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Physical Therapy for Children and Adolescents with Persistent Post Concussion Symptoms



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Course Objectives

- Review current concussion demographics/ epidemiology
- Literature review
- Exertional tests and sub-symptom threshold training
- Components of a physical therapy evaluation
- Musculoskeletal assessment and treatment
- Vestibular/ oculomotor rehabilitation- lecture and lab

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Schedule

- 8:30-10- Concussion overview and active rehabilitation
- 10:30-12- Cervical spine assessment and treatment
- 1:30-3- Vestibular review, assessment, and Vestibular and Oculomotor lab
- 3:15-5- Oculomotor/ vestibular treatment, case studies, test and questions

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Concussion Background

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Terminology

Minor head injury, mild head injury, or closed head injury

"Post concussion syndrome"

Concussion

Mild traumatic brain injury (mTBI)

Complicated mTBI

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What is a concussion?

Sport related concussion is a traumatic brain injury induced by biomechanical forces. Several common features that may be utilized in clinically defining the nature of a concussive head injury include:

SRC may be caused either by a direct blow to the head, face, neck or elsewhere on the body with an impulsive force transmitted to the head.

SRC typically results in the rapid onset of short-lived impairment of neurological function that resolves spontaneously. However, in some cases, signs and symptoms evolve over a number of minutes to hours.

Consensus statement on concussion in sport—the 5th international conference on concussion in sport held in Berlin, October 2016

Paul McCrory,¹ Willem Meuwisse,² Jill Dvorak,^{3,4} Mark Aubry,⁵ Julian Baker,⁶ Devin Brugha,⁷ Robert C. Cantu,⁸ David Cassidy,⁹ Robert F. Echemendia,^{10,11} Rudy J. Castellani,¹² Gunnar A. Dvorak,^{13,14} Richard Ellenbogen,¹⁵ Carolyn Emery,¹⁶ Lars Engelsen,¹⁷ Nina Eide, Hermann Brenner,¹⁸ Christopher C. Giza,¹⁹ Frank M. Goodyear,²⁰ Stanley Herman,²¹ Grant L. Heitman,²² Karen M. Johnston,²³ James Kissick,²⁴ Jeffrey Kutcher,²⁵ John J. Leddy,²⁶ David Maddocks,²⁷ Michael Mancoske,²⁸ Geoff H. Murray,²⁹ Michael McCrea,³⁰ William P. Meehan,^{31,32} Bijl Hagelberg,³³ Jon Paterson,³⁴ Margot Pankaj,³⁵ Kathryn J. Schneider,³⁶ John Sills,^{37,38} Charles H. Soper,³⁹ Kathleen Turner,⁴⁰ Peter Vanheule,⁴¹

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"Concussive Event"

- The same force that caused the concussion can also result in a concomitant injury to other body structures

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Concussion Pathophysiology

Indiscriminate neurotransmitter release

Ionic disruption

Ionic pumps work to restore homeostasis, requiring more energy and glucose

Decreased cerebral blood flow

Disparity between glucose supply and demand, resulting in period of vulnerability

The new neurometabolic cascade of concussion
Giza & Hovda. The new neurometabolic cascade of concussion. *Neurosurgery* 2014 Oct;Suppl:524-33

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Concussion – What Is It?

Halstead et al, 2018

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Concussion Symptoms

- Headache 86-96%
- Neck pain 90%
- Dizziness 65-75%
- Difficulty concentrating 48-61%
- Confusion 40-46%

Halstead et al 2018 and Tiwari et al 2019

Not all concussions are the same

Howell et al., *Acta Ped*, 2016

- Symptom scales are subjective and non-specific to concussion
- Athletes may over- or under-report their symptoms
- Symptoms may not accurately reflect physiologic healing

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Neuroimaging

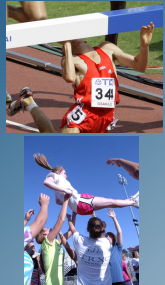
- CT or MRI of the brain contributes little to concussion evaluation and management except when there is a suspicion of more severe intracranial injury or structural hemorrhage (skull fracture or hemorrhage).
- Symptoms of more serious intracranial injury include severe or worsening headache, loss of consciousness for over 30 seconds, deteriorating level of consciousness, repeated vomiting, significant irritability, a combative state, seizures, and worsening symptoms.

Halstead et al 2018

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Concussion Epidemiology

- ~ 1.1-1.9 million sport and recreation-related concussions (SRRCC) per year in US children aged ≤ 18
- Girls > boys
 - Reason behind sex difference is unclear but may be related to female athletes having weaker necks, the role of estrogen, or the possibility that girls are more likely to report a concussion
- Less than 5% of concussions in sports involve loss of consciousness; hence many will be underreported or unrecognized



Halstead et al 2018 and Bryn et al 2016

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Concussion Epidemiology

- Highest Risk Sports:
 - Boys: Football, lacrosse, ice hockey and wrestling
 - Girls: Soccer, lacrosse, field hockey and basketball
 - Other studies found that girls cheerleading was the 2nd most common sport
- Competition has increased risk vs practice
 - Exception – cheerleading
 - Boys lacrosse and soccer have about 7 times higher rate in games vs. practice while football has about 3 times and wrestling is twice as high
 - Girls lacrosse, soccer and basketball have about 5 times higher rate in competition versus practice.

Halstead et al 2018

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Sport	Concussion per 1000 AE
Boy's tackle football	0.54-0.94
Girl's soccer	0.30-0.73
Boy's lacrosse	0.30-0.67
Boy's ice hockey	0.54-0.62
Boy's wrestling	0.17-0.58
Girl's lacrosse	0.20-0.55
Girl's field hockey	0.10-0.44
Girl's basketball	0.16-0.44
Boy's soccer	0.17-0.44
Girl's softball	0.10-0.36
Boy's basketball	0.07-0.25
Girl's volleyball	0.05-0.25
Cheerleading	0.06-0.22
Boy's baseball	0.04-0.14
Girl's gymnastics	0.07
Boy's and girl's track and field	0.02
Boy's and girl's swimming and diving	0.01-0.02

Concussion Rates in High School Sports

Halstead et al 2018

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Concussion Outcomes

- Most children and adolescents fully recover within 1-4 weeks
- Vast majority get better without complications
- Approximately 30% experience persistent post concussion symptoms (PPCS)




