


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



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What is a Concussion?

mild Traumatic Brain Injury (mTBI)



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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.

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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)

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Mechanism of Injury

<p>Contact Forces</p> <ul style="list-style-type: none"> • Direct blow 	<p>Inertial Forces</p> <ul style="list-style-type: none"> • Indirect blow • Rotational forces <ul style="list-style-type: none"> • Damages deep white matter 
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Concussion Pathophysiology

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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

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Epidemiology

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

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Epidemiology

- Athletes likely to sustain multiple concussions in their career
 - Kobayashi FH, editor. Brain Neurotrauma: Molecular, Neuropsychological, and Rehabilitation Aspects. Boca Raton (FL): CRC Press/Taylor & Francis; 2005.
- Gender difference
 - Kobayashi FH, editor. Brain Neurotrauma: Molecular, Neuropsychological, and Rehabilitation Aspects. Boca Raton (FL): CRC Press/Taylor & Francis; 2005.
 - Females are likely to take longer to recover and more likely to have sx's 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. 2007;91(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 2009 DOI: 10.1089/jwh.2008.728a

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Differential Diagnosis

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



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How to Diagnose A Sport Related Concussion (SRC): mild Traumatic Brain Injury (mTBI)

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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

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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

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Neurobehavioral Symptoms

<p>Somatic</p> <ul style="list-style-type: none"> • Physical changes: <ul style="list-style-type: none"> • Headache* • Nausea/vomiting • Dizziness • Fatigue • Sleep disturbance 	<p>Neuropsychiatric</p> <ul style="list-style-type: none"> • Cognitive deficits <ul style="list-style-type: none"> • Attention • Memory • Executive function • Depression • Behavioral <ul style="list-style-type: none"> • Personality change • Depression • Anxiety
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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

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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

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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


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Initial Concussion Screening

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Initial Concussion Screening

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



A cartoon illustration of a pink brain with a face, wearing blue pants and green and white sneakers. The brain has its hands on its head, appearing to be in pain or distress.

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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 RTP**

• Davis GA, et al Br J Sports Med 2017

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SCAT 5



- Step 1: Athlete background
- Step 2: Symptom evaluation (22 sx's 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

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Child SCAT 5

- Eval ages 5 - 12
- Step 2 includes a child's report and a **parent's report** of sx's (each with 21 sx's with severity 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

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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 prolonged recovery
 - Anzalone AJ, et al. *Am J Sports Med.* 2017
- Vestibular and oculomotor sx's early in concussion may signal a prolonged recovery
 - Konto AP, et al 2017

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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 ratio (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.

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Balance Error Scoring System (BESS)

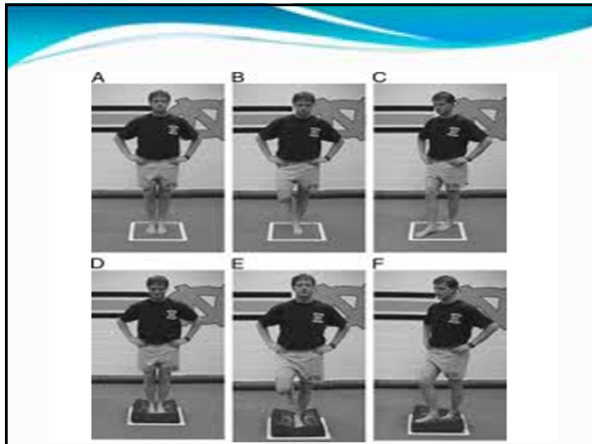
- Quantitative measurement of postural instability to assess concussed athletes developed 1999
 - Riemann and Guskiewicz Journal of Athletic Training 2000;35(1):19-25
- Assesses vestibulospinal aspect of the vestibular system
- Consists of 6 stance conditions, each 20 seconds
 - Double leg
 - Single 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 $> 30^\circ$
 - Lifting foot (toes/heels)
- Max 60 error points

