Rehabilitation of Prolonged Concussion Symptoms in Young Athletes

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Financial Disclosures

- I have no relevant financial disclosures

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

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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
  - Disturbed cerebral blood flow and cerebral autoregulation (ability to maintain constant cerebral blood flow with changes in blood pressure)
  - Altered pulmonary ventilation leading to decreased cerebral blood flow

Leddy 2007

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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 (think you are exercising harder than you are)
- 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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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

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:

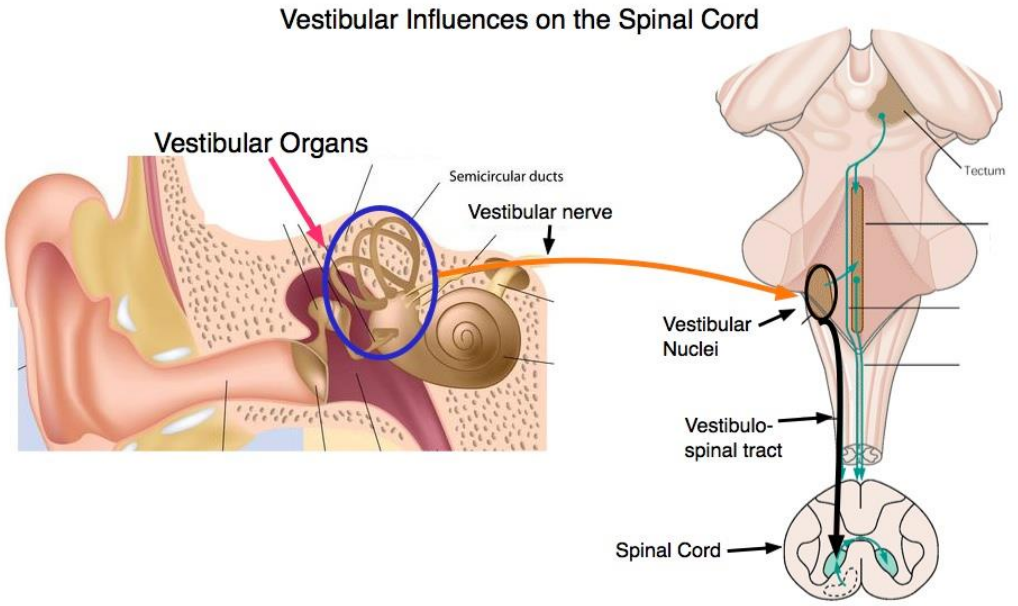
- Vestibulo-spinal component – regulates postural stability
- Vestibulo-ocular component – maintains visual stability during head movements
- Together play a vital role in balance, gaze stabilization, and visual and spatial orientation

Kontos 2017

Vestibulo-spinal component

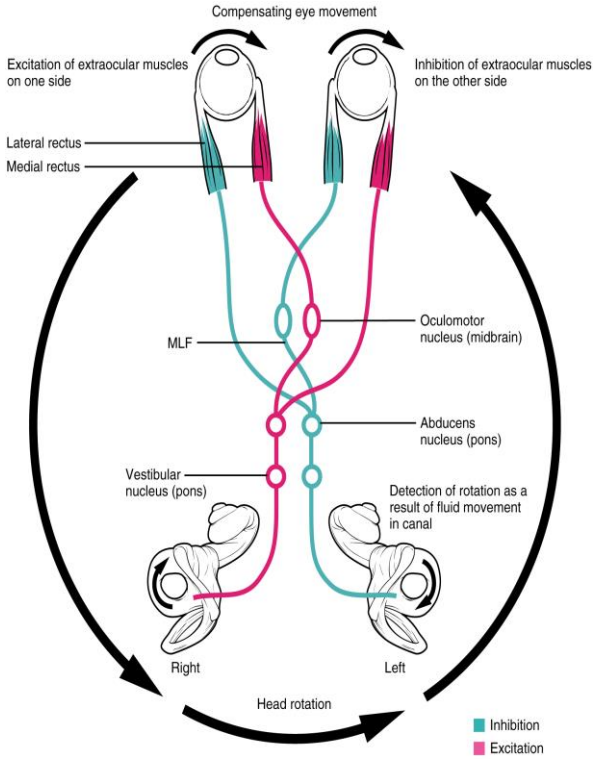
- Helps to regulate postural stability
  - Objective balance impairments usually resolve in 3-5 days post-concussion
  - Screen with:
    - BESS Test
    - Sensory Organization Test (SOT)

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

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

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

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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

