



Updates in Sport-Related Concussion

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Epidemiology

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Youth Statistics

- Approximately 1.7 - 3 million sustained yearly in competitive sports
- 15% of US high school students reported SRC in prior 12 months (CDC 2018)
- 5 – 9% of all sport-related injuries

Concussion Trends in HS Sports

- More prevalent in competition than practice
- Football highest incidence
- Recurrent concussions decreased in football, steady in other sports
- Data from Kerr et al from HS sports from 2013 – 2017
 - Overall rate of 4.17 per 10,000 AEs
 - 64% during competition, 36% during practice

Incidence: High School

- Highest in boys' football, ice hockey, lacrosse
- Followed by girls' soccer, lacrosse and basketball
- Again higher in competition than practice

Marar et al. 2012

Collegiate Data

-  4.13 per 10,000 AEs
-  Higher in competition than practice
-  Highest rates: men's ice hockey, women's soccer
-  Data from NCAA injury surveillance program 2014-19, Chandran et al. 2021

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High School Sport Participation

- **7.98m students participated in high school sports in 2016 - 2017.**
- **8.06m in 2023-2024**
 - 4.6m boys
 - 3.4m girls
- **Football participation increased to 1.03m**



Data from National Federation of State High School Associations

Diagnosis

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What is a concussion?

Consensus statement
Consensus statement on concussion in sport: the 6th International Conference on Concussion in Sport—Amsterdam, October 2022

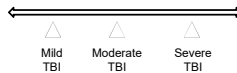
Jon S. Passos ¹, Kathryn Schneider ², J. Aronow ³,
 Christiaan Hendrick ⁴, J. Peter Blum ⁵, J. Robert C. Cantu ⁶,
 Gavin A. Davis ⁷, Robert J. Echemendia ⁸, Michael McCrea ^{9,10},
 Michael McCrea ¹¹, Steven Hopkins ¹², George A. King ¹³,
 Nina Wolfmann-Demars ¹⁴, Gordon West-Jones ¹⁵, Christopher C. Giza ^{16,17},
 Brian M. Ladd ¹⁸, Robert Whitley ¹⁹, Scott K. Weinger ²⁰,
 Jeffrey S. Kutner ²¹, John Ladd ²², David Maddala ²³, Geoff Harney ²⁴,
 Michael Mackay ²⁵, Cassa K. Powell ²⁶, Ragnhildur K. Bjarnardottir ²⁷,
 Markku A. Hanning ²⁸, Michael Lerner ²⁹, Keith Owen Noble ³⁰,
 Shariq A. Hussain ³¹, Wilson Stevenson ³²

Sport-related concussion is a traumatic brain injury caused by a direct blow to the head, neck or body resulting in an impulsive force being transmitted to the brain that occurs in sports and exercise-related activities. This initiates a neurotransmitter and metabolic cascade, with possible axonal injury, blood flow change and inflammation affecting the brain. Symptoms and signs may present immediately, or evolve over minutes or hours, and commonly resolve within days, but may be prolonged. No abnormality is seen on standard structural neuroimaging studies (computed tomography or magnetic resonance imaging T1- and T2-weighted images), but in the research setting, abnormalities may be present on functional, blood flow or metabolic imaging studies. Sport-related concussion results in a range of clinical symptoms and signs that may or may not involve loss of consciousness. The clinical symptoms and signs of concussion cannot be explained solely by (but may occur concomitantly with) drug, alcohol, or medication use, other injuries (such as cervical injuries, peripheral vestibular dysfunction) or other comorbidities (such as psychological factors or coexisting medical conditions).

What is a concussion?

- An injury to the head that results in an “altered state of consciousness”
- Represented by confusion, headache
- May or may not have unconsciousness
- No standard imaging findings

Spectrum of Brain Injury



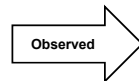
- Best eye response (E)**
1. No eye opening
 2. Eye opening to pain
 3. Eye opening to sound
 4. Eyes open spontaneously

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

- Best motor response (M)**
1. No motor response
 2. Abnormal extension to pain
 3. Abnormal flexion to pain
 4. Withdrawal from pain
 5. Localizing pain
 6. Obeys commands

Jain S, Iverson LM, Glasgow Coma Scale. [Updated 2023 Jun 12]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK513298/> (CC BY-NC-ND 4.0)

Signs and Symptoms



- Can't recall events
- Appears dazed or stunned
- Forgets an instruction, confused about score, opponent
- Moves clumsily
- Answers questions slowly
- Loses consciousness (even briefly)
- Shows mood, behavior, or personality changes

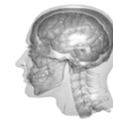
- Headache or "pressure" in head
- Nausea or vomiting
- Balance problems, dizziness, vision blurred
- Bothered by light or noise
- Feeling sluggish, hazy, foggy, or groggy
- Concentration or memory problems
- Just not "feeling right," or "feeling down"

Does Headache = Concussion?

