MINDS MATTER: SEEING CONCUSSION THROUGH NEW EYES

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Ironman World Championship Medical Symposium
Kona, Hawaii
21 October 2024

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IRONMAN WORLD CHAMPIONSHIP MEDICAL SYMPOSIUM
October 20-24,2024
Outrigger Kona Resort, Kailua-Kona Hawai'i

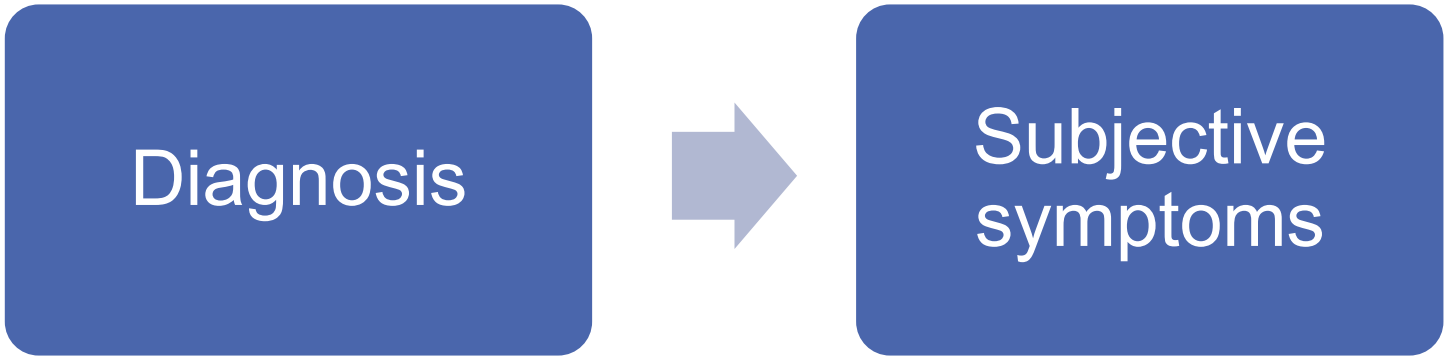
I have no financial relationships to disclose or conflicts of interest to resolve.

Our research is/has been funded by the NIH, CDC, NCAA, DOD, PA Department of Health, AMSSM, CHOP Frontier Program, Toyota Way Forward Foundation

