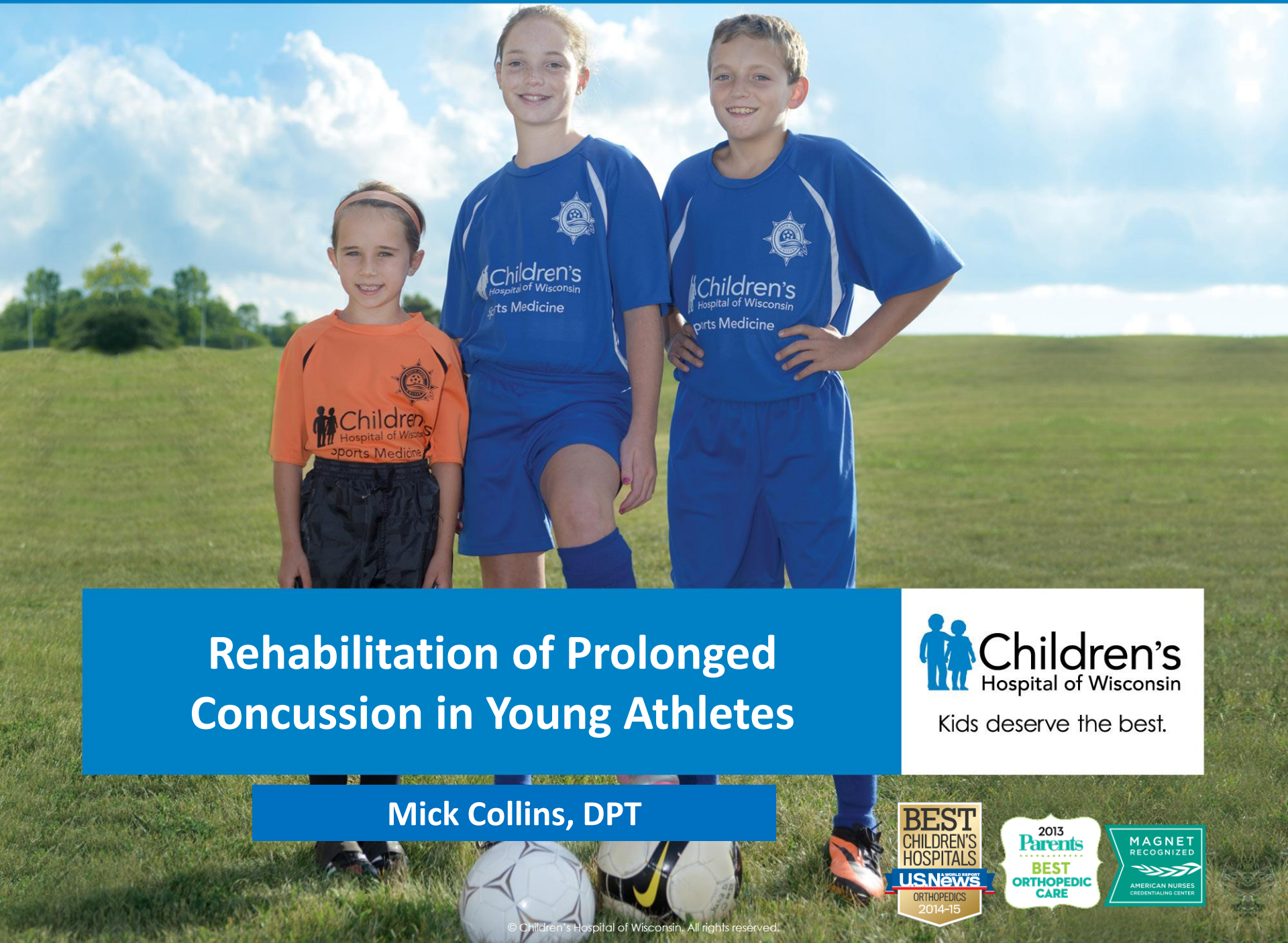

Rehabilitation of Prolonged Concussion in Young Athletes

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Mick Collins, DPT

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Disclosure

- Nothing to disclose
- I have no financial relationships with any entities mentioned in this talk

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Objectives

- Upon completion of this course you will be able to:
  - Explain the epidemiology and pathophysiology of a concussion and identify factors that may put a patient at risk for prolonged recovery
  - Screen, assess and ultimately classify patients with symptoms consistent with post-concussion syndrome into sub-groups in order to direct and optimize treatment.
  - Discuss evidence based management and treatment for patients diagnosed with post-concussion syndrome targeting vestibular/ocular motor dysfunction, cervicogenic pain, exercise intolerance and psychological co-morbidities.
  - Appreciate the role of neuropsychological assessment and cognitive behavioral therapy in the treatment of the complex concussion patient.
  - Understand the evidence regarding methods to reduce the prevalence of pediatric sports related concussion.

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Evidence Based Medicine

"Evidence based practice is the integration of (1) clinical experience and expertise, (2) patient values, and (3) best evidence (research) into the decision making process for patient care"

Sackett et al, 2004

Children's Hospital of Wisconsin Comprehensive Sports Concussion Program

- Medical Lead – Kevin Walter, MD
- Neuropsychology Lead – Jennifer Apps, PhD
- Psychology Lead – Matt Myrvik, PhD
- Rehabilitation Lead – Mick Collins, PT, DPT
- Athletic Trainer Lead – Trina Hoffman, MS
- Research Lead – Mike McCrea, PhD

Access

- Concussion Line: 414-337-8000
- CHW-Greenfield Clinic
  - Psychology and Neuropsychology
- CHW-Mequon Clinic
- CHW-Delafield Clinic

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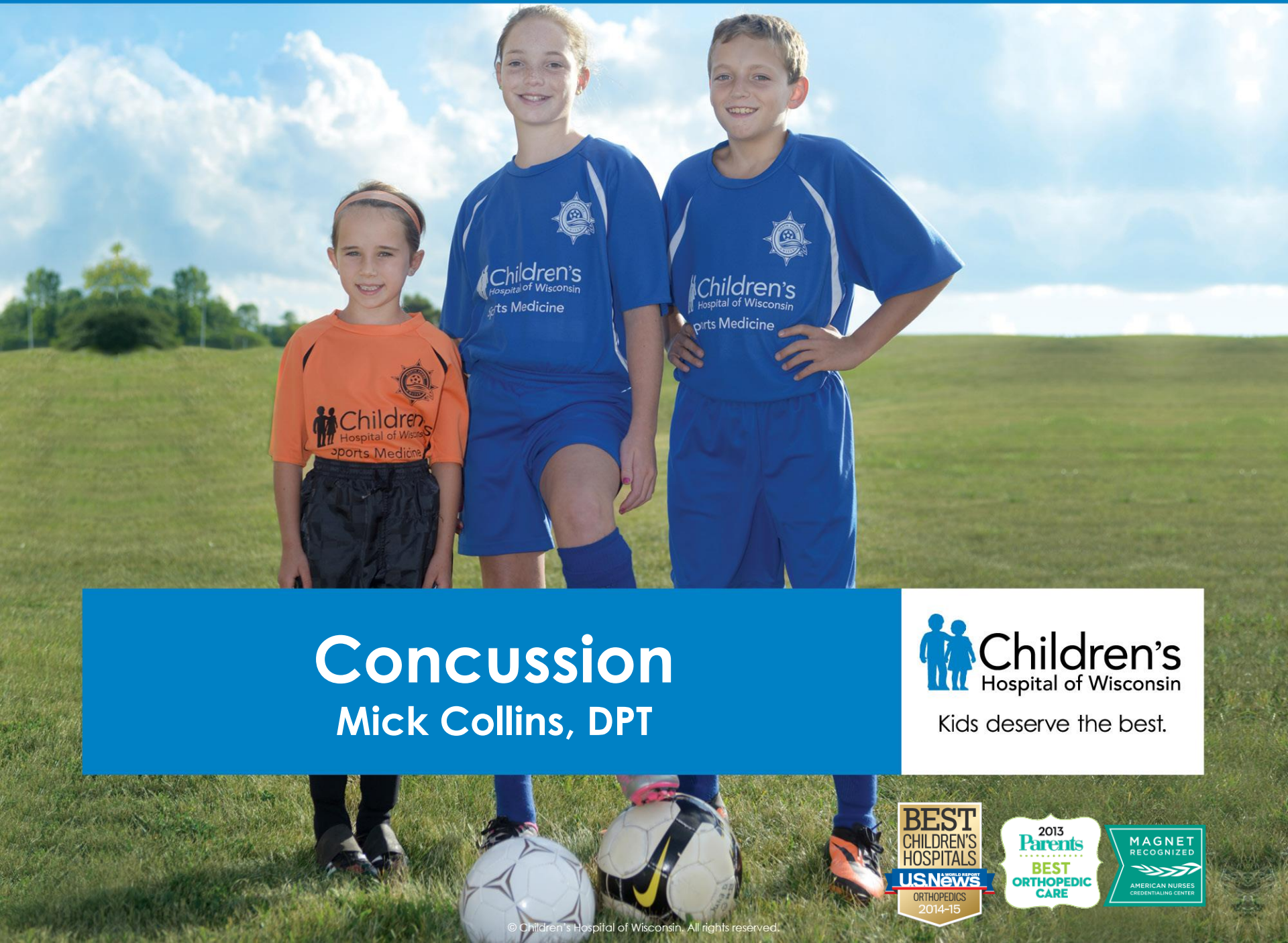
Our Team

- Physicians
  - Kevin Walter; Shayne Fehr; Kim Hornbeck; Patrick Lehman
- Neuropsychologists
  - Jennifer Apps; Michelle Loman; Mike McCrea
- Physical Therapists
  - Mick Collins; Renee Hecker; Erin Meyer; Rob Hofschulte; Erin Fifrick
- Psychologists
  - Matt Myrvik; Kristin Hoff

Research Team

- MCW Neurosciences
  - Mike McCrea; Tim Meier; Lyn Nelson; et al.
- CHW-MCW Emergency Medicine
  - Danny Thomas, MD



Concussion

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Mechanism of Injury

- Can occur from either a direct hit to the head or an indirect hit to the body that transmits force to the head
- Loss of consciousness is not necessary for diagnosis and does not necessarily indicate a more severe injury or prolonged recovery

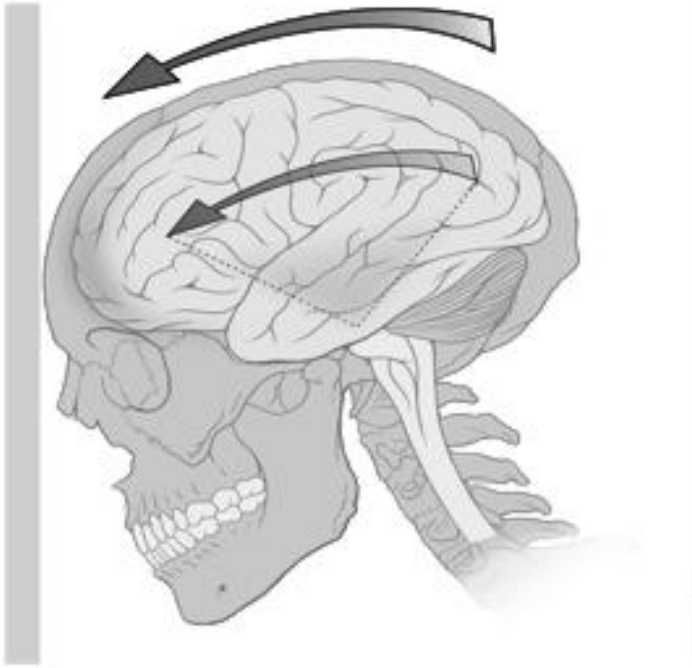

Image - http://en.wikipedia.org/wiki/Concussion

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Pathophysiology of a Concussion

- Linear and rotational acceleration-deceleration forces are transmitted to the brain, causing axonal stretching
- Results in a neurometabolic dysfunction within the neuron cell bodies and axons
  - Cell membrane homeostasis is disrupted
  - Dysregulation of the ion channels
  - Abnormal excitation and depolarization within the brain
  - Lactic acid accumulation

Giza & Hovda 2001

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Acute Evaluation - Signs

- Loss of consciousness
- Confused / dazed
- Behavior /personality changes
- Glassy eyed
- Repeats questions
- Answers questions slowly

Evaluation: Symptoms

Cognitive	Physical	Emotional	Sleep
Confusion	Headache	Irritable	Hard to fall asleep
Disoriented	Nausea/Vomit	Sad	Wakes at night
Amnesia	Dizzy	Nervous	More fatigued
Distractible	Fatigue	Mood swings	
"Foggy"	Vision changes	More emotional	
Slow response	Photo/phono phobia		
	Numbness / tingling		

Commonly Reported Symptoms

High school & collegiate athletes - within 3 days of injury

# 1	**Headache**	71-90 %
# 2	**Feeling slowed down**	58 %
# 3	**Difficulty concentrating**	57 %
# 4	**Dizziness**	55-70 %
# 5	**Fogginess**	53 %
# 6	**Fatigue**	50 %
# 7	**Visual Blurring/double vision**	49 %
# 8	**Light sensitivity**	47 %
# 9	**Memory dysfunction**	43 %
#10	**Balance problems**	43%

AMNESIA (anterograde or retrograde)	30%
LOSS OF CONSCIOUSNESS (usually brief)	<10%

Evaluation – Physical Exam

- ABC's (airway, breathing, circulation)
- Assess neck
  - LOC is assumed c-spine injury
- Complete neurologic exam
- SCAT5 – orientation, memory, concentration, cognition
- Balance & coordination testing

Longer Recovery for Adolescents?