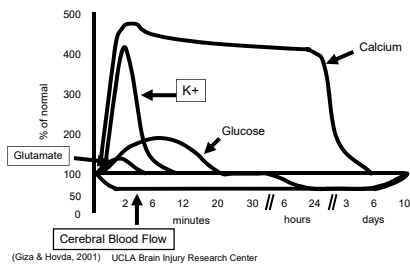
- May be a part of symptoms.
- Headache alone is NOT a concussion.
- Must also have a change in mental status.

Pathophysiology

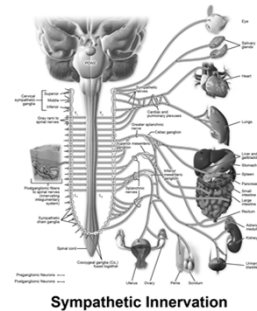
- It is the movement of the brain inside the skull that causes the damage.
- Damaged neurons result in a cascade of metabolic changes.



Neurochemical Cascade Following Concussion



Autonomic Dysfunction

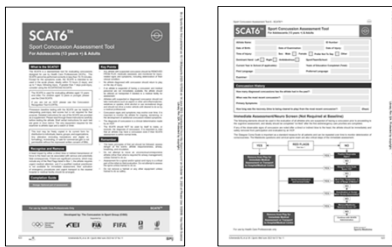


Autonomic Dysfunction

- Altered autonomic control in concussed subjects during exercise.
- Reduced heart rate variability during exercise (ANS imbalance) (Gall et al 2004).
- Increased heart rates during exercise (Gall et al 2004).
- Increased DBP during exercise (Laddy et al 2011).

Initial Assessment

SCAT6

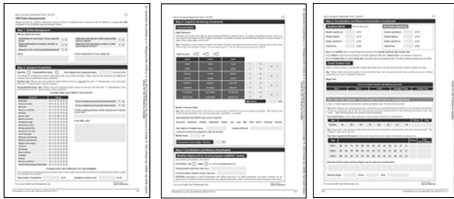


Echemendia RJ, et al. Br J Sports Med June 2023 Vol 57 No 11

When to seek emergency care

- Neck pain or tenderness
- Seizure or convulsive activity
- Loss of consciousness
- Worsening mental status
- Focal neurologic signs (weakness / tingling in more than one extremity)
- Double vision
- Severe / worsening headache
- Vomiting (changed from recurrent)
- Increasingly restless, agitated, combative
- GCS < 15
- Visible skull deformity

SCAT6



Echemendia RJ, et al. Br J Sports Med June 2023 Vol 57 No 11

Symptom Progression

- Symptoms may be delayed
- Other times may resolve
- Serial monitoring
- "Possible, probable, definite"

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Management

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Initial Management

- Remove athlete from play
- Serial monitoring
- Relative physical and cognitive rest

Rest After Concussion



- Thomas et al, Pediatrics 2015.
- Strict rest for 5 days vs usual care (1-2 days rest).
- No difference in neurocognitive or balance outcomes at 3 and 10 days.
- Strict rest group reported more symptoms and slower resolution.

Other factors when resting too long

- Social isolation
- Anxiety / depression
- Physical deconditioning
- Worsened sleep quality

Screens

- Ok in moderation
- No need to confiscate devices
- Stop if symptoms are worsening

Return to School

- No changes from previous recommendations

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

Return to Sport

Concussion statement			
Step	Objective strategy	Activity at each step	Goal
1	Complete baseline activity	Steps activities for an immediate response, for example, walking	Complete resolution of work-related symptoms
2	At-risk activities (to approximately 70% usual level) 20-30 minutes for approximately 70% usual level	Walking (uphill or walking on a flat to medium pace) Swimming (uphill or walking on a flat to medium pace) Swimming (uphill or walking on a flat to medium pace)	Return to normal
3	Individual sport specific exercise	Swimming (uphill or walking on a flat to medium pace) Swimming (uphill or walking on a flat to medium pace)	Return to normal
4	Return to normal activities	Swimming (uphill or walking on a flat to medium pace) Swimming (uphill or walking on a flat to medium pace)	Return to normal
5	Return to normal activities	Swimming (uphill or walking on a flat to medium pace) Swimming (uphill or walking on a flat to medium pace)	Return to normal
6	Return to normal activities	Swimming (uphill or walking on a flat to medium pace) Swimming (uphill or walking on a flat to medium pace)	Return to normal

Patricios JS, Schneider KJ, Dvorak J, et al. Br J Sports Med 2023;57:695-711.

