Concussion: Update on Evidence Base Medicine

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Learning Objectives

- To be able to diagnose a concussion
- To be able to manage a concussion based on evidence based medicine
- To be able to understand the different subsets of concussions

What is a Concussion?

mild Traumtic Brain Injury (mTBI)

Mild Traumatic Brain Injury (mTBI) Criteria

- Glasgow Coma Scale (GCS) score: 13-15
  - Measured 30 min after injury (or upon presentation)
- LOC < 30 min
- Post traumatic amnesia < 24 hrs
- Transient neurological abnormalities after sustaining brain trauma

American Congress of Rehabilitation Medicine (ACRM). Definition of mild traumatic brain injury. *J Head Trauma Rehabil* (1993) 8:86–7.

Concussion (mTBI) Definition

- "…is a traumatic brain injury induced by biomechanical forces…"
  - CISG Berlin 5th ed 2017
- "…a traumatic physiological brain injury…"
  - Leddy, J et al., Exercise is Medicine for Concussion. *Current Sports Med Reports.* 2018; 17:262-270
- "…a heterogeneous mild traumatic brain injury (mTBI)characterized by a variety of symptoms, clinical presentations, and recovery trajectories…"
  - Lumba-Brown A, Teramoto M, Bloom OJ *et al.* Concussion guidelines step 2: evidence for subtype classification. *Neurosurgery* nyz332 (2019)
- "…acute brain injury resulting from mechanical energy to the head from external physical forces."
  - American Congress of Rehabilitation Medicine (ACRM)

