

Benefits of Exercise after Concussion

Canadian Concussion Center Webinar Series

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Professor, University of Toronto



Presentation Objectives

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

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

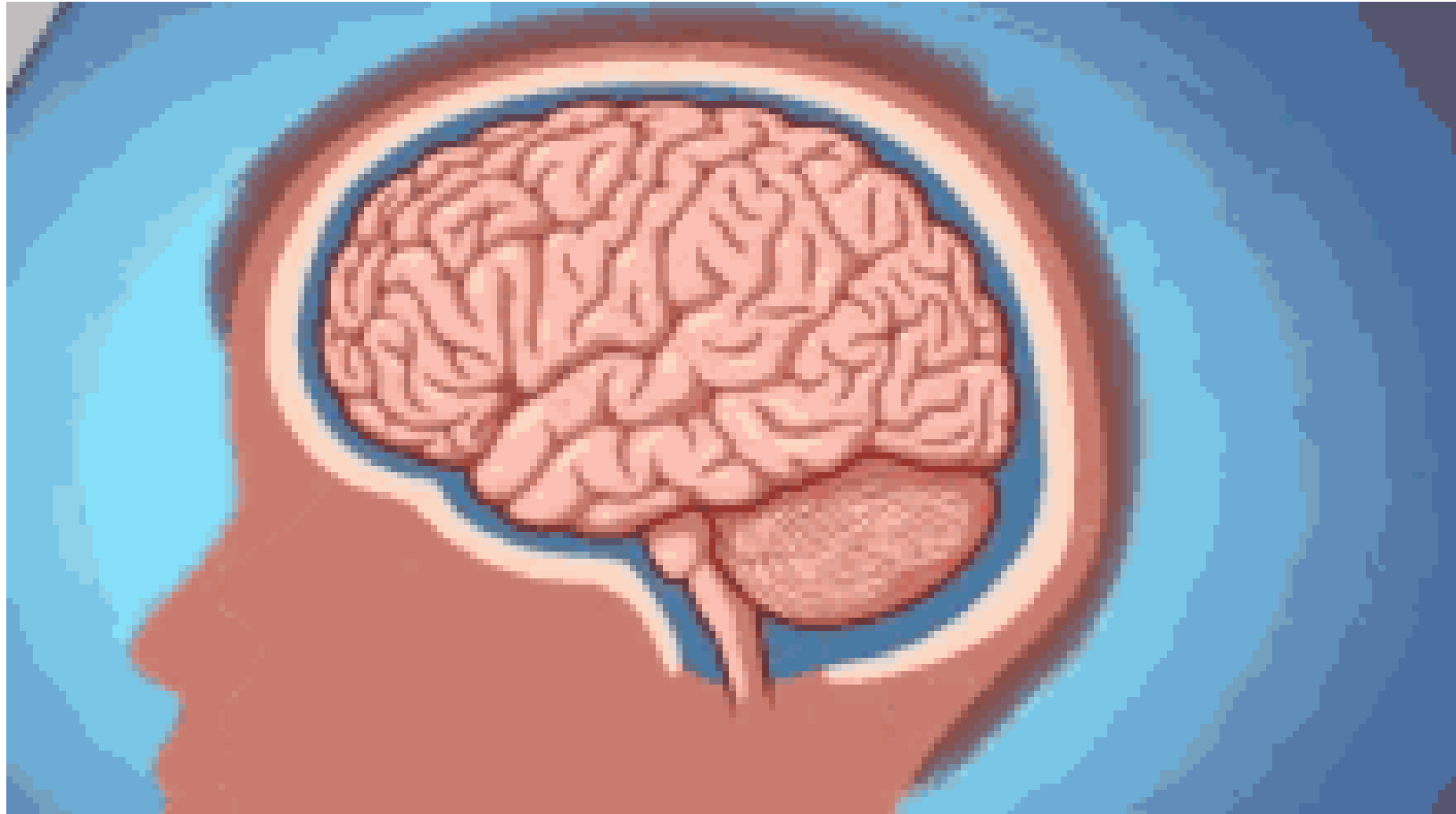
2. **What** is the right dose and intensity of exercise?

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

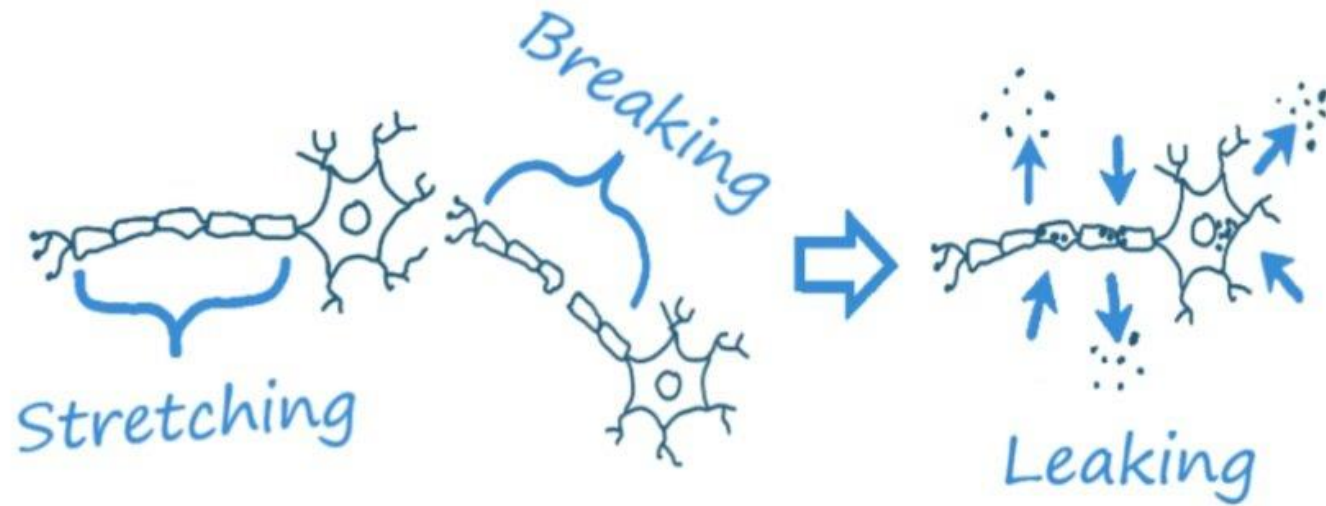
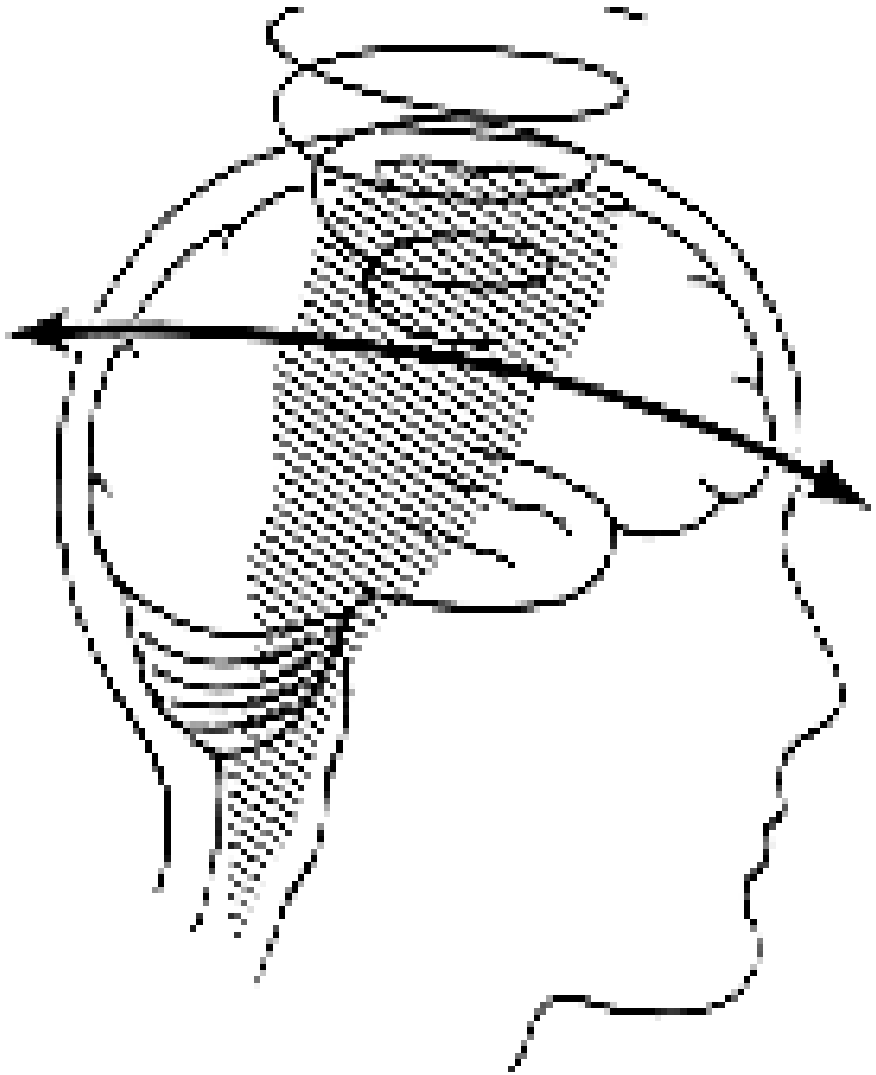
Part 1