Halstead et al 2018, Leddy et al 2018 and 2019

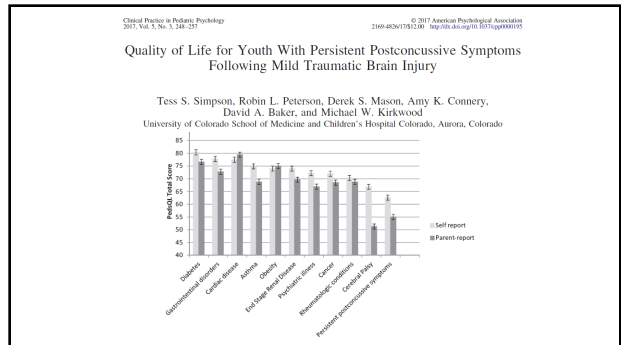
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Prolonged symptoms, > 28 days

- Potential risk factors:
 - More severe head injury (e.g., abnormal CT or MRI)
 - Age (e.g., older age/ high school)
 - Sex (female)
 - Pre-existing conditions
 - Migraine/ headache disorders, ADHD, learning disorder, mental health conditions (anxiety or depression), and sleep disorders
 - PTSD
 - Personality type
 - Parent/family factors and stress
 - Management (iatrogenic effects)
 - History of multiple concussions



Halstead et al 2018



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Current Evidence

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Current evidence for the use of PT after a concussion...

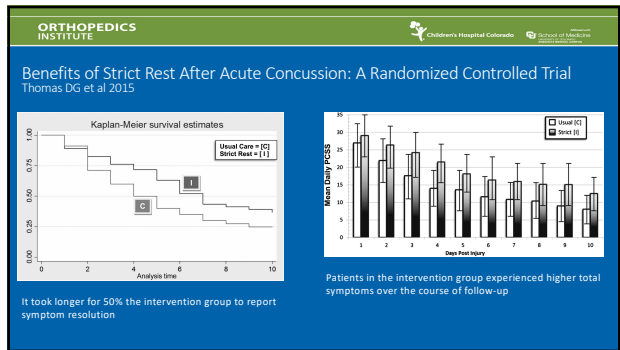
- Moderate levels of physical activity (sub-symptom threshold aerobic exercise) may be beneficial.
 - Leddy 2013, Leddy, 2018, Leddy 2019, McCrory 2016, Gagnon 2009
- A combination of treatments may be beneficial (cervical, vestibular and subsymptom threshold aerobic exercise)
 - McCrory 2016, Schneider KJ 2017, Crodingley 2016, Schneider KJ 2013, Ellis MJ et al 2018, Reneker 2017

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Evidence for rest???- Berlin Guidelines

*There is currently insufficient evidence that prescribing complete rest achieves these objectives. **After a brief period of rest during the acute phase (24-48 hours) after injury, patients can be encouraged to become gradually and progressively more active while staying below their cognitive and physical symptom- exacerbation thresholds (ie, activity level should not bring on or worsen their symptoms). It is reasonable for athletes to avoid vigorous exertion while they are recovering. The exact amount and duration of rest is not yet well defined in the literature and requires further study.***

McCrory et al 2016



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Schneider KJ et al 2014

- Randomized control study of 12-30 year olds
- Both groups received weekly sessions with a PT for 8 weeks or until medical clearance
- Both groups received postural education, ROM exercises, cognitive and physical rest until asymptomatic followed by a protocol of graded exercises
- The intervention group also received cervical spine and vestibular rehabilitation

By 8 weeks 73% of the treatment group was medically cleared vs. 7% in the control group

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Reneker et al 2017

- Looked at subjects 10-23 years old
- Starting PT at 10 days post concussion was safe
- Those in the **intervention group were medically cleared sooner** than those in the control group (intervention group did vestibular rehab and cervical rehab if needed)
 - Cervical spine therapy included manual therapy of the cervical and thoracic spine, exercises for the flexors and extensors, and sensorimotor retraining exercises
 - Vestibular rehab included an individualized program of habituation, gaze stabilization, adaptation exercises, standing balance exercises, dynamic balance exercises and canalth repositioning maneuvers

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Ellis MJ et al 2018

- Found that patients (age 6-19 years old) **with cervical spine dysfunction (CSD) after a sports related concussion took longer** to achieve physician-documented clinical recovery (28 days vs. 17)
- Patients **with CSD were 3.95 times more likely to experience delayed clinical recovery** (> 4 weeks) compared to those without CSD
- Patients diagnosed with SCD and SRC were significantly more likely to be **female**
- Patients with SRC and SCD were **more likely to have coexisting vestibulo-ocular dysfunction** compared to those without CSD

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Crodingley et al 2016

- 106 patients, age 11-19 years old
- Total of 141 treadmill tests
- Modified test to 3.2 mph and stopped if symptoms increased or at exhaustion
- No serious complications related to treadmill testing except sore legs
- Treadmill testing was used to classify patients into subtypes
 1. Physiologically recovered
 2. Physiological Post Concussion Disorder (PCD)- treated with submax exercise prescription 5 days a week- 5 minute warm up, 20 minutes of aerobic exercise at 80% of the Max HR achieved during the test, 5 minute cool down, seen every 2-4 weeks
 3. Vestibulo-ocular PCD- did submax aerobic exercise and targeted vestibular rehab
 4. Cervical PCD- did submax aerobic exercise and cervical spine PT

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Crodingley et al 2016

Treatment Group	Improved (N, %)	Return to play (N, %)
Isolated Physiologic PCD (N=19, 45.2%)	N=17 (89.5%)	N=14 (73.7%)
Physiologic PCD + VT (N=13, 31.0%)	N=11 (84.6%)	N=11 (84.6%)
Physiologic PCD + CPT (N=4, 9.8%)	N=4 (100%)	N=3 (75%)
Physiologic PCD + VT + CPT (N=5, 8.6%)	N=5 (100%)	N=5 (100%)

PCD= post concussion dysfunction
VT= vestibular therapy
CPT= cervical physical therapy

FIG. 2. Clinical outcomes in 41 cases involving pediatric patients with physiologic 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.

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Active Rehabilitation

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Exercise is medicine for concussion- Leddy 2018

- " Evaluation and treatment approaches based on the physiology of concussion suggest that exercise is medicine for concussion, potentially adding a new dimension to concussion care to help safely speed recovery and prevent persistent post concussion symptoms in some patients."
- " The principle of exercise is medicine is that health care systems might begin to think of exercise as a medication that should be prescribed to patients. As with medication, however, it is essential that exercise be prescribed based on a "dosage" that suits the characteristics of the individual."

