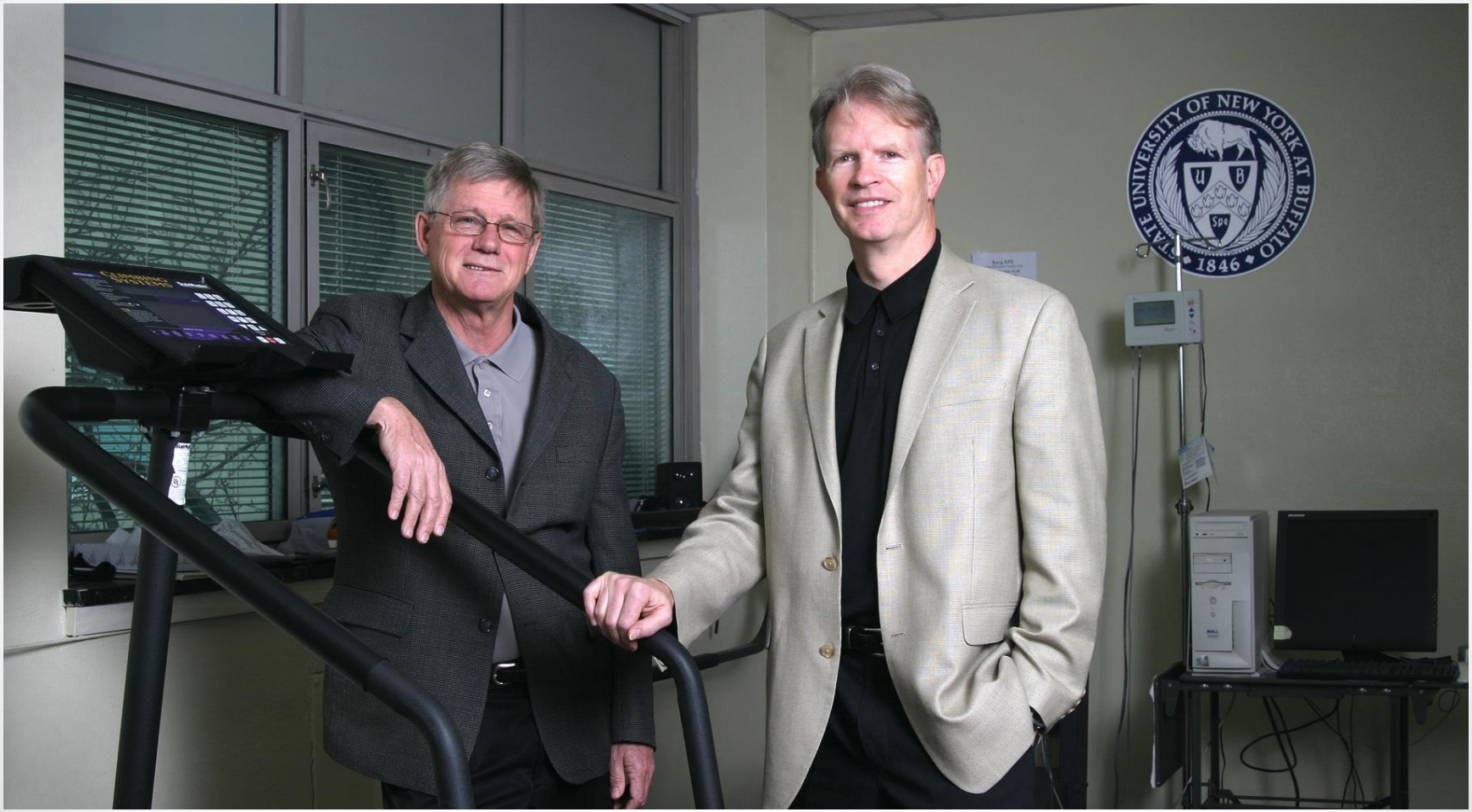
Concussion as a Medical Issue: Physiological Underpinnings

Barry Willer PhD

Concussion.buffalo.edu



First Consensus Conference on Concussion (Vienna 2001)

Guidelines for return to play

1. No activity
2. Light aerobic exercise
3. Sport-specific exercise
4. Non-contact training drills
5. Full contact practice
6. Return to play

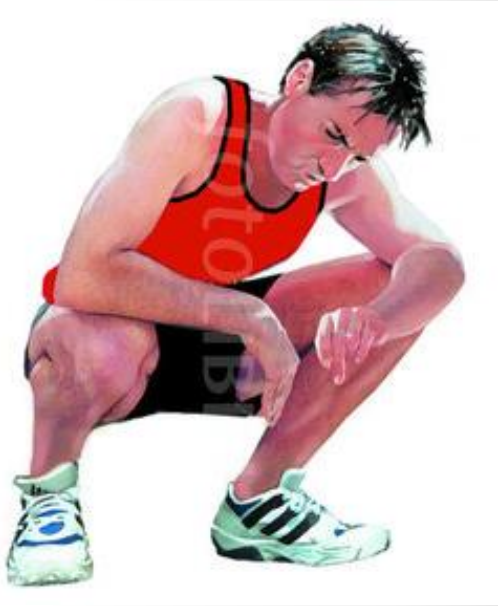
Definition of concussion:

A complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces

Consensus Guidelines

If there is symptom exacerbation at any step return to the previous step.

Return to play when the athlete can exercise fully without exacerbation of symptoms



Established An Evidence Based Concussion Clinic

- Systematize the return to play process (using a treadmill and careful monitoring of symptoms)
- Proposed exercise below the level of symptom exacerbation… even before athlete is asymptomatic

Management of Concussion and Post-Concussion Syndrome

*Barry Willer, PhD**
John J. Leddy, MD

Address
*University at Buffalo, G 96 Farber Hall, 3435 Main Street, Buffalo, NY 14214, USA.
E-mail: willer@vaxxine.com

Current Treatment Options in Neurology 2006, 8:415–426
Current Science Inc. ISSN 1092–8480
Copyright © 2006 by Current Science Inc.

Use of Graded Exercise Testing in Concussion and Return-to-Activity Management

John J. Leddy, MD, FACSM FACP[1] and Barry Willer, PhD[2]

Reliability of a Graded Exercise Test for Assessing Recovery From Concussion

John J. Leddy, MD, John G. Baker, PhD,† Karl Kozlowski, PhD,‡ Leslie Bisson, MD,* and Barry Willer, PhD§*

e: To evaluate a graded treadmill test for retest reliability
d interrater reliability (IRR) in the evaluation of the
ic effects of symptom exacerbation from concussion.