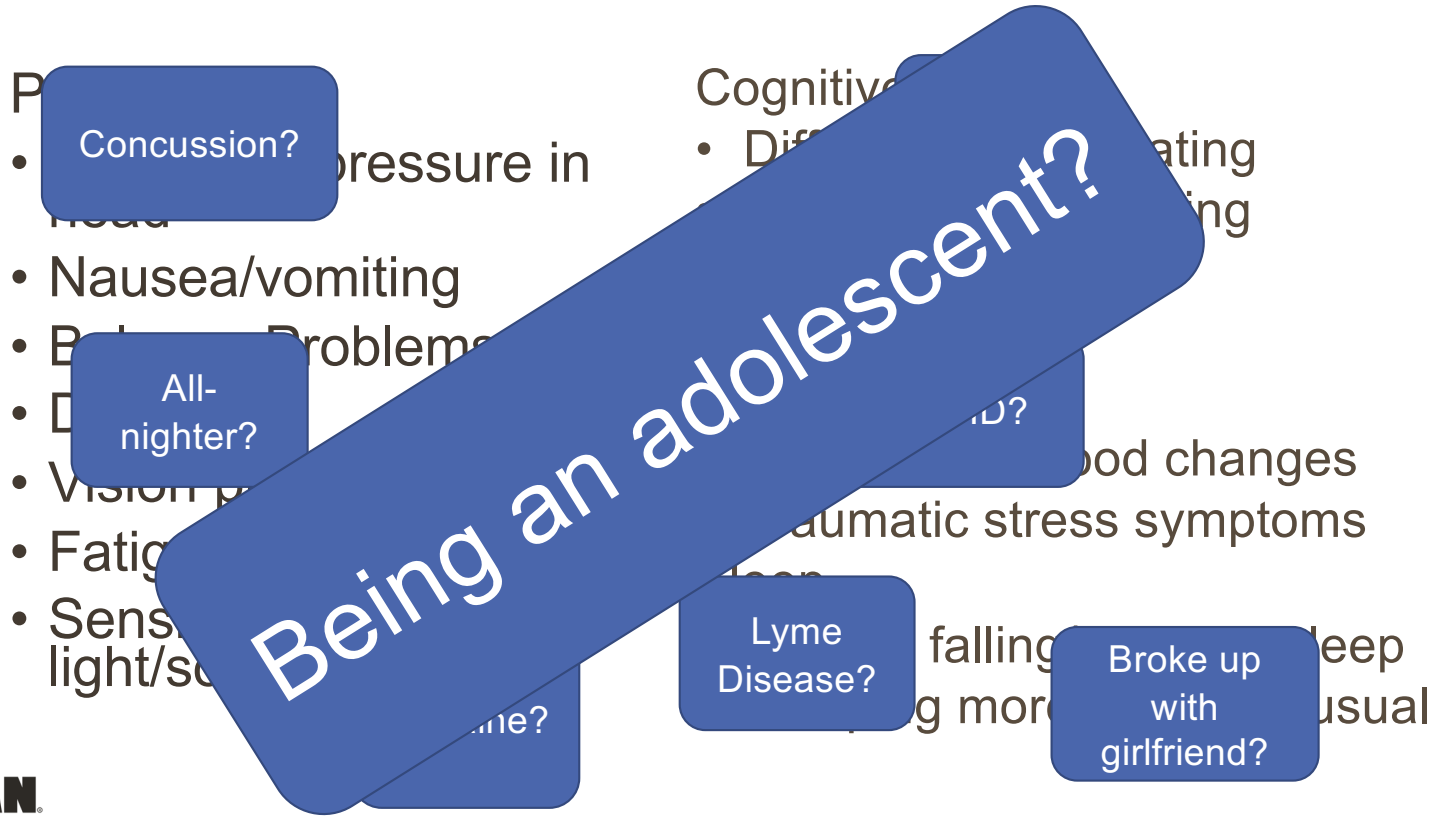
Objectives

- What have learned in the last decade about concussions?
- How can we improve upon our diagnosis of concussion?
- How has management of acute concussion changed (moved from passive to active)?
- What are the targeted treatment strategies for persistent concussion symptoms?
- What are the factors that influence differences in concussion outcomes?
- What are some of the latest developments in our understanding of biological basis of concussion?

Where are we with the diagnosis of concussion?



Symptom-based Concussion Diagnosis



Iverson, *JAMA Peds*, 2015

What do we find if we ask more specifically about vision symptoms?

Table 2. Association of Convergence Insufficiency Symptom Score (CISS) With Vision Diagnosis.

Vision Dignosis	CISS <16	CISS ≥16
(–) Any vision diagnosis	19	12
(+) Any vision diagnosis	15	54
		P = .0002
(–) Convergence insufficiency	24	27
(+) Convergence insufficiency	10	39
		P = .006
(–) Accommodative dysfunction	23	27
(+) Accommodative dysfunction	11	39
		P = .02

High CISS Score Associated with Presence of Vision Diagnoses

Only 29% of patients endorsed vision problems on Post Concussion Symptom Scale (PCSS)

Master, *Clin Peds*, 2016

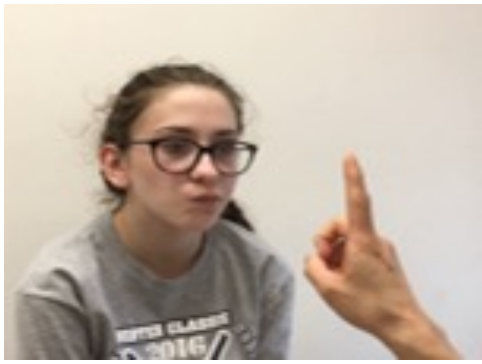
Is there more to concussion than just symptoms?