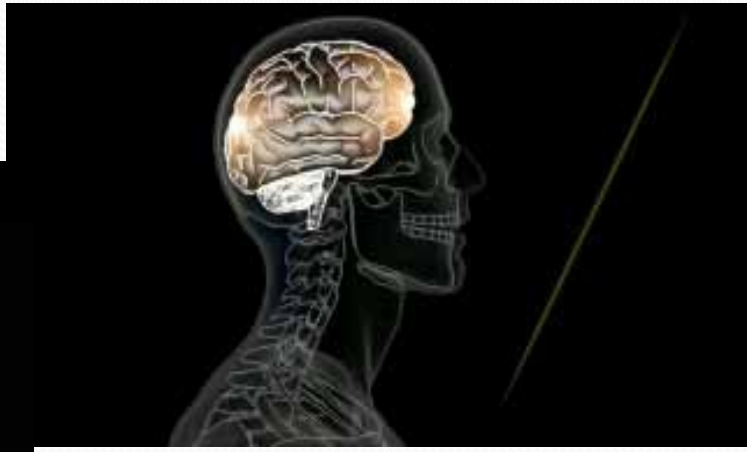
Mechanism of Injury

Contact Forces

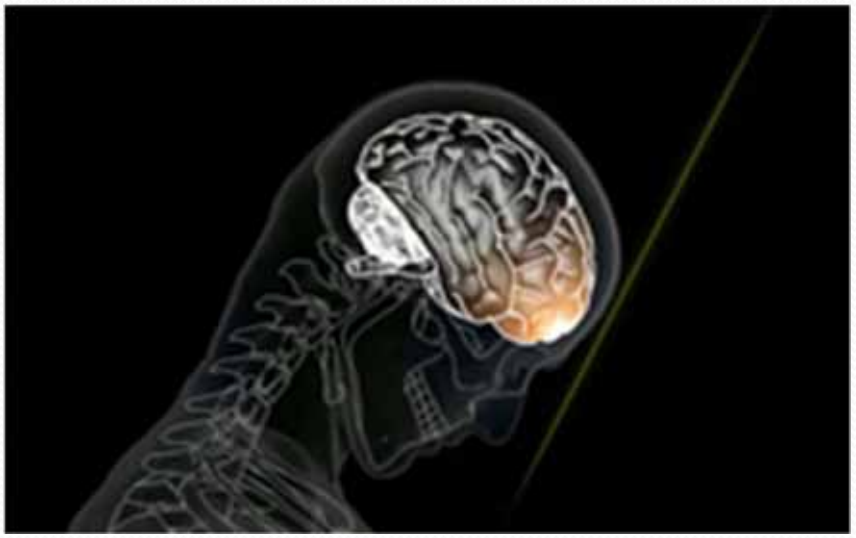
- Direct blow

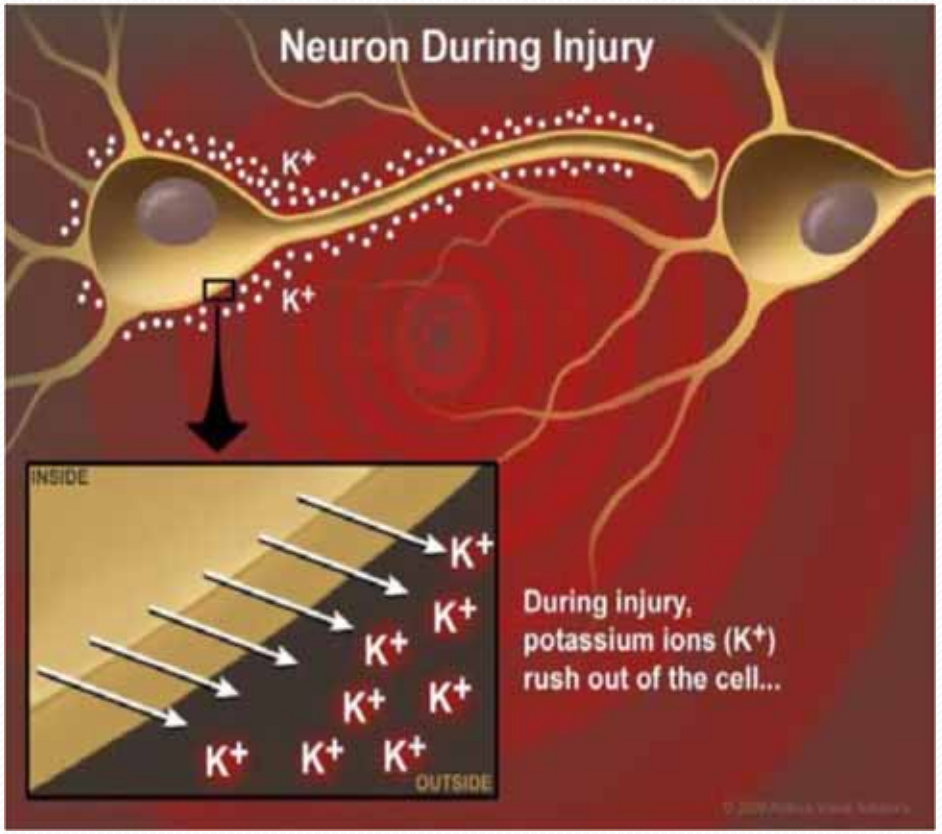
Inertial Forces

- Indirect blow
- Rotational forces
  - Damages deep white matter



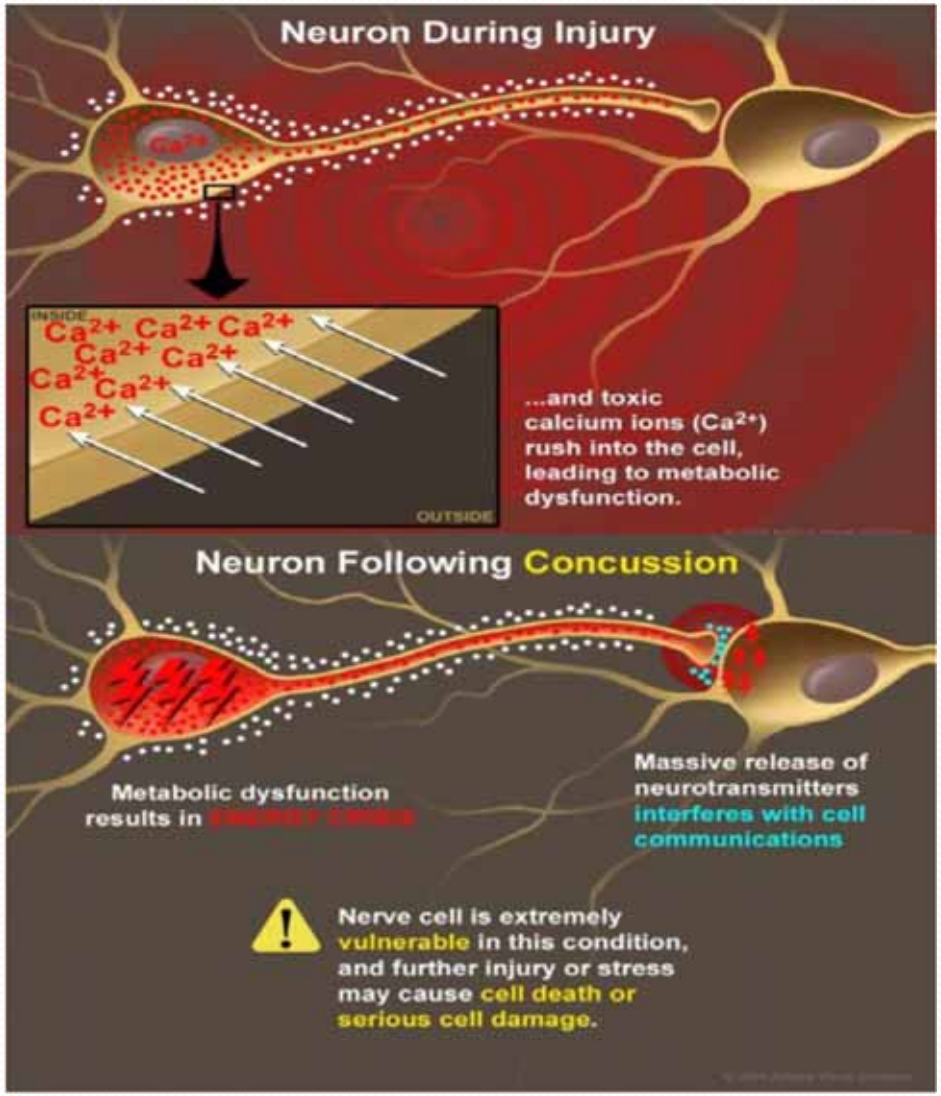
Concussion Pathophysiology





Concussion Pathophysiology

- Vestibular Impact:
  - Complex central system of small sensory inner ear organs, brain stem connections, cerebellum, cerebral cortex, ocular system , thalamus and muscles
  - Alters info related to head movement and position to maintain visual and balance control in time and space