Key Words: traumatic brain injury, treadmill, symptoms, physiology, heart rate

(*Clin J Sport Med* 2011;21:89–94)

Conducted Research on Treatment

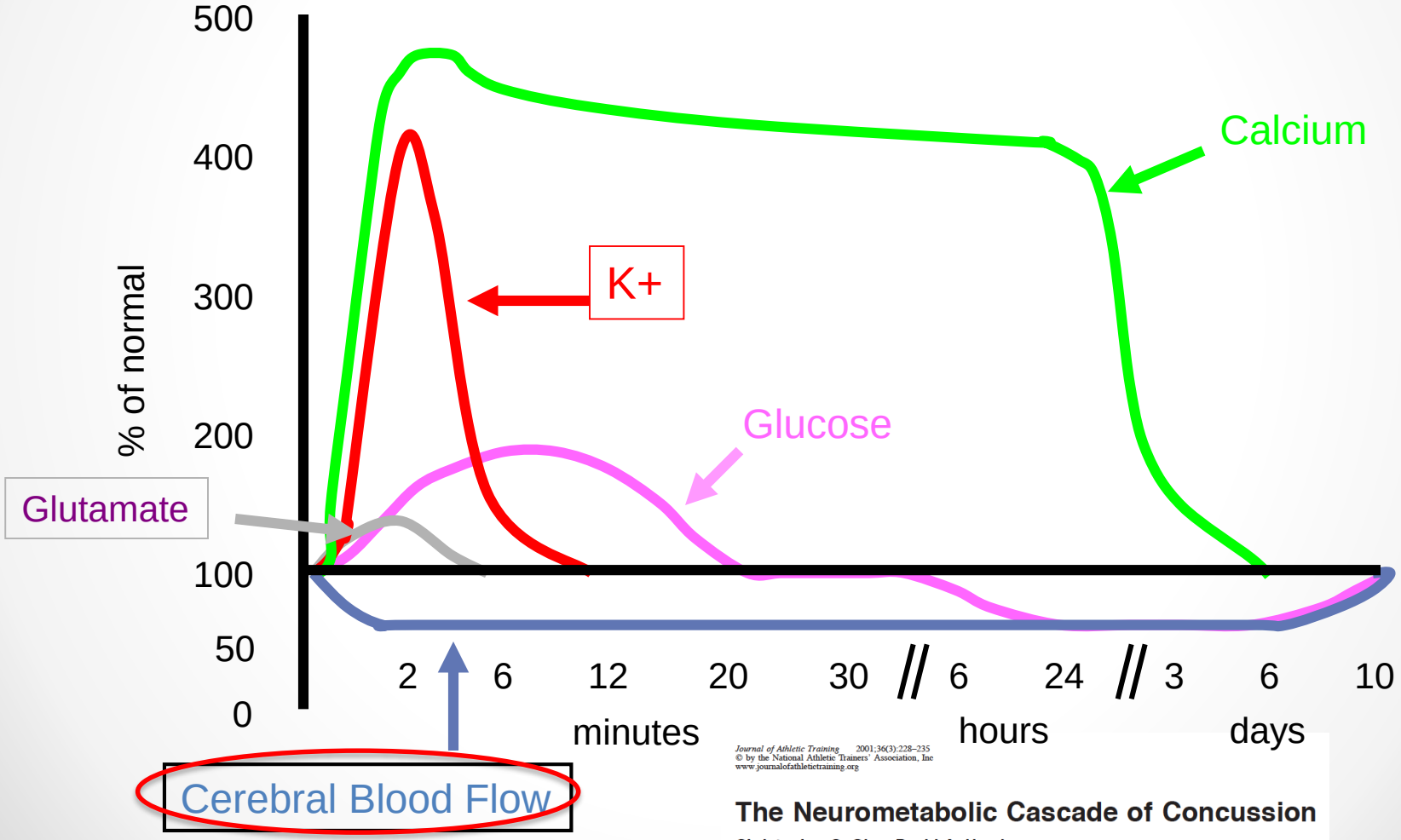
A Preliminary Study of Subsymptom Threshold Exercise Training for Refractory Post-Concussion Syndrome

John J. Leddy, MD,† Karl Kozlowski, PhD,‡ James P. Donnelly, PhD,§ David R. Pendergast, EdD,¶ Leonard H. Epstein, PhD,‖ and Barry Willer, PhD***

- Pilot study used subjects as their own controls
- But why would exercise help recovery?

Neurometabolic Cascade

Following Cerebral Concussion/MTBI



Journal of Athletic Training 2001;36(3):228–235
© by the National Athletic Trainers' Association, Inc
www.journalofathletictraining.org

The Neurometabolic Cascade of Concussion

Christopher C. Giza; David A. Hovda

Neurotrauma Laboratory, Division of Neurosurgery, University of California, Los Angeles School of Medicine, Los Angeles, CA

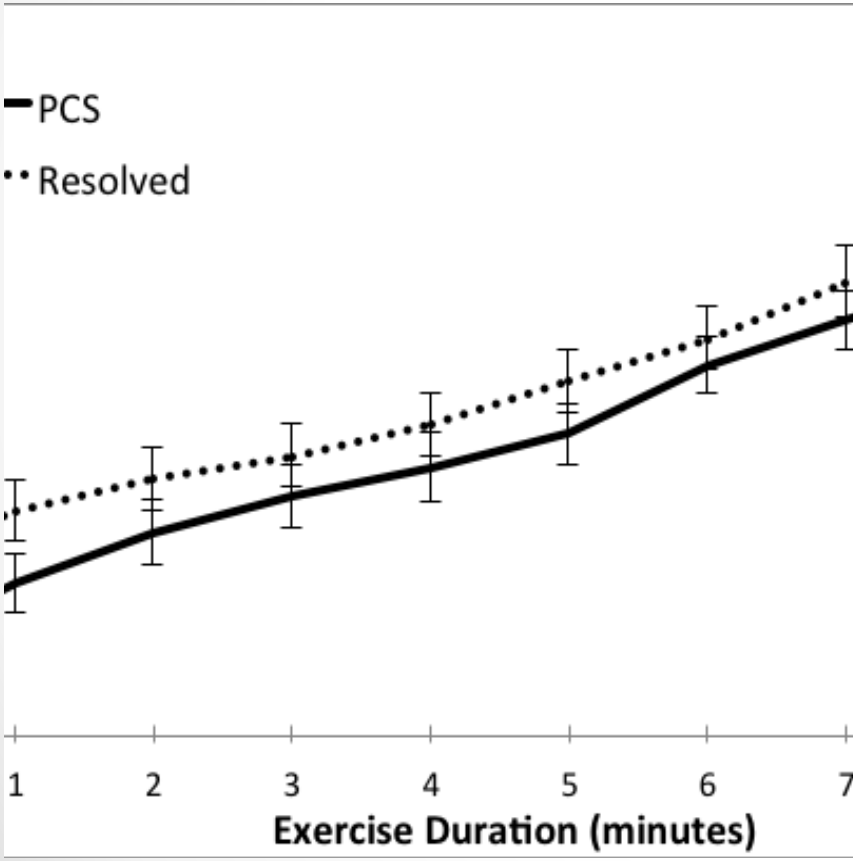
Physiological Findings in Humans with Concussion