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Benefits of Exercise- Leddy et al 2013

- Exercise can **improve brain function via brain neuroplasticity** in as early as 6-8 weeks of exercise
- Moderate aerobic exercise (60% of max HR) for 150 min/ wk
 - Cognitively protective
 - Associated with higher levels of brain-derived neurotrophic factor (BDNF) which is involved in neuro repair after injury
 - Greater hippocampal volume and improved spatial memory
- Premature exercise in the first week may delay recovery but too little activity may also be detrimental

Table I. Theoretical rationale for the Montreal Children's Hospital Rehabilitation After Concussion (MCH-RAC) Programme.

Slide of rationale for exercise (Table 1)- Gagnon Brain Injury 2009

- I. *Aerobic Activity*
 - Increase brain-derived neurotrophic factor (BDNF)
 - Synaptogenesis
 - Increased cardiovascular activity
 - Altered cerebral vascular function and brain perfusion
 - Increased endorphin release
 - Improved brain autoregulation
 - Improve overall fitness level
 - Reduce fatigue/improve energy levels
 - Reduce stress, worry and anxiety
 - Improve mood
 - Improve cognition
 - Improve self-efficacy and performance
- II. *Cordination/Skill Practice (Enjoyed Activity)*
 - Increased endorphin release
 - Improve mood
- III. *Visualization of Positive and Successful Activities Related to Preferred Physical Activity*
 - Reassurance and increased confidence relating to ability to practice sport
 - Activated brain regions linked to motor activities
 - Improve self-efficacy and performance
- IV. *Education and Motivation*
 - Education and reassurance leads to empowerment and improved coping
 - Increased confidence in services provided

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Gagnon Brain Injury 2009

- 16 children and adolescents (8-17 years old) 1 month post injury
- Participated in an active rehab program
 1. sub-maximal (50-60% maximal capacity) aerobic training on either a stationary bike or treadmill up to 15 minutes
 2. Light coordination exercises (tailored to the child's favorite sport, footwork or ball activities) up to 10 minutes
 3. Visualization (sport related) for 5 minutes
 4. Education and motivation, included a HEP
- Stopped if symptoms increased
- All 16 were able to return to their normal lifestyles and sport

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Schneider B J Sports 2013

Articles that met the inclusion criteria

1. The study by [Gagnon et al.](#)
2. [Laddly et al.](#) cross over study with 12 patients with persistent symptoms
 - All patients had symptoms during the treadmill test (Balke)
 - Completed a treadmill test before and after a 2-3 week baseline non-intervention period
 - All patients completed a treadmill phase of exercising 5-6 times per week until they were asymptomatic with exhaustive exercise
 - There was a reduction in symptom score and all patients were able to return to preinjury levels of activity
3. [Schneider et al.](#) Case series of athletes with persistent symptoms of dizziness, neck pain and HA.
 - Found functional improvements and reported symptomatic improvements following a course of combined cervical spine manual therapy, neuromotor retraining, sensorimotor retraining, and vestibular PT
4. [Schneider et al.](#) randomized controlled trial of patients with persistent dizziness, neck pain, and HA following a sport-related concussion
 - Those treated with a combination of cervical spine manual therapy, neuromotor retraining, sensorimotor retraining and vestibular PT were more likely to be medically cleared to return to sport within 8 weeks of initiating treatment

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Lai et al 2018- Systematic Review and Meta- Analysis

- Looked at articles up to 2016
- Search found 1096 articles but only 14 met the inclusion criteria
- Exercise significantly decreased the PPCS score percentage of patients with symptoms after a concussion
- Exercise significantly decreased the percentage of patients with symptoms of a concussion
 - Exercise decreased the duration of symptoms
- Exercise significantly decreased the number of days of missed work
- Exercise did not effect the BESS score

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Leddy et al 2019

- Randomized Control Trial within the 1st week of the concussion of 1.) early aerobic activity or 2.) a stretching group
- The exercise group was instructed to exercise at 80% of the max HR achieved on the test for 20 minutes or if symptoms increased by 2 points
- The stretching group did 20 minutes of whole body stretching
- The aerobic group recovered in a median of 13 days while the stretching group recovered in a median of 17 days
- There was a tendency for the aerobic exercise group to not have a delayed recovery.
- Prescribed subsymptom threshold aerobic activity can begin after 48 hours following a SRC

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Purpose of Exertional Testing- Leddy et al 2013

- Determines tolerance for aerobic activity and diagnoses physiologic dysfunction vs. other injury
 - Quantify the clinical severity of their exercise capacity
 - Compare the HR at the point of symptoms exacerbation to the theoretical max HR
 - If they can finish the test then look for other causes of symptoms
- It is a good indication of how close to full physiologic recovery they are
 - Compare the HR at the point of symptom exacerbation to the athlete's theoretical max HR
- Establish a safe exercise treatment program
- Do not do the test if the patient is experiencing significant cervical dysfunction or severe vestibular/ balance issues.

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Absolute Contraindications

- History
 - Unwilling to exercise
 - Increased risk for cardiopulmonary disease
 - Resting symptoms of 7 or greater on VAS**
- Physical exam
 - Focal neurologic deficit
 - Significant balance deficit, visual deficit or orthopedic injury that would pose a risk for walking on the treadmill

Relative Contraindications

- History
 - Beta blocker use
 - Major depression (may not comply with directions)
 - Does not understand English
- Physical Exam
 - Minor balance deficit, visual deficit, or orthopedic injury
 - SBP > 140 mm or DBP > 90 mm
 - Obesity: BMI > 30

Leddy et al 2013 and 2019

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Visual Analog Scale- assess symptom level every minute, stop if symptoms increase by 3 points

0 No Hurt 2 Hurts Little Bit 4 Hurts Little More 6 Hurts Even More 8 Hurts Whole Lot 10 Hurts Worst

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rating	description
6	NO EXERTION AT ALL
7	EXTREMELY LIGHT
8	
9	VERY LIGHT
10	
11	LIGHT
12	
13	SOMEWWHAT HARD
14	
15	HARD (HEAVY)
16	
17	VERY HARD
18	
19	EXTREMELY HARD
20	MAXIMAL EXERTION

Rate of Perceived Exertion- assess every minute, stop if rate is 17-20

Must use the 6-20 RPE scale!!!

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The tests are stopped if...