- McClincy 2006: 26% HS reported asymptomatic but still neurocognitive deficits
- McCrea - 80% take 2 weeks to recover
- Lovell 2009: 1 of 4-5 teens with symptoms over 1 month
- Barlow 2010: 14% of teens/preteens have symptoms over 3 months
- Kerr 2016: Return to play in >30 days
  - Youth 16.3%
  - HS 19.5%
  - College 7%
  - HS = highest symptom load reporting
- Increased risk for prolonged recovery (Gioia 2008)
  - ADD
  - Chronic HA or migraines
  - Learning Disorder
  - Sleep disorder
  - Seizure disorder
  - Psych (anxiety/depression)
  - Repeat concussion
- Symptoms associated with prolonged recovery???
  - Dizziness
  - Significant cognitive dysfunction
  - Persistent fogginess
  - 2016 Fehr data

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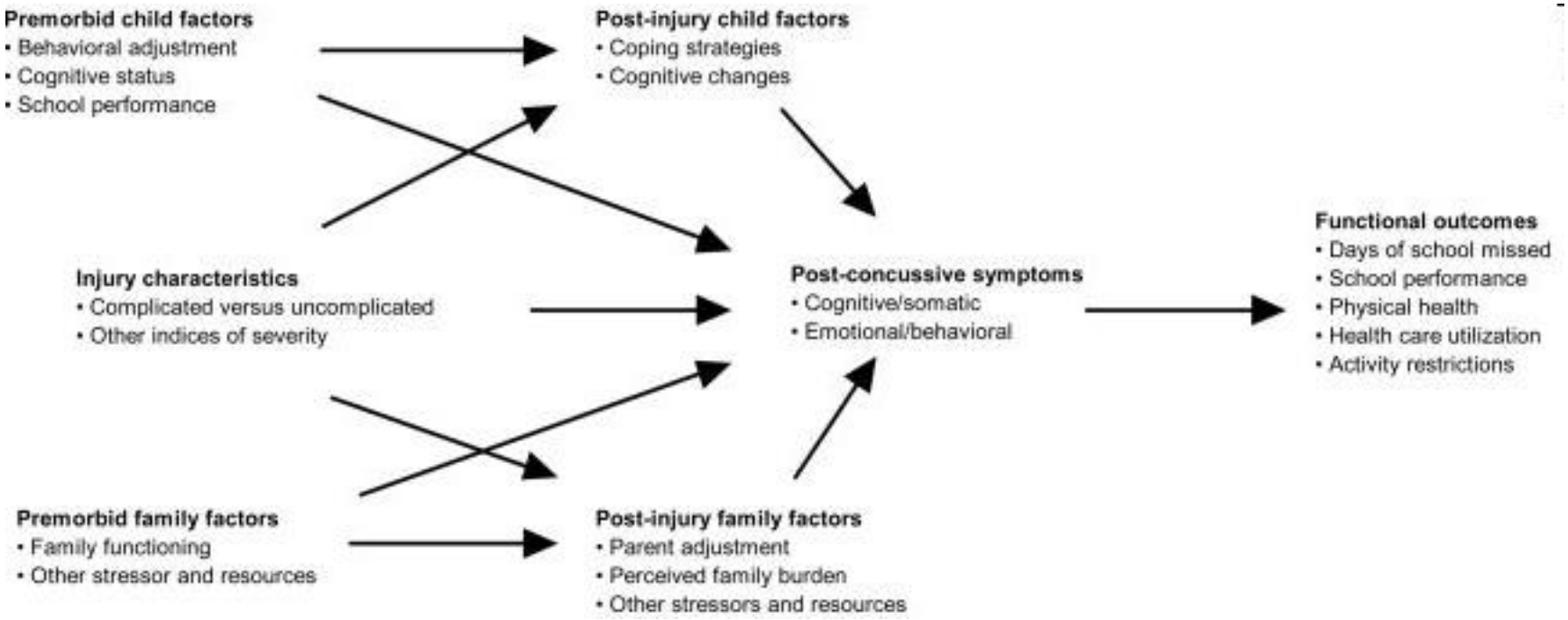
What Influences Recovery?



When to Refer?

- All suspected concussions require medical evaluation & clearance
- Any concussion >10-14 days
- Any athlete with >2 concussions
- Comorbidities
- High pressure families
- History of prior prolonged or difficult recovery

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Injury Management

- When in doubt, hold them out
- They often look “normal”
- No same day return to play
- Never return with symptoms
- All concussions need follow-up care

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Injury Management

- Communicate with coaches & other HCP's
- Recheck frequently – may worsen
  - Never allow athlete to be alone immediately post-injury
- Always speak with caregiver / parents
  - No driving home
  - No after game dance or parties
- Go home to sleep
  - If worried enough to consider waking – send to ER

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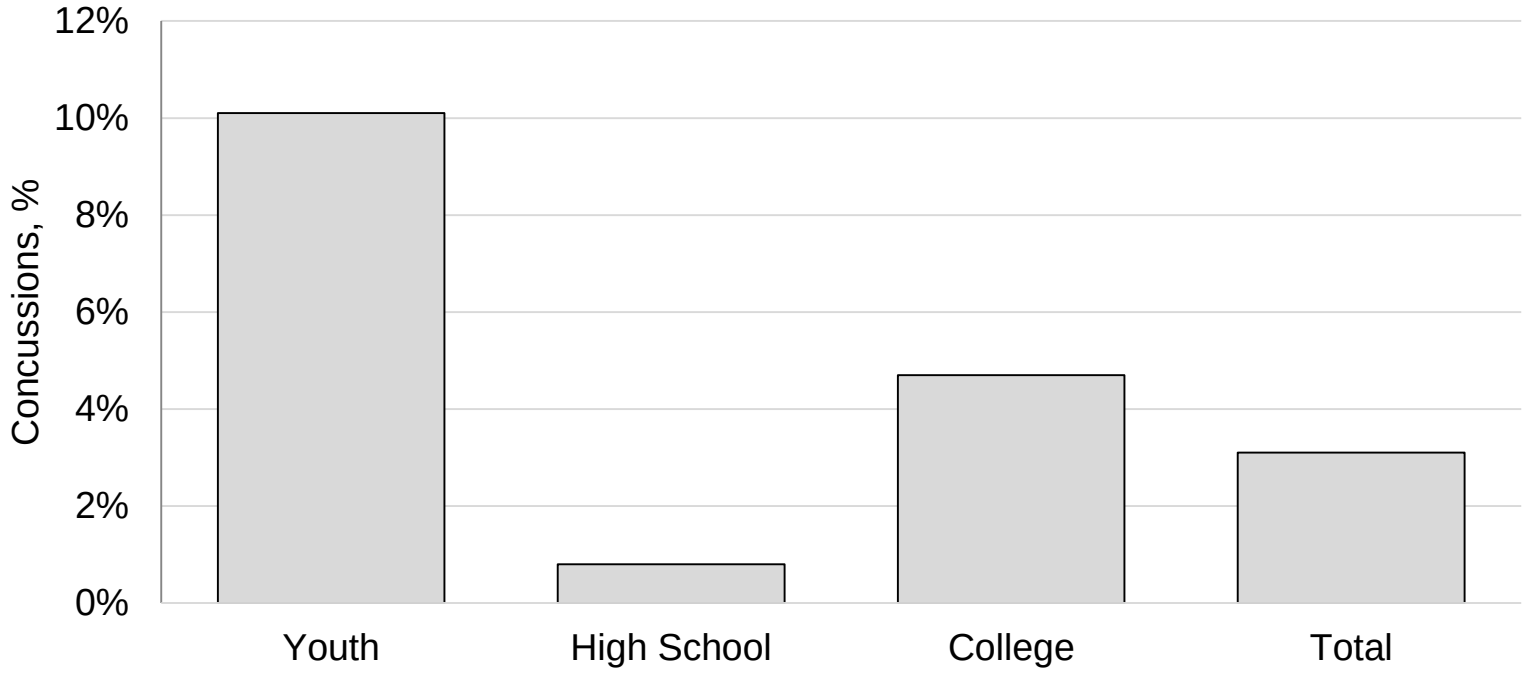
Initial Management

- Rest – physical, cognitive, emotional
- Avoid stimulating environments – e.g. watching practice/games, hallways at school, shopping
- Sensory overload – sensory "filter" not working
- Avoid screen time – phone, computer, TV
- May consider holding from class or tests and quizzes
- Hold from sport or exercise until symptom free > 24 hours – THEN may begin return to play protocol

2016 Kerr Bad News

- 3.1% of concussions resulted in return to play in <24 hours.



Percentage of concussions in youth, high school, and college football with return-to-play time <24 hours, 2012 to 2014 seasons

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Emergency Department?

- Comfort level
  - With injury, patient, parents/caregivers, follow-up care
  - Environmental concerns & psychosocial issues
- LOC = c-spine immobilization
- Abnormal neurologic exam
- Worsening symptoms or function
- Seizure activity
- Repeated emesis
- SEND WITH INFORMATION

Neuroimaging?

- In the hours after an injury if: (CT scan <6h, but reality is more like 48h)
  - Worsening symptoms
  - Declining level of consciousness
  - Worsening amnesia
  - Progressive balance disturbance
  - Focal neurologic deficits
  - *Worry about increased future cancer risk

- Later if: (MRI)
  - Lack of improvement
  - Worsening symptoms
  - Concern for other etiology

How much rest?

- 88 patients through ED (11 to 22y)
  - "Strict rest" for 5 days (no school, work or activity) n=45
  - "Usual care" 1-2 days of rest n=43
- Keep activity & symptom diary
  - Calculate energy exertion
  - Record daily postconcussive symptoms
- BESS and ImPACT 3 & 10 days post injury

Thomas DG, Apps JN, et al. Pediatrics 2015

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How much rest?

- Both groups reported 20% decrease in physical activity & energy expenditure
- Strict rest reported more missed school days 5 to 2
- No clinically significant difference in neurocognitive or balance outcome at days 3 & 10
- The “strict rest” group report more daily symptoms & slower symptom resolution

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How much rest?

- Period of rest is often defined as "until asymptomatic" which is fraught with inconsistencies
  - Relying on subjective symptom reports
  - Symptoms after head injury are not specific to the brain (e.g. cervical spine)
  - Can be interpreted differently (strict bedrest vs relative rest from intense physical activity)
- Clear that some rest, physical and cognitive, is beneficial
- Conversely too much rest may have adverse physiological and psychological consequences

Schneider, 2017

How much rest?

- "Cocoon therapy" appears to have a negative impact
  - May cause an increase in emotional symptoms
- Optimal rest is dependent on many variables
  - Initial management not determined by ED, but after a few days of rest by another capable medical provider
  - Schools need return to learn plan

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Activity

- Going for walks
- Must say no contact, low risk and no resistance training
- No observation of practice

  +/- watching games
- Individual activity is OK – but this may get abused with coaches/athletes/personal trainers

Return to Learning

- Halstead et al, 2013 Pediatrics
- School need a plan!
- Reduce workload
- Allow breaks
- No PE class
  - No music? Lunchroom?
- Adjust for visual stimulus
- Gradually increase as allowed
- Good communication between all stakeholders

What does a Concussion Plan Include?

- Absences
- Schedule of Return to Full Attendance
- Initial Return Issues
  - Schedule Modifications
  - Initial adjustments
- Active Recovery Issues
  - Longer term adjustments
  - “Make up” issues
  - Return to Play issues
- Long-term Recovery Issues

Initial Return Issues

- Allow rest
  - Planned frequent rest periods
  - Study hall or lunch, as well as shorter portions of classes if necessary
  - Regularly scheduled (not random or as needed)
  - Pass for the nurse's/quiet office if symptoms arise
- Emotional/behavioral outbursts due to mental fatigue
- "Double work"
  - Make up work/postponed testing
  - Adds to stress on return and can over-stimulate too quickly
- Postpone or eliminate standardized testing
  - Performance will be lower
  - Unnecessary stress
- Modified Schedules
  - Gym, Shop, Band, Computer classes
  - Noisy environments

"Long-term" Classroom/Work Assistance

- Be flexible with adjustments
- Follow through with adjustments
  - This requires vigilance and increased involvement
- Reassess on at least a weekly basis or more
- Return to learn prior to return to play
  - Academic adjustments means they cannot be considered symptom free

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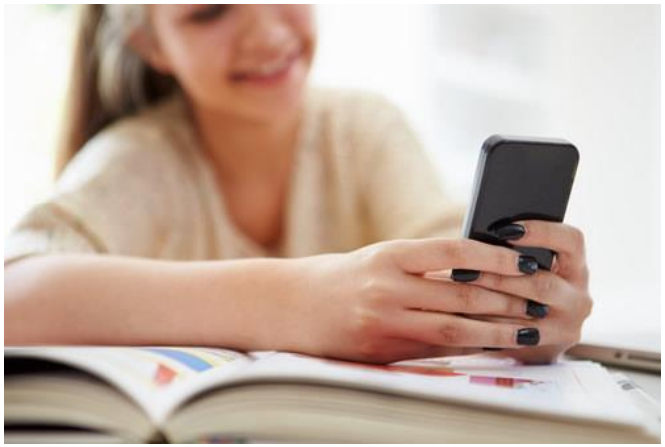
- Created online module for educators
- To be rolled out in the next 1-2 months in SE Wisconsin
- Advocate for RTL protocol in schools
  - There's one for RTP!

Home

- Good sleep
  - 8-12 hours per night
  - Sleep habits?
  - Reduce eliminate naps
- Good diet & hydration
- School first before leisure

Home

- Screens
  - Youtube + TV vs. school computer
  - Phone
  - Video games
- Keep brain occupied
- Social life & major events (wedding or homecoming)
  - Have “escape plan”



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Medications?