- Decreased CBF at rest
- Higher resting HR at rest
- Decreased HRV at rest

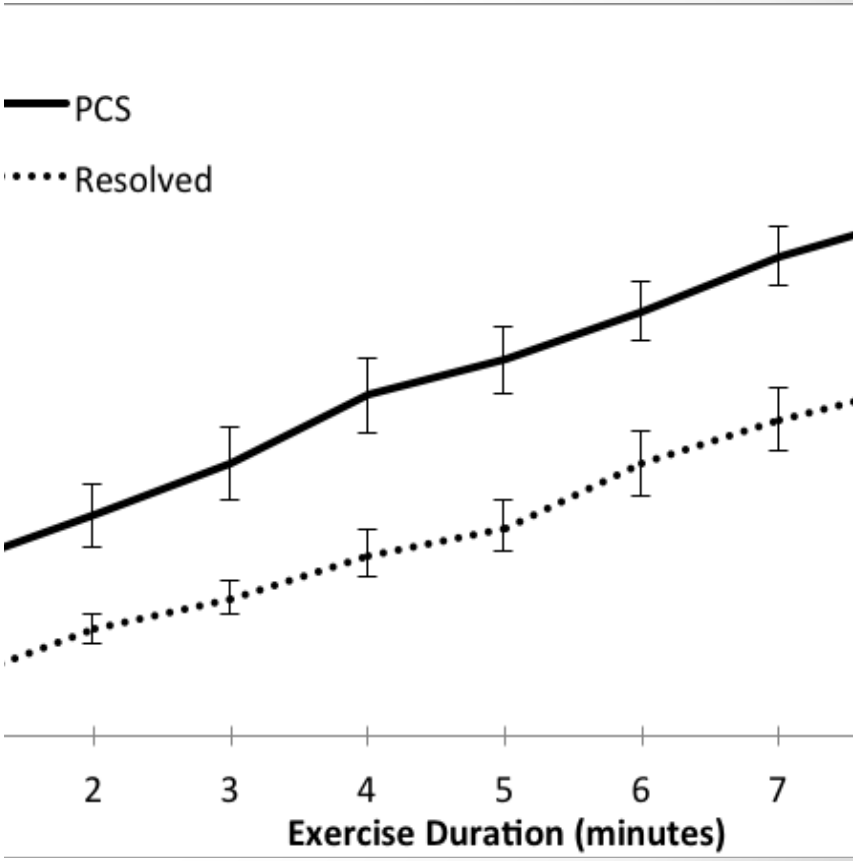
Suggests "sympathetic overdrive"

Cardiovascular performance during exercise

PCS versus Resolved



Heart Rate



Perceived Exertion

Autonomic Nervous System Dysfunction

Difficulty isn't being locked in sympathetic drive or parasympathetic drive but rather, difficulty switching from one drive to the other

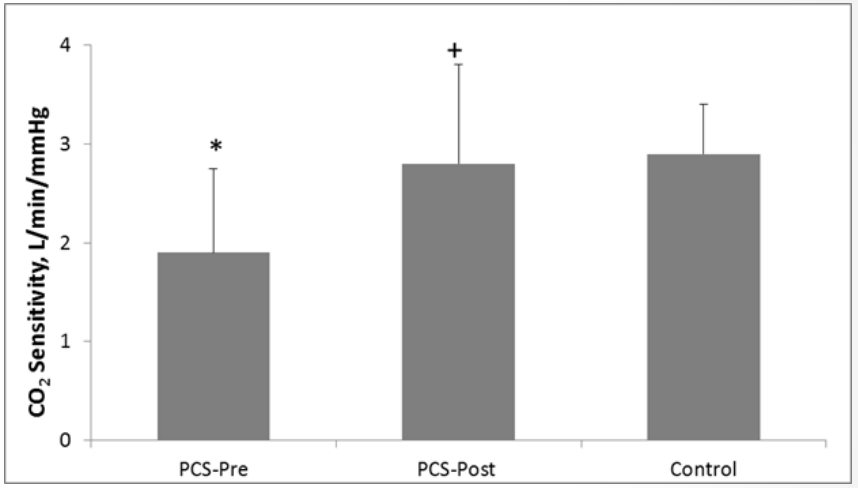
Thus, HR is elevated during rest but decreased during exercise

What the patient experiences is fatigue and sleep difficulty

Altered cerebral blood flow during exercise

CBF during exercise is increased (and associated with symptom exacerbation)

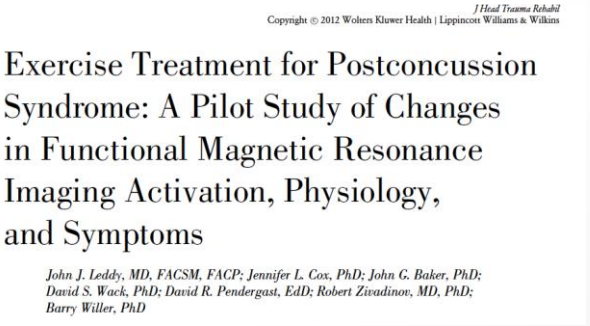
CO_2 Sensitivity reduced



END RESULT IS EXERCISE INTOLERANCE

Functional Imaging Study

- Purpose: To compare subjects with PCS and normal Ss on brain activation patterns during a simple math test
- To compare Ss with PCS who received an exercise based program for recovery and a sham (stretching program)



J Head Trauma Rehabil
Copyright © 2012 Wolters Kluwer Health | Lippincott Williams & Wilkins

Exercise Treatment for Postconcussion Syndrome: A Pilot Study of Changes in Functional Magnetic Resonance Imaging Activation, Physiology, and Symptoms

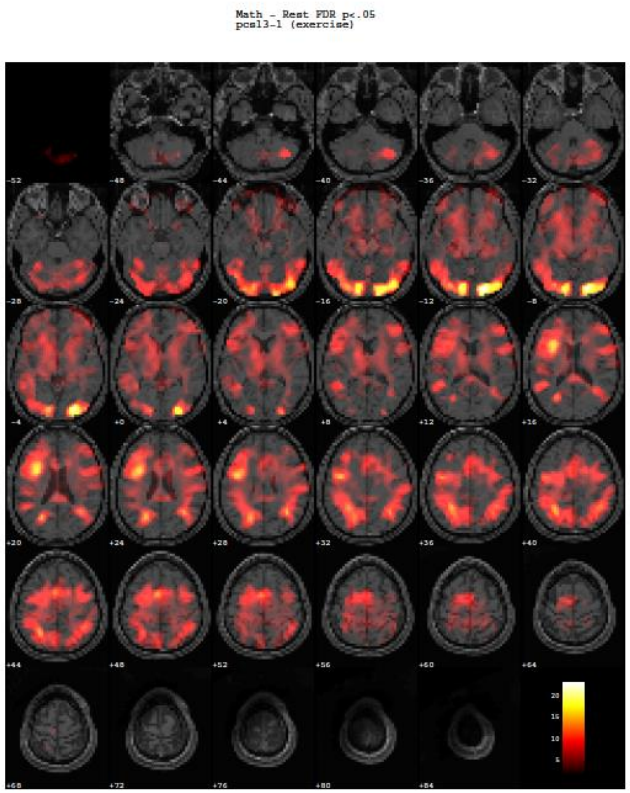
John J. Leddy, MD, FACSM, FACP; Jennifer L. Cox, PhD; John G. Baker, PhD; David S. Wack, PhD; David R. Pendergast, EdD; Robert Zivadinov, MD, PhD; Barry Willer, PhD