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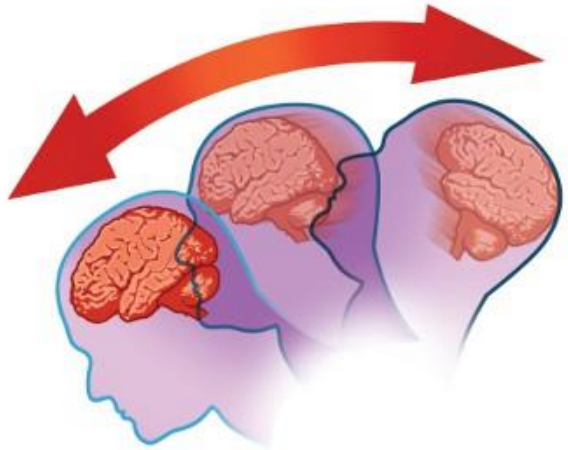
Cervical dysfunction following SRC

- 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

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Evaluating Concussions

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2013 Parents BEST ORTHOPEDIC CARE

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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

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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

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

Objective

- Neuro exam
  - Cranial nerves I-XII
  - DTRs
    - Biceps brachii C5
      Brachioradialis C6
      Triceps C7
  - Myotomes
  - Dermatomes
  - Babinski, Hoffman's

Cook, 2012

- 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

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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

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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

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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

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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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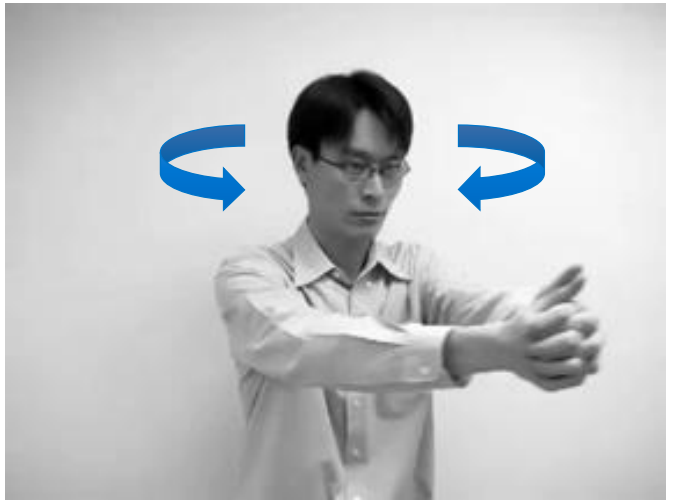
Vestibular-Ocular Reflex (VOR)

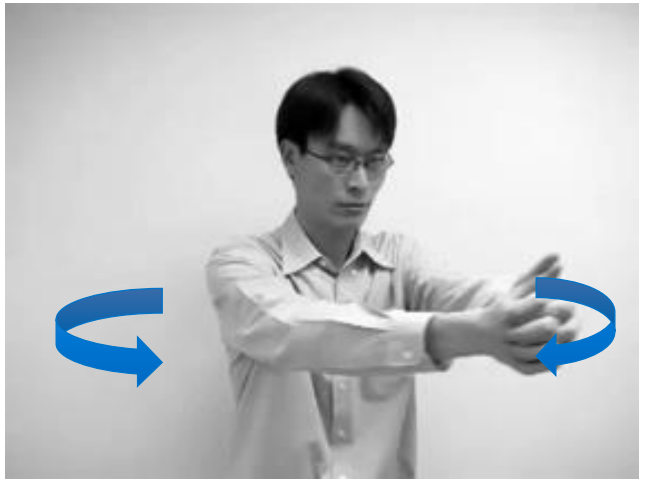
- Patient focuses on a target 3 feet away
- Rotate head horizontally while keeping the target in focus – 20° each direction, 10 cycles
- 180 beats/minute is normal – could use metronome
- Assess symptoms 10 seconds after each test
- Repeat vertically



Whitney, 2016

Visual Motion Sensitivity

- 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

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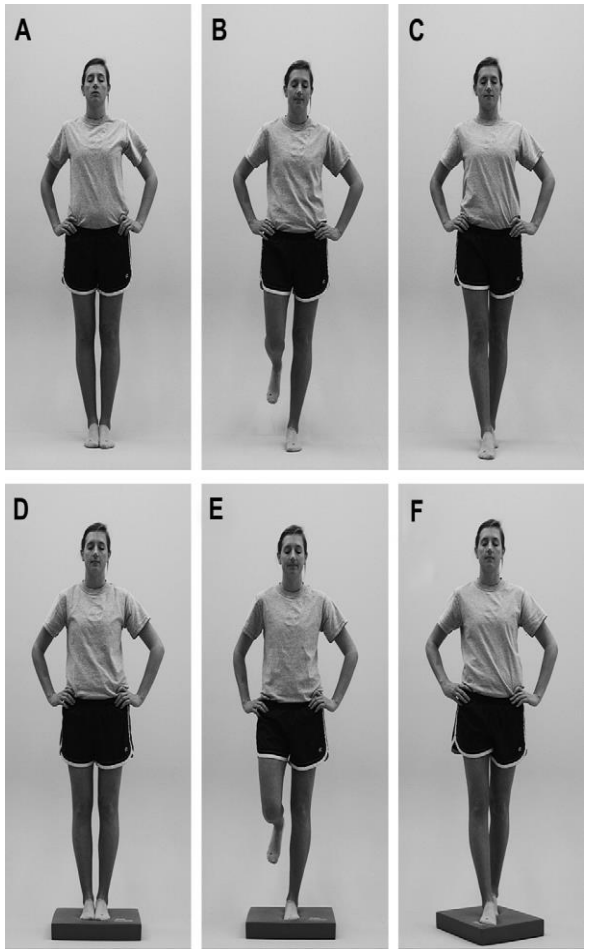
BESS Scoring