Why might Exercise therapy be helpful after concussion?

Brain Moves within the Skull

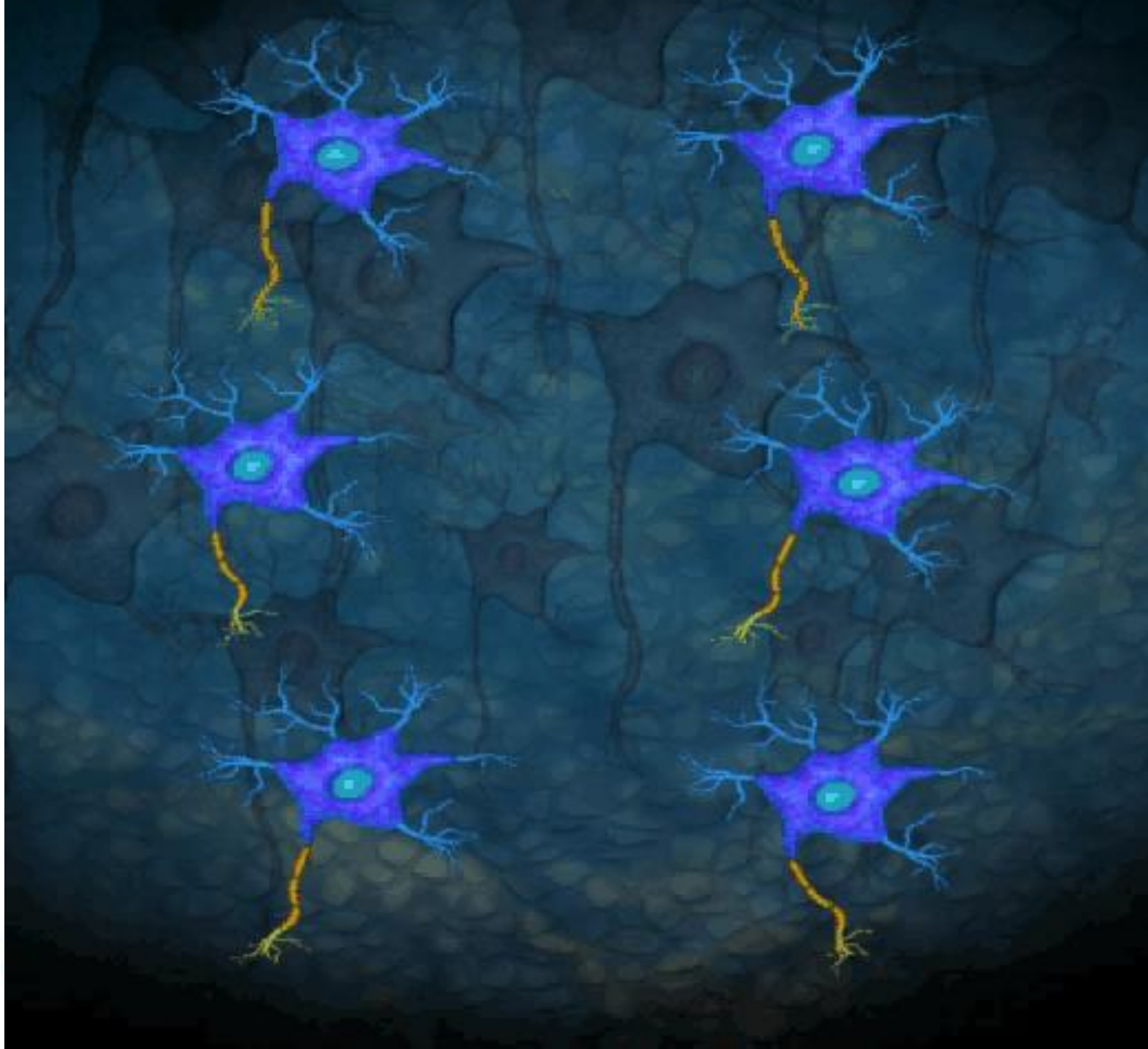


Reminder: Concussion effects on the Brain



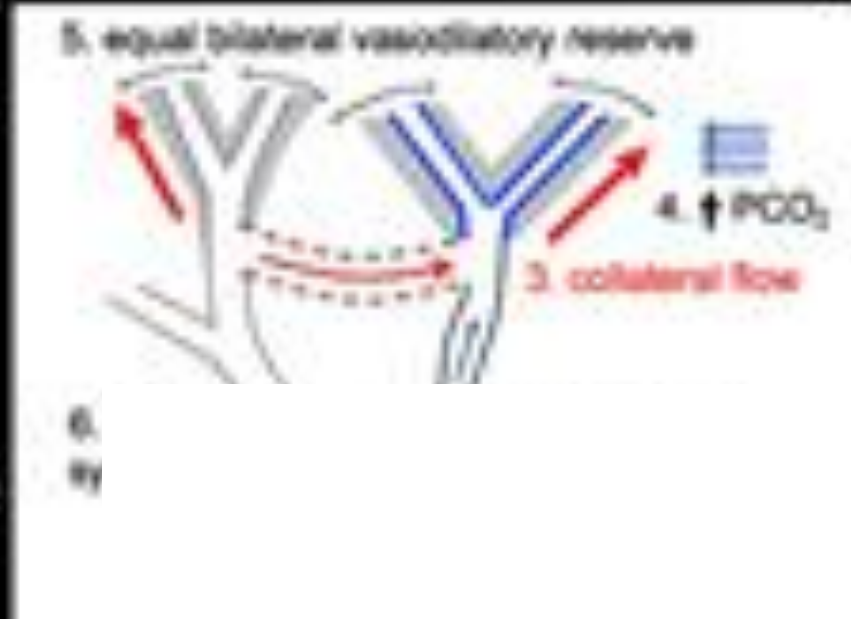
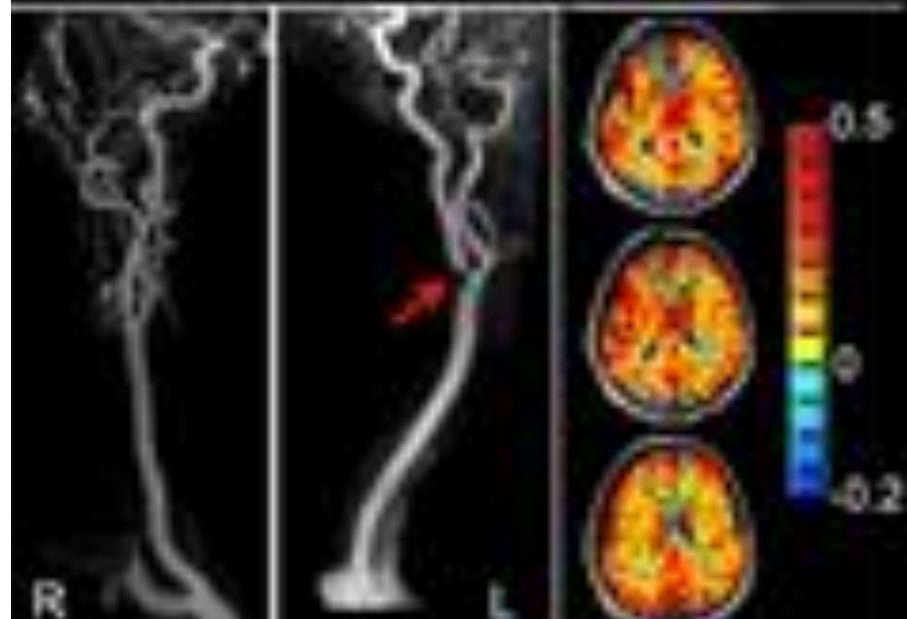
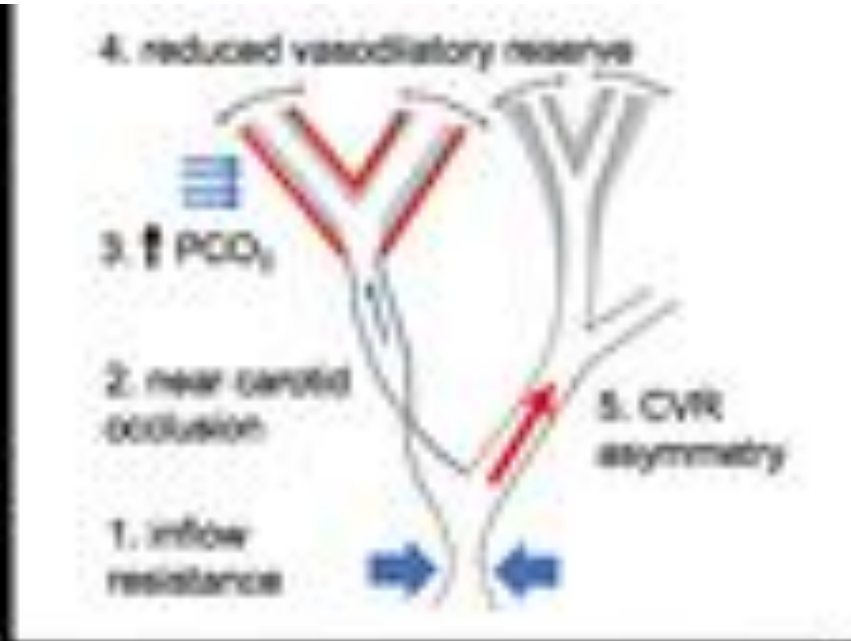
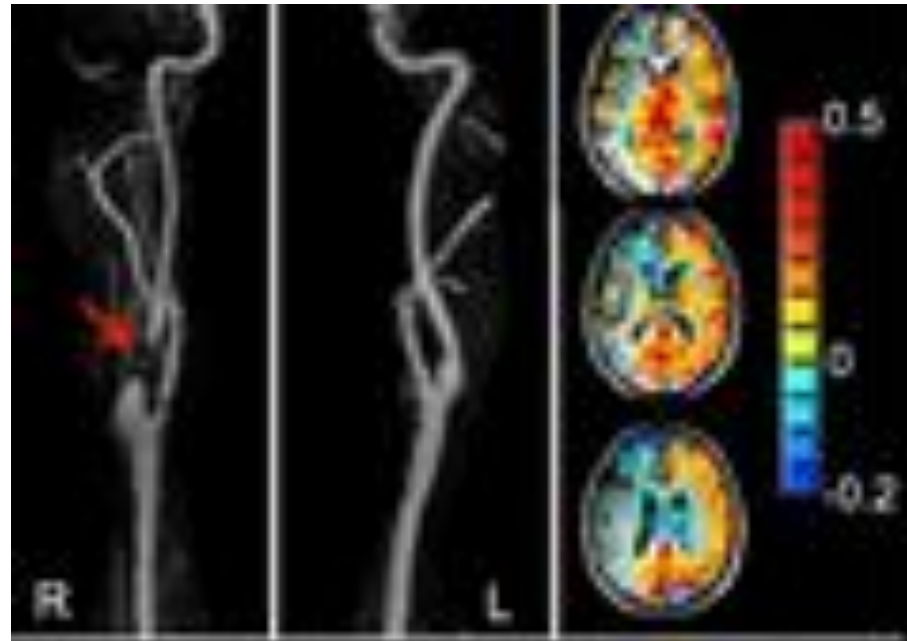
Post- Concussion Changes in Nerve Function