fMRI

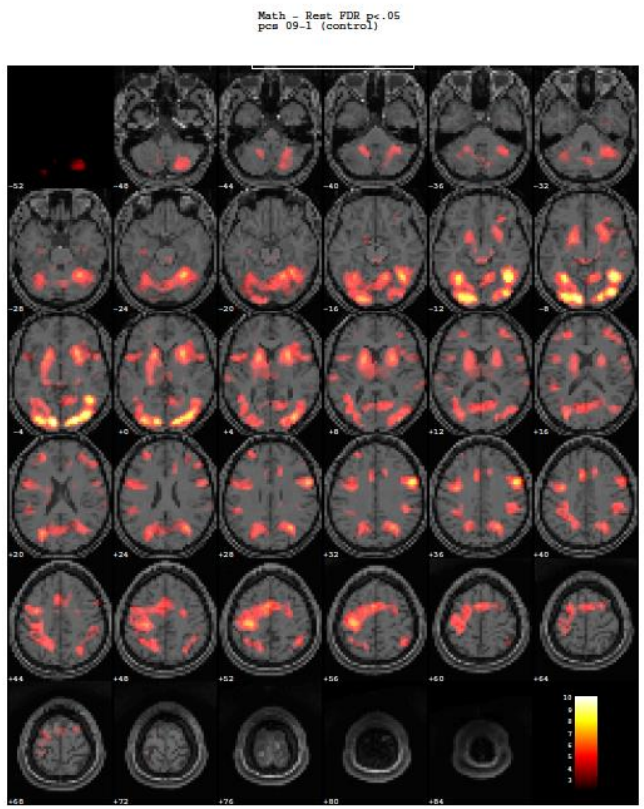
PCS vs Normal (Recovered)

(Leddy et al 2013)

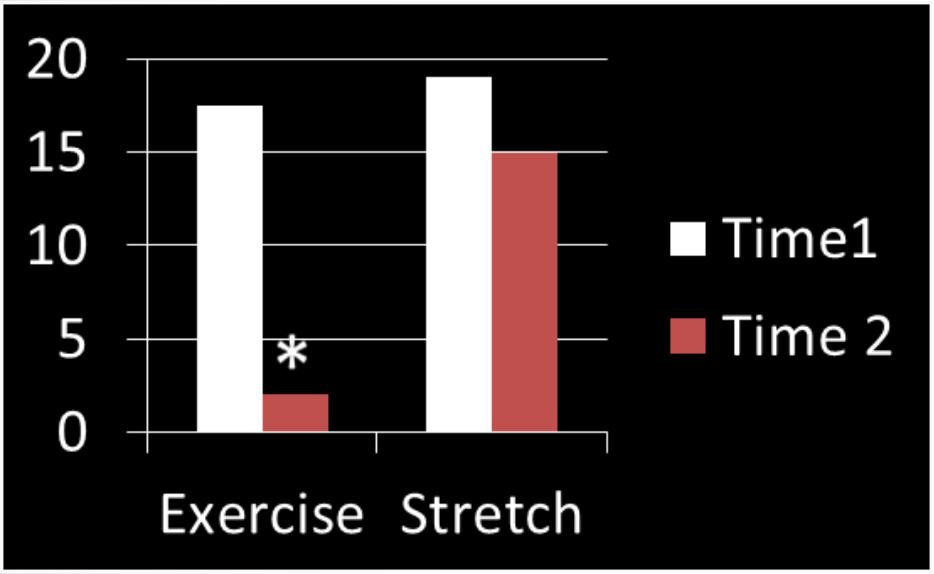
PCS



Recovered

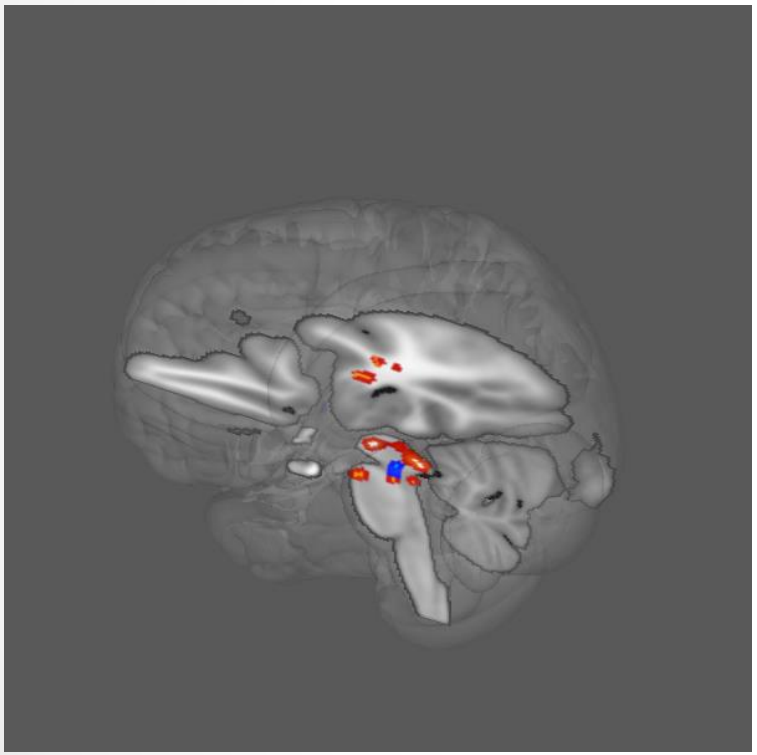


Does Exercise Treatment Work For Everyone?



- 4/4 exercise treated subjects had symptom resolution v. stretching placebo control (Leddy et al. 2013)
- 77% of P-PCD (n=65) treated with aerobic exercise returned to full sport or work (Baker et al. Rehabilitation Research and Practice. 2012)
- *5 of 6 who refused to exercise did not return to full function

Diffusion Tensor Imaging



- When we compared the PCS group with the control group using DTI…. The PCS group had more issues with white matter at the beginning and after treatment.