- No pharmacologic treatment has been shown to speed recovery
  - Medications can be used to treat symptoms of concussion
- Supplements have no research supporting benefits
- Off treating medications prior to RTP
- NSAID and ASA should be avoided in first 48-72h
  - Platelet dysfunction

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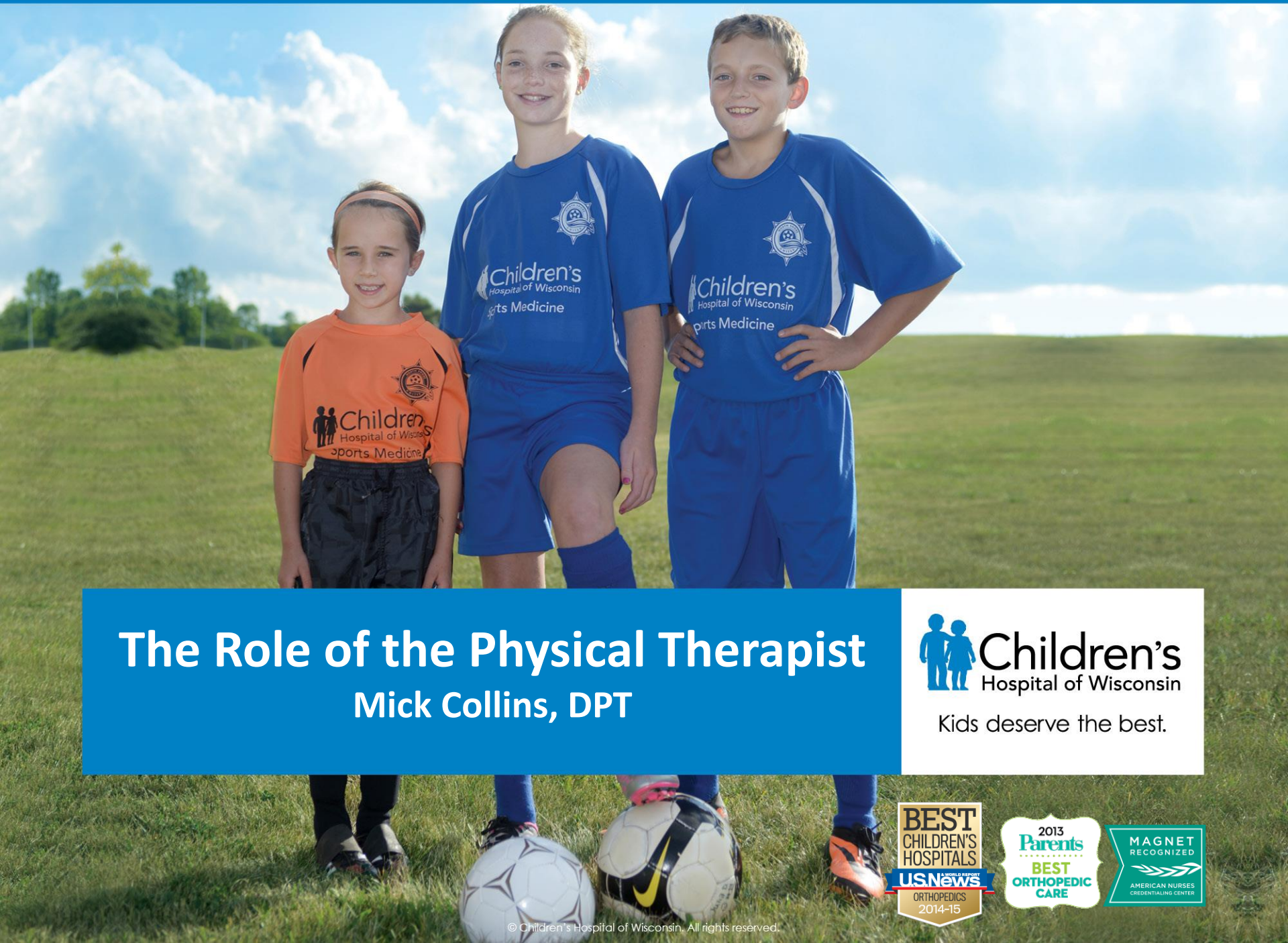
Neuropsychological Evaluation

- Can provide guidance for school and medical interventions
  - Initial plan development
  - Monitoring or assessment of current status
  - Recommendations for level of continued assistance
- Need an experienced neuropsychologist
  - Especially when premorbid diagnosis exist
- Computerized testing
  - Just a tool for medical management
  - Be wary of "group" baselines
  - Expect score improvement as they age
    - Kieslich et al 2002: 9-15y showed greatest changes
  - Have a plan for use



The Role of the Physical Therapist

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Referral to Physical Therapy

- Typically 1-6 weeks post injury. Can be months.
- Patients with ongoing symptoms:
  - Physical (headache, dizziness, cervical pain)
  - Cognitive (memory, attention)
  - Affective (depression, anxiety)
  - Sleep related issues
- Typically demonstrate:
  - Vestibular-oculomotor impairments
  - Exercise intolerance
  - Difficulty with school attendance/participation

Risk Factors for Prolonged Recovery

- *Greater number or severity of symptoms after injury
- *Loss of consciousness
- On-field dizziness or cognitive symptoms
- Subjective reports of “fogginess”
- Migraine-cluster symptoms – headache, nausea, photophobia, phonophobia, visual problems, dizziness
- Age – younger brains still developing
- History of depression, anxiety, migraines, ADD/ADHD, or learning disabilities
- *Female gender
  - Due to decreased head-neck mass?
  - Due to higher levels of estrogen and cerebral blood flow?

*Fehr, 2019; Harmon 2013

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What is happening with prolonged concussion?

- Prolonged symptoms may be due to persistent central/peripheral physiological changes, rather than a direct result of neuronal damage
- Concussed patients have altered autonomic regulation
  - Increased sympathetic ("fight or flight") and decreased parasympathetic ("rest and digest") function
  - Higher heart rate at rest and with physical and cognitive stress
  - Cerebral blood flow and cerebral autoregulation (ability to maintain constant cerebral blood flow with changes in blood pressure) are both disturbed
  - Pulmonary ventilation (tidal volume x frequency) may be altered leading to decreased cerebral blood flow

Leddy 2007

What is happening with prolonged concussion?

- ANS Dysfunction
  - Ventilation is inappropriately low for the level of exercise intensity, raising arterial carbon dioxide (PaCO2) levels.
  - Elevated PaCO2 increases cerebral blood flow (CBF) out of proportion to exercise intensity, which is associated with symptoms that limit exercise performance.
- Thus, elevated exercise PaCO2 may signal incomplete recovery from SRC.
- Subthreshold aerobic exercise treatment increased CO2 sensitivity to normal, which normalized PaCO2, exercise ventilation, CBF, and exercise tolerance, and resolved symptoms.

Leddy 2018

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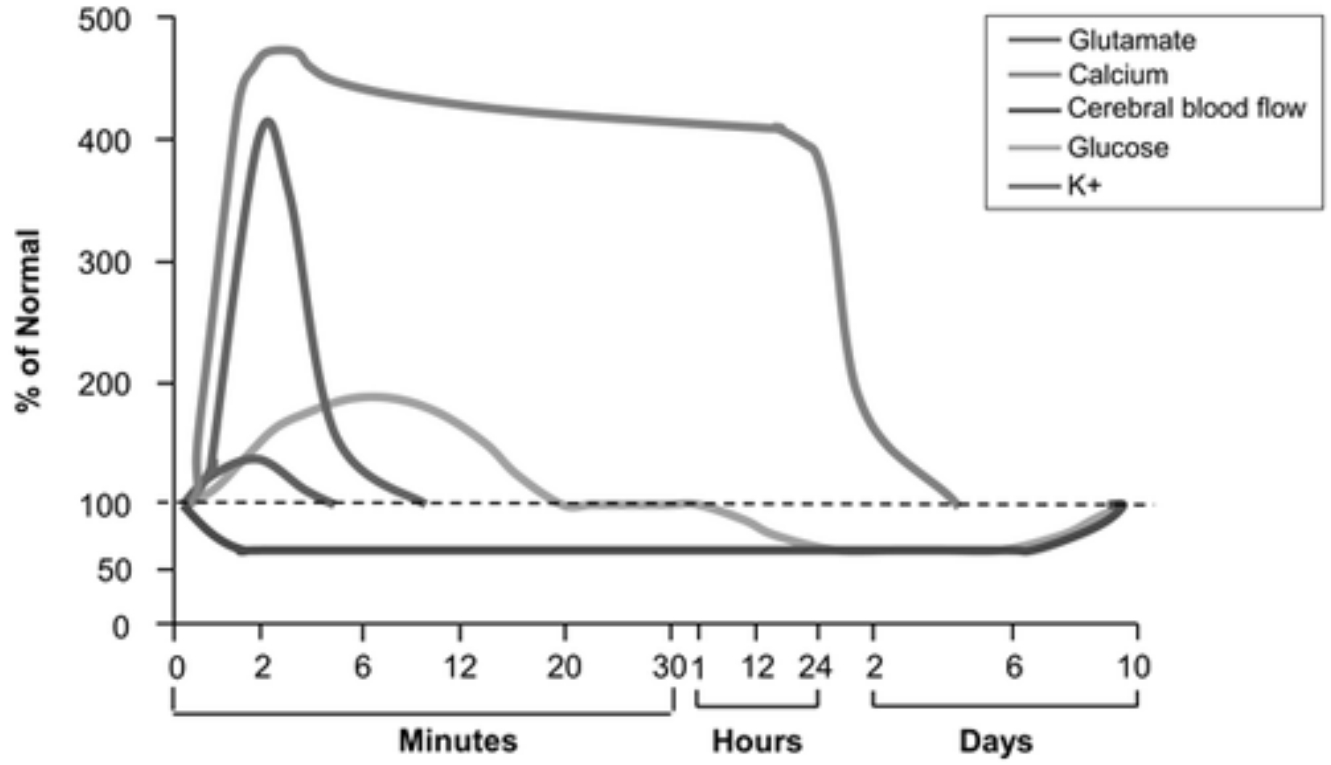
Neurometabolic Cascade Following Cerebral Concussion/mTBI



From Giza CC, et al.[10]

Giza & Hovda 2001

Energy Imbalance

- The brain needs increased energy (glucose) to assist with regaining the normal ionic balance within the brain
- Following the concussion there is decreased cerebral blood flow and mitochondrial dysfunction, which disrupts the normal metabolic function within the brain

Energy Supply < Energy Demand = Acute Concussion Symptoms

Giza & Hovda 2001

Post Concussion Syndrome

- Term used to describe a constellation of nonspecific symptoms
  - Headache, fatigue, sleep disturbance, vertigo, irritability, anxiety, depression, apathy, difficulty with concentration and exercise
- Linked to several possible causes that do not necessarily reflect ongoing physiological brain injury
- Challenge is to determine if prolonged symptoms reflect prolonged concussion pathophysiology or a manifestation of a secondary process

Leddy 2016

Concussion & Dizziness

- Between 50-80% of people experience dizziness, impaired balance and altered coordination after a concussion
- Dizziness found to be the sole on-field factor predictive of prolonged (>21 days) recovery
- Evidence of vestibular-ocular dysfunction detected in a significant proportion of children and adolescents with acute and prolonged concussion

Alsalaheen 2010, Lau 2011, Ellis 2015

The Vestibular System

- Allows eyes to remain fixed on a target while head and body move
- Sensory input from inner ear allows for adjustments in eye movements and motor control that stabilize head and body during movement
- Involves vestibular apparatus, sensory organs, and central processing and coordination in brain
- Specific areas of brain are responsible for integrating sensory information
  - Cerebellum, cerebral cortex, thalamus, reticular formation, brainstem

Kontos 2017

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The Vestibular System

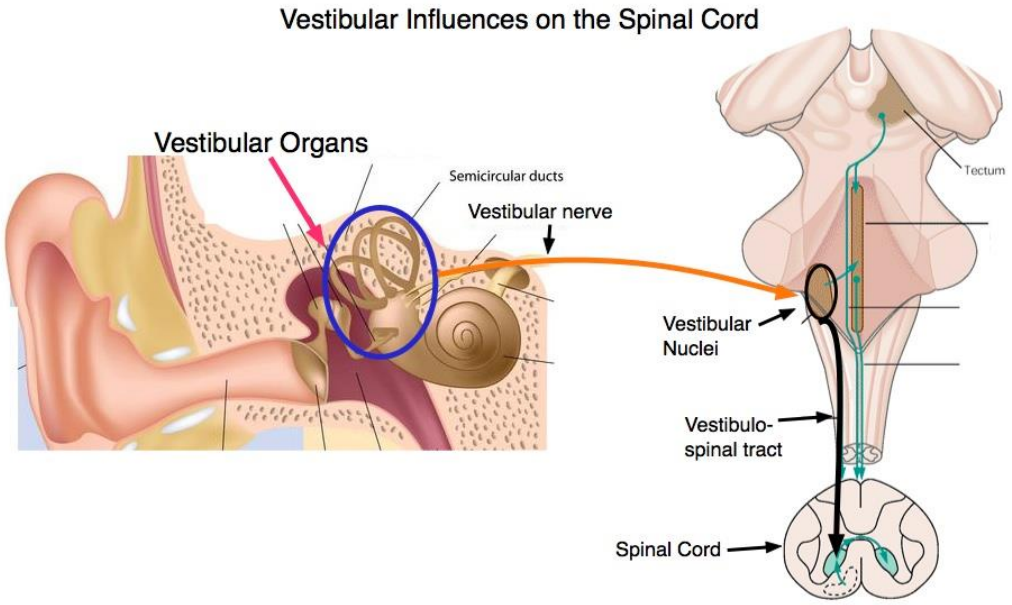
Consists of two systems:

- Vestibulo-spinal component – regulates postural stability
- Vestibulo-ocular component – maintains visual stability during head movements
- Together play a vital role in balance, gaze stabilization, and visual and spatial orientation