- Maximum exertion** (RPE score of 17 or more) or
- Symptom exacerbation** that causes **significant increase in pain or symptom severity (increase of 3 or more)**, or the addition of **several new symptoms**, or a marked increase in severity of symptoms resulting in difficulty continuing the test, or
- Rapid progression of complaints** (HA to searing focal pain), patient appears faint or unsteady, or tester determines that continuing the test poses a significant health risk for the patient, or
- Patient reports an **inability to continue the test safely**

L eddy et al 2013, 2018, and 2019

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Buffalo Concussion Treadmill Test- Leddy et al 2013, 2018, 2019

- Get resting HR
- Start at 3.6 mph and 0% incline (alter speed if needed)- usually start at 3.2 mph
- Incline is increased to 1% at minute 2
- Increase incline by 1% every minute for 15 minutes
 - Then the speed is increased by .4 mph for each minute
- Rating of perceived exertion and symptoms are assessed every minute
- HR and BP are assessed every 2 minutes
- Do a 2 minute cool down

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Buffalo Concussion Bike Test- Leddy et al 2018

- Get resting HR
- Use the power output Excel spreadsheet to calculate resistance to start at in watts (put in body weight in kg)
- From minutes 0 to minute 2 ride at 60 rpms at power level for stage 0
- At the 2nd minute mark increase the resistance for stage 1, the resistance is increased every 2 minutes
- Rating of perceived exertion, symptoms and HR are assessed every 2 minutes
- Do a 2 minute cool down at stage 0 and 30 rpms

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What it tells us...

Exercise intolerance= early symptom limited threshold (at or **below 70% of the age-predicted maximum heart rate**) is consistent with a diagnosis of concussion

- It is believed to reflect a disturbance in autonomic control of the cerebral blood flow during exercise
- Patients with **normal exercise tolerance** (can exercise to RPE>17 or HR>80% of age predicted max) but stop the test because of exhaustion have **recovered physiologically**
 - If they still have symptoms it is recommended to be evaluated for possible anxiety/ depression, cervical spine dysfunction, oculomotor/ vestibular dysfunction, and/or temporomandibular dysfunction as the cause of their symptoms.

Leddy et al 2013 , 2018, and 2019

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Recommended exercise prescription

- Start with 80-90% of the submax HR at symptom exacerbation
- Exercise for 20 minutes a day, 6-7 days a week
 - Warm up for 5 minutes and then do 20 minutes at the HR goal
 - Might need to start with just 5 minutes a day
- Increase by 5-10 beats per minute every 2 weeks
- Stop if symptoms increase by 2 points

Leddy et al 2013 , 2018, and 2019

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BCTT vs. BCBT- Haider et al 2019

- Found that the HR at symptom exacerbation on BCBT is equivalent to the BCTT for the assessment of exercise tolerance after a concussion in adolescents
- Treadmill symptom exacerbation occurred at a mean of 8.1± 2.8 minutes
- Bike test symptom exacerbation occurred at a mean of 14.6± 6 minutes
- The BCBT might be safer if there are vestibular symptoms or you are worried about the patient falling

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Case Studies

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How to determine the target HR zone

- Max HR= 220- age
- Heart rate reserve (HRR)= Max HR- resting HR
- Multiply your HRR by .7 (70%) and add your resting HR
- Multiply your HRR by .85 (85%) and add your resting HR
- These 2 numbers are your target zone.
- Moderate exercise= 50-70% HRR
- Vigorous exercise= 70-85% HRR (target HR zone)

DD- 15 year old male

Baseline VAS	0/10
Baseline HR	114 bpm
HRR	91 bpm
70% HRR	177.7 bpm
85% HRR	191.35 bpm
Test ended	20 minutes
RPE	19
Ending HR	186 bpm
Ending VAS	0/10

- Concussion sustained from a helmet to helmet tackle during football practice
- All symptoms have resolved
- He was cleared to return to sport

JL- 18 year old male, first test

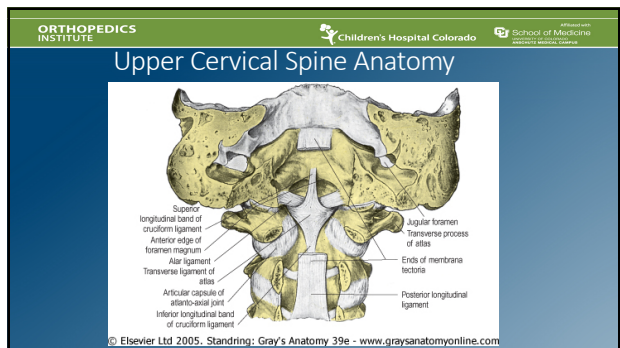
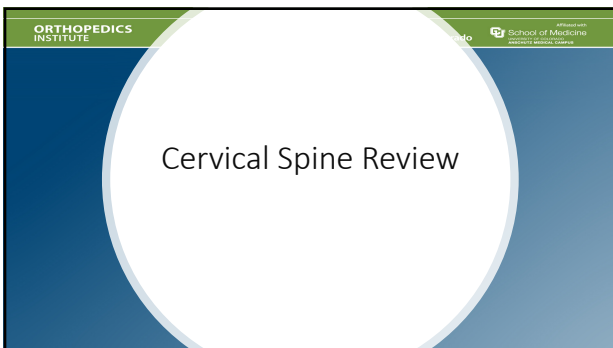
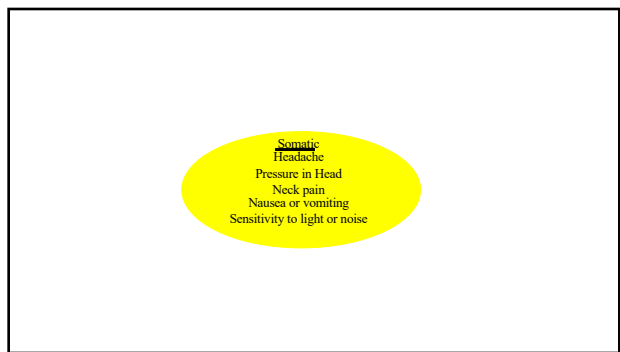
Baseline VAS	4/10 HA and dizziness	<ul style="list-style-type: none"> • Hit in the right temple with an elbow while playing rugby • Had a 3 minute seizure on the field • CT and CTA of the brain and neck were normal • Main symptoms were neck pain, headaches and a lot of dizziness • Tested on his 4th PT visit • Instructed to begin exercise at 80% of 115= 92 bpm
Resting HR	74 bpm	
HRR	128 bpm	
70% HRR	164 bpm	
85% HRR	183 bpm	
Test ended	10 minutes	
RPE	17	
Ending HR	115 bpm	
Ending VAS	7	