Copyright © 2014 Wolters Kluwer Health | Lippincott Williams & Wilkins

Diffusion Tensor Imaging Alterations in Patients With Postconcussion Syndrome Undergoing Exercise Treatment: A Pilot Longitudinal Study

Paul Polak, MASc; John J. Leddy, MD, FACSM, FACP; Michael G. Dwyer, PhD; Barry Willer, PhD; Robert Zivadinov, MD, PhD, FAAN

Diagnosis using SIGNS

- Patients who have exercise intolerance (and orthostatic imbalance) have PCS
- Patients who do not have exacerbation of symptoms may have one or more other conditions but not PCS (mTBI)

Brain or Strain? Symptoms Alone Do Not Distinguish Physiologic Concussion From Cervical/Vestibular Injury

John J. Leddy, MD,† John G. Baker, PhD,‡ Asim Merchant, MD,†§ John Picano, BS,¶ Daniel Gaile, PhD,‖ Jason Matuszak, MD,§ and Barry Willer, PhD***

Diagnosis of Concussion and PCS

BRAIN INJURY

http://informahealthcare.com/bij
ISSN: 0269-9052 (print), 1362-301X (electronic)

Brain Inj, Early Online: 1–11
© 2014 Informa UK Ltd. DOI: 10.3109/02699052.2014.965207

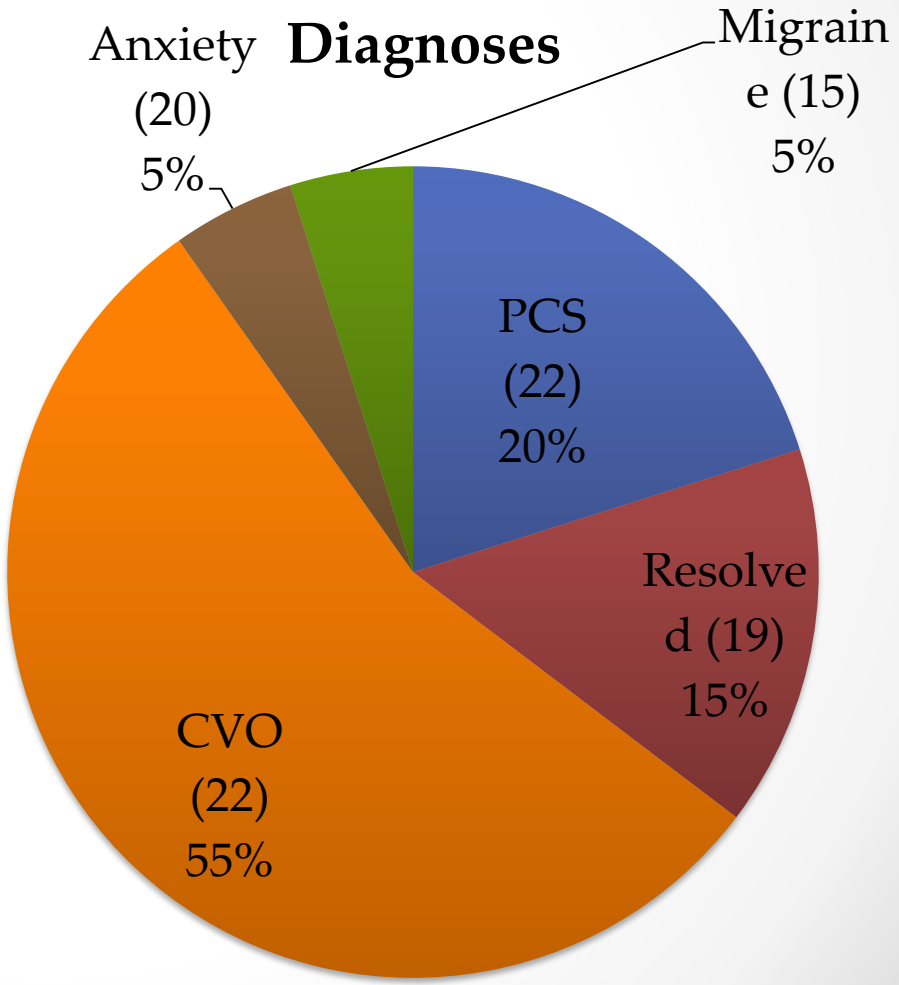
informa healthcare

ORIGINAL ARTICLE

Physiological, vestibulo-ocular and cervicogenic post-concussion disorders: An evidence-based classification system with directions for treatment

Michael J. Ellis[1], John J. Leddy[2], & Barry Willer[3]

[1]Division of Neurosurgery, Pan Am Clinic, University of Manitoba, Winnipeg, Manitoba, Canada, [2]Department of Orthopaedics, and [3]Department of Psychiatry, State University of New York at Buffalo, Buffalo, NY, USA