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

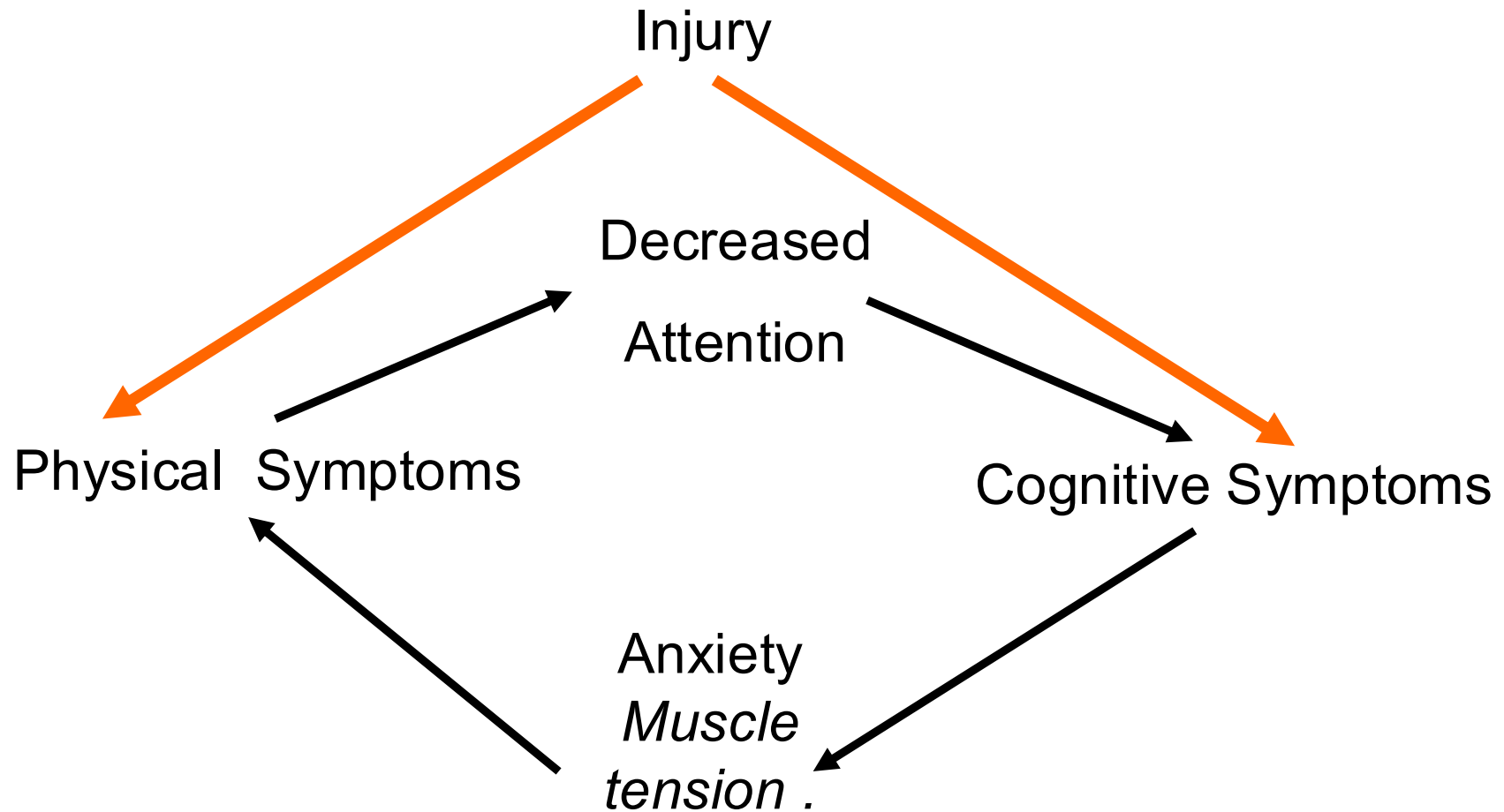


Concussion Changes in Brain blood flow and Vessel Reactivity

Dr. David Mikulis



The Vicious Cycle of Post-Concussion Syndrome



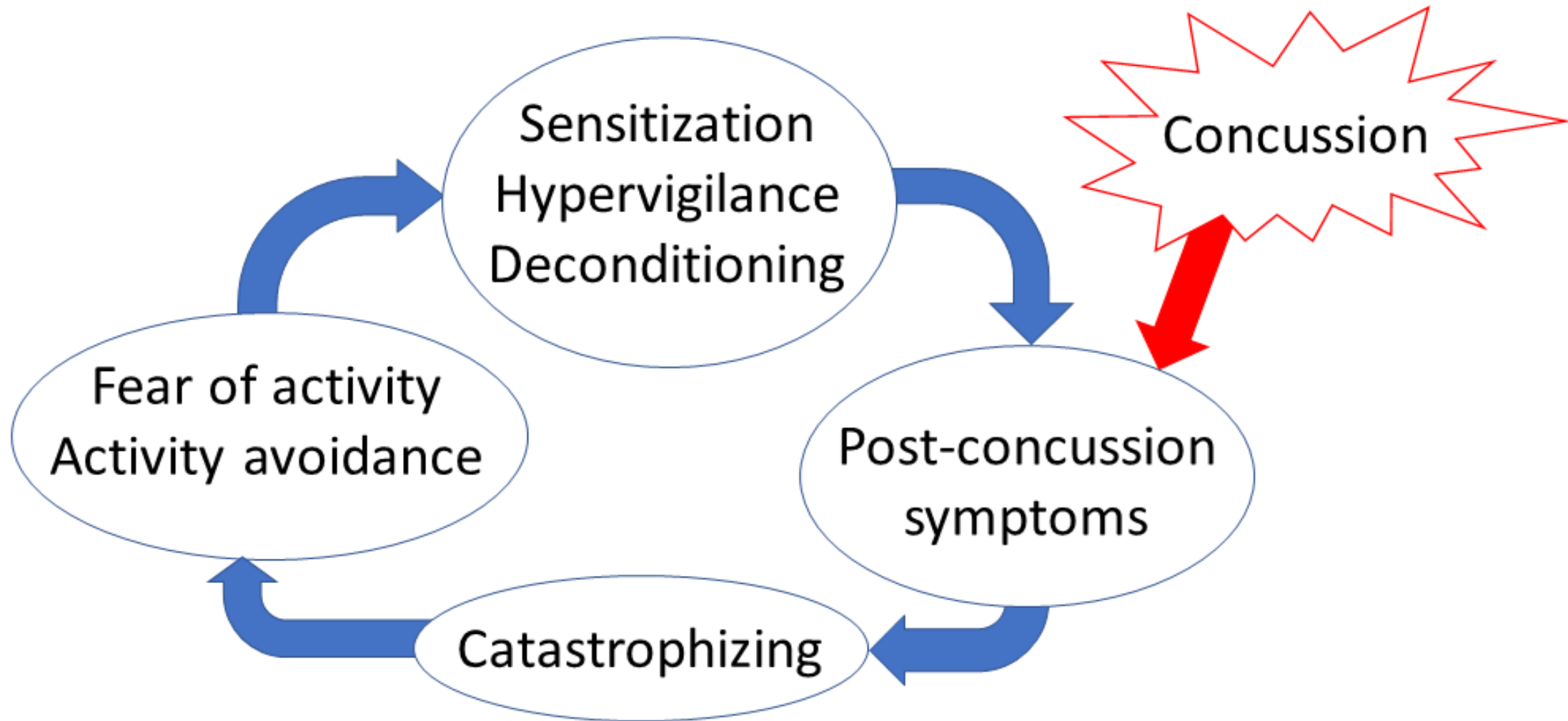
Signs and Symptoms

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)

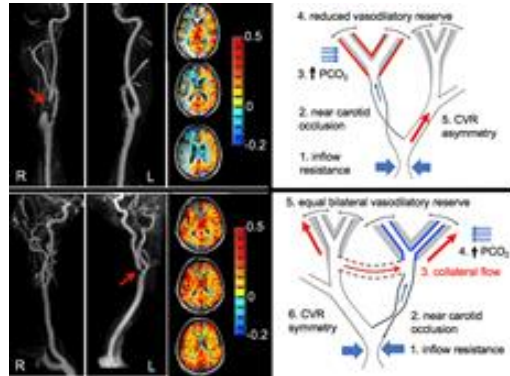
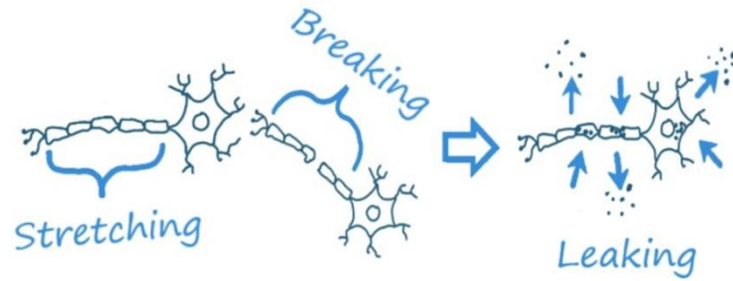


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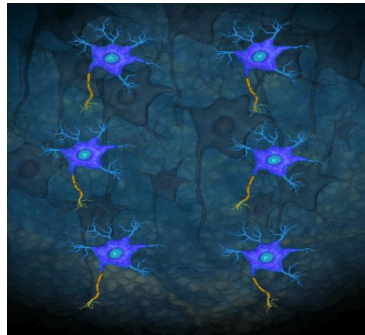
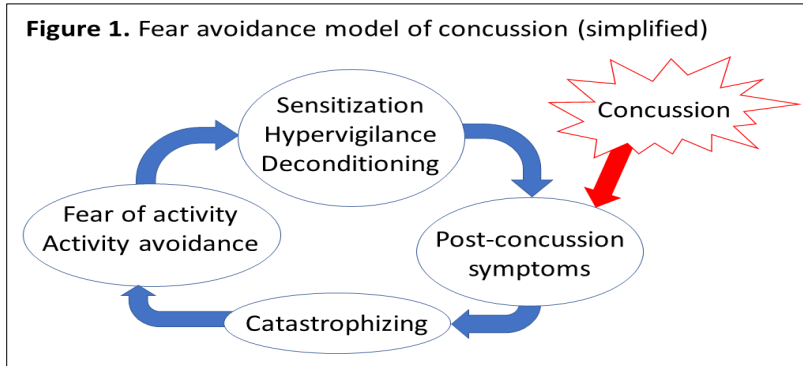
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How Could Exercise Help?



- 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 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 increases 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!

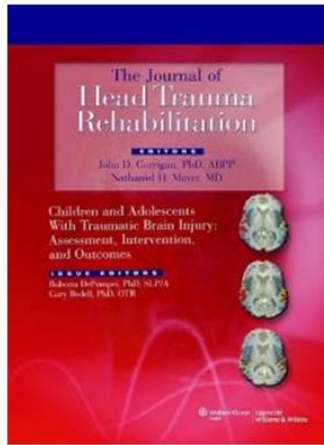
- *There is currently insufficient evidence that prescribing complete rest achieves these objectives. **After a brief period of rest during the acute phase (24–48 hours) after injury, patients can be encouraged to become gradually and progressively more active while staying below their cognitive and 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

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[†]

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

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	



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Research | Diagnosis | Solutions

Promoting Early Aerobic Exercise Initiation After Concussion

A Pilot Study Examining How Prescription Method Can Influence Recovery in a Non-athlete, Adult Population. Results From the Toronto Concussion Study

*Evan Foster, MHS¹, Laura Langer, MSc (Biostats.),¹ Mark Bayley, MD, FRCPC, CCPE,^{1,2,3}
Paul Comper, PhD, CPsych,^{1,3,4} Tharshini Chandra, BSc (Hon),¹ Aidan Snaiderman, BSc (Candidate),^{1,5}
Ainsley Kempenaar, MD,^{1,2} Elizabeth L. Inness, PT, PhD,^{1,3,6}
Cynthia Danells, PT,^{1,6} and David W. Lawrence, MD, MPH^{1,4,7}*