Epidemiology

- High risk sports:
  - Football
  - Hockey
  - Lacrosse
  - Soccer
  - Cheerleading
  - Boxing

Epidemiology

- Athletes likely to sustain multiple concussions in their career
  - Kobeissy FH, editor. Brain Neurotrauma: Molecular, Neuropsychological, and Rehabilitation Aspects. Boca Raton (FL): CRC Press/Taylor & Francis; 2015.
- Gender difference
  - Kobeissy FH, editor. Brain Neurotrauma: Molecular, Neuropsychological, and Rehabilitation Aspects. Boca Raton (FL): CRC Press/Taylor & Francis; 2015.
  - Females are likely to take longer to recover and more likely to have sxs lasting more than 1 month
    - Iverson GL, Gardner AJ, Terry DP, et al. Predictors of clinical recovery from concussion: a systematic review. Br J SportsMed. 2017;51:941–948.
  - Females may be at higher risk of a neck injury associated with a concussion in sports with similar rules as men
    - Sutton M, et al JOURNAL OF WOMEN'S HEALTH 2019 DOI: 10.1089/jwh.2018.7282

Differential Diagnosis

- Cerebral hematoma
- Skull fracture
- Drug induced
- Seizure
- Cerebral edema

How to Diagnose A Sport Related Concussion (SRC):

mild Traumtic Brain Injury (mTBI)

Preseason Screening

- "Best Practice" per NCAA
  - Symptom check list
  - Cognitive Eval
  - Balance assessment
  - Standard Concussion Assessment Tool 5th Ed. (SCAT – 5)
- Computerized Neuropsychological Test
  - Immediate Postconcussion Assessment and Cognitive Testing (ImPact)
  - Cogsport
  - Central Nervous System Vital Signs
  - Automated Neuropsychological Assessment Metrics

Transient Neurological Symptoms

- Symptoms occur with 1st 30 min to 4 hrs post injury
- Headache – most common
- Dizziness
  - Predictor of protracted recovery (> 21 dys)
- Nausea
- Vomiting
- LOC
- Slurred speech
- Decrease concentration
- Dazed
- Visual impairment
- Fatigue
- Foggy feeling
- Tinnitus
- Confusion
- Memory deficits
- Not feeling right
- Phonophobia
- Photophobia
- Mood changes

Neurobehavioral Symptoms

Somatic

- Physical changes:
  - Headache*
  - Nausea/vomiting
  - Dizziness
  - Fatigue
  - Sleep disturbance

Neuropsychiatric

- Cognitive deficits
  - Attention
  - Memory
  - Executive function
  - Depression
- Behavorial
  - Personality change
  - Depression
  - Anxiety

On-Field Assessment

- Initial observation of the athlete
- Basic Life Support protocol
- Do not move the athlete unless cleared to do so and triage plan in place
- Clear the cervical spine with questions and exam
- Eval for red flags
- Maddocks Questions – place/time/memory assessment – *Clin J Sport Med 1995*
- Glasgow Coma Scale (GCS)
- Neuro exam
- Do not remove any equipment unless trained and for airway management
- If no medical personnel immediately available, the athlete should be taken to a medical facility for urgent evaluation

Red Flags:

- Neck pain/tenderness - midline
- Double vision
- Weakness/tingling in extremities
- Severe or increasing headache
- Seizure or convulsion
- LOC
- Deteriorating cognitive function
- Vomiting
- Increasing restlessness, agitation or combativeness

Off-Field Assessment

- Includes: Sideline, emergency care facility or office settings
  - Standard Concussion Assessment Tool 5th Ed. (SCAT – 5)
  - Computerized Testing
  - Return to learning status
- Avoid oral NSAIDS until fully medically evaluated
- Monitor close over 24 – 48 hrs for deterioration

Initial Concussion Screening

Initial Concussion Screening

- SCAT 5
- Vestibular/Ocular Motor Screening (VOMS)
- Balance Error Scoring System (BESS)

Sport Concussion Assessment Tool -5th Edition (SCAT5)

- Standardized tool for concussion assessment for licensed healthcare professionals produced by the Concussion in Sport Group (CISG) in Berlin 2017
  - Concussion Recognition Tool 5 (CRT5) used for nonhealthcare individuals
- For ages 13 y.o. and older
- ***Not used as a stand*** *alone method to diagnose a concussion, measure recovery or make decisions about about RTP*
  - Davis GA, et al Br J Sports Med 2017