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

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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

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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

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

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Concussion Treatment and Rehabilitation

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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

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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

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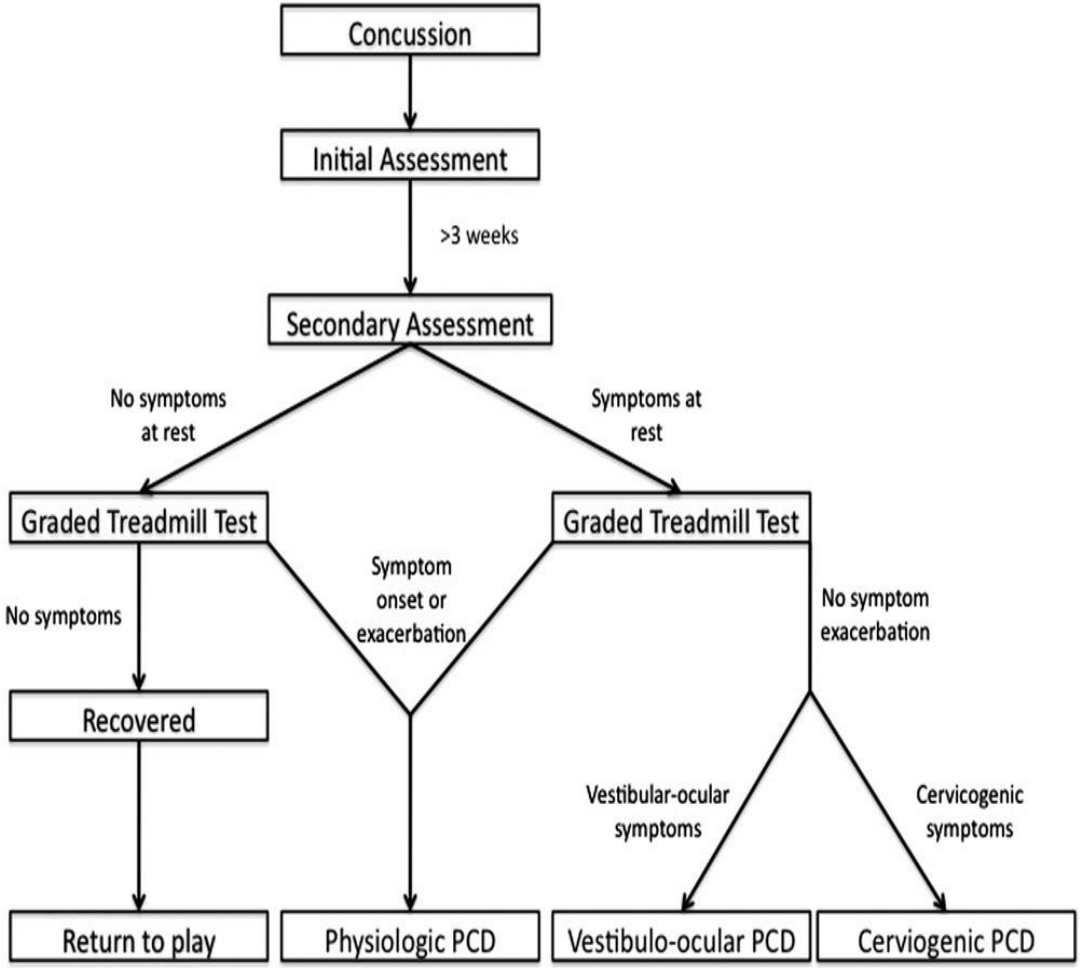
Treatment Classification



- Physiologic
- Vestibulo-ocular
- Cervicogenic

Ellis 2015

Concussion Clinical Trajectories

Collins 2013

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

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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

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

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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

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

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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

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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

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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

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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

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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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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, Behavioural and Psychological

- 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

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