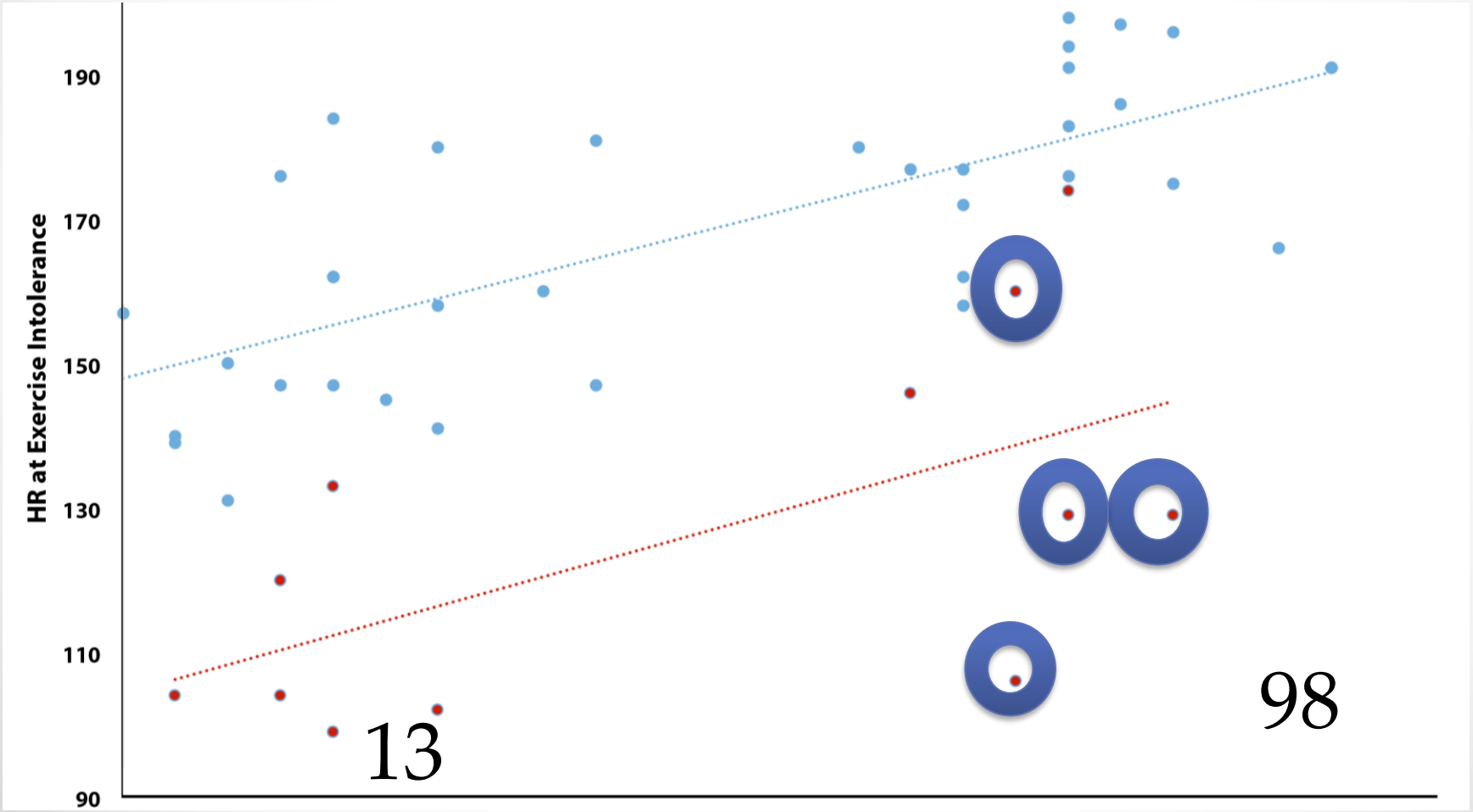


Safety Study

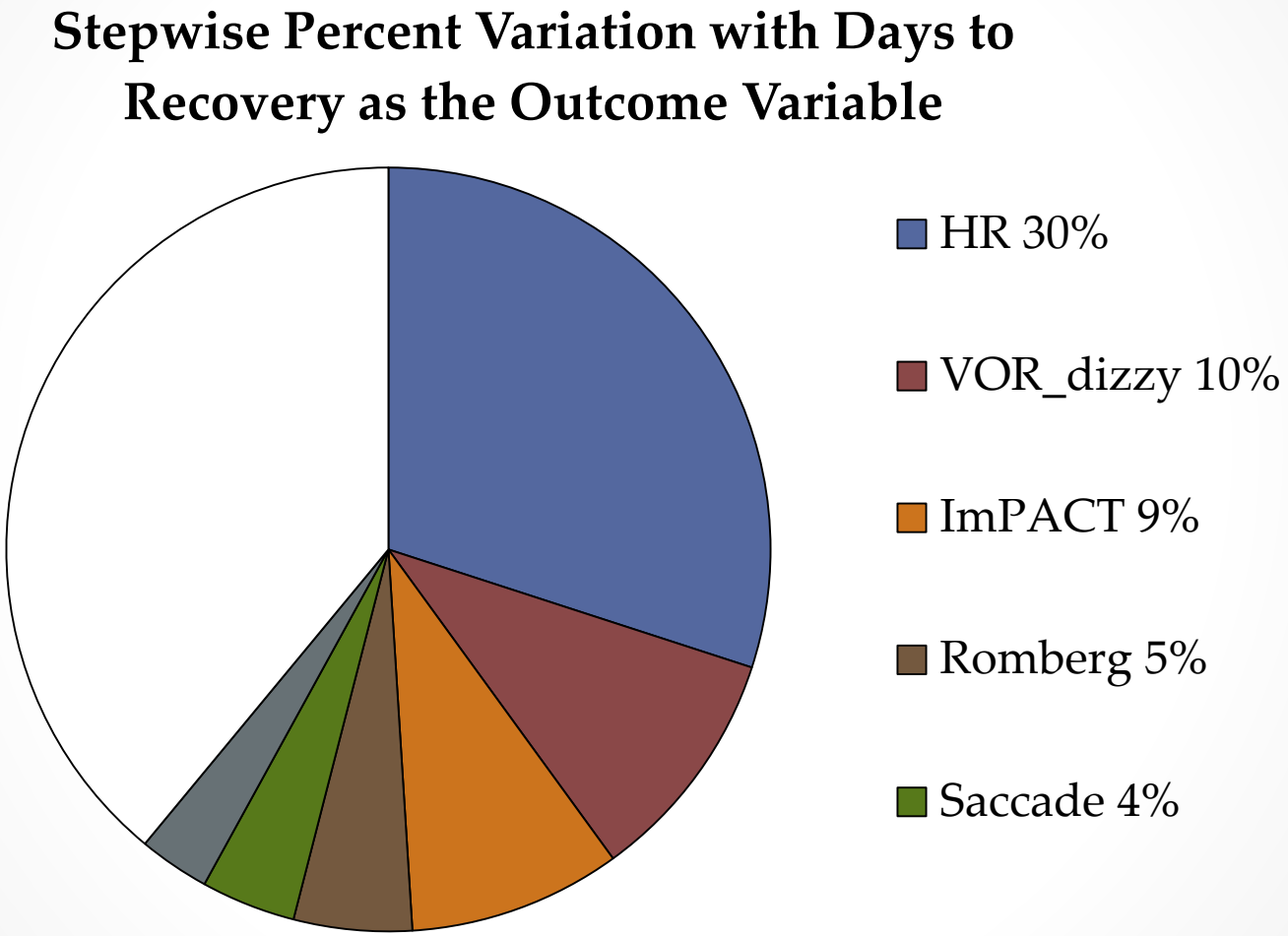
- Assessed 54 adolescents with 27 randomly assigned to receive the BCTT acutely (~ 4 days)
- Tested 2 weeks later
- No negative effect of early (acute) testing

- 48/54 of Ss recovered within 5 weeks

Treadmill Test Results Predict Recovery Rate



Best Predictors of Recovery early after SRC



Future Research

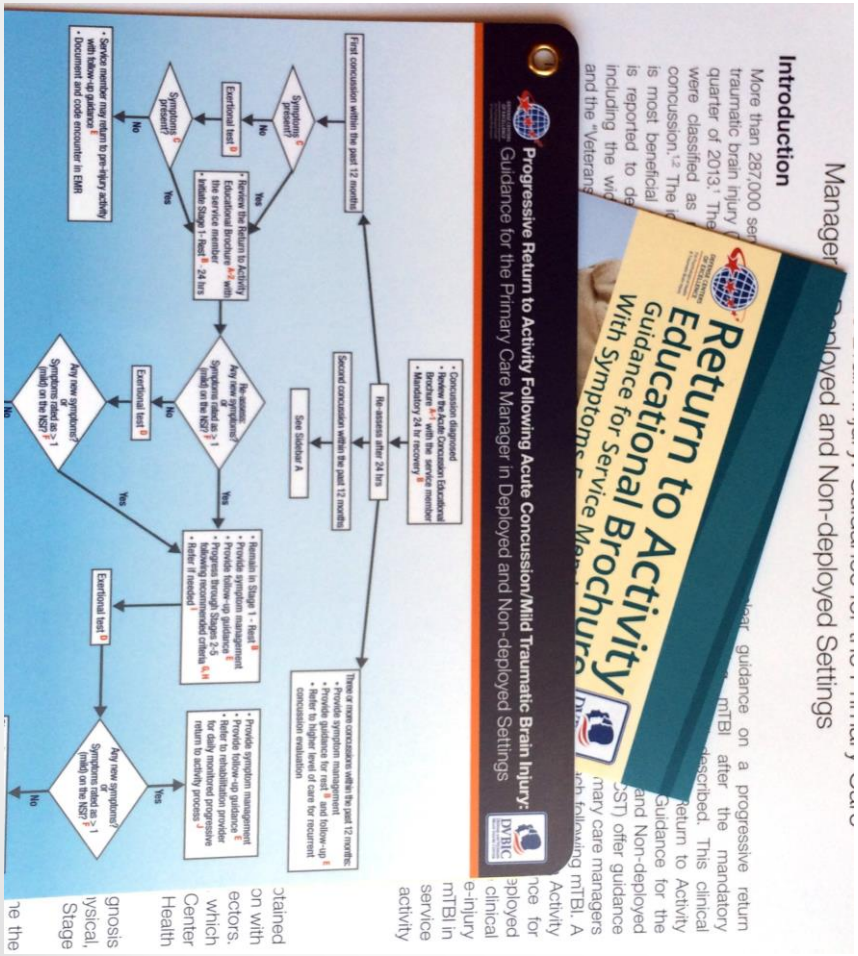
- RCT of controlled exercise versus placebo/sham control
- Interested in standardizing physical exam
- Replicate the safety study (with children?)
- Systematize the school interventions
- Complete the study of aging athletes