SCAT 5

- Step 1: Athlete background
- Step 2: Symptom evaluation (22 sxs with 0-6 severity rating with max score 132)
- Step 3: Cognitive screening (orientation, immediate memory, concentration)
- Step 4: Neurological screen (includes mBESS)
- Step 5: Delayed recall
- Step 6: Decision and score total

Child SCAT 5

- Eval ages 5 – 12
- Step 2 includes a child's report and **a parent's report** of sxs (each with 21 sxs with severety grade 0 - 3 totaling 63 points)
- Step 4 neurologic screen
  - the single leg stance for 10 – 12 y.o. only
  - If child cannot read, they can be asked to describe what they see in a picture

Vestibular/Ocular Motor Screening (VOMS)

- 5 – 10 minute symptom based set of screening tools to identify vestibular and ocular motor impairments
- Includes 5 domains:
  - Smooth pursuit
  - Horizontal and vertical saccades
  - Near point convergence (NPC) distance
  - Horizontal and vertical vestibular-oculomotor reflex (VOR)
  - Visual motion sensitivity (VMS)
- Retrospective chart review cohort study; level of evidence 2
  - 167 pediatric pts (11 – 19 y.o.)
  - Poor scores on any domains except NPC and ACCOM may predict prolong recovery
    - Anzalone AJ, et al. *Am J Sports Med*. 2017
- Vestibular and oculomotor sxs early in concussion may signal a prolonged recovery
    - Konto AP, et al 2017

VOMS

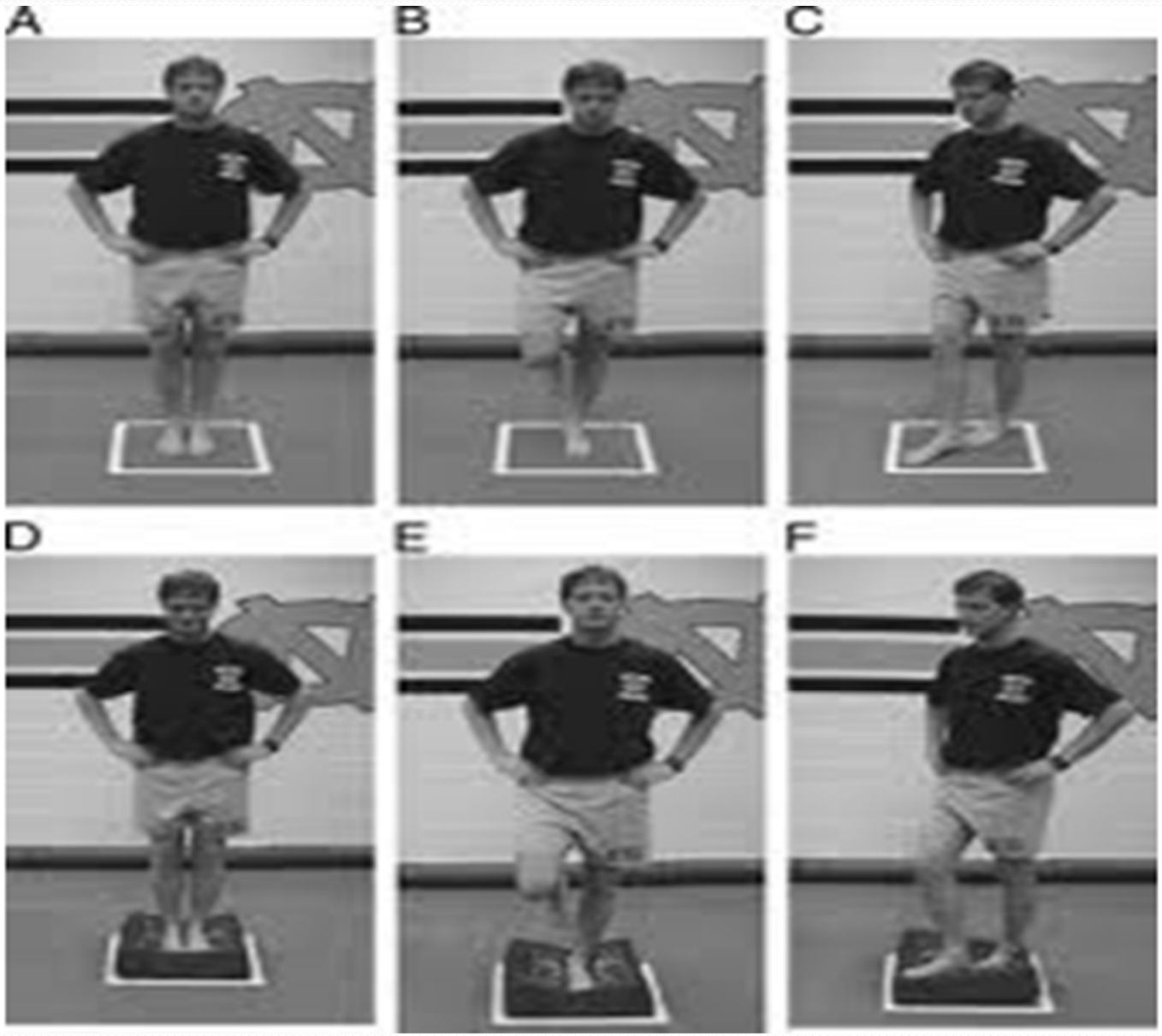
- 2014 cross-sectional study, level of evidence 2
  - Showed internal consistency and sensitivity in identifying a concussion on screening
  - 64 sport related concussed pt (13.9 ± 2.5 y.o.) vs 78 controls VOMS assess 5 domains and Post-Concussion Symptom Scale (PCSS)
  - 61% sxs provocation with 1 VOMS test
  - VOMS correlated to PCSS score
  - VOR and VMS most predictive of concussed group (odds ration {OR}, 3.89; *P* <.001 for VOR and OR 3.37; *P* <.01 for VMS group)
  - NPC distance ≥ 5 cm and any VOMS item symptom score ≥ 2 increased probability of correctly identifying concussed pt 38% and 50%, respectively
    - Mucha et al. Am J Sports Med. 2014 October ; 42(10): 2479–2486. doi:10.1177/0363546514543775.