Kontos 2017

Vestibulo-spinal component

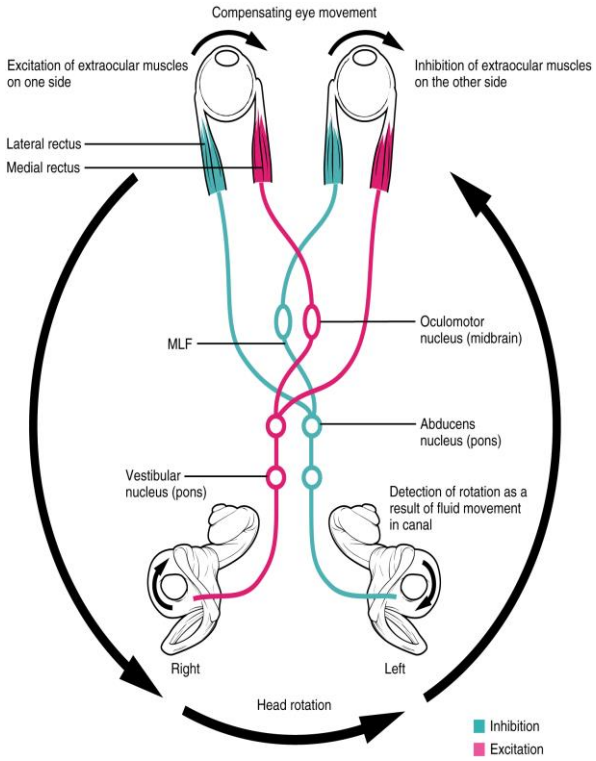
- Helps to regulate postural stability
  - Objective balance impairments usually resolve in 3-5 days post-concussion
  - Screen with:
    - BESS Test
    - Sensory Organization Test (SOT)



Kontos 2017

Vestibulo-ocular component

- Integrates vision and movement of the head
  - 30% of patients with a concussion report visual symptoms in the first week after injury. Symptoms may persist
  - 50-80% of patients experience dizziness
  - Screen with:
    - Vestibular Oculomotor Screen (VOMS)



Kontos 2017

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Oculomotor function

- Underlying pathophysiology of oculomotor dysfunction after SRC is complex
  - Occurs via versional eye movements (pursuits and saccades) and vergence movements (convergence and divergence)
  - Combine with visual fixation movements (gaze holding, optokinetic responses, VOR)
  - Change angle of gaze and hold visual images steady

Kontos 2017

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Vestibular/Oculomotor Symptoms

Vestibular symptoms	Oculomotor symptoms
Dizziness	Headaches
Nausea	Blurred vision
Vertigo	Convergence insufficiency
Blurred or unstable vision	Difficulty reading
Discomfort in busy environments	Diplopia
Loss of balance	Difficulty tracking a moving target
Unsteady gait	Asthenopia
	Problems scanning for visual information

Kontos 2017

Vestibular/Oculomotor Symptoms

- Concussion patients may not always report “dizziness”, may need to ask specific questions about symptoms:
  - Blurry vision, difficulty focusing, “fogginess”
  - Discomfort with motion
    - Stairs, walking, driving
  - Challenged with busy visual environments
    - Crowds, walking through hallways or stores, attending practices or games
  - Impaired balance especially in the dark
- Dizziness Handicap Inventory to help identify impairments

Mucha 2014

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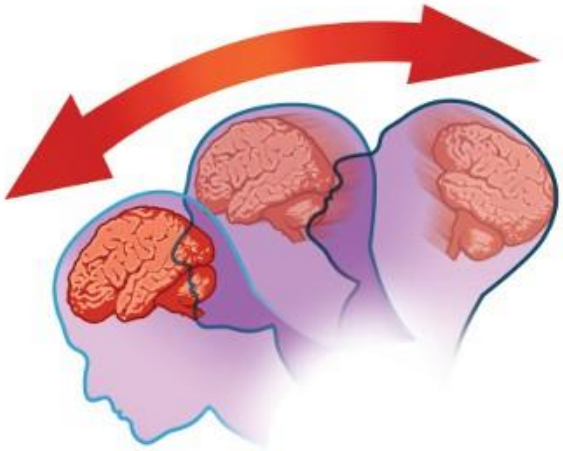
Brain or Strain?

- Study of patients with persistent symptoms for >3 weeks post head injury
- Cognitive, somatic and behavioral symptoms on PCS did not reliably discriminate between:
  - Patients with physiological post concussion disorder (persisting symptoms + exercise intolerance on treadmill test)
  - Patients with cervicogenic and/or vestibular-ocular post concussion disorder (persisting symptoms + normal exercise tolerance + abnormal cervical and/or vestibular-ocular exams)

Leddy 2015

Cervical dysfunction following SRC

- Whiplash mechanisms are similar to impulsive forces described in concussive injuries
- Symptoms of concussion and whiplash-associated disorders display remarkable similarity:
  - Headache, neck pain, disturbance of concentration/memory, dizziness, irritability, sleep disturbance, and fatigue described in concussion and whiplash patients
- Cervical zygapophyseal joints implicated as generators of headache and dizziness



Leslie, 2013

Cervical dysfunction following SRC

- Following neck trauma, there is considerable evidence to support importance of cervical dysfunction in:
  - Dizziness
  - Unsteadiness
  - Visual disturbances
  - Altered balance
  - Altered eye and head movement
- Evaluation of potential impairments should become part of assessment of those with traumatic neck pain
  - Altered cervical joint position and movement sense
  - Static and dynamic balance
  - Ocular mobility and coordination

Treleaven 2008, 2018

Questions?

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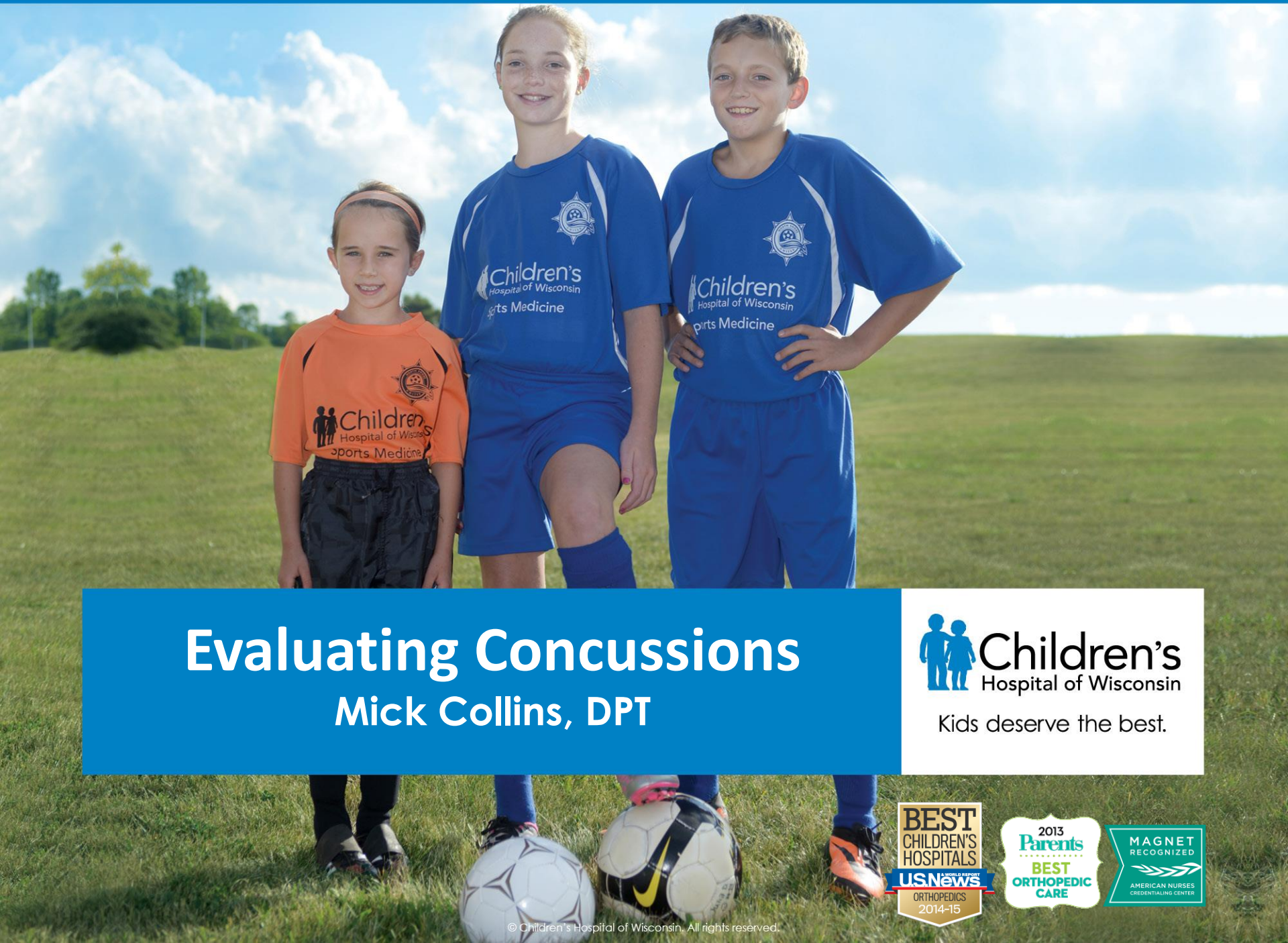

Evaluating Concussions

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PT Eval - Subjective

- Date of injury and mechanism
- Immediate/current symptoms
  - Activities that increase symptoms
  - Symptom patterns – time of day, frequency, severity
- Prior level of function
  - Academics, activity
- Past medical history
  - Concussion hx, orthopedic hx, migraines, cervical pain, mental health, ADD/ADHD, learning difficulty

PT Eval - Subjective

- Social/living situation
- School status
  - Attending full or partial days
  - Using accommodations
- Reading/screen tolerance
- Sleep hygiene
  - Melatonin, valerian root?
- Mood
- Diet/hydration
- Prior imaging, neurocognitive testing

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Education

- Take this opportunity to educate patient and family
- Lots of misconceptions, misunderstandings
- Dispel myths early, reduce fear and anxiety
- Improve rapport and patient compliance

Importance of Early Intervention and Education

- Individuals seen at one week post mTBI and provided with an information booklet reported less symptoms (particularly anxiety and sleep disturbances)
- Those who were only seen at 3 months and not provided with an information booklet reported higher levels of psychological distress

Ponsford, 2002

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So What Do I Say?

- Force transmitted to brain that causes shearing
- Results in nerve cell dysfunction and changes in blood flow
- Less energy produced within nerve, more energy used to return nerve to normal (ATP pumps)
  - Results in supply/demand imbalance in affected nerves
- PT exercises targeted at adaptation/habituation strategies: Expose–Recover–Expose
  - Make unaffected nerves work harder to limit impact on recovering nerves
  - Normalize cerebral blood flow, removal of lactic acid and inflammatory accumulation
  - Sibling chore analogy

Objective

- Neuro exam
  - Cranial nerves I-XII
  - DTRs
    - Biceps brachii C5
      Brachioradialis C6
      Triceps C7
  - Myotomes
  - Dermatomes
  - Babinski, Hoffman's
- Cervical exam
  - ROM/joint mobility
  - Trigger points
  - Special tests
    - Cervical distraction test
    - Flexion rotation test
    - Headache differentiation
      - (C0-1, C1-2, C2-3)
    - Spurling's test
    - Quadrant test
    - Upper limb tension test
    - Alar Ligament stress test
    - Sharp-Purser test
    - Anterior Shear test
  - Muscle performance
    - Scapular endurance test
    - Neck flexor endurance test
    - Lateral lift test

Cook, 2012

Vestibular Oculomotor Screen (VOMS) Methods

- 64 patients, aged 13.9 ± 2.5, 5.5 ± 4.0 days post-SRC
- Administered PCSS and VOMS assessment:
  1. Smooth pursuits
  2. Horizontal and vertical saccades
  3. Near point of convergence (NPC) distance
  4. Horizontal vestibular ocular reflex (VOR)
  5. Visual motion sensitivity (VMS)
  6. *Vertical VOR added in to revision*
- Patients verbally rate changes in symptoms
  - Headache, dizziness, nausea and fogginess

Mucha 2014

Vestibular Oculomotor Screen (VOMS) Results

- 61% reported symptom provocation after 1 VOMS item
- No control subjects reported any symptoms > 2/10 for any item
- VOMS items positively correlated to PCSS total symptom score
- VOR and VMS most predictive of being in concussed group
- Mean NPC distance in concussed group 4cm greater than control

- NPC distance ≥ 5cm increased probability of correctly identifying concussed patients by 34%
  - +LR 5.8
- VOMS item score ≥ 2/10 increased probability of correctly identifying concussed patients by 46%
  - +LR 23.9 (smooth pursuit, vertical saccade), +LR 42.8 (VOR)
- Positive VOR, VMS, & NPC leads to a positive predictive value of 0.89 of identifying concussion

Mucha 2014

Children's Hospital of Wisconsin

VOMS Components

- Convergence – near point
- Smooth pursuits/gaze fixation
- Saccades – horizontal
- Saccades – vertical
- VOR – horizontal
- VOR – vertical
- Visual Motion Sensitivity / VOR Cancellation

Mucha 2014

VOMS Application

- Document baseline symptoms – headache, dizziness, nausea, fogginess, blurred vision, asthenopia (eye strain)
  - Rate symptoms 0-10/10 (similar to NPRS)
- Positive test – eyes not moving together/symmetrically or reproduction of symptoms
- Reassess symptoms after each segment of testing
- Allow them to rest and have symptoms decrease before moving onto next segment

Mucha 2014

Convergence

- Focus on a small target at arms length, then slowly bring it in toward nose
- Stop when two distinct images are seen or outward deviation of eye is observed – blurry vision is okay
- 3 repetitions – measure distance from nose to target
- Abnormal test is > 6 cm
- Reassess symptoms

Whitney, 2016

Smooth Pursuits

- Hold fingertip 3 feet away from patient
- Patient tracks target as you move about 30° left and right (about 1.5 feet each direction) – 2 repetitions
- Should take about 2 seconds to go from left to right
- Reassess symptoms
- Repeat vertically