Return to Sport

Return to School

Application of the Physiological Model to the Military

Return to Activity Guidelines for the DOD



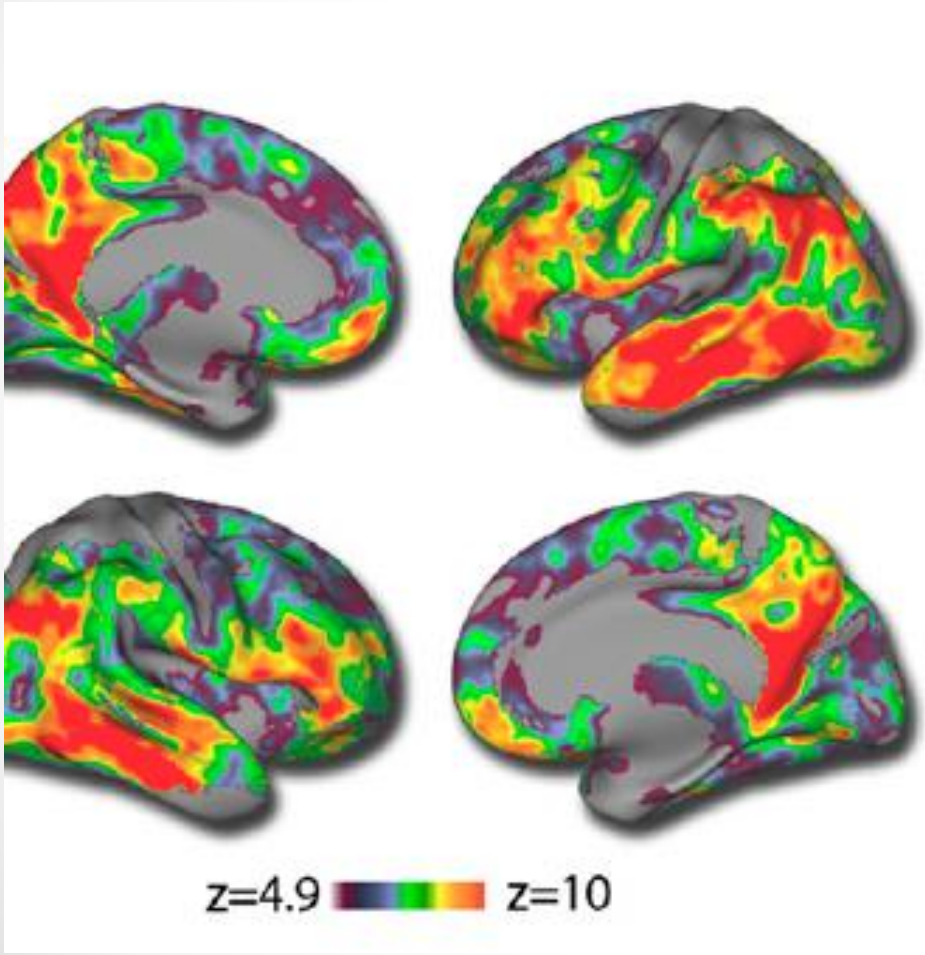
- Get active soon after injury
- "Not too much and not too little"
- Be guided by "exercise intolerance"

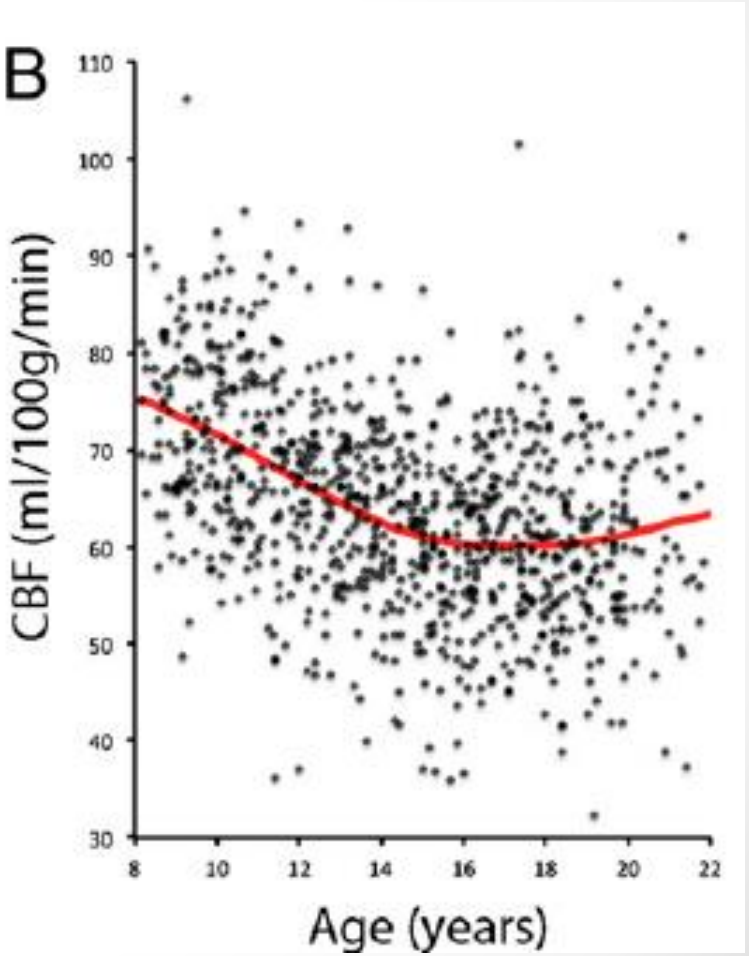
Special Interest In Adolescents

- NYS Legislation regarding concussion
- Return to sport only with a doctor's certificate
- Same for all 50 states
- Special relationship with the schools
- Adolescents are especially vulnerable and females more so