JL- 18 year old male, 2nd test

Baseline VAS	0/10	<ul style="list-style-type: none"> • Retested 2 months later/ included 9 PT visits • Still has been seen for dizziness and HA but they are much better • Not returning to football but is planning on running cross country instead
Resting HR	63 bpm	
HRR	139 bpm	
70% HRR	160 bpm	
85% HRR	181 bpm	
Test ended	20 minutes	
RPE	18	
Ending HR	164 bpm	
Ending VAS	0/10	

CB- 17 year old male

Baseline VAS	HA 5/10	<ul style="list-style-type: none"> • Sustained multiple concussions within a 2 week period while playing football • All symptoms had resolved except HA • His doctor cleared him to return to sport as there was more of a psych/migraine component to his headaches as he was able to complete the BCTT without difficulty. Unable to reproduce symptoms in clinic but headaches still stayed at 4 or 5/10
Resting HR	100 bpm	
HRR	103 bpm	
70% of HRR	172 bpm	
85% of HRR	188 bpm	
Test ended	20 minutes	
RPE	13	
Ending HR	182 bpm	
Ending VAS	HA 5/10	



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Upper Cervical Spine Anatomy Review

- Occipital-atlanto (OA) joint**
 - Principal motion is flexion (15-20 degrees), nodding
 - Side flexion is approximately 10 degrees, no rotation
 - Several ligaments stabilize the OA joints
 - Tectorial membrane- broad band covering the dens and it's ligaments, found in the vertebral canal
- Alar Ligaments**
 - limit flexion and rotation
 - 2 strong rounded cords on each side of the upper dens, they pass up and laterally to attach on the medial sides of the occipital condyles
- Atlanto-Axial joint (C1-C2)**
 - Most mobile articulation in the spine (provides about 50% of all rotation)
 - flexion and extension is about 10 degrees, side flexion is 5 degrees and rotation is about 50 degrees
 - Main supporting ligament is the transverse ligament- holds the dens against the anterior arch of the atlas

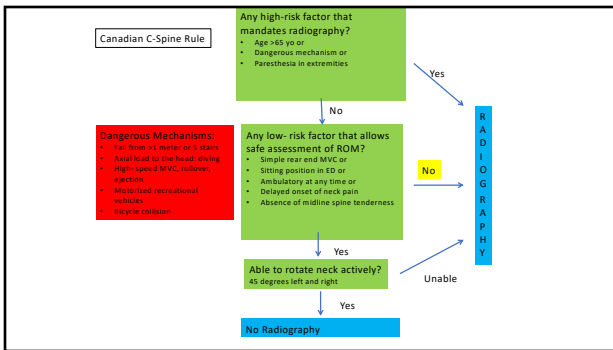
Dutton

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Deep Muscles — Neck and Upper Back

- Rectus capitis posterior minor
- Rectus capitis posterior major
- Obliquus capitis superior
- Obliquus capitis inferior
- Splenius capitis
- Splenius cervicis
- Sternocleidomastoid
- Levator scapulae
- Splenius cervicis
- Levator scapulae
- Scalenus medius
- Scalenus posterior
- Longissimus cervicis
- Buccalinator
- Longissimus thoracis

Serratus posterior superior, Rhomboides minor (C1), Rhomboides major (C2), Longissimus cervicis, Nucleus pulposus, Intervertebral disc, Ligamentum flavum, Spinous process of vertebrae, Transverse process of vertebrae, Superior process of ribs.



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Primary headache (HA) disorder- ICHD 3 rd ed 2013	Migraine HA	Tension HA	Cervicogenic
Duration	2-72 hours	30 min-several hours	Variable
Severity	Moderate-severe	Mild-moderate	Mild-moderate
Description	Throbbing, pulsating	Steady, squeezing	Dull, steady, aching
Unilateral or bilateral	Unilateral or bilateral	Bilateral	Unilateral, bilateral or occipital
other	+ Nausea/ vomiting, + photophobia and phonophobia, +/- aura, worse with exercise	- Nausea/ vomiting, possible photo and phonophobia, not worse with exercise	Triggered by neck movement

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Physical Therapy Evaluation- focus on musculoskeletal system

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PT Concussion Evaluation

- Detailed history
 - Mechanism of injury, associated injuries
 - Symptom checklist (#, severity, change since injury)
 - Prior concussions (how long they took to resolve)
 - Past medical history- esp. screen for high risk of prolonged recovery
 - Family medical history
- Exam
 - Upper cervical ligament tests
 - Upper and lower quarter screen- includes dermatomes, myotomes, and reflexes
 - Cranial nerve exam
 - Posture
 - Joint mobility- includes upper cervical spine
 - Soft tissue mobility
 - Cervical ROM
 - Thoracic ROM

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PT Evaluation Continued

- Cervical, thoracic and lumbar spine examination and special tests
- Oculomotor screen
 - Tracking, eye ROM, saccades, convergence, VOR cancellation, sustained hold
- Vestibular testing
 - Head impulse test
 - VOR- horizontal and vertical
 - Dynamic visual acuity test
 - Find a successful settling technique
 - BPPV tests
- Gait/Balance testing
 - BESS or mCTSIB, tandem walk, dual task gain
- Exertional Test- Buffalo Concussion Treadmill or Bike Test
- Cervical Proprioception if time or at another session as needed
- Test shoulder or other areas as needed

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Tiwari et al 2019

Impairments

- Posture= 99%
 - Forward head, scapular anterior tilt and increased kyphosis most common
- Myofascial= 98%
 - Upper trap and suboccipitals most tension
- Joint mobility= 86%
- Muscle strength= 62%
 - Rhomboids, middle and lower trap and neck flexor endurance most common weakness
- Cervical joint proprioception= 29%

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Cervical instability tests- Always Do First!!!

