



Benefits of Exercise after Concussion
Canadian Concussion Center Webinar Series

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Presentation Objectives

At the conclusion of this presentation, participants should be able to describe :

1. **Why** consider Exercise therapy after Concussion?

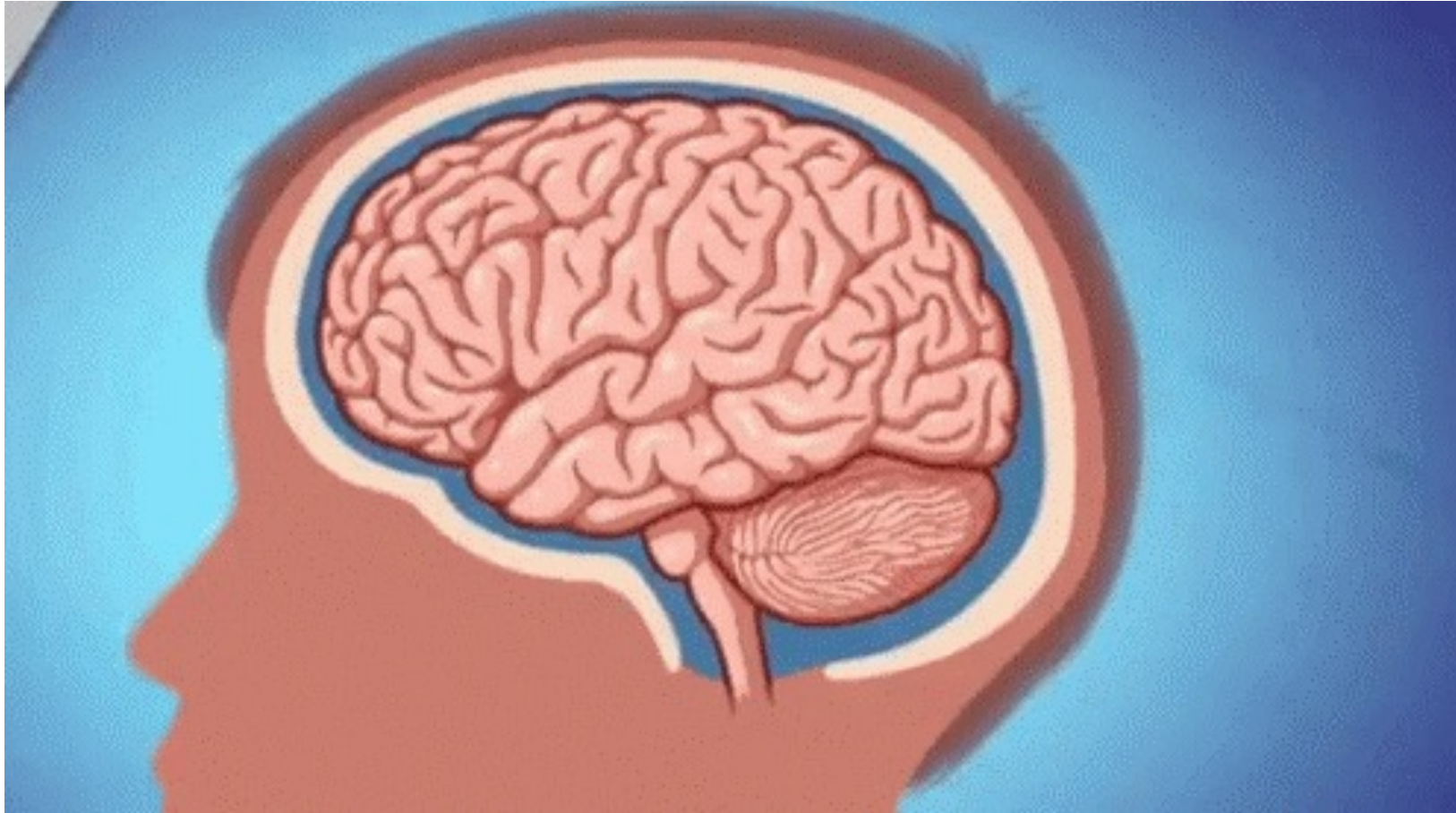
2. **What** is the right dose and intensity of exercise?

3. **How** to gradually return to activity?

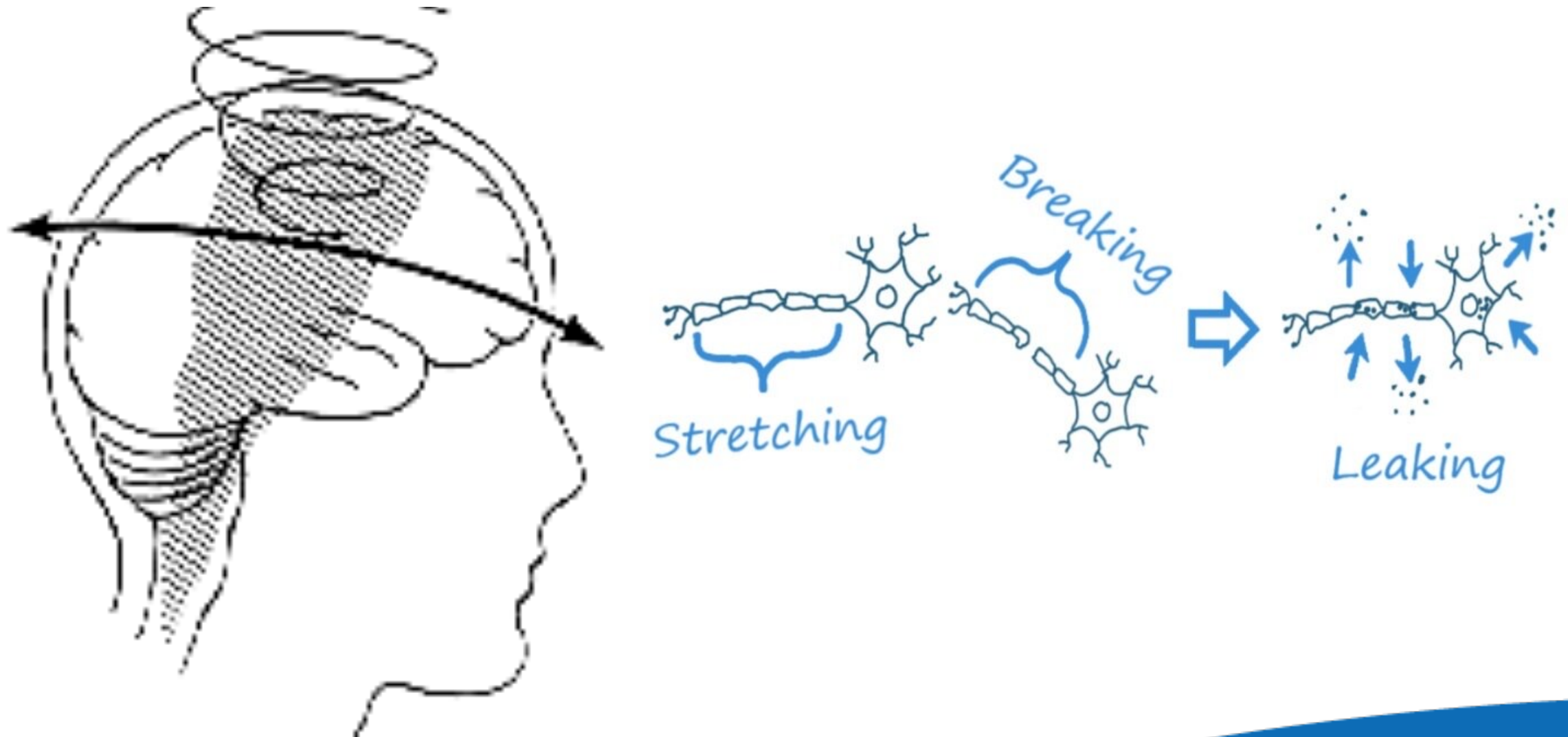
Part 1

Why might Exercise therapy be helpful after concussion?

