonin for Sleep Disturbance in Children with Persistent Post-Concussion Symptoms: Secondary Analysis of a Randomized Controlled Trial

- 3 mg also associated with reduction in depressive symptoms

CBT


A Pilot Randomized Controlled Trial of Cognitive-Behavioral Therapy for Insomnia in Adolescents With Persistent Postconcussion Symptoms

- CBT improved overall post-concussion and sleep symptoms.

Rehabilitation

- I use a multidisciplinary approach with our therapists at Ohio State for patients with prolonged symptoms
- Speech/cognitive therapy for cognitive symptoms
- Physical therapy for graded aerobic exercise program, cervical and vestibular therapy
- Ocular rehabilitation for athletes with difficulty with convergence, saccades, vestibule-ocular system
- Psychological therapy for persistent mood symptoms (CBT!)
- Pharmacologic therapy (usually for headaches or mood)
- Avoid “appointment fatigue!”

The Commonly Asked Question

- How to tell the difference between post-traumatic headache and migraine?
- In a patient with a previous history of migraine or a young patient with a family history of migraine but no personal migraines, how can you tell?
- Signs the post-traumatic headache may have reverted back to migraine:
  - All other concussion symptoms resolved
  - The headaches do not worsen with exercise
  - The headaches are random and do not correlate with increased mental or physical activity
  - The frequency and character are now similar to what they were prior to the injury
- What if the patient is on migraine/posttraumatic headache prophylaxis?
  - Controversial
  - Exercise caution
  - There is always concern that medications mask symptoms. That said, an underlying migraine disorder could worsen off the medication even though the concussion recovery itself has completed.

Return to Play

- Once symptoms have completely resolved at rest, and the athlete is back to work/school, return to play progression may begin under the supervision of a health professional (preferably one with training in concussion)

Table 1 Graduated return-to-sport (RTS) strategy

Stage	Aim	Activity	Goal of each step
1	Symptom-limited activity	Daily activities that do not provoke symptoms	Gradual reintroduction of work/school activities
2	Light aerobic exercise	Walking or stationary cycling at slow to medium pace. No resistance training	Increase heart rate
3	Sport-specific exercise	Running or skating drills. No head impact activities	Add movement
4	Non-contact training drills	Harder training drills, eg, passing drills. May start progressive resistance training	Exercise, coordination and increased thinking
5	Full contact practice	Following medical clearance, participate in normal training activities	Restore confidence and assess functional skills by coaching staff
6	Return to sport	Normal game play	

NOTE: An initial period of 24–48 hours of both relative physical rest and cognitive rest is recommended before beginning the RTS progression.
There should be at least 24 hours (or longer) for each step of the progression. If any symptoms worsen during exercise, the athlete should go back to the previous step.
Resistance training should be added only in the later stages (stage 3 or 4 at the earliest). If symptoms are persistent (eg, more than 10–14 days in adults or more than 1 month in children), the athlete should be referred to a healthcare professional who is an expert in the management of concussion.

McCrory P, Meeuwisse W, Dvorak J, et al. Br J Sports Med 2018;51:838–847.

Post-Concussion Syndrome

- Many athletes recover within 10-14 days (adults) and 30 days (children)
- Some take longer, sometimes up to three months or more. These patients (>3 months) generally get grouped into “post-concussion syndrome.”
- A multidisciplinary team and neuropsychological testing are sometimes needed for these patients.
- Very uncommon for patients to have persistent symptoms still remaining from a concussion after one year, especially with normal brain imaging. This is controversial.

Long-Term Effects

- There is no absolute number of concussion threshold where retirement is recommended. This is a decision involving athlete, parents (if under 18), and their physicians
- There has not yet been a cause and effect relationship established between concussions and chronic traumatic encephalopathy (CTE)
- Do a certain number of concussions cause CTE? Or many sub-concussive repetitive blows?

CTE

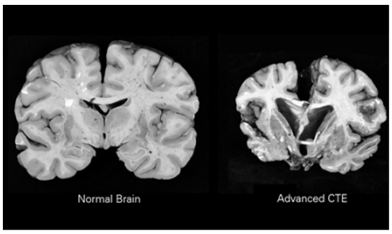


Image source: Wikimedia commons