OHSAA Form

Ohio High School Athletic Association
4302 Rosinsky Place, Columbus, Ohio 43214
714-644-3310; 1-800-621-3177

(Print Name)

MEDICAL AUTHORIZATION TO RETURN TO PLAY AFTER A SUSPECTED CONCUSSION

This form is to be used by a physician or other qualified medical professional to authorize a student-athlete to return to play after a suspected concussion. It is not to be used for a student-athlete who has not been evaluated by a physician or other qualified medical professional. The physician or other qualified medical professional must complete this form and return it to the student-athlete's school principal or administrator. The physician or other qualified medical professional must also complete this form and return it to the student-athlete's school principal or administrator. The physician or other qualified medical professional must also complete this form and return it to the student-athlete's school principal or administrator.

Physician or other qualified medical professional name: _____ M.D. D.O. _____
 School: _____
 Student Name: _____
 Date: _____
 Signature: _____
 Title: _____

PLEASE INDICATE YOUR DIRECTIONS BELOW

Return to play protocol for concussion not required, and the student may return to participation in practice and competition on the date: _____
 Return to play protocol for concussion not required, and the student may return to participation in practice and competition on the date: _____
 Return to play protocol for concussion not required, and the student may return to participation in practice and competition on the date: _____

Other (specify): _____

VALID ONLY WITH ALL INFORMATION COMPLETED

Version: 08/2018 (Professional)

Biomarkers

FDA Clears First Rapid Handheld Blood Test for Concussion

Megan Brooks
January 14, 2021

Source: Medscape

Concussions Can Be Detected With New Blood Test Approved by F.D.A.

Source: The New York Times

- Take away point:
 - Not a diagnostic tool to determine concussion.
 - Used to determine if a more serious injury has occurred.





Concussion: Prolonged symptoms and treatment strategies

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Learning Objectives

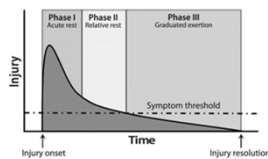
- Prolonged concussion recovery
- Multidisciplinary clinical care
- Retirement from sport



- Disclosures: I have no financial relationships or conflicts of interest
- I am funded by the NIH to study inflammation in TBI: 1R01EY035307

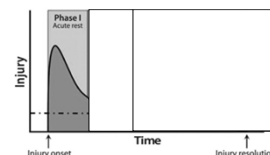
Concussions resolve

- Returned to all activities without return of symptoms
- Symptom free
- No medications
- Recovery is a clinical decision
- Depending on the normal recovery timeline: 60-90% of patients recover as expected



Glax and Kutcher, 2014

Also Normal Recovery?



- Phase I: Acute Rest
- Phase II: Relative Return to life
- Phase III: cannot return to all activities

Adapted from: Glax and Kutcher, 2014

Prolonged Post Concussion Symptoms



PPCS are generally agreed upon as 3 or more symptoms that do not resolve after mTBI

There is a tension between evaluating a patient having PPCS as the effect of mTBI vs a psychological response to a stressor not related.

There is no consensus for how long symptoms must persist for a patient to be considered post concussive syndrome.

Baseline: ADHD, migraine, anxiety, depression, sleep disorder

Surveyed 33,125 healthy adolescent athletes:

597 physicians surveyed:
Minimum duration of symptoms required to diagnose PCS, respondents answered: <2 weeks (26.6%), 2 weeks to 1 month (20.4%), 1-3 months (33%) and >3 months (11.1%)
PCS is 10 to >90 days?