Balance Error Scoring System (BESS)

- Quantitative measurement of postural instability to assess concussed athletes developed 1999
  - Riemann and Guskiewicz Journal of Athletic Training 2000;35(1):19-25
- Assesses vestibulospinal aspect of the vestibular system
- Consists of 6 stance conditions, each 20 seconds
  - Double leg
  - Single leg
  - Tandem
- Nondominant leg used
- Eyes closed
- Performed on both normal and medium density foam surface
- Errors:
  - Inability to maintain stance
  - Eye opening
  - Hip flexion or abduction > 30°
  - Lifting foot (toes/heels)
- Max 60 error points

Modify BESS (M-BESS)

- Assesses balance only on firm surface
- Excellent for sideline assessment
- Max score of 30 points (10 pts for each stance)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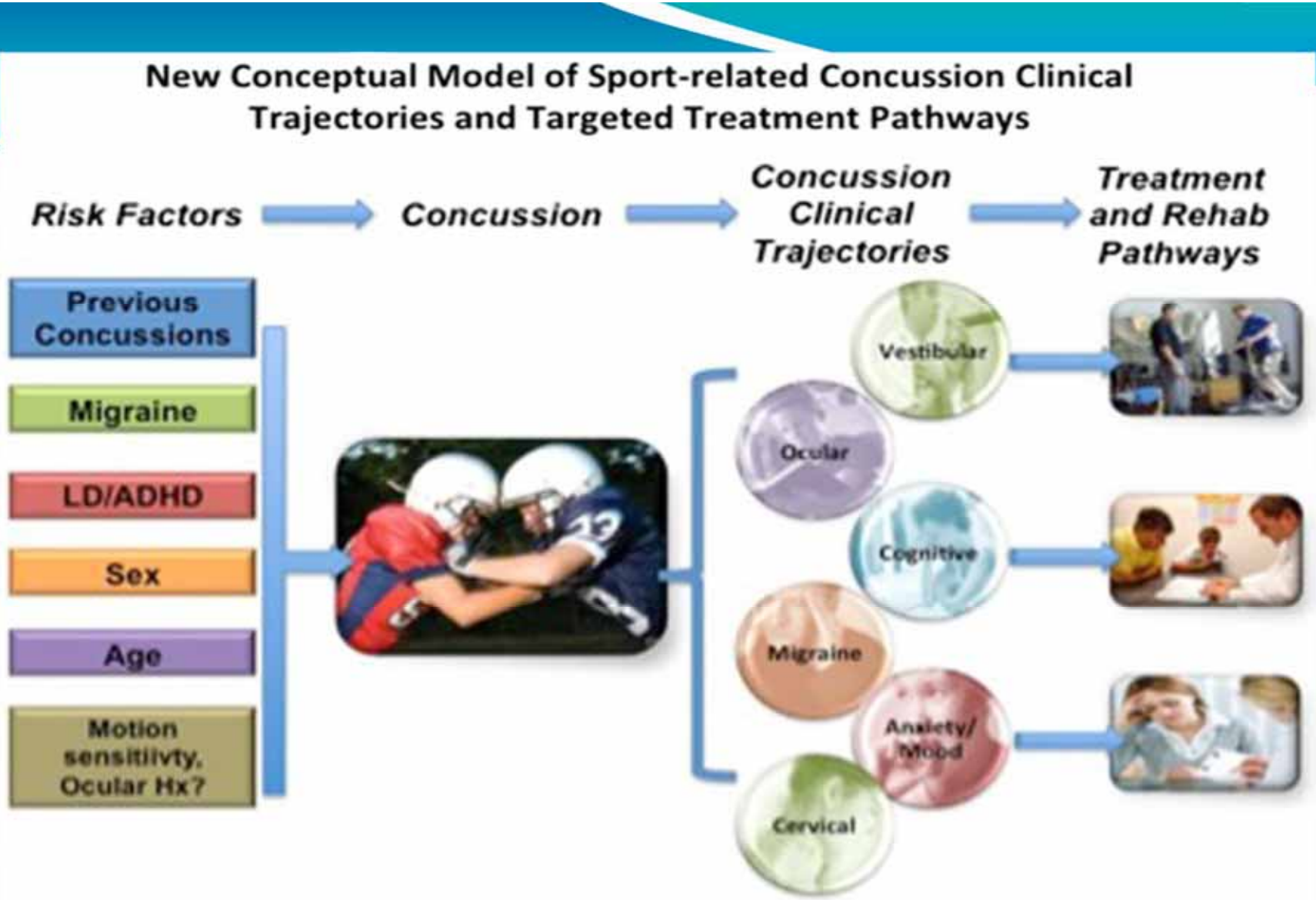
Concussion Subtypes