Whitney, 2016

Horizontal & Vertical Saccades

- Sit 3 feet from patient and hold each of your index fingertips about 3 feet apart horizontally (1.5 feet to the left/right of midline)
- Patient quickly switches gaze from one target to the other
- Reassess symptoms
- Repeat vertically

Whitney, 2016

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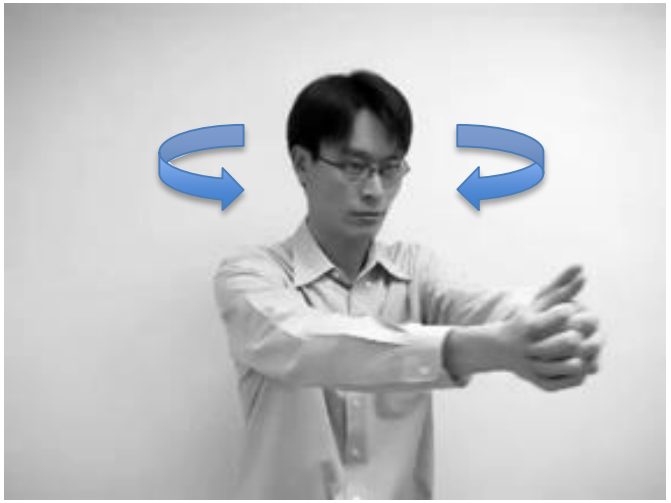
Vestibular-Ocular Reflex (VOR)

- Stabilizes or focuses vision on a target while the head moves
- If the head rotates 10° to the right, eyes should move 10° to left to keep object focused
- Impairment results in dizziness or blurred vision when the eyes and/or head moves
- Can be impaired due to central and/or peripheral problems

Whitney, 2016

Vestibular-Ocular Reflex (VOR)

- Patient focuses on a target 3 feet away
- Rotate head horizontally while keeping the target in focus – 20° each direction, 10 cycles
- 180 beats/minute is normal – could use metronome
- Assess symptoms 10 seconds after each test
- Repeat vertically



Whitney, 2016

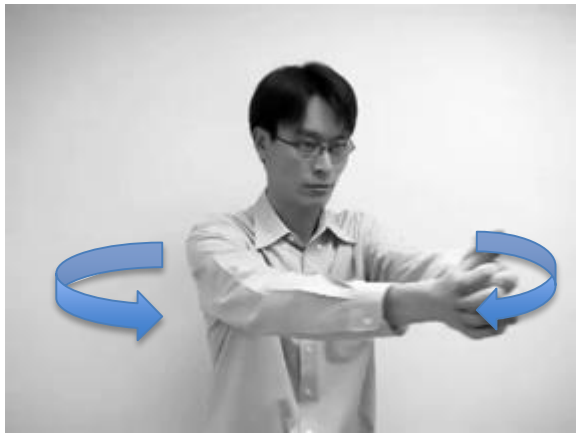
Visual Motion Sensitivity

- Discomfort or uneasiness created by visual stimuli
- Moving in crowds, supermarkets, busy patterns, stairs, heights
- “Heightened awareness of normal visual motion” – visual filter not working
- Known comorbidity with migraines/anxiety

Furman 2010, Mucha 2014

Visual Motion Sensitivity

- May be referred to as VOR cancellation
- Patient holds arms outstretched, focus on thumb or another target and rotate arms left/right 80°
- 50 beats/minute for 5 cycles (10 swipes) is normal – could use metronome
- Assess symptoms



Whitney, 2016

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Other Vestibular Tests

- BPPV Testing – Dix Hallpike, Horizontal Roll Test
- Cover & Uncover Tests (Tropias/Phorias)
  - Look for head tilt or misalignment of eyes
- Optokinetic nystagmus
- Head Thrust Test (VOR)
- Head Shake Nystagmus Test (VOR)
  - Requires Frenzel goggles

Mucha 2014

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Balance Assessment

- Balance Error Scoring System (BESS) Test
  - 6 segments: each lasts 20 seconds
  - Eyes closed, hands on hips, no shoes
  - Feet together, tandem stance, single leg stance
  - May skip single leg if < 13 years old
  - Test on both solid ground and on airex pad
  - Non-dominant side for single leg stance, non-dominant foot behind for tandem stance
  - Spot patient for safety

Riemann 1999

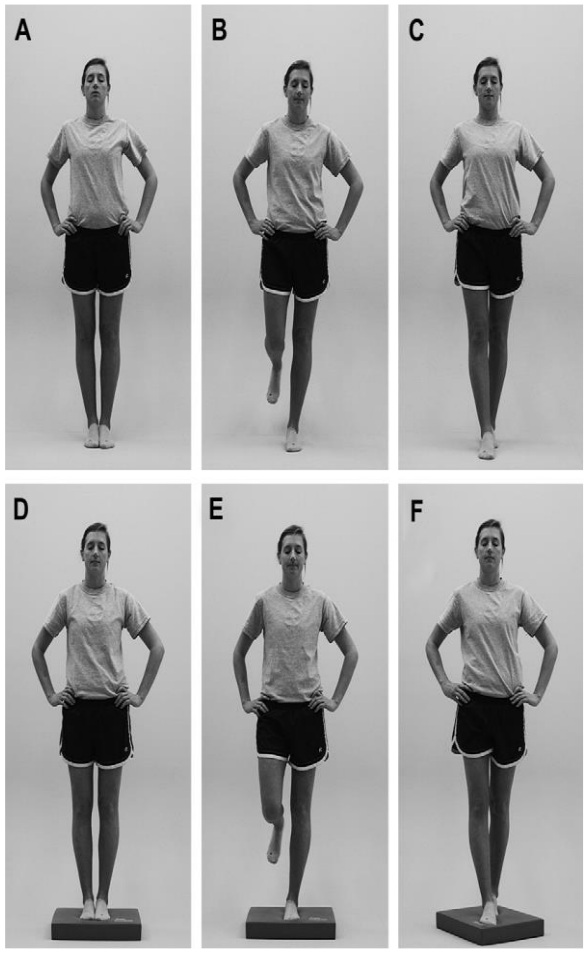
BESS Scoring

Errors

1. Hands lifted off of iliac crest
2. Opening eyes
3. Step, stumble, or fall
4. Moving hip into > 30 degrees abduction
5. Lifting forefoot or heel
6. Remaining out of test position > 5 seconds

Add one point for each error during each of the six 20-second tests

If unable to hold position for 5 seconds, score the maximum number of errors (10)



Riemann 1999

BESS Reliability

- 241 pediatric, 102 adult patients, concussion symptoms lasting longer than 10 days
- Reliability

ICC	Standard BESS	Excluding firm double	Excluding firm double and foam double	'Modified BESS'
All patients (n = 343)	0.800	0.820	0.816	0.596
Paediatric (n = 241)	0.778	0.795	0.797	0.587
Adult (n = 102)	0.829	0.851	0.846	0.615

- ICC minimally improved with omission of firm double and foam double stance
- Study demonstrates high reliability for BESS in cohort of patients with prolonged concussion symptoms

Cushman 2018

COBALT

- 576 athletes, 10-25 years old
- 4 conditions, 20sec trials
  - C3: EC, firm, head shake (baseline)
  - C4: VOR cancellation, firm (baseline)
  - C7: EC, foam, head shake
    - Feet shoulder width, 120bpm, 30 degrees each direction
  - C8: VOR cancellation, foam
    - Feet together, 40bpm, 30 degrees each direction
- Error and sway scores collected
- 7.9% had more than one error on C7
  - 92.1% able to complete C7 with one error or less
  - >1 error, likely not ready to RTP
- 1.7% had more than one error on C8
  - 98.3% able to complete C7 with one error or less
  - >1 error, VERY likely not ready to RTP

Massingale, under revision

Graded Exertion Testing

- Looking to assess sub-symptomatic threshold
- Can help determine treatment classification
- Assists with safe exercise prescription
- Balke Treadmill test (BCTT)
  - 15mins, 3.3mph, progress to 15% incline increasing incline 1% every minute
  - HR monitored throughout
  - Terminate test with symptom provocation (increase of >3 from baseline)
  - Symptoms should subside with rest
    - If they don't, maybe emotional component to recovery

Leddy 2010

Safety, clinical use and outcomes

- 106 patients, mean age 15.1 years old, range 11-19 years, 141 tests total
  - 97.9% of treadmill tests were well tolerated (3 tests discontinued due to LE soreness)
- 61 underwent treadmill testing to classify PCS subtype
  - Diagnosed 58 of 61 patients with physiological PCS, 1 with cervicogenic PCS, 2 indeterminate
- 65 underwent treadmill testing to confirm physiological recovery
  - Confirmed physiological recovery in 96.9% of patients, with successful RTP in 93.8%
- 41 with physiologic PCS underwent complete clinical follow up and treated with submaximal aerobic exercise
  - 90.2% clinically improved, 80.5% RTP

Cordingley, 2016

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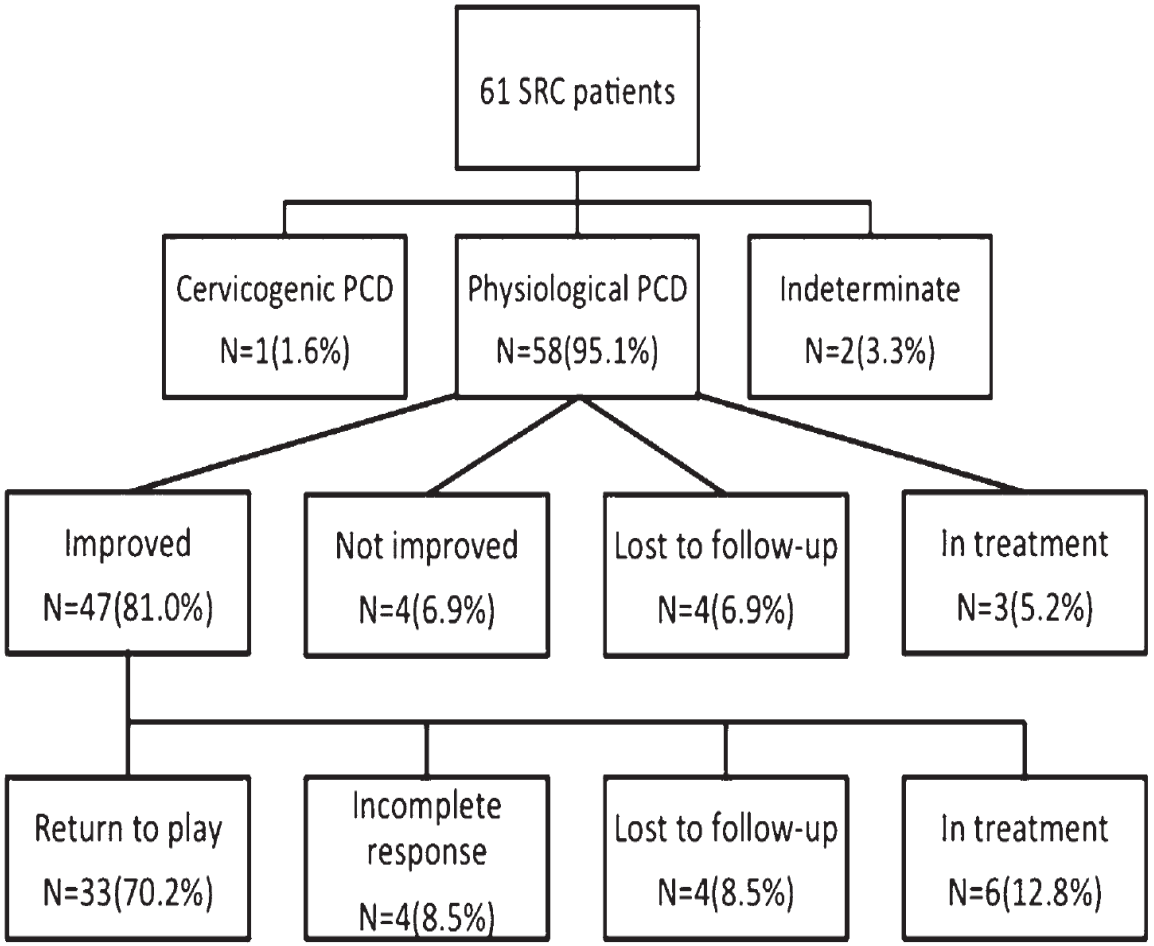

FIG. 1. Clinical outcomes in 61 cases involving pediatric patients with sports-related concussion (SRC) who underwent graded aerobic treadmill testing for assessment of exercise tolerance and post-concussion syndrome (PCS) subtype classification. PCD = post-concussion disorder.