Brain Moves within the Skull

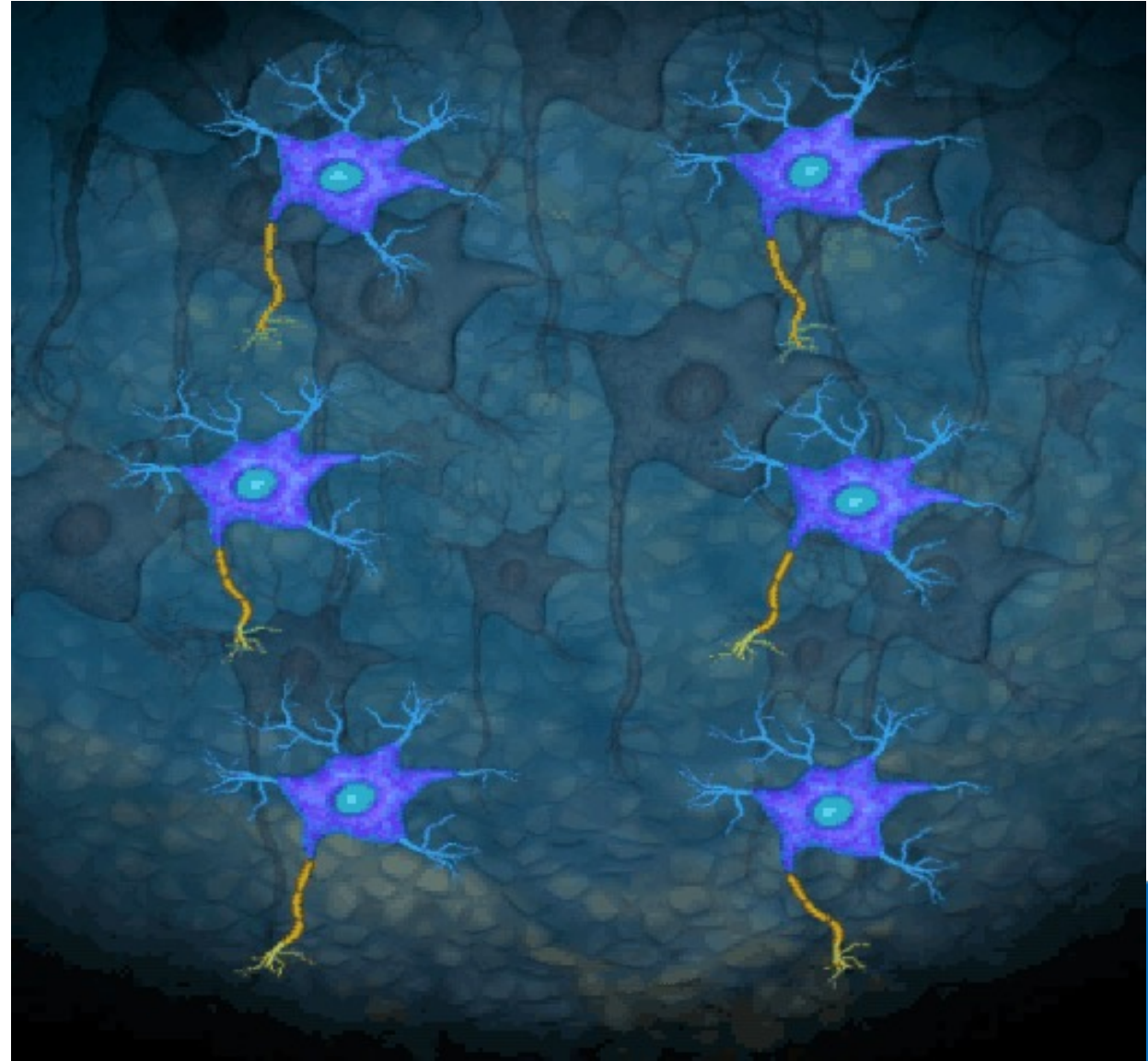


Reminder: Concussion effects on the Brain



Concussion Changes in Nerve Function

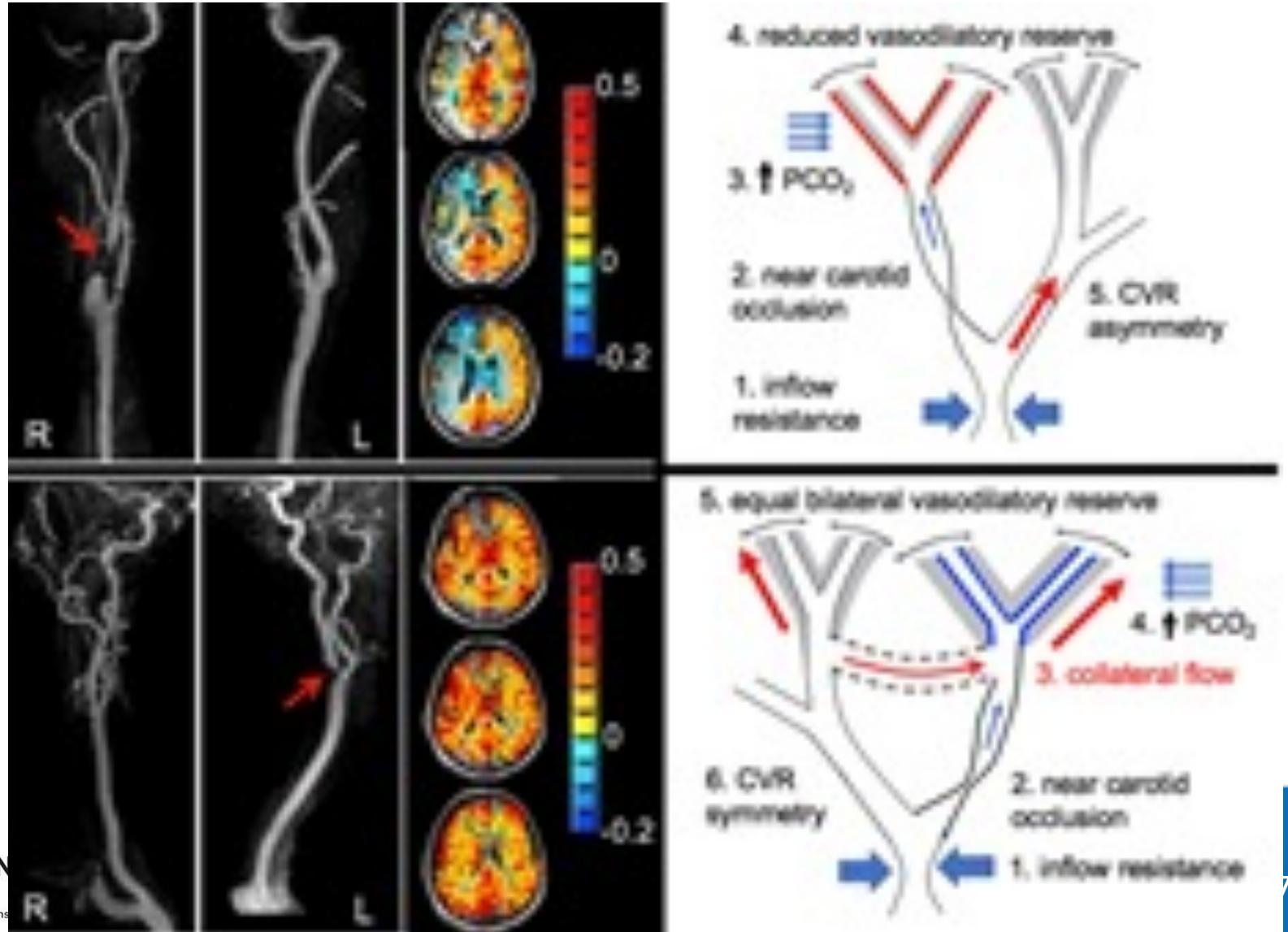
- Changes in Nerve cells
- Speed of Processing
- Neurotransmitter changes-
Decreases in Serotonin



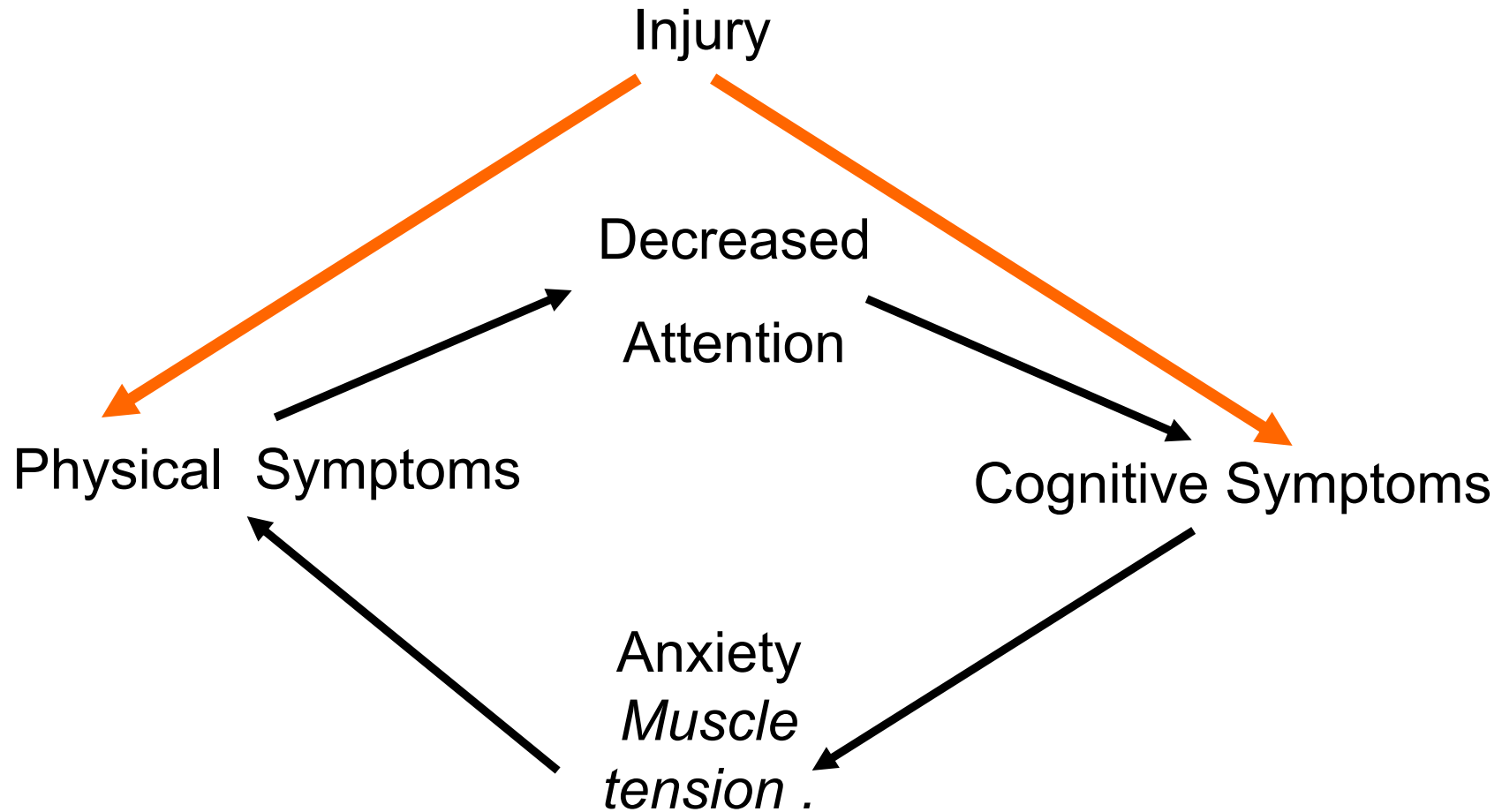
Post Concussion Changes in Brain blood flow and Vessel Reactivity