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Methods

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

Eligible participants underwent 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
- ✗ Heart rate increase <30 bpm from rest on Week 1 treadmill test
- ✗ Deemed asymptomatic from concussion by clinic physician
- ✗ Unable to follow commands

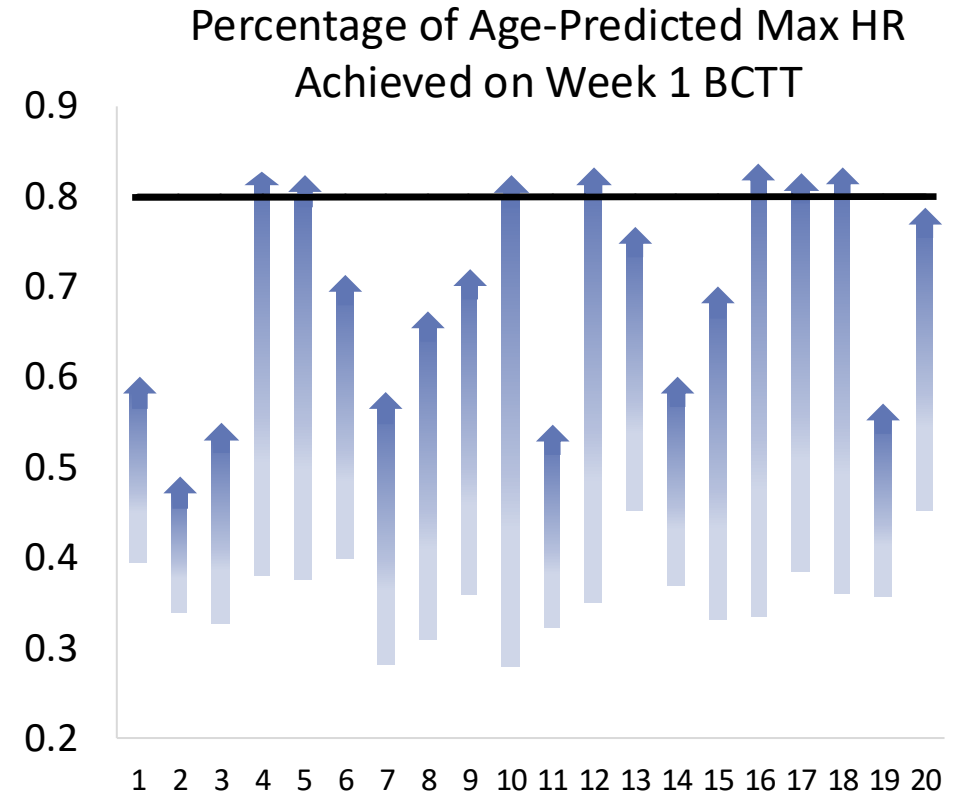
TABLE 1. Participant and injury characteristics

Participant Demographics

	Exercise Testing Cohort (<i>n</i> = 20)			<i>P</i> ^a
	Usual Care (<i>n</i> = 55)	Exercise Testing Plus Usual Care (<i>n</i> = 10)	Exercise Testing Plus Individualized Prescription (<i>n</i> = 10)	
Age, median (IQR)	28.0 (24.5; 36.0)	26.0 (23.5; 26.8)	29.5 (24.2; 36.2)	0.324
Female sex, <i>n</i> (%)	36 (65.5%)	4 (40.0%)	4 (40.0%)	0.151
Number of previous concussions, median (IQR)	0 (0; 1.0)	0 (0; 1.0)	0 (0; 0.8)	0.888
History of psychological disorder, <i>n</i> (%)	20 (36.4%)	2 (20.0%)	5 (50.0%)	0.389
History of migraine disorder, <i>n</i> (%)	10 (18.2%)	2 (20.0%)	1 (10.0%)	1.000
Years of education, median (IQR)	16.0 (14.0; 16.0)	16.0 (16.0; 17.5)	13.0 (12.0; 15.5)	0.039 ^b
Income, median (IQR) ^c	\$50,000 (\$30,000; \$70,000)	\$40,000 (\$30,000; \$50,000)	\$70,000 (\$50,000; \$95,000)	0.118
Mechanism of injury, <i>n</i> (%)				
Pedestrian	4 (7.3%)	0 (0.0%)	0 (0.0%)	0.304
Bicycle	10 (18.2%)	0 (0.0%)	0 (0.0%)	
Sport-related	11 (20.0%)	4 (40.0%)	1 (10.0%)	
Fall/falling objects	20 (36.4%)	4 (40.0%)	6 (60.0%)	
Hit head on something	8 (14.5%)	2 (20.0%)	1 (10.0%)	
Violence-related	2 (3.4%)	0 (0.0%)	2 (20.0%)	
Days to first clinic visit, median (IQR)	5.0 (4.0;7.0)	5.0 (5.0;7.0)	6.0 (5.0;6.0)	
Loss of consciousness, <i>n</i> (%)	17 (30.9%)	1 (10.0%)	3 (30.0%)	0.489
Posttraumatic amnesia, <i>n</i> (%)	1 (21.8%)	2 (20.0%)	2 (20.0%)	1.000
Initial Glasgow Coma Scale (IQR)	13.0 (12.0;14.0)	48.5 (39.8;64.0)	55.0 (30.0;76.0)	0.324

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"/>
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"/>