Collins MW, et al. Knee Surg Sports Traumatol Arthrosc 2013

Sports Related Concussions Subtypes

- Vestibular-spinal (postural/balance)
- Oculomotor (visual stability)
- Cognitive-fatigue
- Anxiety-mood
- Post-traumatic headache/migraine

- Can occur concomitantly or independent – not mutually exclusive
- Subtype predominance may change
- Associated conditions:
  - Cervical strain
  - Sleep disturbance
- Treatment specific

Headache/Migraine Subtype

- Most prevalent (0.52; 95% CI=0.37, 0.67)
  - Lumba-Brown, et al 2020
- Can involve different types of headaches with migraine
- Can worsen preexisting headache frequency and severity
- Consideration being considered for refine classification within subtype – i.e. migraine vs nonmigraine subtype
- Nausea
- Vomiting
- Light, sound and smell sensitivity

Vestibular Subtype

- Complex central system of small sensory inner ear organs, brain stem connections, cerebellum, cerebral cortex, ocular system , thalamus and muscles
- Provides info related to head movement and position to maintain visual and balance control in time and space
- Sxs highly prevalent in concussions
  - 23% - 81% dizziness first days of injury
    - *JNPT* 2010;34: 87–93
  - Highly prevalent in pediatric group
- Includes: vestibul-ocular (VOR and VMS), vestibulo-spinal(balance) and gait dysfunction

- Dizziness
- Fogginess
- Lightheadedness
- Nausea
- Vertigo
- Disequilibrium
- Impaired balance
- Associated with:
  - Diminished verbal memory
  - Diminished processing speed
  - Diminished reaction time

Oculo-motor (Visual) Subtype

- Up to 45% of SRC athletes may experience convergence insufficiency (CI)
  - Konto AP, et al 2017
- CI may be associated with increased cognitive impairment and prolong recovery
  - Pearce KL, et al 2015
- Can lead to impaired academic performance

- Blurred vision
- Diplopia
- Difficulty reading
- Eyestrain (asthenopia)
- Photophobia
- Headache
- Dizziness
- Poor vision concentration
- Nausea

Anxiety-Mood Subtype

- Pre existing conditions may predispose/contribute to this subtype
- Aggravated by social isolation and decrease physical activity
- May occur in 1/3 of adults and children within 3 days post concussion
  - Lumba-Brown, et al 2020

- Increased:
  - Anxiety/nervousness
  - Feeling more emotional
  - Hypervigilance
  - Ruminative thoughts
  - Feelings of being overwhelmed
  - Depressed mood/sadness
  - Anger
  - Hostility/irritability
  - Loss of energy
  - Fatigue
  - Feeling of hopelessness

Cognitive-Fatigue Subtype

- Deficits in testing
- Can have exacerbation of preexisting of cognitive dysfunction
- Impaired:
  - Attention
  - Reaction time
  - Speed of processing/performance
  - Working memory
  - New learning
  - Memory storage and retrieval (amnesia)
  - Organization of thoughts

Concussion-Associated Conditions

Cervical Strain

- Share common MOI to concussion
- Occipital headache
- Neck stiffness, weakness
- Occurs with other concussion sxs
- Injury to the neck can affect vestibular pathways to the brain

Sleep Disturbance

- Difficulty initiating and/or maintaining quality sleep
- Does not occur in isolation of other concussion sxs
- May affect recovery
- Can lead to fatigue, daytime drowsiness and tiredness

Neuroimaging

Neuroimaging

- Reserved for deteriorating neurological sxs or another diagnosis being considered, GSC < 13
- Non – contrast CT
  - Test of choice for acute eval to assess for intracranial bleed or fracture
- Magnetic Resonance Imaging
  - Usually reserve for persisting postconcussion sxs