Cordingley, 2016

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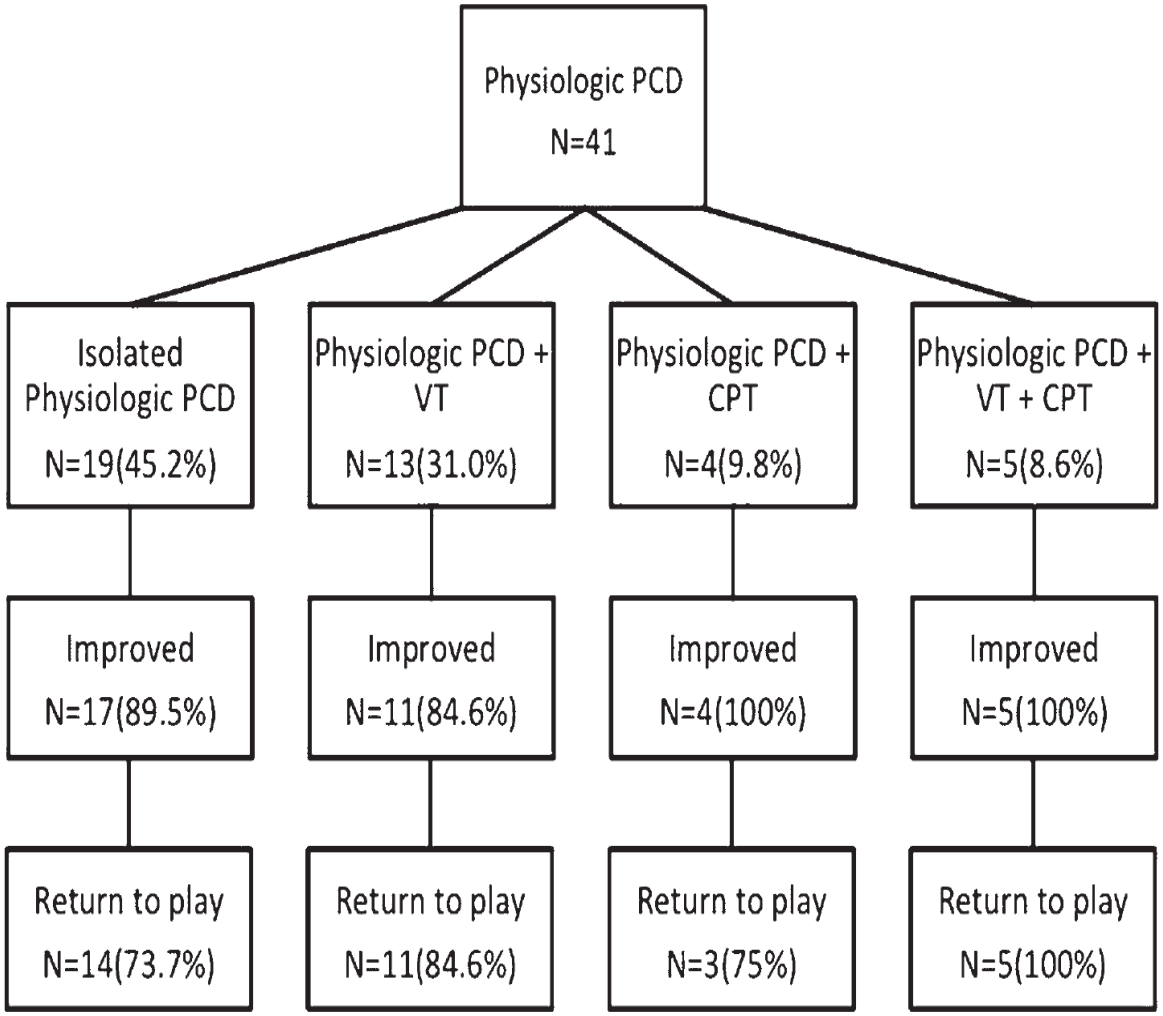

FIG. 2. Clinical outcomes in 41 cases involving pediatric patients with physiological PCD who had complete follow-up and underwent submaximal exercise therapy alone or submaximal exercise therapy and targeted multidisciplinary interventions. CPT = cervical spine physiotherapy; VT = vestibular physiotherapy.

Cordingley, 2016

How soon is safe?

- 54 patients, mean age 15 years, 4 days post injury
  - 27 performed BCTT on visit 1, 27 did not
  - Heart rate threshold (HRt) at symptom exacerbation established
  - Patients recorded symptoms daily for 14 days then had follow up BCTT
  - Recovery defined as return to normal symptoms and exercise tolerance
- Days to recover and typical vs prolonged recovery not different between groups
  - Symptom severity scores decreased in both groups and were similar 1 day post BCTT
  - Lower HRt on day 1 associated with prolonged recovery
- Use of BCTT within first week did not affect recovery
  - Degree of early exercise tolerance important for prognosis

Leddy, 2017

Questions?

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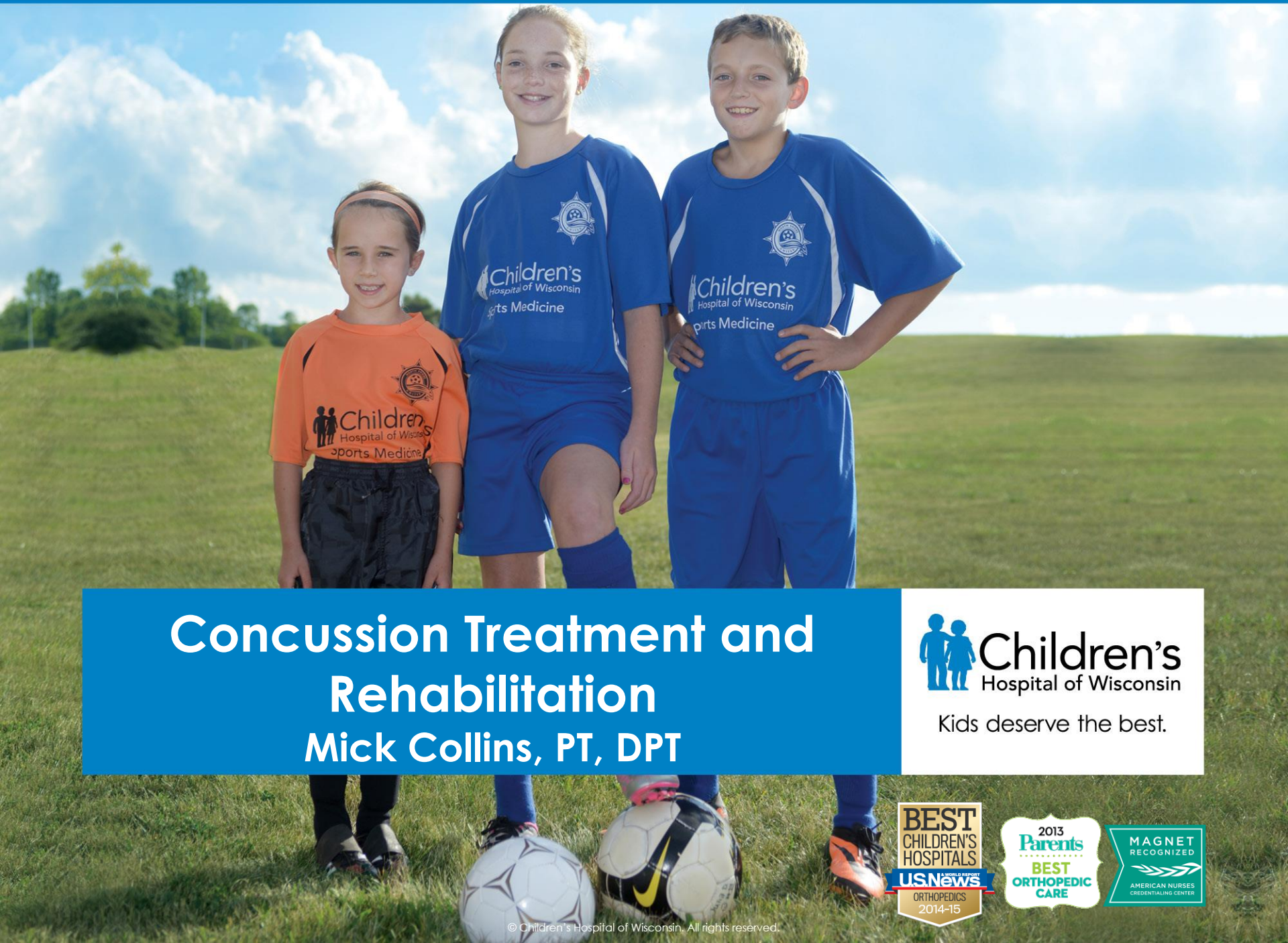

Concussion Treatment and Rehabilitation

Mick Collins, PT, DPT

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BEST CHILDREN'S HOSPITALS U.S.News & WORLD REPORT ORTHOPEDICS 2014-15

2013 Parents BEST ORTHOPEDIC CARE

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Concussion Treatment

- Usually multi-faceted:
  - Address cervicothoracic dysfunction
    - Cervicothoracic and soft tissue mobilization
    - Scapular and deep cervical flexor strengthening
  - Postural retraining and ergonomics
  - Gaze stabilization/vestibular exercises
  - Balance and proprioception
  - Active rehabilitation
  - Cardiovascular/aerobic activities progressing to sport specific activities

Broglio 2015, Leddy 2016, Ellis 2016, Grabowski 2016

When to start?

- 677 patients, 7-18 years old
- Intervention
  - Aerobic activity, coordination skill/practice, visualization, education and motivation
- All patients experienced improvement of symptoms while participating in active rehab
  - Patients starting at 2 or 3 weeks post injury demonstrated lower symptom severity at f/u (2 weeks later) than those starting at 6 weeks or more
  - Patients starting at 2 weeks post injury demonstrated lower symptom severity at f/u than those starting at less than 2 weeks, 4 weeks and 5 weeks

Dobney, 2017

When to Start?

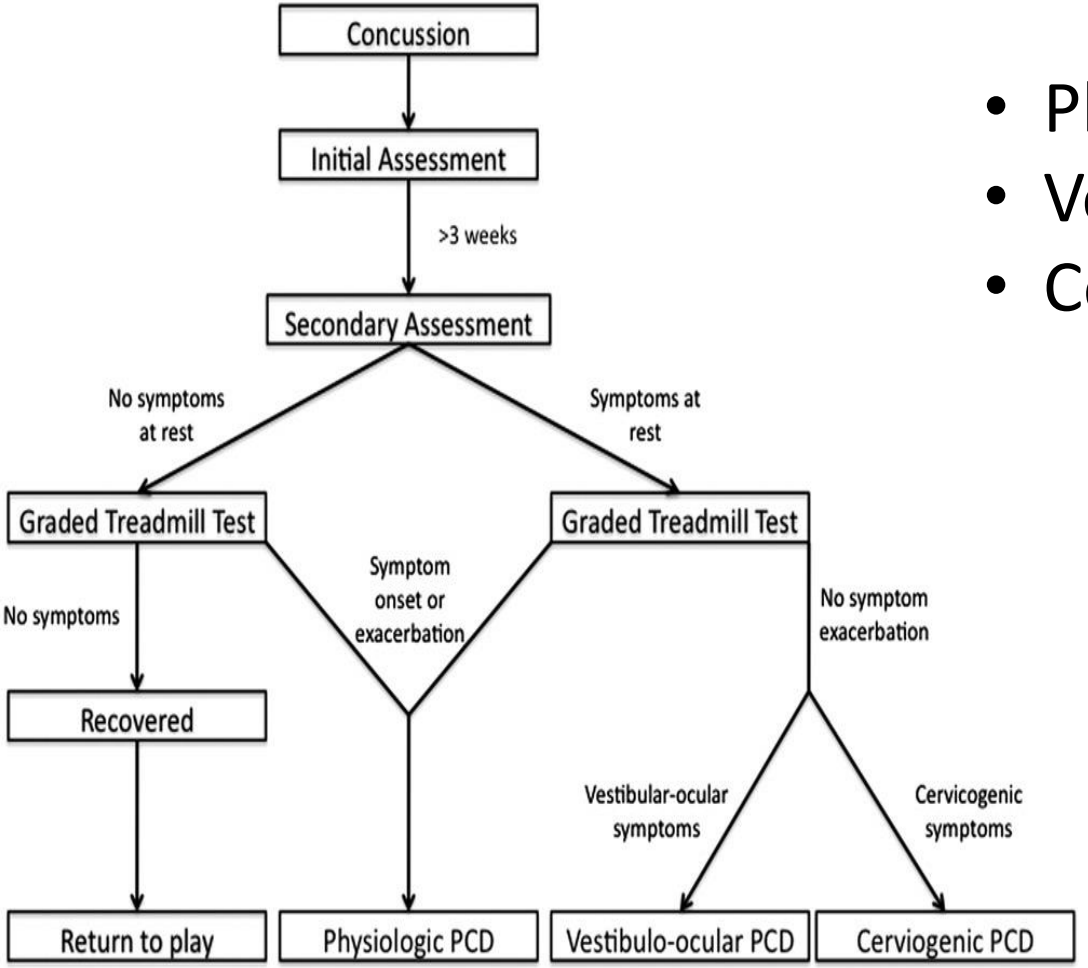
- Study found getting kids back into aerobic activity sooner after concussion led to decreased probability of delayed function
- Less favourable recovery each day exercise was delayed
- Stationary bike protocol
  - 15mins 100-120bpm → 30mins 100-120bpm → 30min at 140bpm → intervals 1min max sprint every 5mins for 30mins
  - Minimum of 2 sessions tolerated at each level before progression

Day Aerobic Exercise is Initiated	Reduced probability of a faster return to sport
3	36.5%
5	59.5%
7	73.2%
14	88.9%

Day Aerobic Exercise is Initiated	Reduced probability of a faster return to school/work
3	45.9%
5	70.5%
7	83.1%
14	94.7%

Lawrence, 2018

Treatment Classification



- Physiologic
- Vestibulo-ocular
- Cervicogenic

Ellis 2015

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Concussion Clinical Trajectories

Collins 2013

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Treatment Classification

- Cervicogenic
  - Headaches, migraines, dizziness
- Vestibular/Oculomotor
  - VOR, saccades, convergence, motion sensitivity
  - Positional changes
- Physiologic
  - Exercise intolerance
- Emotional
  - Depression, anxiety, irritability, frustration, self-esteem, confidence, fatigue

Lots of overlap between treatment groups both initially and as treatment progresses

Cervicogenic

Pathophysiology	Symptoms	Physical exam findings
• Muscle trauma and inflammation • Joint dysfunction • Dysfunction of cervical spine proprioception	• Neck pain, stiffness • Decreased ROM • Occipital headaches exacerbated by movement not physical or cognitive activity • Lightheadedness and postural imbalance	• Decreased cervical lordosis and ROM • Paraspinal and sub-occipital tenderness • Impaired cervical proprioception • Positive cervical special tests • Tolerated max exertion on graded treadmill testing