} See below for details

↓ 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**

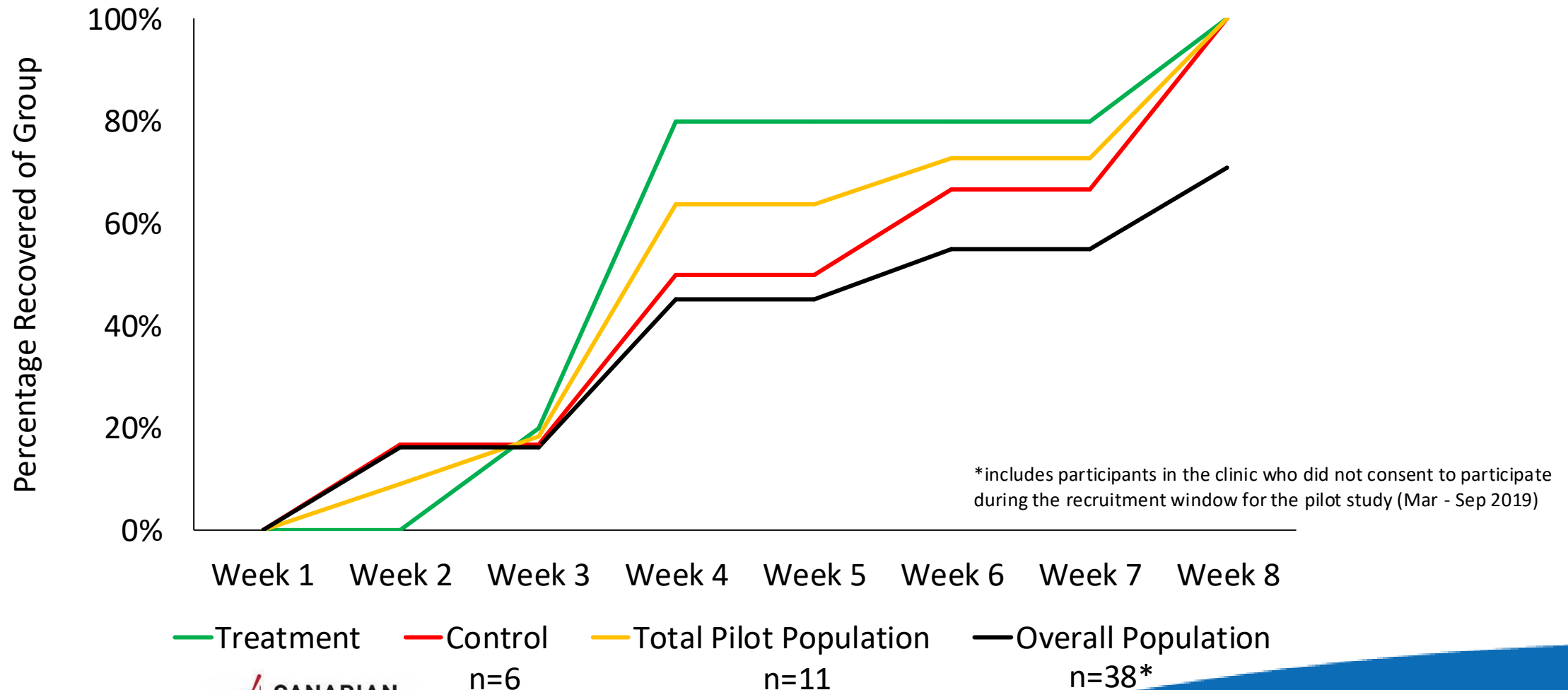
Recovery Criteria for Pilot Study

Recovery 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

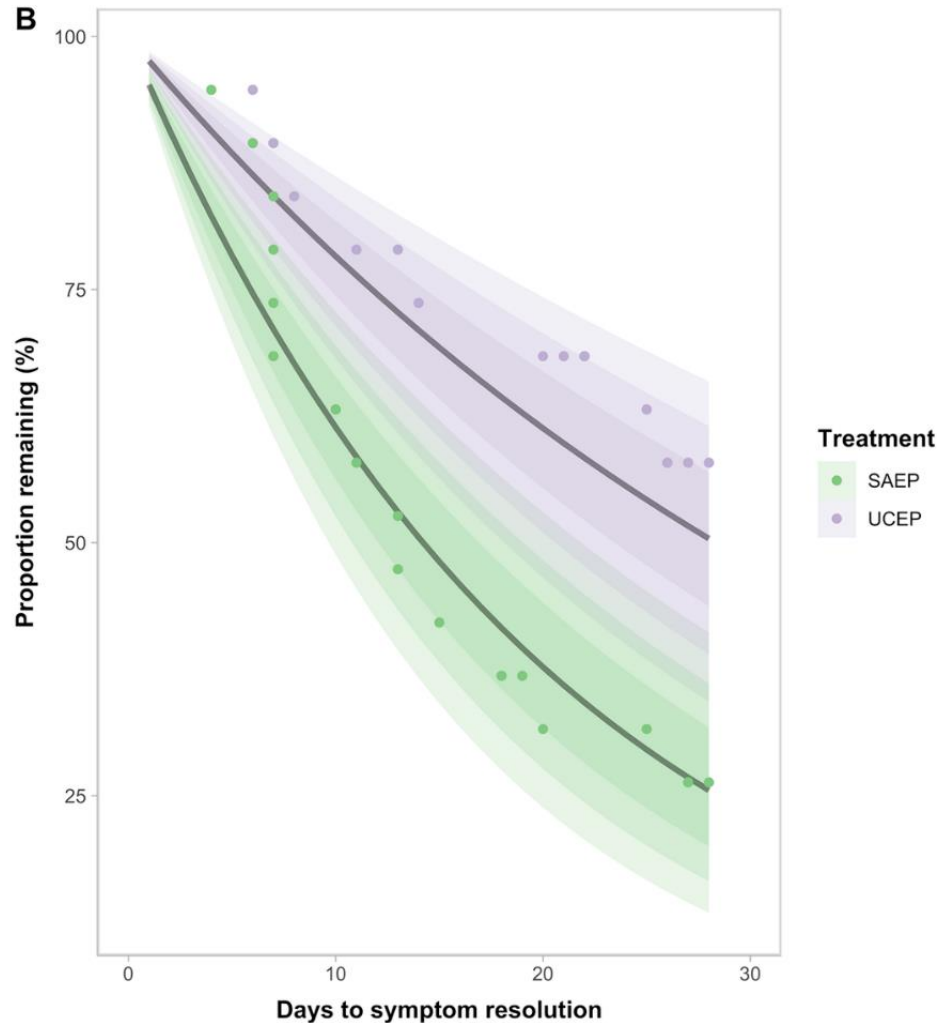
Recovery vs. Arm in Clinic



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

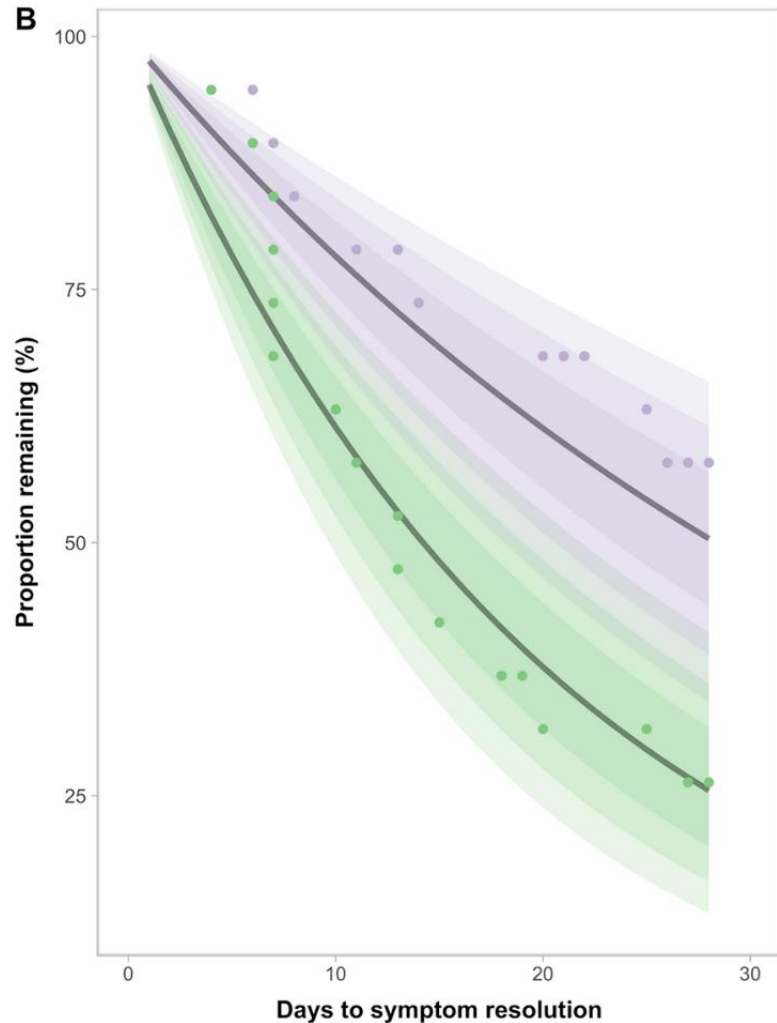
- BCTT requires access to a treadmill (or a stationary bike for Buffalo Concussion Bike Test [BCBT])