- Sharp Purser Test
- Transverse Ligament Test
- Alar Ligament Test
- Vertebral Artery Test

Dutton

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Modified Sharp Purser Test- tests the transverse ligament

- Sharp Purser Test:** always do first but use extreme caution
 - First ask the patient to flex the head around the craniovertebral axis, if no symptoms then...
 - With patient sitting the therapist stabilizes C2 with 1 hand and applies a posterior force to the forehead with the other hand
 - Positive if the examiner feels the head slide backwards (indicates that the subluxation of the atlas has been reduced), may be a clunk
- Specificity= 96% and Sensitivity= 88%

Dutton

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Transverse Ligament Test

- Patient is supine, examiner holds occiput with palm, 3rd, 4th, and 5th fingers, places index finger in the space between the occiput and C2 spinous process; the head and C1 are lifted anteriorly together (ant. Shear is normally resisted by the transverse ligament. Hold the position for 15 seconds)
 - Positive if there is a soft end feel, muscle spasm, dizziness, nausea, paresthesia of the lip, face or limb, nystagmus, lump sensation in the throat
- Only performed when sharp purser test is negative
- Specificity= 95% and Sensitivity= 95%

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Alar Ligament Test

- Alar ligament 1.) lateral flexion stress test, 2.) rotational stress test
 1. Patient is sitting or supine with head in neutral, examiner stabilizes the axis with a wide pinch grip around spinous process and lamina; examiner then attempts to side flex the head
 - Normally, if the ligament is intact, minimal side flexion occurs, with a strong capsular end feel
 2. Patient is sitting or supine, examiner grips lamina and spinous process of C2 between finger and thumb. While stabilizing C2, the examiner passively rotates the patient's head moving to "no symptom" side first
 - If more than 20-30 degrees of rotation is possible without C2 moving, indicates injury to contralateral alar ligament, especially if the lateral flexion test is also positive

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Vertebral Artery

- Potential Red Flags:
 - Altered taste
 - Visual changes
 - Unusual headache/ neck pain
 - Tinnitus
 - Gait disturbances
 - Hoarseness
 - Vomiting
 - Memory loss
 - Motor loss
- Vertebral Artery Test
 - Patient is supine, take head back into extension and lateral flexion, then rotate towards the same side and hold about 30 seconds
 - Positive if complaints of dizziness or nystagmus
 - Debate if it should be used as the test has poor psychometric properties
 - Use the 5D's, 2 A's and 3N's instead?

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Symptoms of Possible Serious Problems

- Vertebral artery or vertebrobasilar injury

5 D's	And	3 N's
Dizziness	Ataxia	Nausea
Drop attacks	Anxiety	Numbness
Diplopia		Nystagmus
Dysarthria		
Dysphagia		

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Sensory Screen

- C5: mid- deltoid
- C6: dorsal aspect of web space
- C7: dorsal aspect of middle finger
- C8: medial border of 5th MC
- T1: medial forearm

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Myotome Motor Function

- C1 and C2: neck flexion
- C3: neck side-bending
- C4: shoulder elevation
- C5: shoulder abduction
- C6: elbow flexion/ wrist extension
- C7: elbow extension/ wrist flexion
- C8: thumb abduction
- T1: finger abduction
- Positive finding is significant weakness or diminished resistance relative to the opposite side

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Cranial Nerve Exam

- I Olfactory- identify smells
- II Optic- sight
- III Oculomotor- upwards, downward, and medial gaze, reaction to light
- IV Trochlear- downward and lateral gaze
- V Trigeminal- corneal reflex, face sensation, clench teeth
- VI Abducens- lateral gaze
- VII Facial-close eyes tight, smile and show teeth, whistle and puff cheeks
- VIII Vestibulocochlear- hear fingers rub together or watch ticking, hearing tests
- IX Glossopharyngeal- gag reflex, ability to swallow
- X Vagus- gag reflex, ability to swallow, say "Ahhh"
- XI Accessory- resisted shoulder shrug
- XII Hypoglossal- tongue protrusion

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Normal Cervical Range of Motion

- Neck Flexion= 80-90 degrees
 - Inclinometer placed on the top of the patient's head aligned with external auditory meatus and zeroed
- Extension= 70 degrees
 - Inclinometer placed on the top of the patient's head aligned with external auditory meatus and zeroed
- Side bending= 20-45 degrees
 - Inclinometer is positioned in the frontal plane on top of the patient's head in alignment with the external auditory meatus
- Rotation= 70-90 degrees
 - Standard goniometer with patient seated, stationary arm aligned with the acromion process of the shoulder and moveable arm bisecting the patient's nose

Dutton and Child's et al 2008

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Palpation

- Looking for soft tissue or lymph node swelling, tissue texture abnormalities, pain, and/or **reproduction of symptoms**
 - Feel for soft tissue mobility, especially with suboccipital and SCM muscles
 - Treat with soft tissue mobilization and/or modalities (including dry needling)
 - Especially looking to see if you can reproduce their headache
- Tiwari's group classified myofascial tension as no, mild, moderate and severe for each muscle using a 0-3 Likert scale
 - 0= no tension, 3= severe tension

Dutton and Tiwari et al 2019

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Joint mobility

- Cervical segmental exam to test for segmental movement and pain response.
 - Central Posterior to anterior (PA) mobility- test is positive if it produces symptoms, then label mobility as normal, hypermobile or hypomobile
 - Lateral glides, up glides and/or down glides
 - Treat with mobilizations

Childs et al 2008

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OA Joint Restrictions/ Treatment

- About 30 degrees rotation, slight sidebend to other side and then flex (like you are rolling a tire around an axis)
- Treat with hold relax technique by taking to end range and asking patient to "look up at me with only your eyes", hold 6-10 seconds and then look down while taking into more flexion

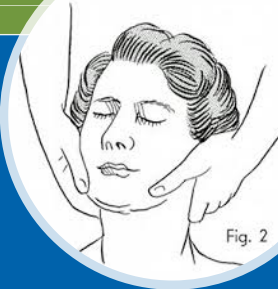


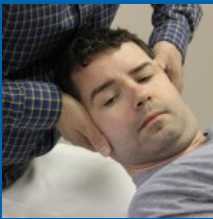
Fig. 2
Dutton

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AA Joint Restrictions/ Treatment

Cervical Flexion-Rotation Test (CFRT)

- Bring into full flexion with rotation, look for pain or asymmetries (more than 10 degree difference) or less than 32 degrees
- Treat with hold relax technique by taking to end range rotation, ask patient to push lightly into your hand turning to the opposite side, hold 6-10 seconds, as they relax take into new rotation end range




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Cervical Rotation Lateral Flexion (CRLF) Test- 1st rib mobility

- Tests 1st rib hypomobility
- Not a provocative test, look for asymmetry
- Patient is seated. The cervical spine is passively and maximally rotated away from the side being tested. While maintaining rotation, the spine is gently flexed as far as possible moving the ear toward the chest.
- Positive when the lateral flexion movement is blocked
- Treat with muscle energy



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Thoracic Mobilizations

- C7/T1- seated
- Middle and low thoracic- prone or supine
- Follow up with foam roller at home
- Contraindications to thrust manipulation**
 - Vertebral fractures, multiple adjacent radiculopathies, osteoporosis or osteomalacia, acute disc herniation, active spondy, ligament joint instability, congenital joint laxity (EDS or Down Syndrome), bony joint instability, myelopathy

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Tests for the present or absence of cervical radiculopathy