Ellis 2015

Manual therapy and exercise

- Combination of manual therapy and exercise indicated for cervical treatment
- Manual therapy:
  - Joint mobilization/manipulation
  - Soft tissue mobilization, stretching
  - Muscle energy techniques
  - Dry needling if available
- Exercise
  - Postural strengthening (scapular stabilizers, deep cervical flexors)

Cook, 2012

Cervical Proprioception

- Measure cervical joint position sense
  - Laser pointer mounted on headband
  - Patient seated 90cm from wall, starting position of laser marked
  - Patient eyes closed performs an active neck movement and returns to starting position
  - Distance between start and finish measured
- Train cervical joint position sense
  - Relocate head back to natural head posture and to predetermined positions

Treleaven, 2018

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Vestibular/Oculomotor

Pathophysiology	Symptoms	Physical exam findings
• Dysfunction of the vestibular and oculomotor systems	• Dizziness, vertigo, nausea, light-headedness • Gait and postural instability • Blurred or double vision • Difficulty tracking objects • Motion sensitivity • Photophobia • Symptoms exacerbated by visual stimulus (reading, riding in car, screen time)	• Impairments on standardized balance and gait testing • Impaired VOR, fixation, convergence, horizontal/vertical saccades • Tolerated maximal exertion on graded treadmill testing

Ellis 2015

VOR Exercises

- Place target on wall or hold in front of you, shake head left/right or nod up/down while keeping the target focused
- Start with slow speed, few repetitions
- Eventual goal
  - at least 1 minute, 180 beats/minute, can use a metronome
- Progressions
  - Busier backgrounds/environments, VOR with walking/running forward/backward or with balance challenges

Whitney, 2016

Convergence

- Bring target in toward nose and back out
  - Pencil pushups
  - Brock string
  - Playing catch
- Switch focus from near target to far target within the same line of sight

Whitney, 2016

Saccades

- Quickly switch gaze from one target to another
- Horizontal or vertical
- Can vary the distance between or the depths of the targets
- Can progress to diagonals
- Can vary background

Whitney, 2016

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Eye Tracking

- Lazer pen
  - Follow with eyes
  - Tag
- Eye maze
- Number find
  - Can vary patterns 1-15, 15-1, odds up/evens down to add in cognitive dual task
- Can incorporate balance challenges for sensory integration

Whitney, 2016

Visual Motion Sensitivity

- Hold target in front of you at arms' distance
- Rotate left/right with head/arms while keeping target focused
- Progression – core rotations, PNF patterns

Whitney, 2016

Dynamic VOR activity

- Familiar exercises with visual focus on target
  - Sit-ups with ball overhead
  - Russian twists with rotation
  - Med ball chops on BOSU
  - Step ups with overhead press
  - Wall sits with rotation
  - Lunges with rotation or with overhead lean
  - Resisted trunk rotation

Whitney, 2016

Cervicovestibular rehabilitation

- 31 patients - 18 male, 13 female, 18-30years, diagnosed with SRC – dizziness, headache, neck pain
- Weekly sessions with a PT for 8 weeks or until medical clearance
- Control group
  - Postural education, ROM, cognitive and physical rest followed by graded exertion protocol
- Intervention group
  - Same as control + cervical spine and vestibular rehab
- 73% of treatment group medically cleared within 8 weeks vs 7% in control group

Schneider, 2014

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Physiologic

Pathophysiology	Symptoms	Physical exam findings
• Persistent alterations in neuronal depolarization, cell membrane permeability, mitochondrial function, cellular metabolism and cerebral blood flow	• Headache exacerbated by physical and cognitive exertion • Nausea, intermittent vomiting, photophobia, phonophobia, dizziness, fatigue, difficulty concentrating, slowed speech	• No focal neurological findings • Elevated resting HR • Graded treadmill tests are often terminated early due to symptom onset or exacerbation

Ellis 2015

Graded exertion and Active rehabilitation

- Patients with persistent post-concussion symptoms may have impaired autonomic dysfunction and impaired cerebral auto-regulation
- Aerobic training may increase parasympathetic activity, decrease sympathetic activity and improve cerebral blood flow
- Usually start active rehab/cardio activity after patient is asymptomatic or if symptoms are lasting > 2-4 weeks

Leddy 2010, Cordingley 2016

Active Rehabilitation

- Gradually increase cardiovascular activity
- Heart rate monitored throughout
- Start at 80% of subsymptomatic threshold (20mins, 6-7 days/week)
- Progress low to high impact activity (stationary bike to elliptical to running)
- Increase 10bpm per week

AGE	60%	70%	80%
13	124	145	165
14	123	144	165
15	123	144	164
16	122	143	163
17	122	142	162
18	121	141	162
19	121	141	161

Leddy 2010, Leddy 2018

Sport-Specific

- Increasing impact and intensity of activity as tolerated
- Remain below symptom threshold
  - Intervals
  - Plyometrics
  - Circuit training
  - Agility and coordination
  - Sport-specific drills and exercises

Gagnon 2015

Discharge and Return to Play Considerations

- No symptoms reported during ADLs including school for >1 week
- Negative VOMS
- Negative cervical screen – ROM, deep flexor endurance, cervical rotation test, trigger points
- BESS within age appropriate norms
- Tolerates sustained cardio >15mins at 60-70% max HR without an increase in symptoms
- Tolerates sport specific activity at 80%+ max HR without an increase in symptoms
  - Short burst, high intensity, sport related movements
- Dual task? Reaction time? Y-balance?

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Discharge and Return to Play Considerations

- Communicate with referring provider to ensure RTP is appropriate
- Patient must then progress through 5 step RTP protocol

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Return to Play

Rehabilitation Stage	Functional Exercise	Objective of Each Stage
0. No activity	Symptom-limited physical and cognitive rest	Recovery
1. Light aerobic exercise	Walking, swimming, stationary cycling at <70% max HR, no resistance training	Increase HR
2. Sport-specific exercise	Skating drills, running drills, no head-impact activity	Add movement
3. Non-contact drills	Progression to more complex training drills e.g. passing in football/hockey Progressive resistance training	Exercise, coordination, cognitive load
4. Non-contact practice	Following medical clearance, participate in normal training activities	Restore confidence, assess functional skills by coaching staff
5. Return to play	Normal game play	

McCrory 2013

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Emotional

- Emotional and psychological factors can play a role in recovery
- Pre-existing conditions can be exacerbated
- Injury can cause increased levels of anxiety, depression, sleep disturbances, decreased motivation, confidence and self esteem
- Important to refer appropriately if necessary

Team Approach

- May need to involve additional treatment team members if symptoms are not responding as expected – discuss with patient and referring physician
  - Psychologist – cognitive-behavioral therapy
  - Neuropsychologist – continued difficulty with focusing/concentrating/schoolwork
  - Neuro-opthalmologist – persistent ocular symptoms
  - Otolaryngologist (ENT) – vestibular/ear symptoms

Leddy 2016

Concussion: The Great Unmasker

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Kids deserve the best.

Mick Collins, DPT

Credit: Matthew Myrvik, PhD

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Signs/Symptoms of Concussion

Physical	Cognitive	Emotional	Sleep
• Headache • Nausea • Vomiting • Poor balance • Visual problems • Fatigue • Light sensitivity • Noise sensitivity	• Fogginess • Cognitive slowing • Poor concentration • Memory concerns • Confused • Slow processing	• Irritability • Sadness • Emotional • Nervous	• Drowsiness • Sleeping more • Sleeping less • Difficulty falling asleep

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Psychological Symptoms?

Physical	Cognitive	Emotional	Sleep
• Headache • Nausea • Vomiting • Poor balance • Visual problems • Fatigue • Light sensitivity • Noise sensitivity	• Fogginess • Cognitive slowing • Poor concentration • Memory concerns • Confused • Slow processing	• Irritability • Sadness • Emotional • Nervous	• Drowsiness • Sleeping more • Sleeping less • Difficulty falling asleep

Cognitive Behavior Therapy (CBT) for Persistent Concussion Symptoms

Potter et al, 2012

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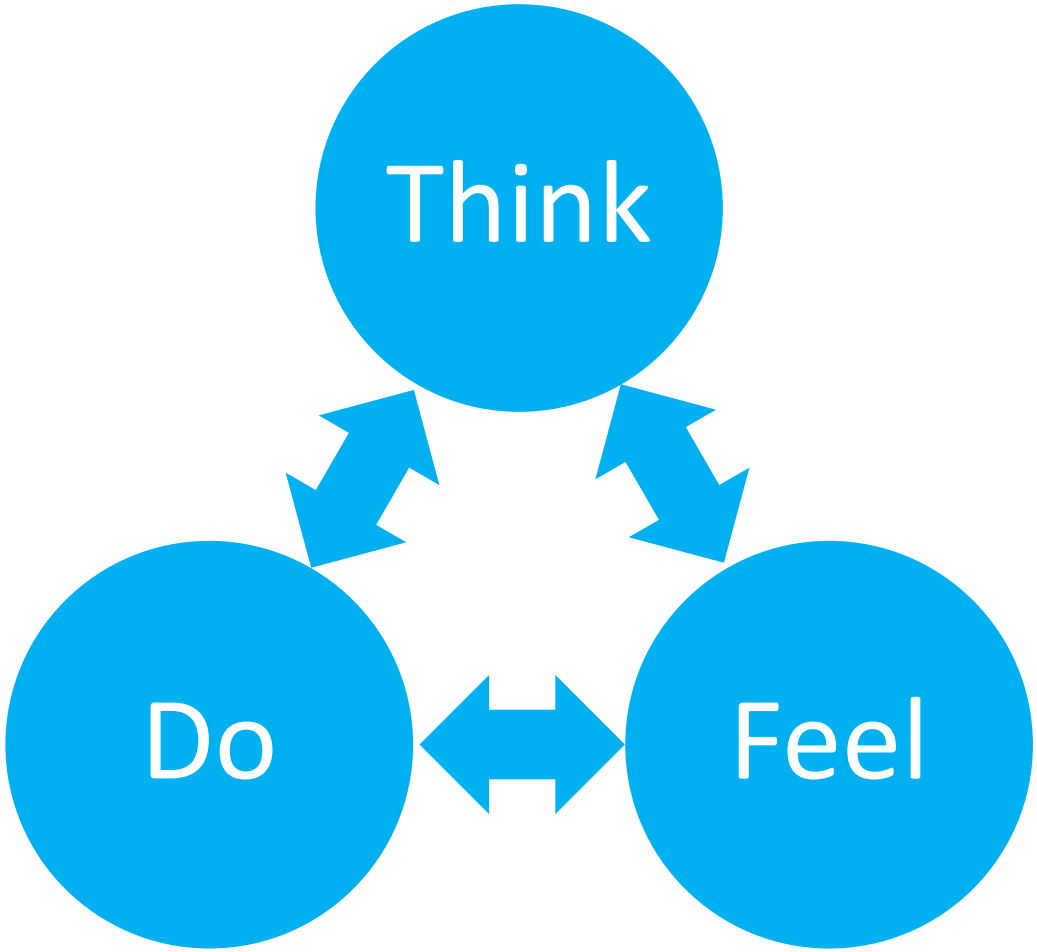
General CBT Model



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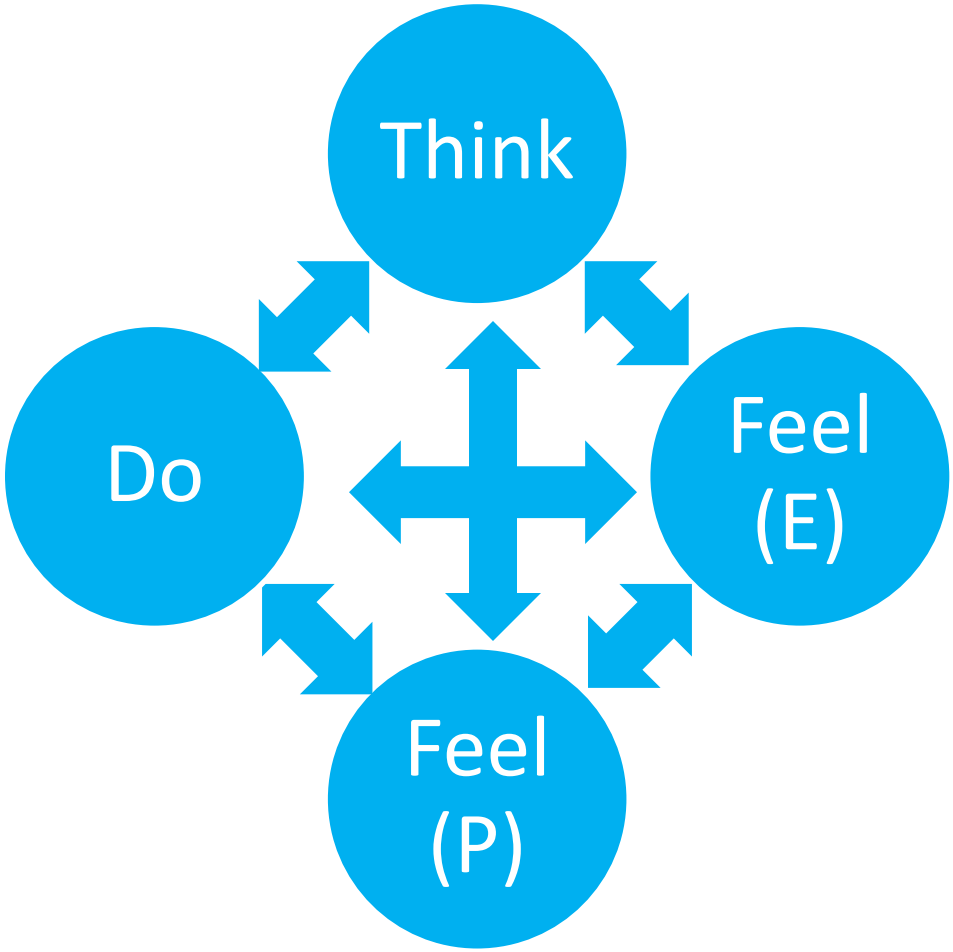
Concussion CBT Model



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“Feel (P)”

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Symptom Self-Management

Goal: Symptom management

- Headaches
- Nausea

Education:

- Creaky house
- Gas pedal vs. brake pedal

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Creaky House

Live in old creaky house…

- Night 1: Hear noises, it's just windows and floor
- Night 2: Hear noises, it's just windows and floor
  - Wake up in morning, someone broke in!
- Night 3: Hear noises, what is it?