- These devices may not be accessible in non-specialized clinics (i.e., family doctor's offices, walk-in clinics, etc.)
- Can exercise be prescribed effectively without rigorous testing?

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)

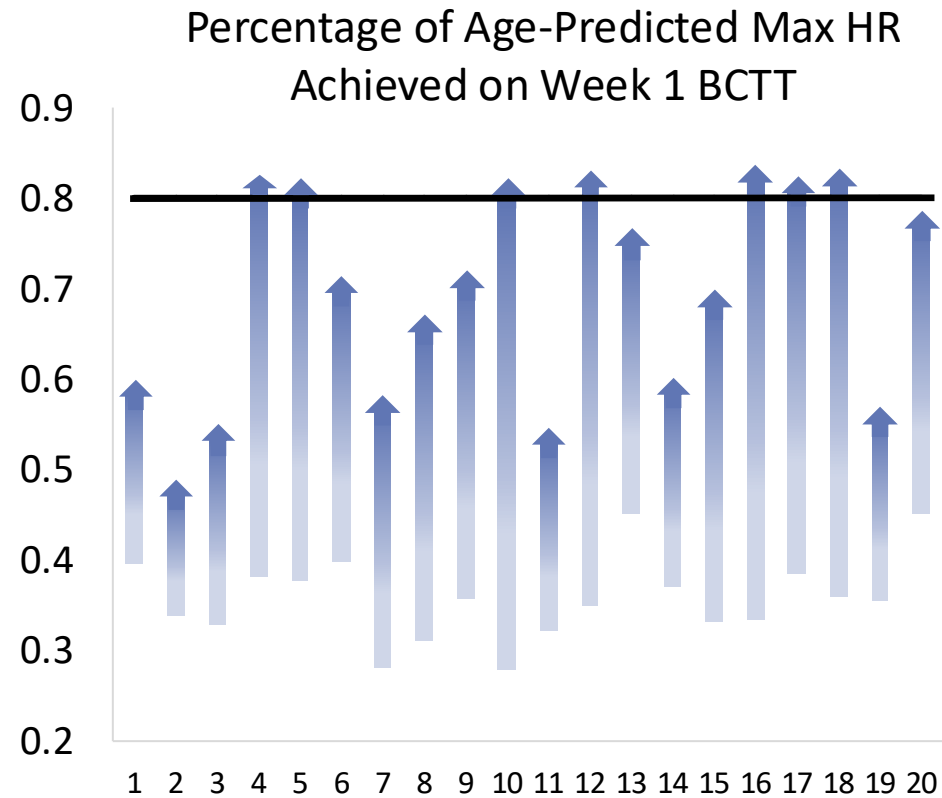


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****By one month, 74% of the participants who underwent SAEP were asymptomatic compared to a mean of 50% in those in the UCEP group.**