- **Spurling's Test:** Patient is seated. Examiner sidebends the neck towards the affected side and applies approximately 7 kg of compression force
 - Considered + if symptoms are reproduced
- **Cervical Distraction Test:** Patient is supine. The examiner grasps under the chin and occiput while slightly flexion the patient's neck and applies a distraction force of approximately 14 lbs.
 - Considered positive if symptoms are reduced

Childs et al 2008

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Deep Neck Flexor Endurance Test(DNFET)

- DNF muscle endurance test- Childs et al 2008
 - Don't do it if it hurts
 - Patient is in hooklying, ask to "tuck your chin" and "hold your head up" while maintaining flexion, raise head off table 2.5 cm. Time stops when they can no longer hold head up or can't maintain chin tuck (look at skin folds)
 - Normal for 20-80 year olds was 38.9 seconds for males and 29.4 seconds for females (Domenech et al 2011)
 - Normal for those 14-22 years old was 35.57 seconds for males and 31.86 seconds for females (Jarman et al 2017)

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Joint Position Error Test

- Tests the ability to relocate the head to neutral following rotation and extension
- Sit 90 cm away from target with laser pointer on head
- Patient is given 1 practice trial with their eyes open
- Center the target. Patient closes their eyes and moves their head within non painful ranges of motion, then attempts to return to neutral and says when they think they are there. The examiner marks it.
- 3 tests in each direction
- Errors of > 4.5 degrees (beyond the yellow circle) are likely to be significant



Teleaven J Rehab Med. 2003

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Musculoskeletal Treatment

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Summary of the CPG for neck pain- Childs et al 2008

- Combining cervical manipulation/ mobilization with exercise is more effective to reduce headache and neck pain
- Stretching should be focused to the anterior/ medial and posterior scalenes, upper trapezius, levator scapulae, and pectoralis major and minor
- Should use coordination, strengthening, and endurance exercises to decrease neck pain and headache
 - Low load endurance exercises to train muscle control of the cervicospinal region
 - Begin in supine with craniocervical flexion exercises targeting deep neck flexors
 - Add isometric exercises using a low level of rotatory resistance to train the co-contraction of the neck flexors and extensors
- Consider upper quarter nerve mobilizations
- Patient education and counseling
 - Early return to normal
 - Provide reassurance that a good prognosis and full recovery commonly occurs

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General Cervical Treatment- Combine manipulation/ mobilization with exercise

- Manual therapy
 - Thoracic spine mobilization/ manipulation
 - Upper cervical joint muscle energy techniques
 - Treat any cervical or thoracic joint restrictions
 - First rib
 - Manual stretching
 - Treat soft tissue impairments
 - Manual traction
 - Suboccipital release
- Pain reduction
 - Positioning
 - Taping
- Stretching
- Posture training
- Strengthening
- Patient education- be reassuring!

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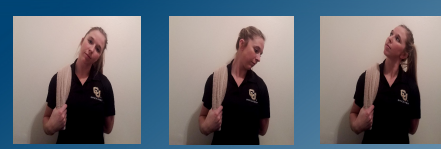
Whiplash Injury Recovery: A Self Help Guide
2nd edition by Jull and Sterling, The University of Queensland 2015

- A good alternative to performing the exercises while sitting is to do them while kneeling on your hands and knees. It is often easier.
- Push through your hands so your back is not slumped.
- Practice turning your head and looking to each side and up/down.
- Each movement should be performed slowly and purposefully taking about 3-6 seconds to perform.
- Repeat each exercise 10 times.



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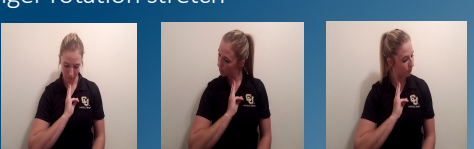
Cervical sidebend stretch



Seated with proper posture, place towel over shoulder, grasp the towel and pull shoulder gently downward, lean head away from towel until a stretch is felt in the neck. Try looking toward the ground or up toward the ceiling to change where you feel the stretch. Hold for 60-90 seconds.

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3 finger rotation stretch



Seated with proper posture, place your hand on your chest with 3 fingers held up, tuck chin to tap the top of your fingers, maintain the chin tuck and turn your head both directions. Repeat for 10-15 turns each direction.

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Strengthening

- Deep neck flexors
 - Train coordination of deep and superficial muscles (start small nod before moving to bigger motion)
- Neck extensors
- Cervical isometrics
- Core exercises
- Scapula stabilizers- especially shoulder ER, prone I,T, Y, lat pull downs and rows
- Postural re-education

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Exercises to retrain muscle control

Head nod and holding exercise
This is an important exercise to retrain the deep neck muscles of the front of your neck for pain relief and muscle control. Lie on your back with knees bent without a pillow under your head and neck.

- If this is not comfortable, place a small, folded towel under your head for support.
- Start by looking up at a point on the ceiling. Then with your eyes, look at a spot on the wall just above your knees. Feel the back of your head slide up the bed as you perform a slow and gentle nod as if you were indicating 'yes'.

While doing the exercise, place your hand gently on the front of the neck to feel the superficial muscles. Make sure they stay soft and relaxed when doing the head nod movement. Stop at the point you sense the muscles are beginning to harden, but keep looking down with your eyes.


Hold the position for 10 seconds and then relax. Look up to a point on the ceiling to resume the starting position. Repeat the exercise 10 times.



Whiplash Injury Recovery: A Self Help Guide 2nd edition by Jull and Sterling, The University of Queensland 2015

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Deep Neck Flexor Training



- Train coordination of deep and superficial muscles (start small nod before moving to bigger motion)
- Start in supine, move to sitting against the wall or on ball
- Start with holding for 5-10 seconds and working up to 10 reps.

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Neck Extensor Training

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Neck Extensor Training

- 1.) Just concentrate on your chin. Tip it up and down as if saying 'yes'. It is a gentle but important exercise for the small muscles in the upper part of your neck.
- 2.) This time, gently turn your head from side to side as if you were saying 'no'. In other words, you only need to turn your head about 30 degrees to each side. Again it is a gentle but important exercise for other small muscles in the upper part of your neck.
- 3.) First lower your head and neck to look at your chest. Then raise and curl your neck back up. Pretend you have a book between your forearms. As you lift your head back, keep reading your book. This helps to keep the upper neck in a neutral position to focus the exercise on the lower region of your neck.