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Sympathetic Activation

	Pain	Run	Excited	Worried	
Heart Rate	↑	↑	↑	↑	
Respiration Rate	↑	↑	↑	↑	
Blood Pressure	↑	↑	↑	↑	

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Parasympathetic Activation

	Pain	Run	Excited	Worried	Relax
Heart Rate	↑	↑	↑	↑	↓
Respiration Rate	↑	↑	↑	↑	↓
Blood Pressure	↑	↑	↑	↑	↓

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Gas Pedal vs. Brake Pedal

	Pain	Run	Excited	Worried	Relax
Heart Rate	↑	↑	↑	↑	↓
Respiration Rate	↑	↑	↑	↑	↓
Blood Pressure	↑	↑	↑	↑	↓
	GAS				BRAKE

Relaxation Training

Diaphragmatic Breathing

– Promotes parasympathetic response

Progressive Muscle Relaxation

– Reduces muscle tension/promotes body awareness

Guided Imagery/Visualization

– Distraction

Biofeedback

- Most lack interoceptive awareness
- Biofeedback:
  - Physiological processes recorded
  - Physiological information presented
  - Patient attends to information and attempts to alter process
    - Heart rate
    - Respiration
    - Blood pressure
    - Muscle tension
    - Peripheral blood flow

Provide signal
Process feedback

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“DO”

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Behavioral Interventions

Goal: Increase functioning

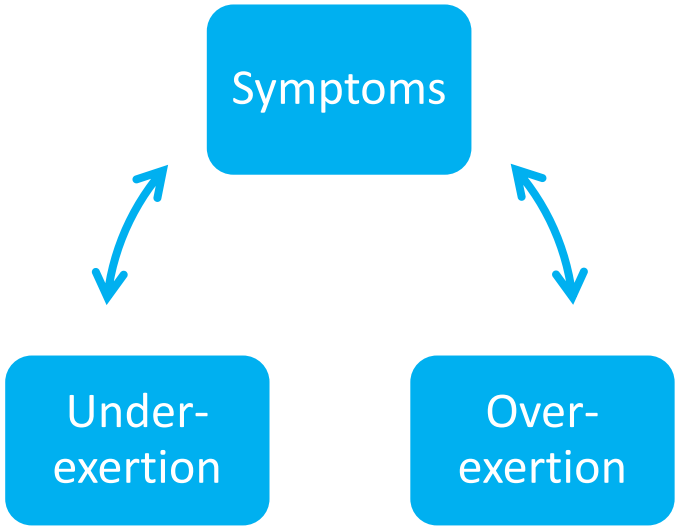
Problems:

- Typical recommendation is "rest" post-injury
- Perceived worsening symptoms after earlier attempts to return to previous activities
    - Kinesiophobia
    - Cogniphobia
- High desire to return to "normal" functioning

Behavioral Regulation

Two types of activity patterns:

1. Under-exertion: fear of pain, avoidance, deconditioning, disability
2. Over-exertion: unhealthy high levels of activity, task persistence, disability



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Dog Phobia Example

Think that every dog bites…

Avoidance

If I think that “every dog bites”…

- I will never be around a dog
- If never around a dog, will my thought ever change?

Avoidance of Symptoms

Behavioral Experiments

- Goal: correct the belief that all activity will result in symptom exacerbation

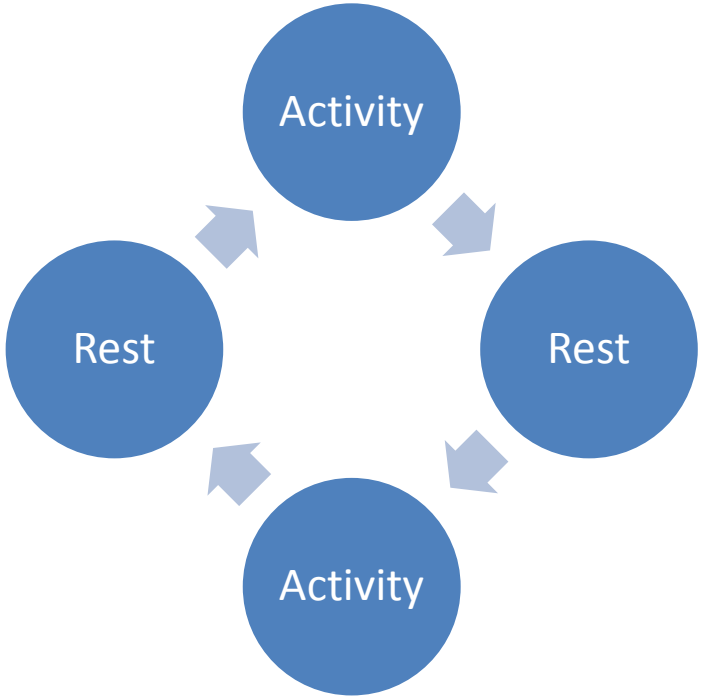
- Set up small experiments to prove…

Activity≠ Symptoms

Over-Exertion/Pushing Too Hard

Pacing

- Goal: Address behavior resulting in symptom exacerbation
- Work in “bursts”



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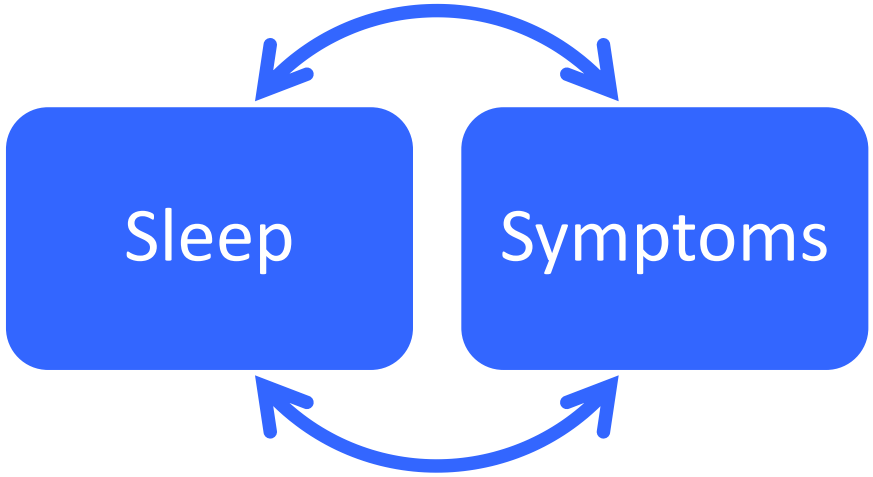
Sleep hygiene

- Consistent bedtime and wake time
- Consistent bedtime routine
- Avoid spending non-sleep time in bed
- Avoid screen time prior to bed
- Avoid caffeine
- 20-10 rule
- Shift bedtime



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"Think"

Cognitive Interventions

Goal: reduce maladaptive thoughts about symptoms

Problems:

- Underestimation of pre-injury symptoms (good old day bias)
  - Perceptions of existence, hypervigilance, differences in responding
- Perfectionism
  - Concerns about failing to meet standards
  - Self-evaluation even more polarized
  - Self-criticism and/or procrastination maintain unmet standards

Cognitive Distortions

Identify negative beliefs:

- *Black & white thinking*: I can't remember anything
- *Generalization*: Can't remember that answer, so here we go again
- *Mental filter*: Can't believe I got 5 wrong on test

Cognitive Distortions

Identify negative beliefs:

- *Fortune telling*: My memory will never come back
- *Mind reading*: Others do not believe my symptoms
- *Catastrophizing*: Due to my grades, I will never get into college

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Cognitive Modification

Re-attributing problems

- Pre-morbid functioning
- Alternative influencing factors

Interpreting perceived mistakes

- Not end of world
- Behavioral experiments

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What to refer to CBT for?

- Mood/anxiety concerns
- Poor compliance with physical therapy
- Poor adjustment with injury/activity limitations
- Continued focus on injury or recovery
- Unclear etiology of symptoms
- Not meeting treatment goals
- Pain management

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How to refer?

- Never say due to stress or anything "psych" related
- Focus on the need to "aid recovery" and impaired functioning (school, pain, sleep, not playing sport)
- Focuses on goal of returning to normal functioning
- Not "talk therapy"

Questions?

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Retirement

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Kids deserve the best.

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Odds & Ends

- HS FB players (n=438) no different from HS band members (n=140) for future Dementia (3%:1.4%); Parkinson (2.3%:3.6%); ALS (0.5%:0.7%) Savica, 2012
  - NFL speed positions higher risk of Alzheimer, Parkinson, ALS than general population/non-speed Lehman 2012

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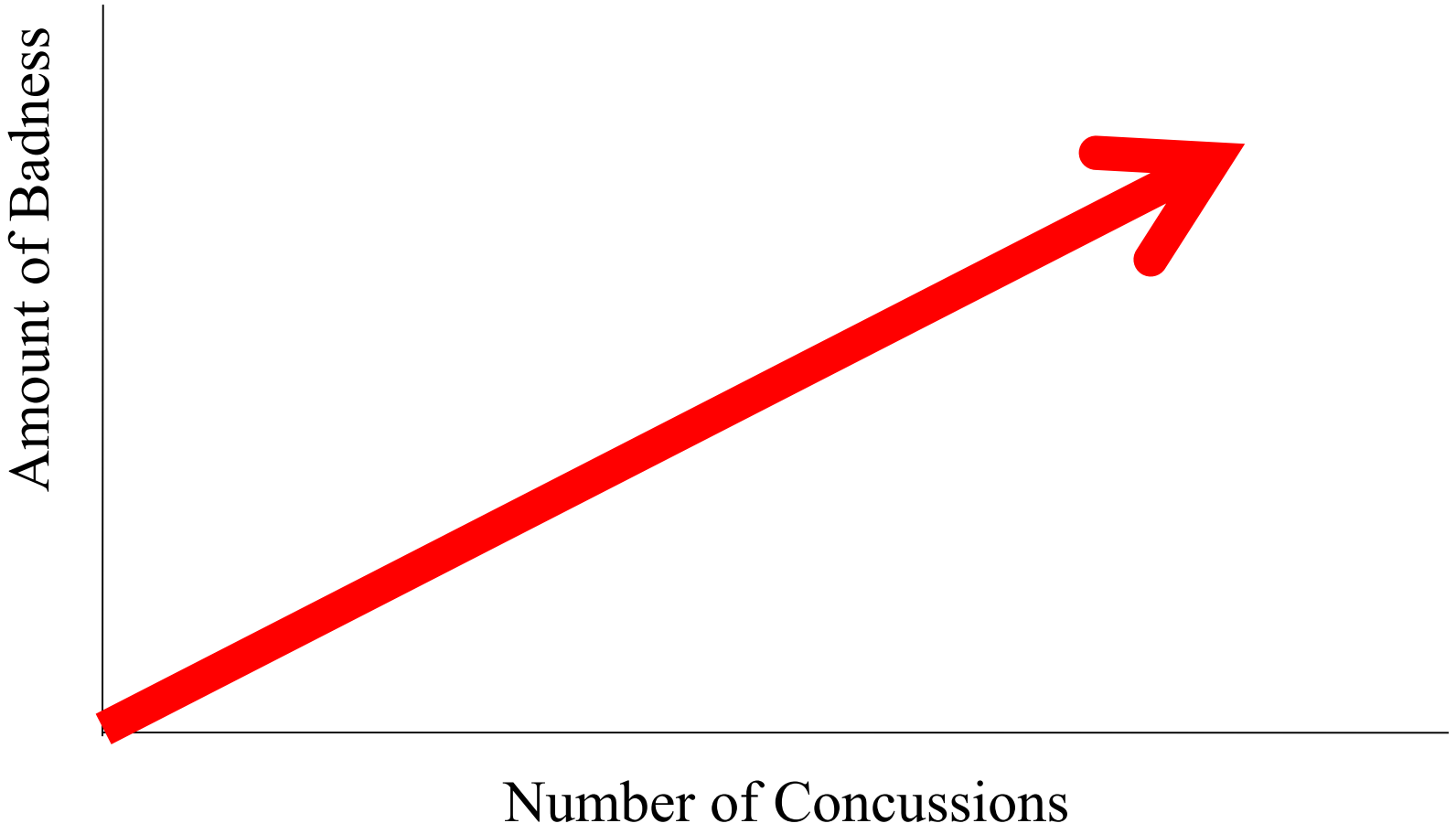

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Unique and Variable

- Incomplete recovery
- How many overall?
  - Per season: 2-3
  - Rapid occurrence
  - Prolonged recovery
- Decreasing mechanism of injury or "easy concussibility"
  - ApoE4 gene – worse outcomes
- Impact on life
- Neuroimaging abnormalities
  - Chiari, hemorrhage
- Parental or athlete anxiety

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Protective Equipment

- 2015 Zuckerman et al – acute outcomes in helmeted v unhelmeted sports are similar
- Helmets
  - Excellent for reducing catastrophic head injury
- Mouthguards
  - Excellent for reducing dental injury
- There is no "Concussion-Proof" helmet or mouthguard
  - Helmets may reduce amount of impact to skull, but there is no evidence that this has actually reduced concussion incidence

McCrory et al 2013; Daneshevar et al. 2011; Benson et al. 2009; Guskiewicz et al. 2014

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Questions?

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