- Boys: 60% reported one symptom
- 19.3% 3 or more
- Girls: 73% reported one symptom
- 28% 3 or more

Finally, in a subset of patients, you have to consider secondary gain

Rose et al. 2021
Moser et al. 2017
Iverson et al. 2015

Concussion Symptoms Revisited

Post Concussion Symptom Score

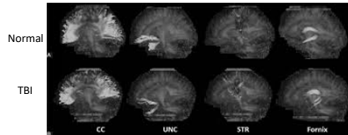
	None	Mild	Moderate	Severe			
Somatic:							
Headache	0	1	2	3	4	5	6
"Pressure in head"	0	1	2	3	4	5	6
Neck pain	0	1	2	3	4	5	6
Nausea or vomiting	0	1	2	3	4	5	6
Dizziness	0	1	2	3	4	5	6
Balance problems	0	1	2	3	4	5	6
Visual disturbances	0	1	2	3	4	5	6
Photo/Phonophobia	0	1	2	3	4	5	6
Sleep:							
Trouble falling asleep	0	1	2	3	4	5	6
Sleeping more	0	1	2	3	4	5	6
Sleeping less	0	1	2	3	4	5	6
Affective:							
Emotional Lability	0	1	2	3	4	5	6
Anxiety	0	1	2	3	4	5	6
Irritability	0	1	2	3	4	5	6
Sadness	0	1	2	3	4	5	6
Cognitive:							
Confusion/Disorientation/Fatigue	0	1	2	3	4	5	6
Amnesia	0	1	2	3	4	5	6
Foggy thinking	0	1	2	3	4	5	6
Inattention	0	1	2	3	4	5	6
Delayed verbal response	0	1	2	3	4	5	6
Slurred speech	0	1	2	3	4	5	6

10-40% of mTBI do not resolve in 2-4 weeks.

Anderson et al. 2020
McCrory et al. 2017
Gosney et al. 2014
http://www.bjpt.com/2014/09/01/

Chronic brain injury symptoms are associated with changes in brain connectivity

Research studies show that TBI patients have chronic changes in regions of their brain after mTBI by Diffusion tensor imaging (DTI).



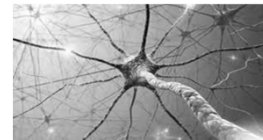
- Regions of the brain most affected:
- Corpus callosum
 - fornix
 - longitudinal fasiculus
 - internal capsule/corona radiata
 - pontine tegmentum

D'Souza MM, Trivedi R, Singh K, Grover H, Choudhury A, Kaur P, et al. Traumatic brain injury and the post-concussion syndrome: A diffusion tensor tractography study. Indian J Radiol Imaging 2015;25:404-14. CC BY-NC-ND 4.0

Khong et al. 2016

Long term concussion symptoms are treatable

- Therapies
 - Physical therapy
 - Vestibular therapy
 - Vision therapy
- Symptomatic medications
 - Mood changes: TCAs, SSRIs, SNRIs
 - Headache: supplements, TCAs, AEDs, triptans
 - Foggy thinking: NMDA augmentors
 - Poor sleep: melatonin, TCAs
- Neuropsychology evaluation
 - Neuropsychological testing
 - Cognitive behavioral therapy



Groff et al. 2017
Saxton 2015
Elin et al. 2015

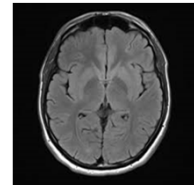
Identify Barriers to Recovery

- Concurrent neck injury
- Vestibular involvement
- Visual symptoms
 - Convergence insufficiency
- Insufficient cognitive and physical rest
- Insomnia and other sleep problems
- Pre-existing disease
 - Headache
 - Psychiatric disease
 - Learning disorders
 - Sleep problems



Imaging

- Brain CT or conventional MRI brain contributes little to initial concussion evaluation.
- Should be considered in prolonged symptoms
 - whenever suspicion of an intracerebral or structural lesion (eg: skull fracture) exists.
 - focal neurological deficit
 - worsening symptoms that is unexplained



McCrory et al. 2013
Tennant et al. 2015



Sleep and mTBI:

- Sleep disturbances are very common (30-41%)
- Sleep more, sleep less, wake up frequently, don't feel rested.
- Sleep is important:
 - Replenishes energy stores of neurons and glial cells
 - Glial lymphatics remove protein debris, metabolic waste
- Melatonin:
 - Mostly studied in pediatric mTBI
 - Improves sleep quality 1-10 mg
 - Speeds return to life activities
- In animal models: Anti-oxidant properties regulating
 - NF-Kb pathways (inflammation)
 - AMPK pathway (excitotoxicity)
 - CREB (calmodulin and cell survival)