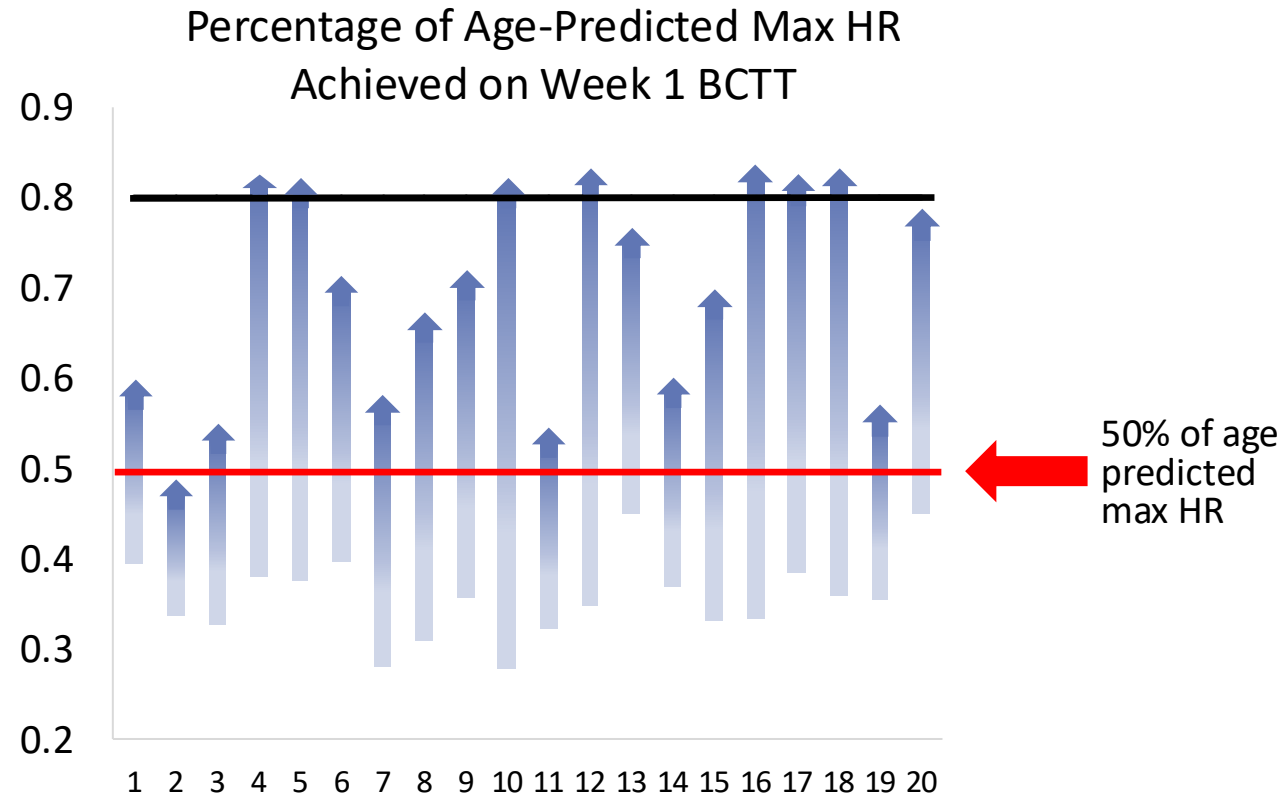
Structured Aerobic Exercise Protocol (SAEP) feasibility in the General Adult Population?

Recall:



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

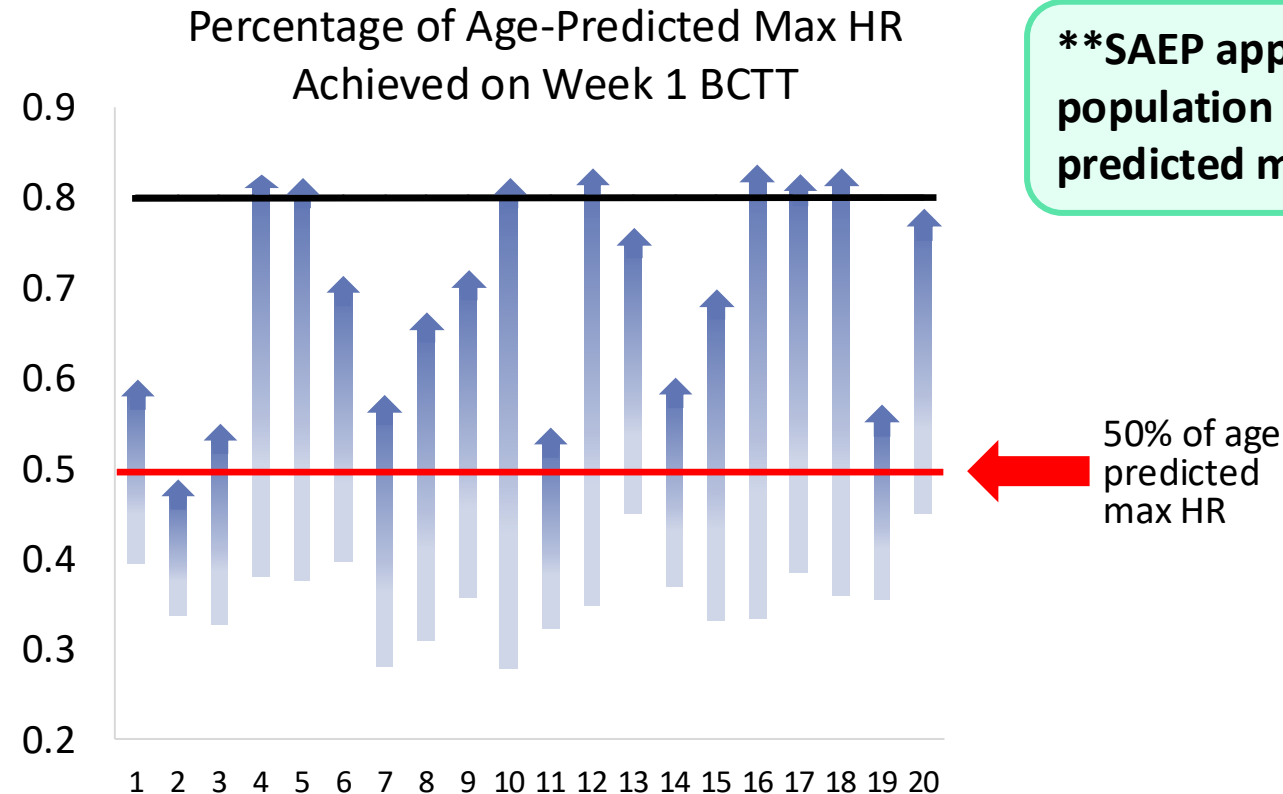
Recall:



- 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?