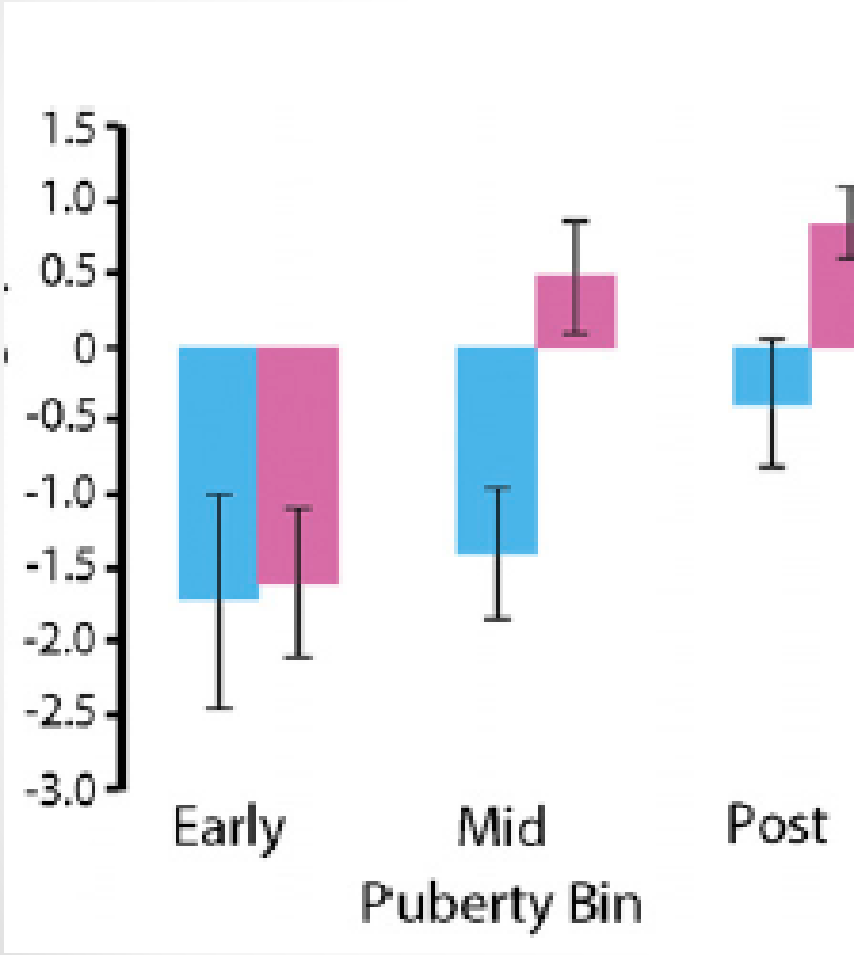
CBF in Adolescents

Satterthwaite et al 2014 (N=922)



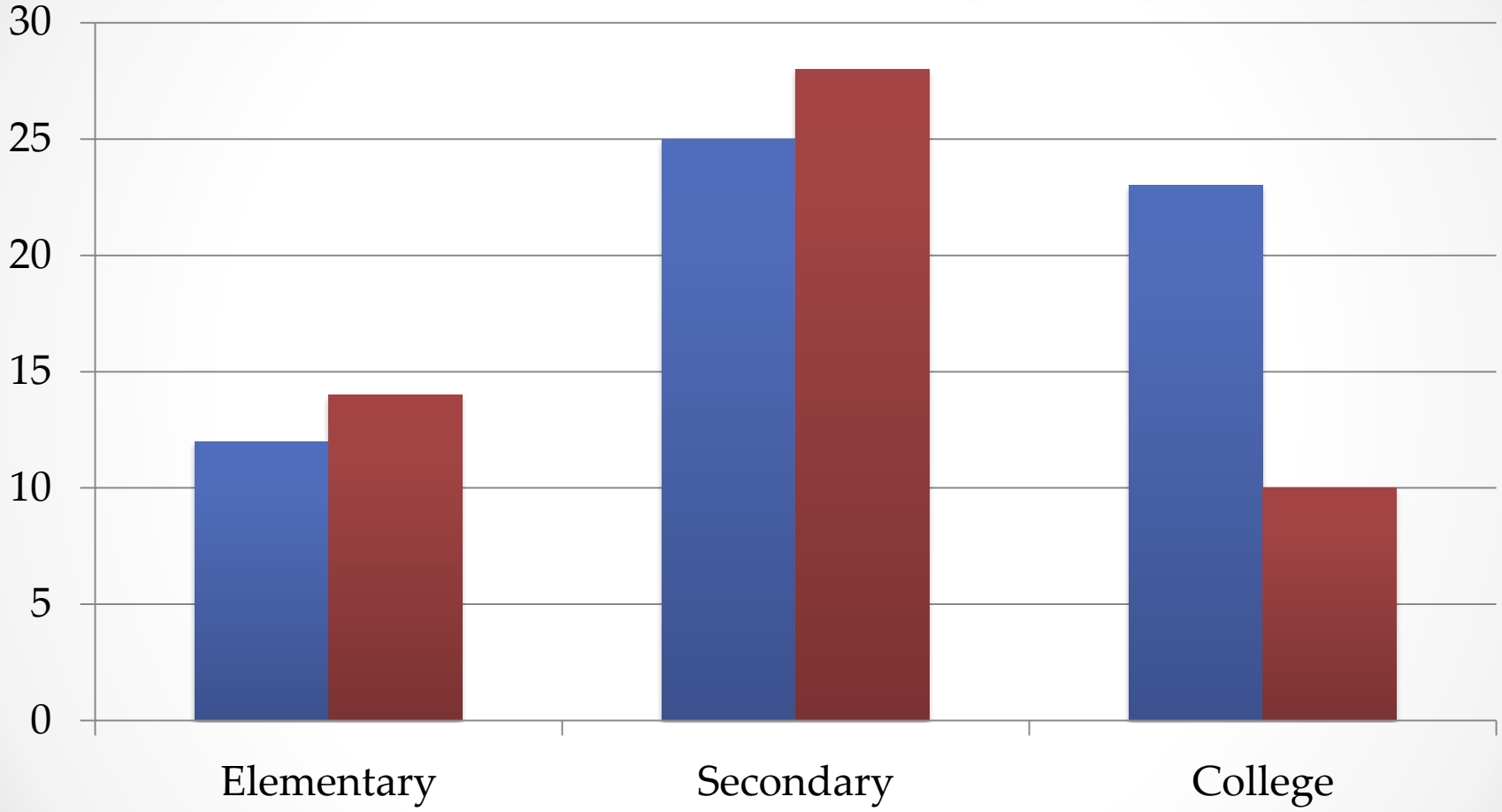


CBF In Adolescent Females



- In early adolsecence males and females demonstrate identical decline in CBF
- In Mid to Late adolescence females increase in CBF while males continue to decline
- Females greater CBF than males throughout adulthood

Days to Recovery by Age



Carson et al 2014