Hoffman et al 2020
Singh et al 2016
Widawa et al 2016
Narain et al. 2015

Post traumatic headache



TABLE 1. INTERNATIONAL CLASSIFICATION OF HEADACHE DISORDERS CRITERIA FOR POSTTRAUMATIC HEADACHE	
Acute Posttraumatic Headache	
Definition: Headache of <3 months' duration caused by traumatic head injury	
Diagnostic criteria	Traumatic injury to the head has occurred AND headache developed within 7 days of injury to the head OR regaining consciousness after head injury OR medications that impair ability to sense or report headache discontinued after head injury AND not better accounted for by another ICHD-3 diagnosis AND time since injury is <3 months
Persistent Posttraumatic Headache	
Definition: Headache of ≥3 months' duration caused by traumatic injury to the head	
Diagnostic criteria	as above except during is ≥3 months
Abbreviation: ICHD-3, International Classification of Headache Disorders, 3rd edition	

- Symptoms include:
 - Nausea/vomiting
 - Photo/phonophobia
 - Decreased attention/forgetfulness
 - Sleep disturbances
- Tension type
- Migrainous type

source citation: <https://ichd-3.org/>

Ashley and Nasser 2020

Headache treatment

Treatment:

- Lifestyle modifications
- Preventatives
- Abortive medications
- Lifestyle Modifications: changes in lifestyle known to decrease headache risk:
 - Sleep
 - Hydration
 - Exercise
 - Avoid toxins (alcohol, drugs, cigs, excessive caffeine)

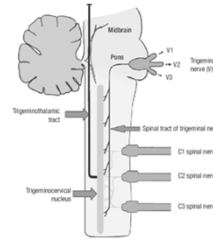
Preventative: medications taken every day to reduce headache frequency and intensity:

- TCAs: amitriptyline or nortriptyline
- SNRIs: venlafaxine or duloxetine
- Supplements: Magnesium, Riboflavin, Feverfew
- Anti-epileptics: Topiramate, Depakote, Gabapentin

Abortive: Medications taken at the time of headaches to stop the headache:

- OTC NSAIDs, Acetaminophen
- Prescription NSAIDs
- Triptans
- Anti-nausea medications

Physical Therapy: Cervicalgia



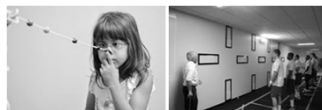
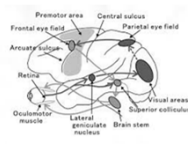
J Korean Med Sci. 2016 Apr;31(4):479-488.
<https://doi.org/10.3346/jkms.2016.31.4.479>

Liddy et al. 2015
 Kennedy et al. 2019
 Bagduk and Gervasi. 2006

- Physical therapy: concurrent neck injury is common due to shared mechanism
- Strengthening, stretching, and manipulation are first line management
- Early identification and intervention is beneficial
- 7.5 weeks post injury for first evaluation: 90% (18/20 concurrent patients) had persistent neck pain contributing to ongoing symptoms

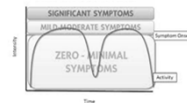
Vestibular and Vision Therapy

- Network injury: cranial nerves, frontal and parietal eye fields, visual cortex
- Dizziness, nausea, difficulty reading, riding in a car, headache
- Perform habituation and adaptation exercises to overcome vision and head movement triggered symptoms



Makoto 2004

Return to Learn and Work



- The school or work environment commonly provokes symptoms
 - Cognitive fog
 - Headaches
 - Phono and photophobia
 - Mood swings

- Provide a letter for support
 - Accommodations/breaks
 - Adjust assignment/test schedule
- Adjustments may be informal for a short period of time
- Symptoms lasting longer than 4 weeks may need specialist care (neuropsychologist)
- Academic/work performance should be normal prior to returning to full sports or other extracurricular activities

Holstead et al 2013
 Brannstrom 2008

Neuropsychology

- Neuropsychological assessment: performance-based method to assess cognitive functioning. This method is used to examine the cognitive consequences of brain damage, brain disease, and mental illness.
- Assess: memory, attention, processing speed, reasoning, judgment, and problem-solving, spatial, and language functions.
 - Cognitive testing
 - Extensive psychological history taking
- Many roles in the care of mTBI patients
 - Collection of diagnostic information
 - Cognitive impairment
 - Differential diagnostic information
 - TBI
 - Anxiety, depression
 - Secondary gain
 - Assessment of treatment response
 - Anti-depressant
 - Cognitive behavioral therapy
 - Predict functional potential and functional recovery.
 - Cognitive resilience