Dr. David Mikulis



The Vicious Cycle of Post-Concussion Syndrome



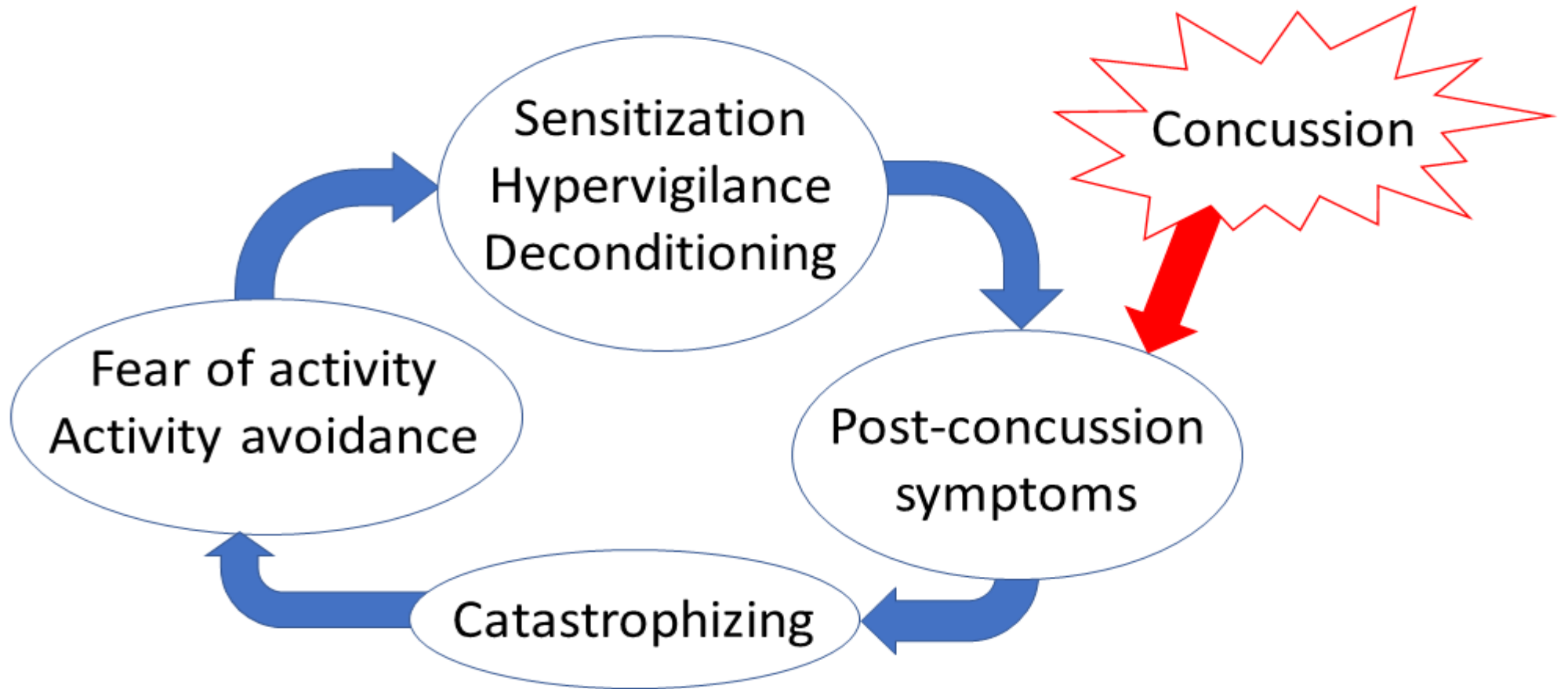
Signs and Symptoms

Signs and symptoms of MTBI generally fall into four categories: physical, cognitive, emotional, and sleep, and may include:

| Physical | Cognitive | Emotional | Sleep |
|---|---|---|---|
| <ul style="list-style-type: none">• Headache• Nausea• Vomiting• Balance problems• Dizziness• Visual problems• Fatigue• Sensitivity to light• Sensitivity to noise• Numbness/ Tingling• Dazed or stunned | <ul style="list-style-type: none">• Feeling mentally “foggy”• Feeling slowed down• Difficulty concentrating• Difficulty remembering• Forgetful of recent information or conversations• Confused about recent events• Answers questions slowly• Repeats questions | <ul style="list-style-type: none">• Irritability• Sadness• More emotional• Nervousness | <ul style="list-style-type: none">• Drowsiness• Sleeping less than usual• Sleeping more than usual• Trouble falling asleep |

Overcoming Avoidance of Symptoms

Figure 1. Fear avoidance model of concussion (simplified)

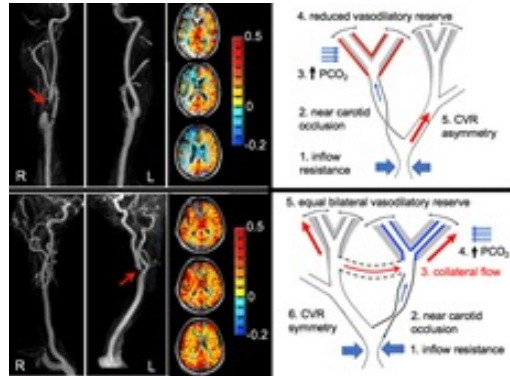
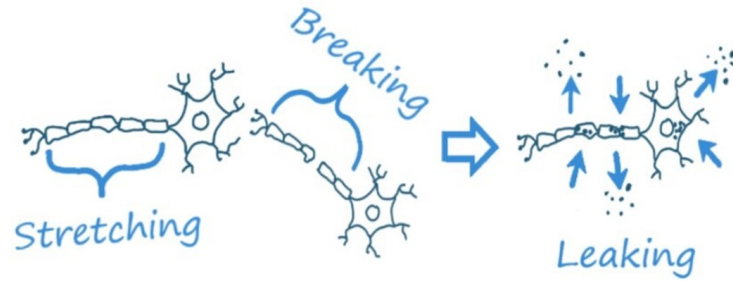


Signs and Symptoms

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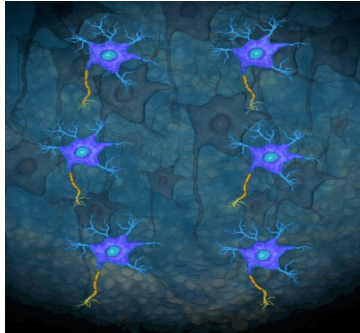
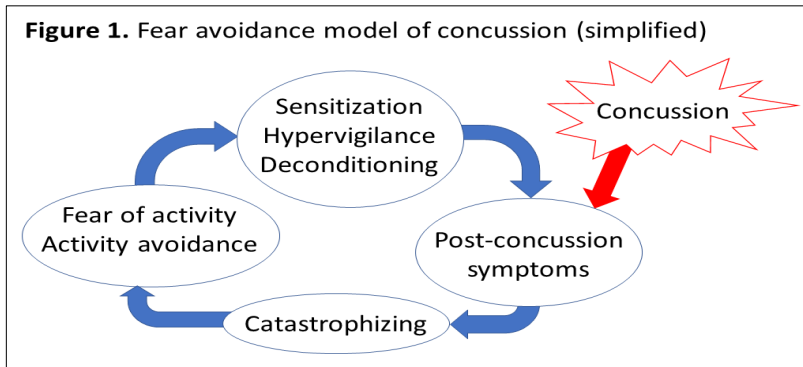
| Physical | Cognitive | Emotional | Sleep |
|---|---|---|---|
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How Could Exercise Help?



- Exercise appears to increase nerve Growth factors like Brain Derived Neurotropic Factor (BDNF)
- Exercise could stimulate blood flow to the brain and correct changes in the autonomic system and regulation of blood vessel size.
- Exercise is known to reduce the perception of pain and reduce migraine intensity in those with severe headaches

How Could exercise help?