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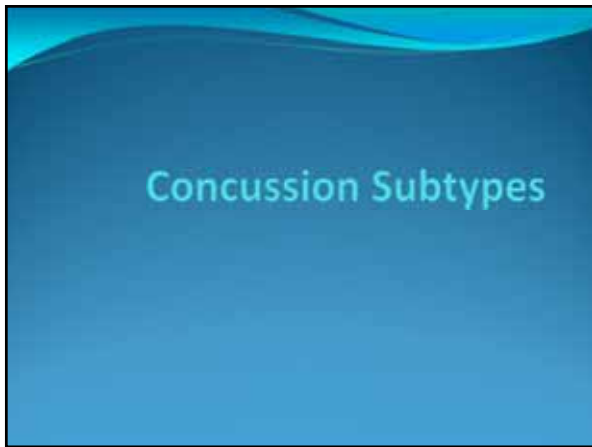
Modify BESS (M-BESS)

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

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

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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

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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

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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

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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

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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

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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

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Concussion-Associated Conditions

Cervical Strain	Sleep Disturbance
<ul style="list-style-type: none">• Share common MOI to concussion• Occipital headache• Neck stiffness, weakness• Occurs with other concussion sx• Injury to the neck can affect vestibular pathways to the brain	<ul style="list-style-type: none">• Difficulty initiating and/or maintaining quality sleep• Does not occur in isolation of other concussion sx• May affect recovery• Can lead to fatigue, daytime drowsiness and tiredness

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Neuroimaging

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Neuroimaging

- Reserved for deteriorating neurological sx 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 sx

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Evidence-Based Treatment Options

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- ### Evidence-Based Treatment Options
- Vestibular and Visual Rehab
 - Exercise
 - Exertional assessments using self reported sx's, 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. 2010;39(4):CPG6-CPG73. doi:10.2519/jospt.2010.0391
 - Pharmacological Treatment
 - Diet/Nutrition
 - Education and Reassurance

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- ### 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)

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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.*

• Alshalheen BA, et al. Vestibular Rehabilitation for Dizziness and Balance Disorders After Concussion. *JNPT* 2010;34: 87-93. DOI: 10.1097/NPT.0b013e3181d4e568.

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Vestibular and Visual Rehab

<p>Postconcussion Complaints</p> <ul style="list-style-type: none"> • Benign Paroxysmal Positional Vertigo (BPPV) • Vestibulo-ocular reflex (VOR) impairment • Visual motor sensitivity • Balance impairment • Cervicogenic dizziness • Exercise induced dizziness 	<p>Rehab Intervention</p> <ul style="list-style-type: none"> • 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
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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

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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
 - Kozłowski 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

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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

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Exercise

- What is the proper dose of “prescribed exercise” and type of exercise for each individual?
 - Subthreshold aerobic exercise
 - Leddy JJ, Kozłowski 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

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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 JC, Kozlowski K, et al. Reliability of a graded exercise test for assessing recovery from concussion. Clin J Sport Med. 2006; 21:893-94. Epub 2006/10/01. doi: 10.1097/JSM.0b013e318016167a. 16642775-10000-00001 [pii]. PubMed PMID: 17194477-98.
 - Gives specific goals to achieve without focus on speed to recovery
 - Does not increase sx's 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 VO₂ for each treadmill stage

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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 sx's exacerbation based on 2 pt increase from preexercise baseline
 - Recovery goal reached at ≥80% of max. HR for 20 min multiple days without sx's aggravation

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Manual Therapy and Neck Rehab

- Concussion injuries are associated with neck strains (“whiplash”)
 - Canadian study suggest 100% of the time
 - Cross over sx's between concussion and neck strain
 - Atlanto-occipital joint dysfunction can cause headache and neurological symptoms
- 70-120 G's (9.8m/s²) 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.