Evidence-Based Treatment Options

Evidence-Based Treatment Options

- Vestibular and Visual Rehab
- Exercise
  - Exertional assessments using self reported sxs, HR and BP measures
  - Emerging evidence suggests safe and effective in treatment
- Physical Therapy:
  - Manual Therapy
  - Neck Rehab
  - Active Rehabilitation
    - *J Orthop Sports Phys Ther. 2020;50(4):CPG1-CPG73. doi:10.2519/jospt.2020.0301*
- Pharmacological Treatment
- Diet/Nutrition
- Education and Reassurance

Vestibular and Visual Rehab

- There has been increasing interest in the use of vestibular rehabilitation for the treatment or management of patients with vestibular dysfunction
  - Chang 2008; Giray 2009; Hoffer 2011
- The original protocols by Cooksey and Cawthorne used group activities in a hierarchy of difficulty to challenge the central nervous system
  - (Cooksey 1946)

Vestibular and Visual Rehab

- Addresses dizziness and visual/gaze dysfunction leading to trouble with postural stability, memory and concentration
- Step wise progression of provocative stimuli in an expose-recover manner to restore normal function of balance and vision
- Involves challenging the visual, somatosensory and vestibular systems
- *Vestibular rehabilitation should be considered in the management of individuals post concussion who have dizziness, gait and balance dysfunction that do not resolve with rest.*

  - Alsalaheen BA, et al. Bestibular Rehabilitaion for Dizziness and Balance Disorders After Concussion. *JNPT* 2010;34: 87–93. DOI: 10.1097/NPT.0b013e3181dde568.

Vestibular and Visual Rehab

Postconcussion Complaints

- Benign Paroxysmal Positional Vertigo (BPPV)
- Vestibulo-ocular reflex (VOR) impairment
- Visual motor sensitivity
- Balance impairment
- Cervicogenic dizziness
- Exercise induced dizziness

Rehab Intervention

- **BPPV:** Dix-Hallpike/Roll test
- **VOR:** Adaptation exercises
- **Visual motor sensitivity:** gradual and systemic exposure to provocative stimuli focused on graded exercises for visual, somatosensory and vestibular rehab
- **Cervicogenic dizziness:** treat underlying muscle injury
- **Exercise induced dizziness:** treatment controversial

Ocular Therapy for mTBI

- Goal:
  - Non-surgical therapy for ocular muscle dysfunction
  - Can improve reading function
- Addresses convergence insufficiency, accommodative insufficiency, impaired version movements and minor ocular misalignments
- Involves use of eye patches, penlights, mirrors, lenses, prisms alternating monocular and binocular actions
- Limited empirical data for support of VT
  - 2011 Cochran review, Scheiman 2011a and 2011b
  - Ciuffreda, et al 2008
  - Thiagarajan, et al 2014
- Home software programs can be purchased

Exercise

- Rest, rest and more rest…Oh Wait!…Exercise!
  - "Rest is Best" concept
    - "The concept of physical and cognitive rest as the cornerstone of concussion management was developed…by the International Concussion in Sport Group…"
      - Broglio, SP, et al. *Clin Sports Med*. 2015 April ; 34(2): 213–231. doi:10.1016/j.csm.2014.12.005.
    - Related to vulnerable period early after a concussion, but extended to postconcussive period as well
    - Insufficient evidence that rest promotes recovery
      - CISG-5 2017
- Oh Wait!…Exercise!
  - RTC trial showed strict rest beyond 2 days prolonged recovery
    - Kozlowski KF, Graham J, Leddy JJ, et al. Exercise intolerance in individuals with postconcussion syndrome. *J Athl. Train.* 2013; 48; 48:627-35
  - Reduced physical activity is detrimental to the athletes mental health
    - Thomas DG, et al. 2015

What Constitutes Rest?

- Based on expert consensus
  - 24 – 72 hrs
- No agreement/No prospective RTC trials
- "Shut down" or "Dark Closet"
  - Restriction from all physical and cognitive activity until symptoms resolve

Exercise

- What is the proper dose of “prescribed exercise” and type of exercise for each individual?
  - Subthreshold aerobic exercise
    - Leddy JJ, Kozlowski K, Donnelly JP, et al 2010
  - Unforced, voluntary exercise vs forced exercise
    - Influence on brain-derived neurotrophic factor (BDNF) levels
      - Griesbach GS, et al 2014; Griesbach GS, et al 2012

Exercise

- The Buffalo Concussion Treadmill Test (BCTT)
  - "*A systematic and reliable method to determine the symptom-exacerbation exercise threshold in concussed patients*"
    - Leddy JJ, Baker JG, Kozlowski K, et al. Reliability of a graded exercise test for assessing recovery from concussion. Clin. J. Sport Med. 2011; 21:89Y94.Epub 2011/03/02. doi: 10.1097/JSM.0b013e3181fdc721 00042752-201103000-00003 [pii]. PubMed PMID: 21358497.36.
  - Gives specific goals to achieve without focus on speed to recovery
  - Does not increase sxs the day post test or delay recovery when stop criteria are followed
- The Buffalo Concussion Bike Test (BCBT)
  - Based on stationary bike resistance required to achieve an equivalent VO_2 for each treadmill stage