Whiplash Injury Recovery: A Self Help Guide 2nd edition by Jull and Sterling, The University of Queensland 2015

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Cervical Proprioceptive Training

- Laser on target with eyes closed
 - Use the test as the treatment
- Progress base of support (sit on ball)
- Combine with balance challenge

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Motor Control Training

- Laser maze
- Trace a pattern on wall (figure 8)
- Look for objects on a wall
- Progression is to increase speed, more difficulty and intricate patterns, smaller/finer movement
- Try to keep laser on a target while adding arm movement

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Tips

- Play calming music for the patient
- Dim the lights
- Use a quiet room
- BE ENCOURAGING!!!
- Be in contact with the care team, especially before you make any recommendations to see additional providers
 - Communication is key!!!

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Home Exercise Program (initial visit example)

- Postural Awareness/ Education
- Cervical stretching
- Chin tucks/ deep neck flexor strengthening
- Light aerobic activity. Don't let symptoms increase by more than 2 points. Usually cleared to start at 50-70% max HR.
- Balance activities
- Sitting statue if they have sensation of movement at rest

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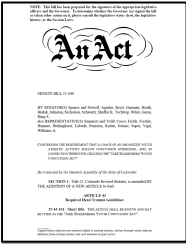
Return to play

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Colorado Concussion Law

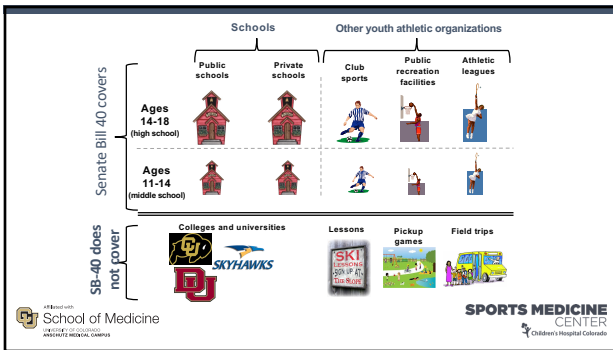
Senate Bill 40:
"The Jake Snakenberg Youth Concussion Act"

Signed March 2011
Enacted January 2012
Modified May 2019



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SPORTS MEDICINE CENTER



Senate Bill 40 Requirements

- 1 Training of coaches
- 2 Removal from play
- 3 Notification of parent or guardian
- 4 Medical clearance for return to play

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SPORTS MEDICINE CENTER

Return to Sports

Evaluated by a health care provider

- Physician
- Neuropsychologist
- Nurse practitioner
- Physician assistant
- Physical therapist with training in pediatric neurology or concussion evaluation and management (added May 2019)

Written clearance for return to play
** Certified athletic trainer can manage return to play after athlete receives medical sign off **




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SPORTS MEDICINE CENTER

Risk of Re-Injury

- 16 studies in the past 5 years have shown an association between concussion and increased risk of subsequent musculoskeletal injury



Slide courtesy of David Howell, PhD, ATC

Return to Play

- Symptom-free \geq 24 hrs
- Attending full days of school
- Tolerating full academic workload
- Off any medications started for concussion
 - Excludes previous ADHD & antidepressant medications or migraine medicines
- No same-day RTP**



Table 1 Graduated return-to-sport (RTS) strategy

Stage	Aim	Activity	Goal of each step
1	Symptom-limited activity	Daily activities that do not provoke symptoms	Gradual reintroduction of work/school activities
2	Light aerobic exercise	Walking or stationary cycling at slow to medium pace. No resistance training	Increase heart rate
3	Sport-specific exercise	Running or skating drills. No head impact activities	Add movement
4	Non-contact training drills	Harder training drills, eg, passing drills. May start progressive resistance training	Exercise, coordination and increased thinking
5	Full contact practice	Following medical clearance, participate in normal training activities	Restore confidence and assess functional skills by coaching staff
6	Return to sport	Normal game play	

NOTE: An initial period of 24-48 hours of both relative physical rest and cognitive rest is recommended before beginning the RTS progression. There should be at least 24 hours (or longer) for each step of the progression. If any symptoms worsen during exercise, the athlete should go back to the previous step. Resistance training should be added only in the later stages (stage 3 or 4 at the earliest). If symptoms are persistent (eg, more than 10-14 days in adults or more than 1 month in children), the athlete should be referred to a healthcare professional who is an expert in the management of concussion.

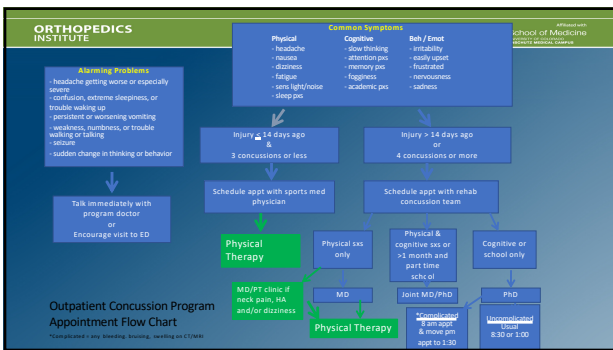
McCorry et al., *BJ Sports*, 2016

Early subsymptom threshold aerobic exercise is not equivalent to return to sport specific play. It is an early active intervention intended to improve recovery to the point where it is safe for the athlete to begin the graduated process of returning to their sport". Leddy et al 2019

Children's Hospital Colorado Concussion Program

Children's Hospital Colorado Program Overview

- >2000 clinic visits per year since 2014
- > 20 Certified Athletic Trainers in clinics and the community
- 7 Nurses with mTBI training
- Designated Staff Assistant to ensure optimized scheduling and care coordination
- School Advocacy through dedicated learning specialist
- Mental Health support
- Physical Therapy Team (>25 PTs)
 - Available at 6+ Network of Care Locations from Colorado Springs to Broomfield



Children's Hospital Colorado Concussion Program

Rehabilitation Department:

- Pamela Wilson, MD
- Amy Kanallakan, MD
- Anne Stratton, MD
- Mike Diciaro, MD
- Scott Laker, MD
- Wendy Pierce, MD
- Aaron Powell, MD
- Matt Mayer, MD
- Michael Kirkwood, PhD
- David Baker, PsyD
- Amy Connery, PsyD
- Robin Peterson, PsyD
- Tess Simpson, PhD

Sports Medicine (orthopedics):

- Aaron Provanca, MD
- Julie Wilson, MD
- Katherine Dahab, MD
- Emily Sweeney, MD
- Gregory Walker, MD

Concussion Hotline
720-777-2806

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Questions?

Thank you!

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Special thanks to Wendy Pierce, MD, David Howell PhD,ATC, Julie Wilson MD and Tess Simpson PhD

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