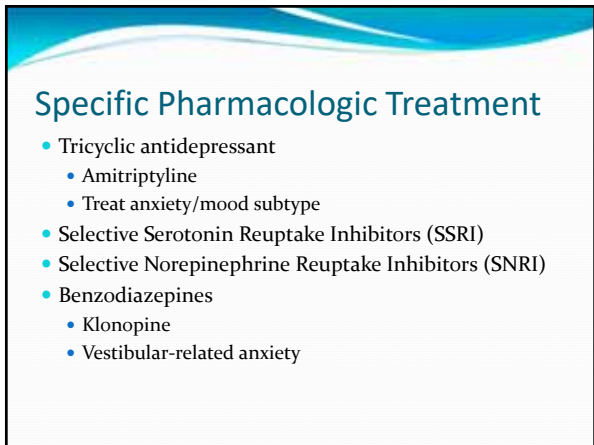
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Pharmacology Treatment

- 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

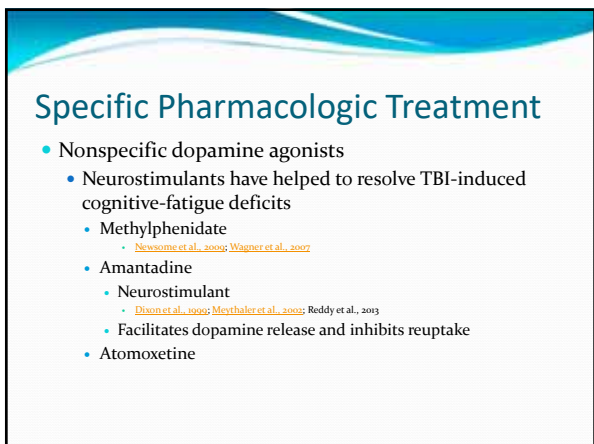
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Specific Pharmacologic Treatment

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

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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., 2009; Meythaler et al., 2009; Reddy et al., 2003
 - Facilitates dopamine release and inhibits reuptake
 - Atomoxetine

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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

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Other Non-Pharmacologic Treatment

- May be beneficial
 - Biofeedback
 - Cognitive Behavioral Therapy

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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

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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

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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

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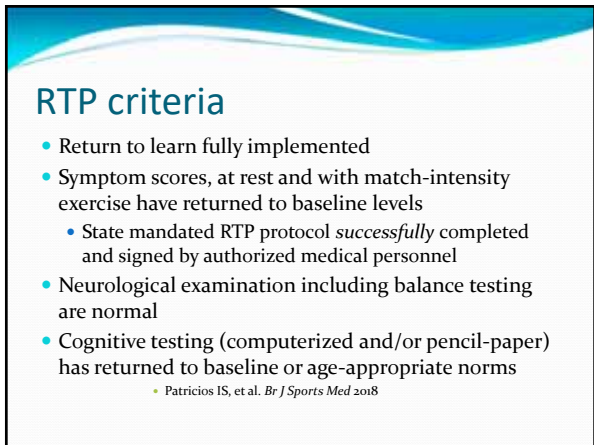
Biomarkers

- 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
 - Gial fibrillary acidic protein
 - Ubiquitin carboxy-terminal hydrolase L1 (UCHL1)

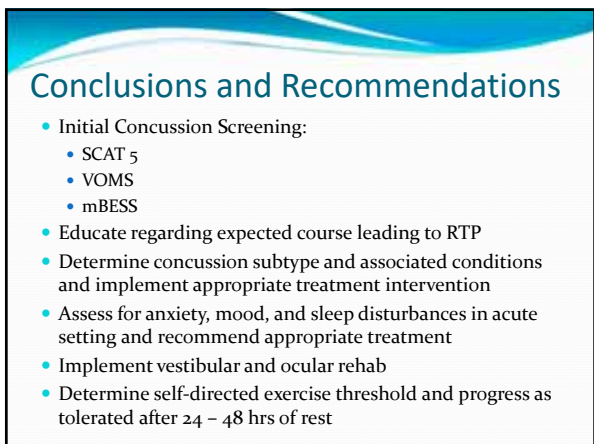
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