- Graded reactivation with supervision could reassure people that exercise is safe without markedly increasing symptoms
- Exercise increases levels of serotonin and adrenaline and is almost as effective as medications for low mood and anxiety
- Exercise can increase the depth and quality of sleep

Exercise- What are the risks/concerns

- Concerns that injured nerves may become more inflamed and swollen
- Early after concussion the brain cells may be stressed with alterations in blood flow and over doing exercise may cause some to sustain damage
- Exercise could increase excitatory neurotransmitter levels that may be high and could be toxic to nerves that are injured
- NB In animal research the evidence is that this window of concern appears to be in the first 24-48 hours after injury

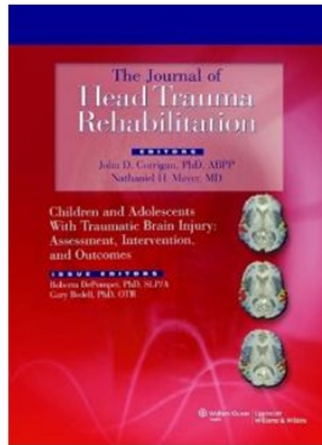
How long should Rest be prescribed = NO more than 48 hours!

- *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.*

Summary: Why Exercise?

- Exercise after 24-48 hours could
 - Enhance Brain Growth Factors
 - Restore normal blood flow
 - Reduce Pain Perception
 - Reduce anxiety and reassure people that activity is safe
 - Increase mood elevating neurotransmitter
 - Improve Sleep

2. What is the right dose and intensity of exercise?



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Is Rest After Concussion “The Best Medicine?”: Recommendations for Activity Resumption Following Concussion in Athletes, Civilians, and Military Service Members

Noah D. Silverberg, PhD; Grant L. Iverson, PhD

- **“Graded resumption of regular pre-injury activities** (with the exception of competitive sports) as tolerated within the first few days to weeks postinjury, regardless of symptomatic status, **is more likely to speed up than delay recovery.**
 - Multiple randomized clinical trials of early intervention including guided activation component found benefit. In one study, starting this process on day after injury temporarily exacerbated symptoms but achieved the same long-term outcome as delaying it by a few days.
 - **Delaying graded resumption of regular activities** beyond a month may worsen outcome.

Review Article

Physical exercise for people with mild traumatic brain injury: A systematic review of randomized controlled trials

Sally Vuu^{1,*}, Christopher J. Barr², Maggie Killington³, Jill Garner⁴

The Role of Subsymptom Threshold Aerobic Exercise for Persistent Concussion Symptoms in Patients With Postconcussion Syndrome

A Systematic Review

McKyla McIntyre, MD, Ainsley Kempenaar, MD, Mohammadreza Amiri, PhD,
Seyed Mohammad Alavinia, PhD, and Dinesh Kumbhare, MD, PhD

The Role of Active Rehabilitation in Concussion Management: A Systematic Review and Meta-analysis

KATHRYN M. CARTER, ALEXANDRA N. PAUHL, and ANITA D. CHRISTIE

Faculty of Health Sciences, School of Kinesiology, Western University, Ontario, CANADA

Exercise for Sport-Related Concussion and Persistent Postconcussive Symptoms

Mohammad Nadir Haider, MD,^{*,†} Itai Bezherano, BS,[†] Alex Wertheimer, DO,[‡]
Akas H. Siddiqui, MD, MPH,[§] Emily C. Horn, MSc,[†] Barry S. Willer, PhD,^{||} and John J. Leddy, MD[†]

Overview of studies

Table 1
Study characteristics

| Study | Country | Setting | Diagnosis | Cause of injury | Time since injury | Age | Gender | Type of exercise | CASP score |
|----------------------------|---------|---------------------------------|--|-----------------|--------------------|--------------|------------------------|----------------------|------------|
| Bailey et al. (2019) | USA | Hospital | Post-concussion symptoms | Mixed | ≥4-weeks | 14–18 | 9 males 7 females | Aerobic | Low |
| Chan et al. (2018) | Canada | Concussion clinic | Post-concussion symptoms | Sport | ≥4-weeks | 12–18 | 5 males 14 females | Aerobic | Medium |
| Dobney et al. (2018) | Canada | Hospital | Post-concussion symptoms | Unknown | ≥2-weeks | 9–17 | 12 males 8 females | Aerobic | Medium |
| Kleffelgaard et al. (2019) | Norway | Hospital | Dizziness following a mild-to-moderate TBI | Mixed | ≥4-weeks | 16–60 | 20 males 45 females | Vestibular | Medium |
| Kurowski et al. (2017) | USA | Clinic, community, and hospital | Post-concussion symptoms | Mixed | ≥4-weeks | 12–17 | 13 males 17 females | Aerobic | Medium |
| Leddy et al. (2019) | Canada | Concussion clinic | Concussion | Sport | ≤10-days | 13–18 | 65 males 48 females | Aerobic | High |
| Maerlender et al. (2015) | USA | Not reported | Recently concussed | Sport | Recently concussed | Not reported | 8 males 20 females | Aerobic | Low |
| Micay et al. (2018) | Canada | Sport medicine centre | Symptomatic following sport-related concussion | Sport | ≤10-days | 14–18 | 15 males | Aerobic | High |
| Reneker et al. (2017) | USA | Sport medicine centre | Post-concussion symptoms in the migraine cluster | Sport | ≥10-days | 10–23 | 25 males 16 females | Vestibular | High |
| Rytter et al. (2019) | Denmark | Hospital | Post-concussion symptoms in attention and/or memory | Mixed | >6-months | 18–65 | 30 males 59 males | Strength and aerobic | High |
| Schneider et al. (2014) | Canada | Medical centre | Post-concussion symptoms of dizziness, neck pain and/or headache | Sport | ≥10-days | 12–30 | 18 males 13 females | Vestibular | High |

General Rule of Thumb for activity

“Know your Limit and stay within it”



“How do we know what the limit is?”

Buffalo Concussion Treadmill Test (BCTT)

- Participant walks at a “brisk” pace on a treadmill (exact speed is dependent on height)
- Speed is constant for first 15 minutes
- Every minute, treadmill incline is increased by 1°
 - Once treadmill reaches max incline, speed is increased by 0.4mph each minute
- Heart rate, rating of perceived exertion, symptom severity (as measured using a visual analog scale) is recorded every minute

BCTT Video

Buffalo Concussion Treadmill Test (BCTT)

- The test is stopped when:
 - (i) Total visual analog scale symptom score increases by 3 points from baseline, OR
 - (ii) 20 minutes have elapsed, OR
 - (iii) Reached 80% of age predicted max-HR, OR
 - (iv) Rating of perceived exertion (Borg 6-20 scale) >18, OR
 - (v) Any cardiac or respiratory distress or severe muscle fatigue

Summary: What Dose and intensity?

- Heart rate and duration of exercise before onset of symptoms on testing provides a maximal threshold to guide the prescription of exercise

3. How to progress through gradual return to activity?

Return to Play

| Rehabilitation stage | Functional exercise at each stage of rehabilitation | Objective of each stage |
|-----------------------------|--|---|
| No activity | Physical and cognitive rest | Recovery |
| Light aerobic exercise | Walking, swimming or stationary cycling keeping intensity, 70 % maximum predicted heart rate. No resistance training | Increase heart rate |
| Sport-specific exercise | Skating drills in ice hockey, running drills in soccer. No head impact activities | Add movement |
| Non-contact training drills | Progression to more complex training drills, eg passing drills in football and ice hockey. May start progressive resistance training | Exercise, coordination, and cognitive load |
| Full contact practice | Following medical clearance participate in normal training activities | Restore confidence and assess functional skills by coaching staff |
| Return to play | Normal game play | |

The Toronto Concussion Study: The feasibility and effects of early prescribed aerobic exercise on recovery and post-concussive symptoms in adults – a pilot study

Mark Bayley^{1,3}; Evan Foster¹; Tharshini Chandra¹; David Lawrence¹; Elizabeth L Inness^{1,4}; Laura Langer¹;
Ainsley Kempenaar^{2,3}; Cynthia Danells^{1,2}; Paul Comper^{1,4}

¹ University Health Network - Toronto Rehabilitation Institute, Toronto, ON;

² University of Toronto, Toronto, ON;

³ Division of Physical Medicine and Rehabilitation, Department of Medicine, University of Toronto, Toronto, ON;

⁴ Rehabilitation Sciences Institute, University of Toronto, Toronto, ON

Methods

Patients who are eligible and consent are evaluated by a clinic physician for exercise tolerance

Eligible participants will undergo a 20 minute treadmill test, using the Buffalo Concussion Treadmill Test protocol; to determine the threshold for concussion symptoms

- Participants are randomly assigned to 1 of 2 arms:
 - 30 minutes per day of prescribed high intensity, symptom-limited aerobic exercise 5 times a week [treatment group] or;
 - Usual care= exercise recommendations [control group]
- Each participant are assigned a heartrate monitor bracelet
- Participants undergo treadmill testing at weeks 1, 2, 4, 6, and 8, or until recovered

Eligibility Criteria for Pilot Study

Inclusion Criteria:

- ✓ 18-45 years of age
- ✓ SCAT score > 9 @ Week 1
- ✓ Low risk for cardiac disease (as determined by the clinic physician)
- ✓ Willing to exercise

Exclusion Criteria:

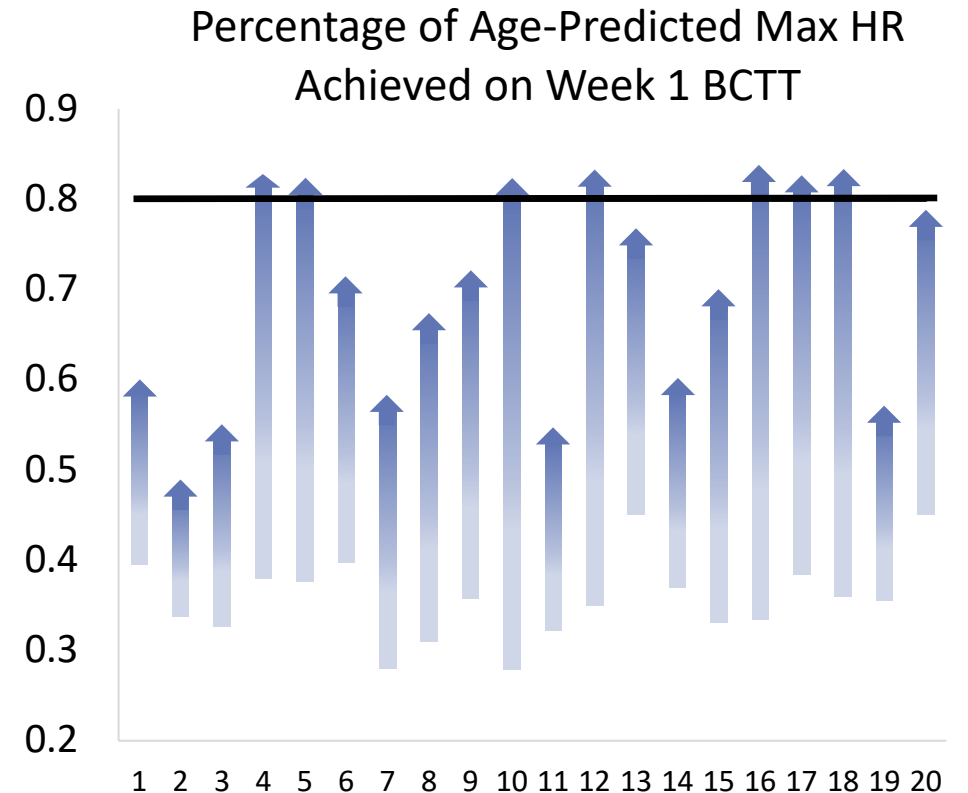
- Beta-blocker medication
- Tricyclic anti-depressant medication
- Orthopedic injuries preventing exercise
- Pre-morbid vestibular disease preventing exercise
- Heartrate increase <30 bpm from rest on Week 1 treadmill test
- Deemed asymptomatic from concussion by clinic physician
- Unable to follow commands

Participant Demographics

| Category | All Hull-Ellis Participants (n=403) | PC Exercise Pilot Participants (n=20) |
|---|--|--|
| Average Age (years) | 33.4 (12.7) | 28.1 (7.0) |
| % Female | 60% | 40% |
| Median Education | Bachelors | Bachelors |
| Median Income | \$40,000 to \$60,000 | \$40,000 to \$60,000 |
| Three most common pre-existing conditions | Depression, Anxiety, and Migraine | Anxiety, Depression, and ADD (Migraines, fourth) |
| Employment Status | Employed or Students | Employed or Students |
| Involved in some form of sports activity pre-injury | 223 (55.3%) | 9 (45%) |
| Patients who sustained sports related concussion | 103 (25.5%) | 5 (25%) |

Results – BCTT Feasibility within 1-week of Concussion

- All participants were able to increase their heart rate by at least 30bpm at week 1
- On average:
 - Participants completed **10.4 mins** of the BCTT
 - Heart rate at test termination – **131.9 bpm**
 - Achieved **69%** of their age-predicted max heart rate
- 8/20 participants were “exercise tolerant” at wk 1
 - 7 participants exercised to 80% of their age-predicted max HR, without symptom exacerbation
 - 2 participants exercised to a RPE of 18/20, signifying “very hard” work
 - 1 participant met both during the same minute



****The BCTT is feasible in a non-athletic, adult population**



Exercise Prescription

| Return to Activity Stages | STOP or AVOID | START or CONTINUE | |
|--|-----------------------|-----------------------|-------------------------|
| Daily activities: Examples: walking, house chores, commuting, errands, grocery shopping, etc. | <input type="radio"/> | <input type="radio"/> | |
| Aerobic activity with minimal head movement: (Stage 2) Examples: Stationary bike, elliptical, intensive purposeful walks, walk-jog program | <input type="radio"/> | <input type="radio"/> | } See below for details |
| Aerobic activity with additional head movement: (Stage 3) Examples: Jogging, swimming, treadmill, light yoga | <input type="radio"/> | <input type="radio"/> | |
| Sport specific individual drills: (Stage 3) Examples: shooting, passing, dribbling, puck handling, throwing | <input type="radio"/> | <input type="radio"/> | |
| Team based sport drills: (Stage 4) | <input type="radio"/> | <input type="radio"/> | |
| Controlled practice, minimal risk, 'Noncontact': (Stage 4) | <input type="radio"/> | <input type="radio"/> | |
| Activities with 'Valsalva': (Stage 5) Examples: weight training or resistance training | <input type="radio"/> | <input type="radio"/> | |
| Unrestricted practice, 'Contact': (Stage 5) | <input type="radio"/> | <input type="radio"/> | |
| Competition: (Stage 6) | <input type="radio"/> | <input type="radio"/> | |

↓ Details for aerobic activity (Stage 2 & 3) ↓

| | | | |
|--|----------------------|----------------------|----------------------|
| Heart Rate at which the treadmill test was discontinued: | <input type="text"/> | | |
| HR target for prescription (90% of symptom-threshold reserve): | <input type="text"/> | | |
| Type of activity: | Volume | | Intensity |
| | Minutes per session | Sessions per week | HR Target |
| <input type="text"/> | <input type="text"/> | <input type="text"/> | <input type="text"/> |

Additional Info:

Adherence – Wearing Heart Rate Monitor

- Participants were instructed to wear the heart rate monitor for at least 12 hours a day (the battery life of the monitor)
- Compliance re: wearing heart rate monitor was determined to be 8/12 hours/day

| | Mean | Standard Deviation | Range |
|-----------------------------------|--------------|--------------------|-------------|
| Days Enrolled | 18.9 days | 15.9 days | 1 – 53 days |
| Compliant with Wearing HR Monitor | 5.6 days | 6.6 days | 0 – 26 days |
| Compliance Rate | 32.2% | 31.3% | 0 – 100% |

Adherence – Exercise Prescription

- Participants assigned to the treatment arm were prescribed:
 - 30 minutes per day of prescribed high intensity, symptom-limited aerobic exercise 5 times a week [experimental group]
- Participants were deemed ‘compliant’ if they completed their prescription at least 3/5 days per week
- 10 participants enrolled in the exercise arm
 - 28 “enrolled weeks” combined
 - Ranged from 1-7 “enrolled weeks”
 - **12 out of 28** “enrolled weeks” participants complied with their prescription
 - 3 participants complied with their prescription every week they were enrolled

****Prescribing exercise to non-athletic, adults is challenging**

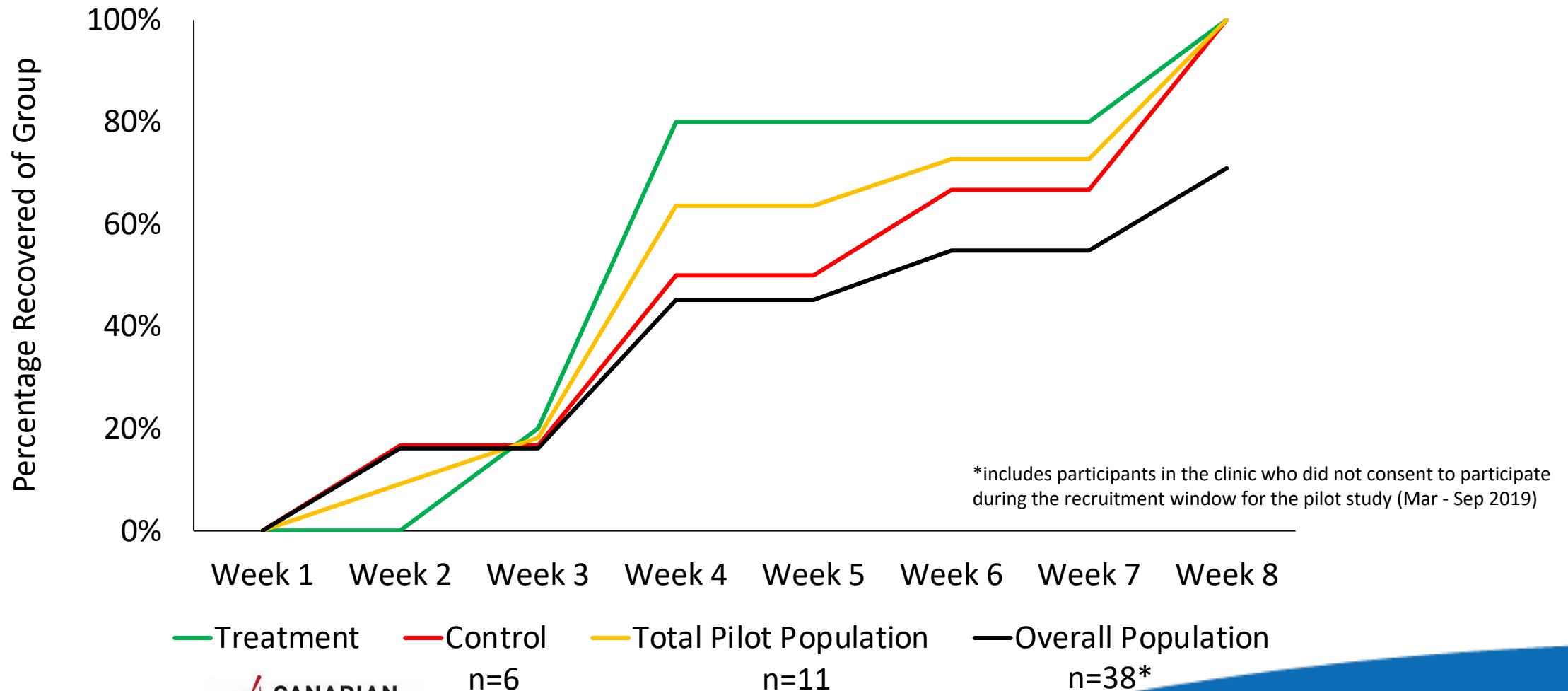
Recovery Criteria for Pilot Study

Recovery will be determined by the following criteria:

1. Patient self-reporting a normal **(SCAT score \leq 9)** or **baseline level** of symptoms;
2. Receiving **confirmation from the clinic physician that the participant is ready for discharge** (i.e. recovery is sufficient and the clinic physician is OK to no longer follow the patient);
3. And exercise tolerant (i.e., able to exercise **to 18 or above on the Borg RPE scale OR 80% of their age-predicted maximum heart rate** without symptom exacerbation).

Recovery Trajectory

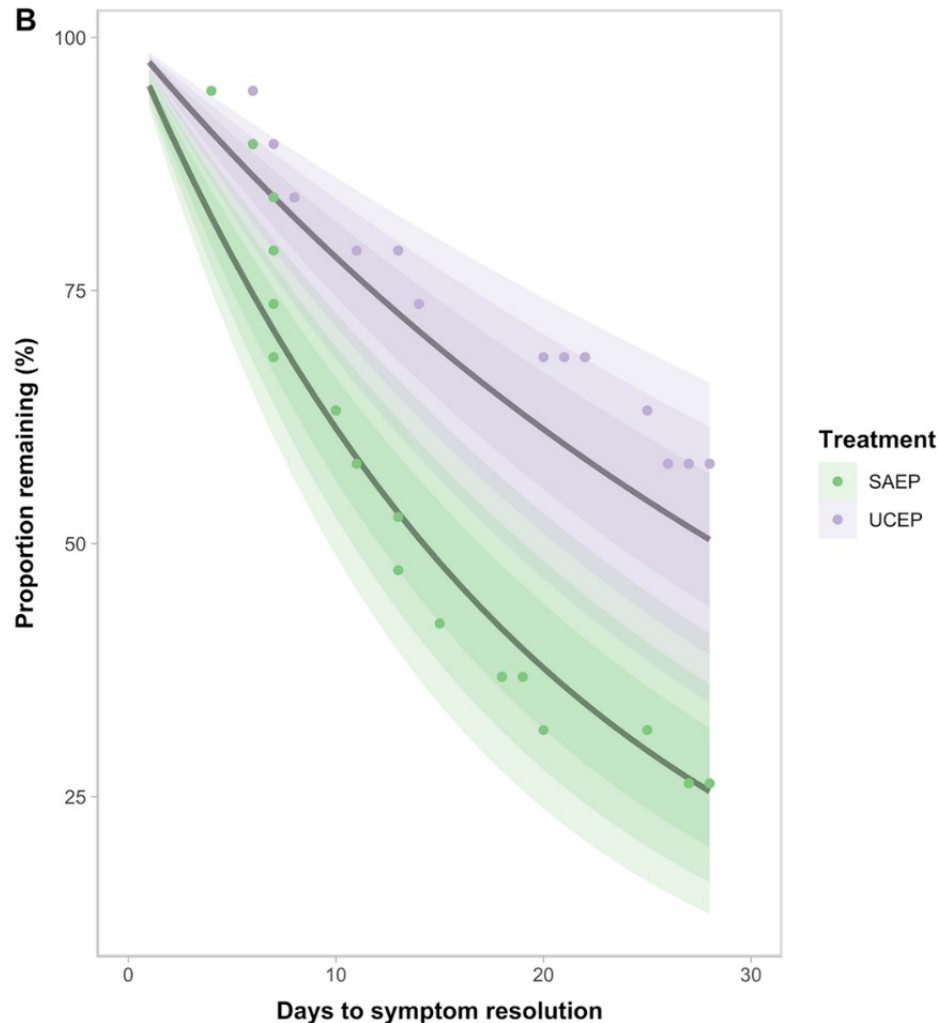
Recovery vs. Arm in Clinic



Recall – Buffalo Concussion Treadmill Test (BCTT) feasible, but how practical?

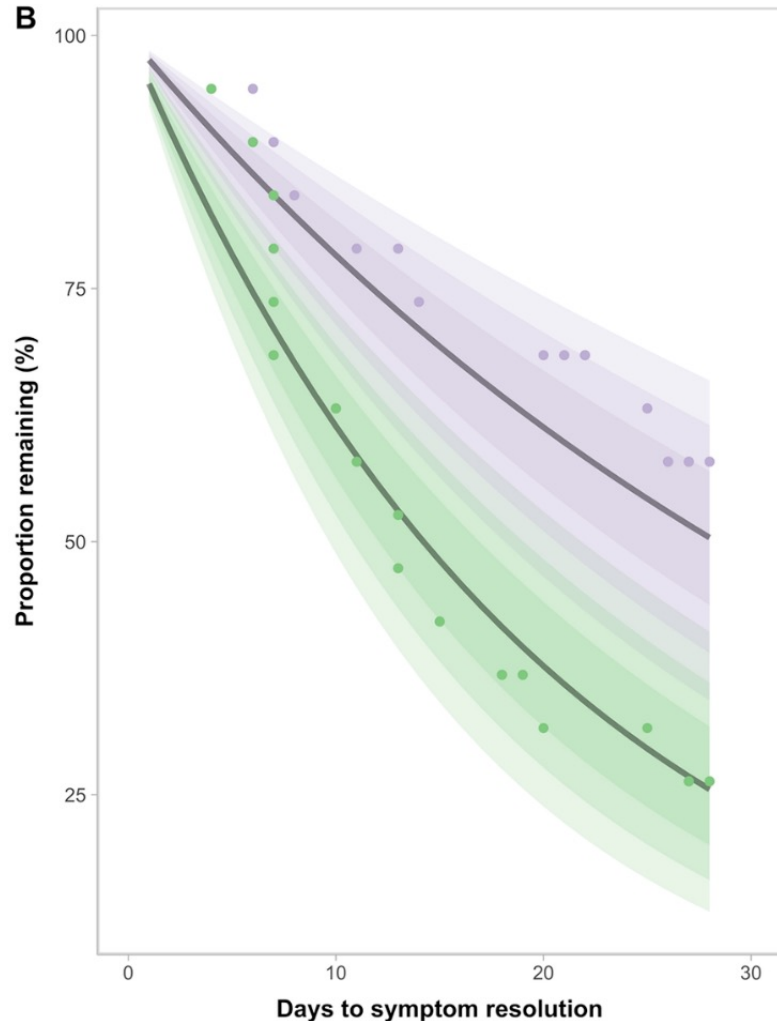
- BCTT requires access to a treadmill (or a stationary bike for Buffalo Concussion Bike Test [BCBT])
- These devices may not be accessible in non-specialized clinics (i.e., family doctor's offices, walk-in clinics, etc.)
- Can exercise be prescribed effectively without rigorous testing?

Structured Aerobic Exercise Protocol (SAEP)



- RCT, n=39 participants, 16-22 years of age; sport-related concussion
- Randomized to:
 - Usual Care Exercise Prescription (UCEP), or
 - Structured Aerobic Exercise Protocol (SAEP)
 - Begin 3-days post-injury
 - Eight, 20-minute sessions over 11-days (two days of exercise, one day of rest)
 - First session performed at 60% of age-predicted max HR for 15-minutes (w 5-min warm-up and cool-down)
 - Subsequent sessions, first:
 - First, increase duration to 20-minute exercise at the prescribed intensity
 - Then, increase intensity by 5% of age-predicted max HR (back to 15 min duration at the prescribed intensity)
 - Final stage at 75% of age-predicted max HR

Structured Aerobic Exercise Protocol (SAEP)