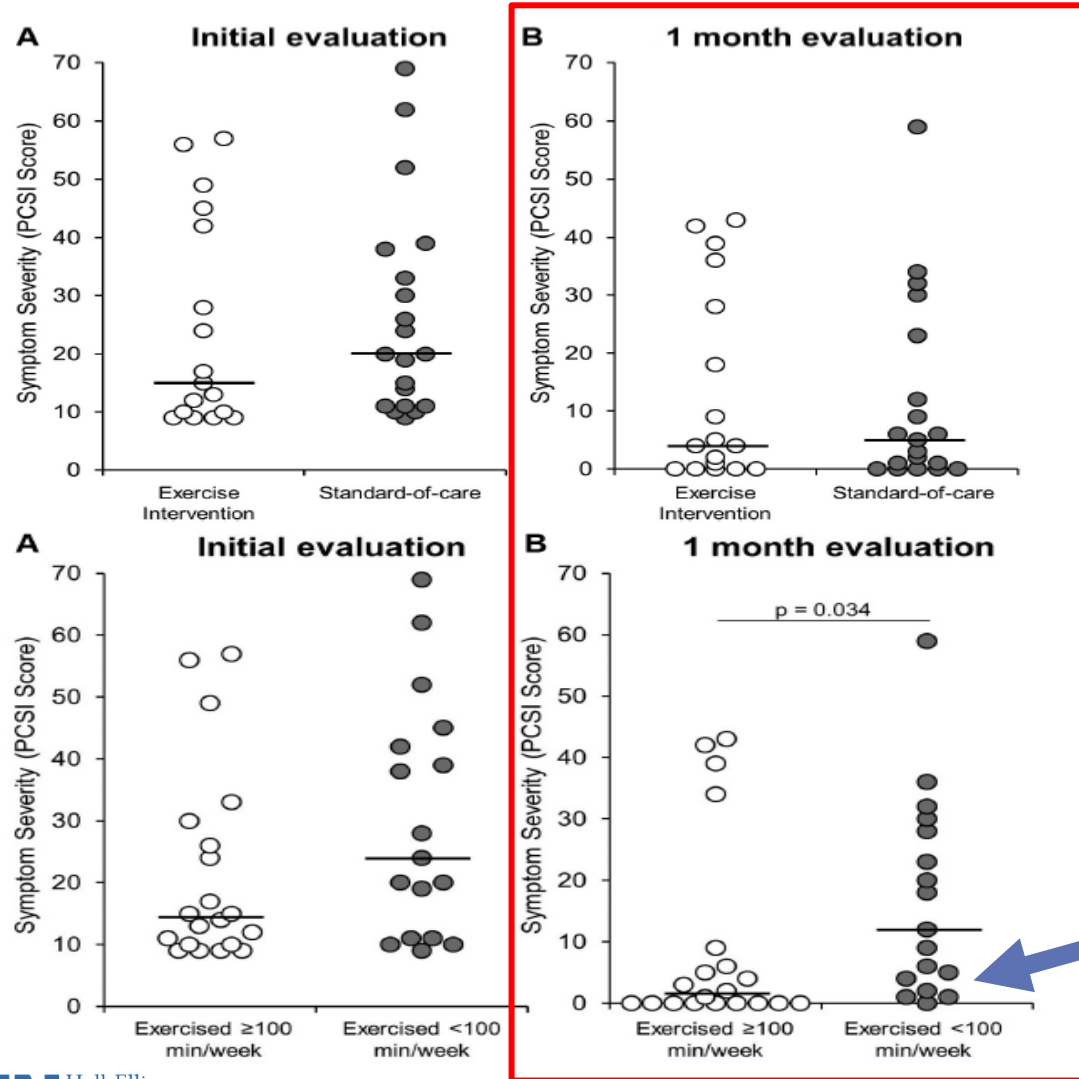
Recall:



****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.**

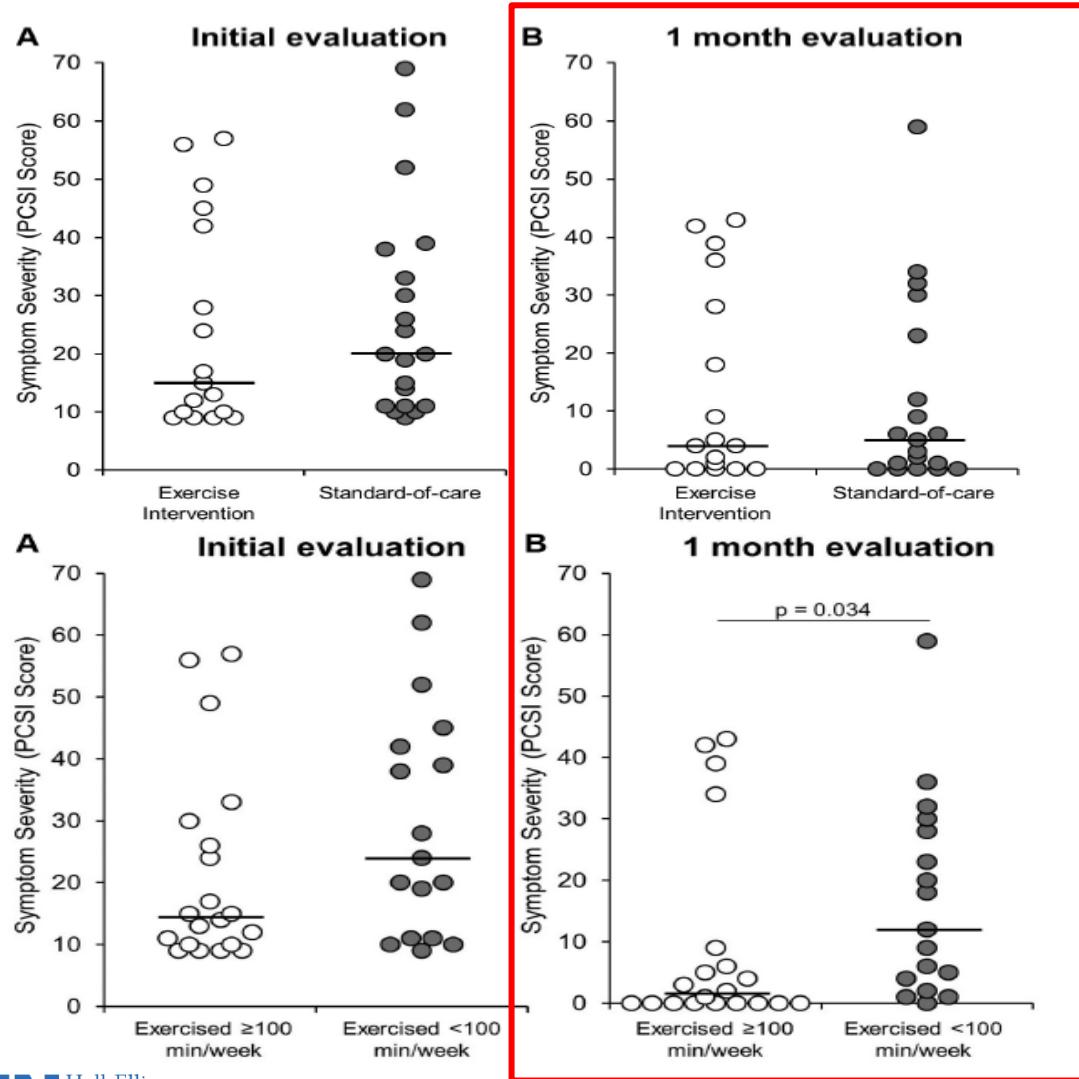
- 19/20 (95%) participants were able to exercise to 50% of their age-predicted max HR within one week of concussion

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.**

Few takeaways- How intense should you go?

- 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- your age) e.g. 220-45 yr old = 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 Resistance Exercise/strength training

The evidence that resistance training independently accelerates symptom recovery is limited.

- Resistance training appears safe when introduced progressively after the acute phase

Therefore, clinical practice guidelines and expert consensus:

- Do not recommend resistance training as first line therapy
- Support graded introduction once aerobic exercise is tolerated
- Emphasize symptom limited progression and avoidance of Valsalva early

Neck strengthening Relevance to recovery

Improved neck strength may:

- Reduce headache caused by injury to the muscles, ligaments and joints (AKA Cervicogenic headache)
- Improve sensorimotor control of the head and neck
- Support rehabilitation for dizziness
- **However, no trials demonstrate faster symptom resolution directly attributable to neck resistance training.**

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 publi

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 you can base heart rate target on your age

3.How?

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

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