Harvey 2012
Mazzione et al. 2017

Exercise in PPCS

- Sub-symptom threshold exercise is safe and beneficial in improving mTBI symptoms.
- Leddy and Willer at U. Buffalo pioneered the Buffalo Concussion Treadmill Test (BCTT).
- This has been expanded to now dynamic sub-symptom exercise that is flexible for different types of patients.
- Can be used for acute injury or long-term symptom recovery



BORG RPE	Modified RPE	BREATHING	% MAX HR
6	0	No exertion	
7	0		
8	1	Very Light	50% - 60%
9			
10			
11	2	Notice breathing deeper, but still comfortable. Conversations possible.	60% - 70%
12			
13	3	Aware of breathing harder; more difficult to hold a conversation	70% - 80%
14	4		
15	5	Starting to breathe hard and get uncomfortable	80% - 90%
16	6		
17	7	Deep and forced breathing, uncomfortable, don't want to talk	
18	8	Extremely hard	90% - 100%
19	9		
20	10	Maximum exertion	

Leddy et al. 2010
Petrovich et al. 2014
Battistuzzi.org

Exercise is Medicine for Concussion

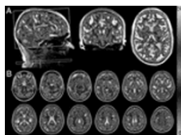
John J. Leddy, MD, FACS, FACP¹; Muhammad N. Haider, MD²; Michael Ellis, MD, FRCSC³; and Barry S. Wilke, PhD⁴

Goal: start with 5-10 minutes at home daily

Increase until by 5 minute increments until goal of 30 minutes a day.

If you have symptoms back off, slow down.

Enough to break a sweat after 20 minutes, but light enough to carry on a conversation with your friend



• Cardiovascular exercise: produces neuroprotective growth factors and anti-inflammatory cytokines (BDNF, IGF-1, GCSF, IL-10, TGF- β)

• Improves cerebral blood flow and autonomic function

Citation: Kleinloger JPD, Mensink RP, Ivanov D, Adam JJ, Ukudag K and Joris PJ (2019) Aerobic Exercise Training Improves Cerebral Blood Flow and Executive Function: A Randomized, Controlled Cross-Over Trial in Sedentary Older Men. *Front Aging Neurosci.* 11:333. doi: 10.3389/fnag.2019.00333 - CC BY 4.0

Preddy et al. 2015
Preddy 2010
Leddy et al. 2018
Kleinloger et al. 2019

Establish expectations

- All causes mTBI:
 - Young 18–39 years (n=583) 68% discharged home
 - Middle-aged 40–59 years (n=420) 61%
 - Elderly 60–99 years (n=476) 44%
- Adults MVA average 7170 MVA <18 in Canada, 1780 mTBI patients.
 - Average was 100 days of symptoms
 - 23% had symptoms at 1 year
- Adolescents 13-21y/o
 - MVA: 97 symptomatic days (n=20)
 - Football: 32 symptomatic days (n=38)
- 6th International Conference on Concussion in Sport 2023
 - Adults: normal recovery less than 14 days
 - Adolescents: normal recovery less than 30 days

Forsberg et al. 2023
Casper et al. 2021
Casper et al. 2024
Leddy et al. 2018

Retirement from sport or activity

- When to retire from an activity is based on expert opinion.
- Clear contraindications:
 - Structural abnormality on imaging:
 - skull fracture
 - Blood
 - Cyst
 - Progressive concussions that occur with less significant contact
 - Subsequent concussions with worsening symptoms and longer recoveries
 - Focal neurological deficit
- The more difficult decisions:
 - Continued symptoms that do not resolve (>3 months)
 - Multiple concussions within one season
 - Change in behavior
 - Seizure or posturing at the time of concussion

Quinn-Tamm et al 2018
Covatta et al 2018
Wolcott et al 2016
Battistone et al 2017

Conclusions

- Prolonged recovery from SRC is common: 10-40%
- It is important to identify symptom driving barriers to recovery: Sleep, neck, vestibular, vision, headache, pre-existing medical issues
- Multi-disciplinary care is essential for treatment and recovery from prolonged post concussion symptoms
- Set expectations, patients with prolonged recoveries will improve gradually
- It may be necessary to temporarily or permanently retire athletes who do not recover.