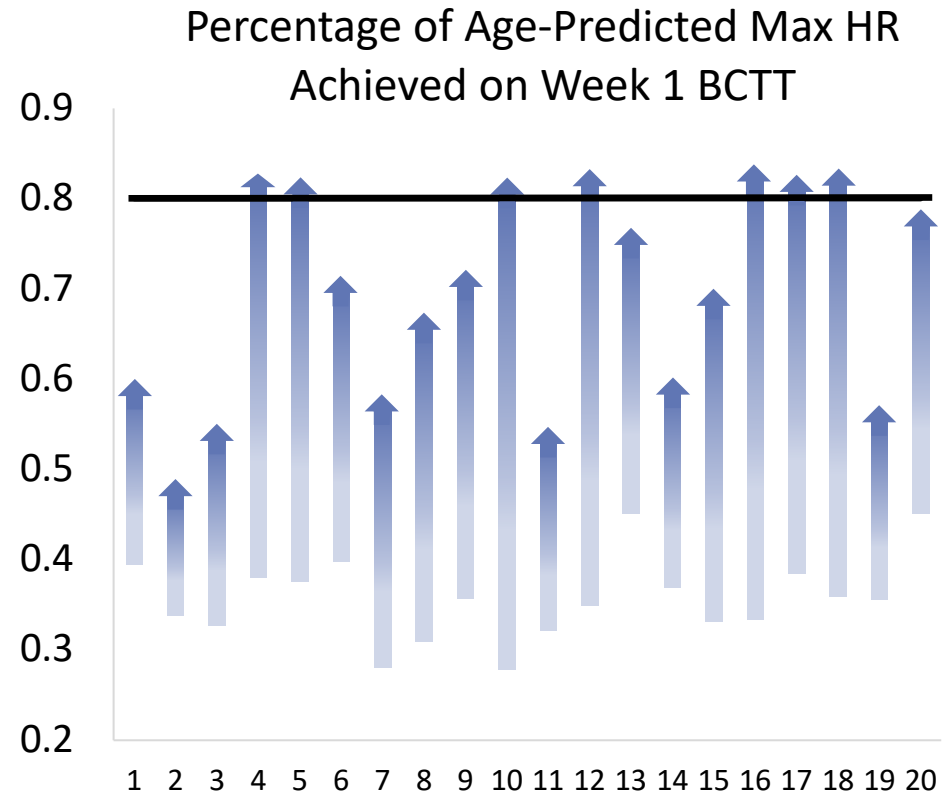


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****By one month, 74% of the participants who underwent SAEP were asymptomatic compared to a mean of 50% in those in the UCEP group.**

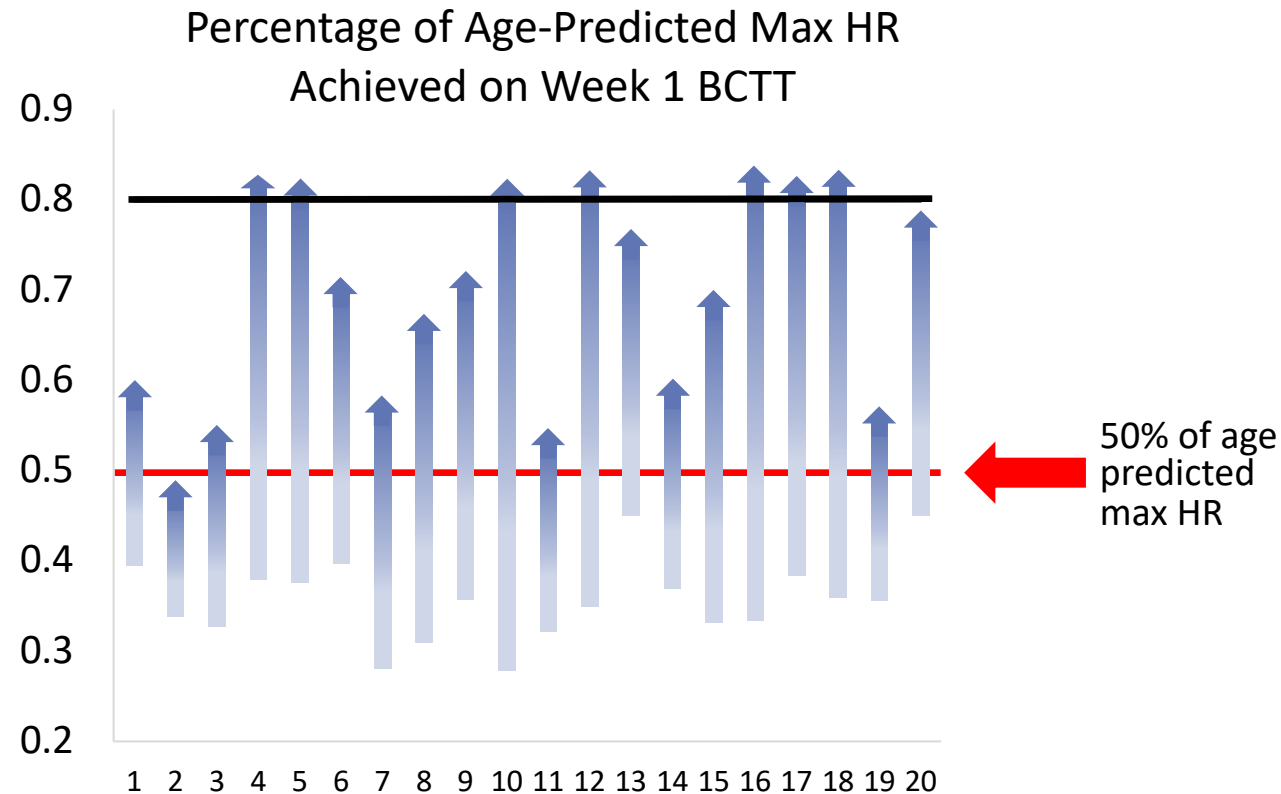
Structured Aerobic Exercise Protocol (SAEP) feasibility in the General Adult Population?

Recall:



Structured Aerobic Exercise Protocol (SAEP) feasibility in the General Adult Population?

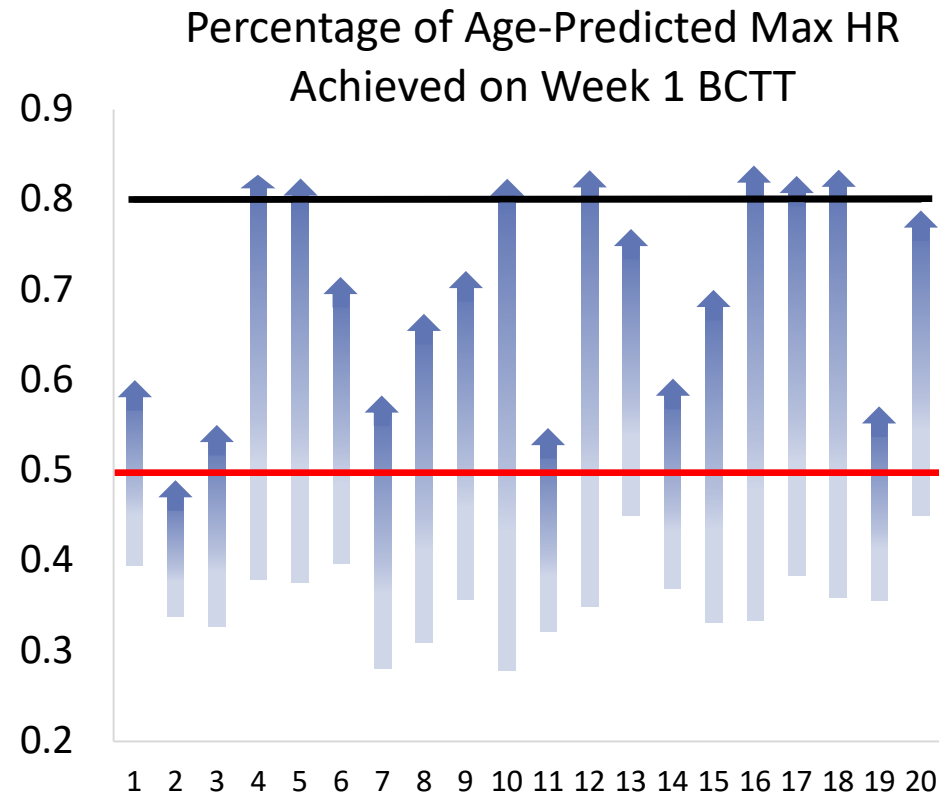
Recall:



- 19/20 (95%) participants were able to exercise to 50% of their age-predicted max HR within one week of concussion

Structured Aerobic Exercise Protocol (SAEP) feasibility in the General Adult Population?

Recall:

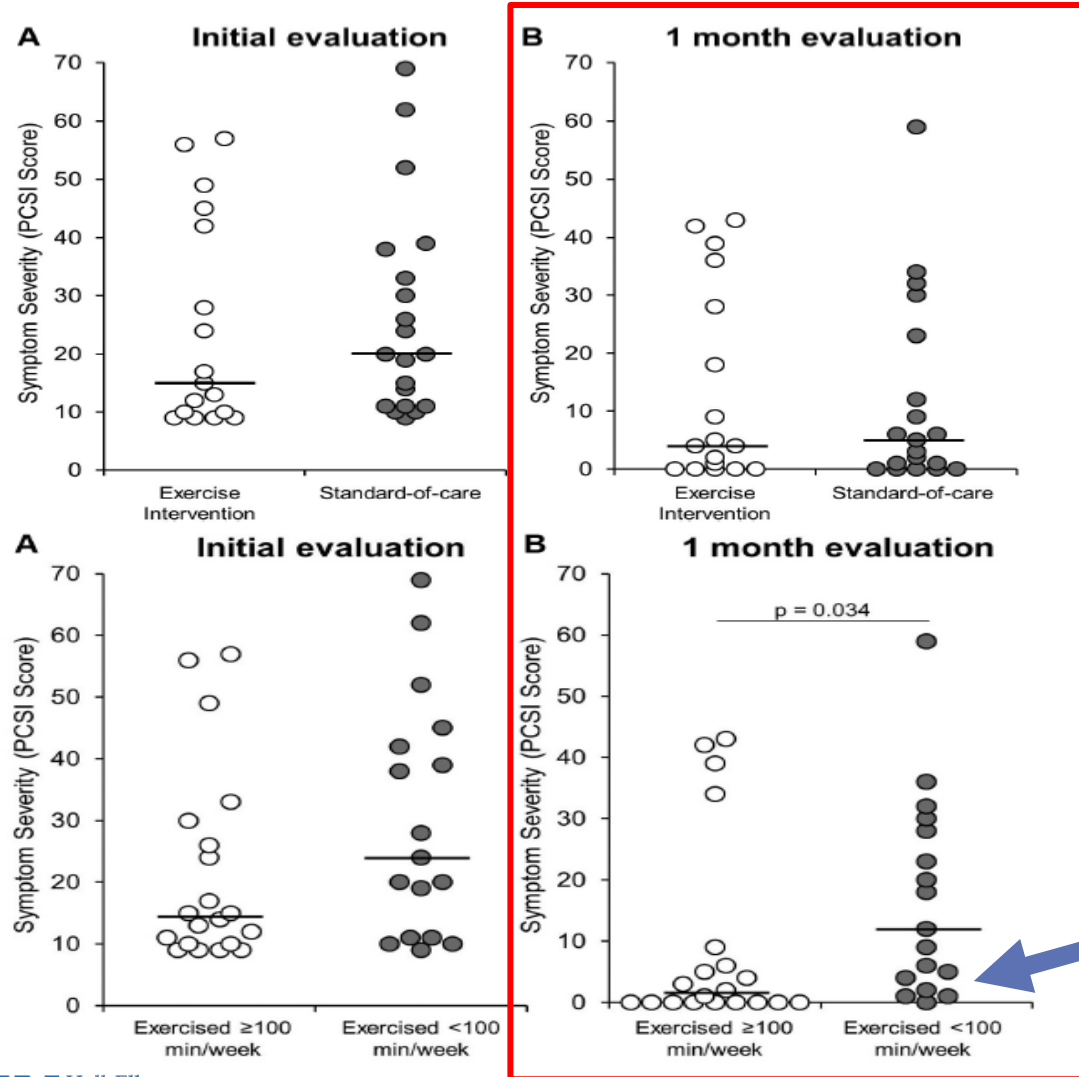


****SAEP appears to be a feasible protocol in a general adult population as well, especially if modified to start at 50% of age-predicted max HR.**

- 19/20 (95%) participants were able to exercise to 50% of their age-predicted max HR within one week of concussion

50% of age predicted max HR

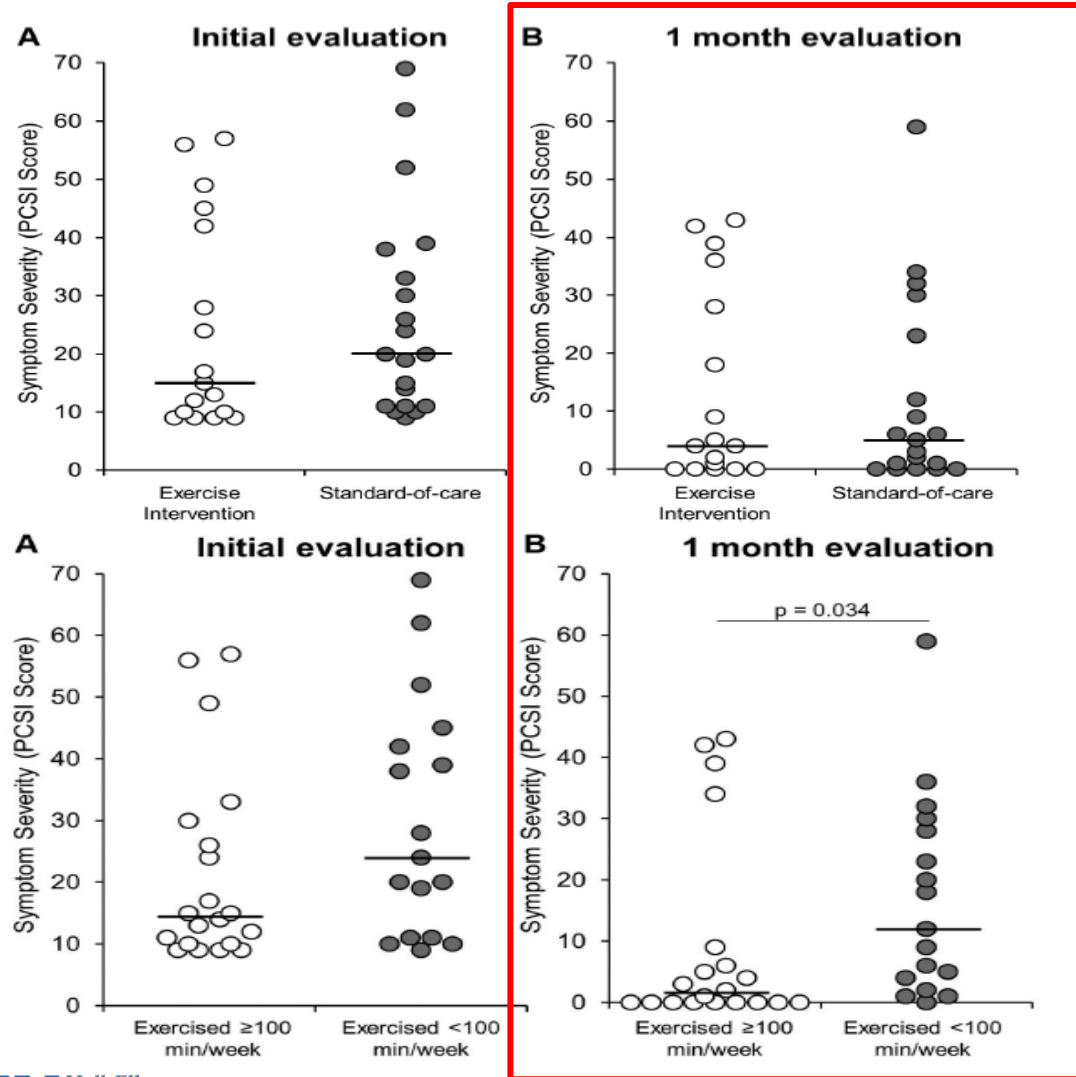
What about individualized prescriptions?



- RCT, n=37 participants, mean age 17.0 years of age; sport-related concussion
- Randomly allocated to:
 - Specific exercise prescription (intensity individualized based on a symptom-limited exercise test), or
 - Standard of care physician recommended physical activity
- Minutes of exercise monitored for both groups



What about individualized prescriptions?



- RCT, n=37 participants, mean age 17.0 years of age; sport-related concussion
- Randomized to:
 - Specific exercise prescription (intensity individualized based on a symptom-limited exercise test), or
 - Standard of care physician recommended physical activity
- Minutes of exercise monitored for both groups

****Group assignment did not impact symptoms, but actual amount of exercise (≥100 min/week) significantly decreased symptoms.**

How intense should you go? Few takeaways

- IF you don't have access to a BCT Test
- Start activity that is tolerable given your other potential causes of pain like neck, knees, hips, ankles – examples- walking , stationary biking or swimming
- Calculate your age predicted maximum heart rate ($220 - \text{your age}$) e.g. $220 - 45 \text{ yr old} = \text{max of } 175$
- Aim to try to get to 50-60% of your max for your session
- Plan to exercise for less than the maximum time
- Consider going for activity more than once per day.

What about exercise as prevention of concussion?

Systematic review



Efficacy of exercise interventions on prevention of sport-related concussion and related outcomes: a systematic review and meta-analysis

Branimir Ivanic ,¹ Anna Cronström ,¹ Kajsa Johansson,² Eva Ageberg ¹

- Found 25 articles looking at benefit of warmup, neck strengthening static and dynamic exercises
- Neck Strengthening Exercise improved strength but did not reduce significantly linear or rotational head accelerations
- Dynamic and multimodal exercises seemed to improve neck strength more than just resistance
- No studies showed that reduction in Sport Related Concussion incidence

So we don't know if it is better at reducing concussion

Br J Sports Med: first published

Take Home Messages about Exercise RX

1. Why?

Exercise after 24-48 hours post concussion may improve the recovery through better brain function, blood flow, neurotransmitter levels, mood, pain and sleep .

2. What Dose?

Know your limit and stay within it. The Buffalo Concussion Treadmill Test is feasible way to establish maximum symptom thresholds however perhaps you can base on your age

3. How?

Early, sub-symptom, aerobic exercise in the general adult population is a promising intervention post-concussion.

With thanks...

- The clinical/research team at The Hull-Ellis Concussion and Research Clinic and collaborators including:

- Laura Langer
- Jane Cosgrove
- Dr. Cristina Saverino
- Dr. Jonathan Gladstone
- Michelle Sweeny
- Cynthia Danells
- Dr. Paul Comper
- Dr. Lesley Ruttan
- Dr. Catherine Wiseman-Hakes
- Dr. Elizabeth L. Inness
- Dr. John Leddy
- Dr. Nadir Haider
- Dr. Barry Willer
- Evan Foster
- Dr. Alan Tam
- Dr. David Lawrence
- Dr. Alice Kam
- Dr. Julia Alleyne
- Dr. Daniel Warshafsky
- Dr. Marcus Jansen
- Dr. George Mochizuki
- Dr. Olinda Habib Perez
- Ainsley Kempenaar
- Hannah Qalip
- Ontario Neurotrauma Foundation
- David Mikulis
- Bharvi Sharma

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