Exercise

- BCTT/BCBT exercise prescription:
  - Submaximal symptom exacerbation threshold determined
  - Prescribed exercise starts with bike for 1 week, treadmill for 20 min/dy 6-7 dys/wk at 80-90% of threshold HR
  - Exercised stopped at first sign of sxs exacerbation based on 2 pt increase from preexercise baseline
  - Recovery goal reached at ≥80% of max. HR for 20 min multiple days without sxs aggravation

Manual Therapy and Neck Rehab

- Concussion injuries are associated with neck strains("whiplash")
  - Canadian study suggest 100% of the time
  - Cross over sxs between concussion and neck strain
  - Atlanto-occipital joint dysfunction can cause headache and neurological symptoms
- 70-120 G's($9.8 m/s^2$) vs 4.5G's
- 2nd CISG Consensus Statement
- Incooperating neck rehab with VRT has been shown that pts do better within 8 weeks of treatment

- Diaz DS. Management of athletes with postconcussion syndrome. Semin Speech Lang. 2014;35(3):204–210.

Pharmacology Treatment

- OTC meds most common for nonspecific treatment
- For prolong symptoms meds usually started about day 10
    - Giza, et al. Neurology, 2013
- No FDA-approved med for sport related concussion
- Most athletes recover from concussions, therefore need to weigh risk vs benefits with pharmacological treatment

Specific Pharmacologic Treatment

- Tricyclic antidepressant
  - Amitriptyline
  - Treat anxiety/mood subtype
- Selective Serotonin Reuptake Inhibitors (SSRI)
- Selective Norepinephrine Reuptake Inhibitors (SNRI)
- Benzodiazepines
  - Klonopine
  - Vestibular-related anxiety

Specific Pharmacologic Treatment

- Nonspecific dopamine agonists
  - Neurostimulants have helped to resolve TBI-induced cognitive-fatigue deficits
    - Methylphenidate
      - Newsome et al., 2009; Wagner et al., 2007
    - Amantadine
      - Neurostimulant
        - Dixon et al., 1999; Meythaler et al., 2002; Reddy et al., 2013
      - Facilitates dopamine release and inhibits reuptake
    - Atomoxetine

Specific Pharmacologic Treatment

- Post traumatic Migraine treatment
  - Anecdotal evidence, no empirical studies
    - Tricyclics
    - SSRI
    - Anticonvulsants
    - Beta blockers
    - Triptans
- Sleep disturbance treatment
    - Melatonin
    - Ambien
    - Lunesta
    - Amitriptyline
    - trazodone

Other Non-Pharmacologic Treatment

- May be beneficial
  - Biofeedback
  - Cognitive Behavioral Therapy

Diet/Nutrition

- Focus on anti-inflammatory properties of nutritional substances
- Avoid proinflammatory foods?
- Supplements:
  - Omega 3
  - Creatine
  - Curcumin
  - Magnesium glycinate
  - Melatonin
  - Vitamin B
  - Ketogenic diets

Mental Health Intervention

- Sport and exercise in general are protective
- Subacute headache and depression risk factors for > 1 month to recovery
- "…Ultimately, removing an athlete from sport may increase the risk for depression and other concussion-like symptoms to develop…"
  - Broglio et al. Page 3 *Clin Sports Med*. Author manuscript; available in PMC 2016 April 01.
- Requires multifactorial assessment and approach to treatment

Helmets

- Designed to prevent skull trauma and intracranial bleeding
- Some newer helmets designed to absorb more force at impact
- Sensor systems
  - Measure linear and angular force
  - Limited as force causing concussion is inconsistent amongst athletes

Biomarkers

- Level of evidence is low for using fluid (blood, cerebrospinal fluid, saliva) biomarkers
- Brain trauma biomarkers
  - FDA approved for cerebral bleeds and brain structural damage
    - Gilal fibrillary acidic protein
    - Ubiquitin carboxy-terminal hydrolase L1 (UCHL1)

Return to Play

Can I Play?

RTP criteria

- Return to learn fully implemented
- Symptom scores, at rest and with match-intensity exercise have returned to baseline levels
  - State mandated RTP protocol *successfully* completed and signed by authorized medical personnel
- Neurological examination including balance testing are normal
- Cognitive testing (computerized and/or pencil-paper) has returned to baseline or age-appropriate norms
    - Patricios IS, et al. *Br J Sports Med* 2018

Conclusions and Recommendations

- Initial Concussion Screening:
  - SCAT 5
  - VOMS
  - mBESS
- Educate regarding expected course leading to RTP
- Determine concussion subtype and associated conditions and implement appropriate treatment intervention
- Assess for anxiety, mood, and sleep disturbances in acute setting and recommend appropriate treatment
- Implement vestibular and ocular rehab
- Determine self-directed exercise threshold and progress as tolerated after 24 – 48 hrs of rest