Visio-vestibular examination

- Vision
  - Convergence (abnormal 6 cm or greater)
  - Accommodation (age-related; Hofstetter's formula)
- Vestibular-oculomotor
  - Smooth pursuit
  - Saccades (20 repetitions)
  - Vestibular-ocular reflex (20 repetitions)
- Vestibular-balance
  - Complex tandem gait
    - 5 steps, 4 conditions
    - Eyes open/closed, forwards/backwards

https://www.youtube.com/watch?v=Uy8V5MGX8Ag

https://guldenophthalmics.com/product/near-point-rule/



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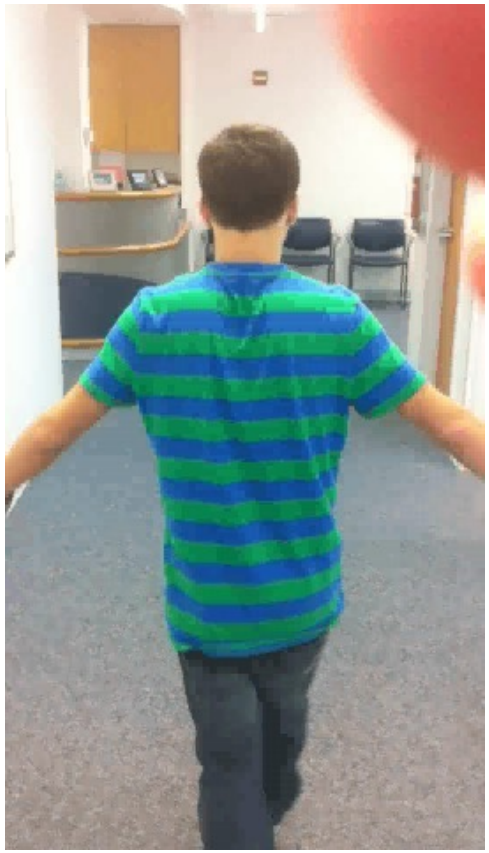
Mucha, *Am J Sports Med*, 2014; Corwin, *J Peds*, 2015; Master, *Clin Peds*, 2016; Storey, *Clin J Sports Med, 2020*


58
57

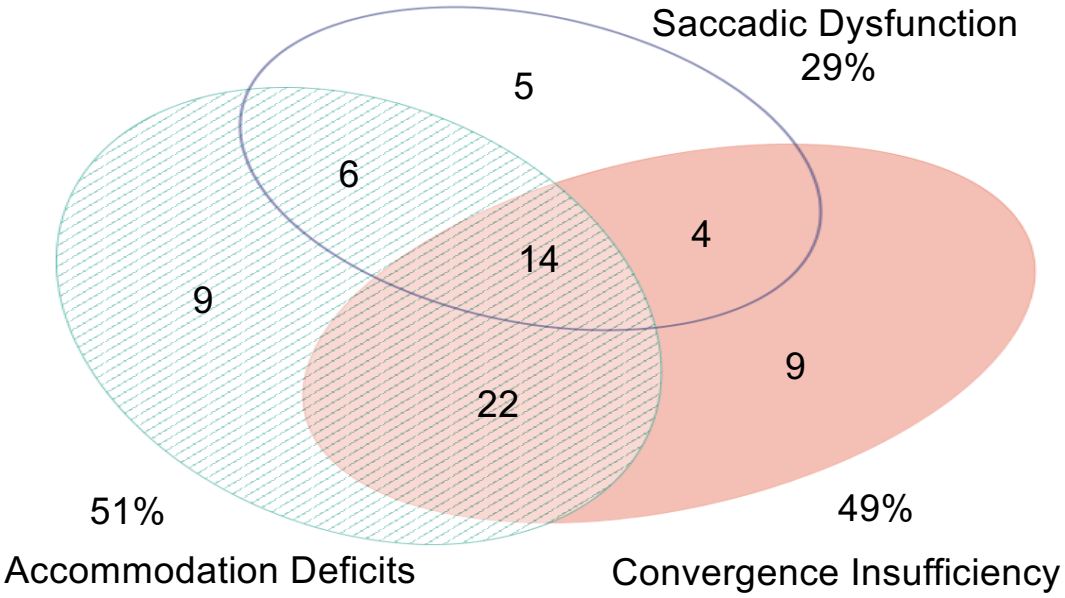
Balance deficits after concussion



Vision deficits after concussion

Abnormal smooth pursuit

What do we find when we look for vision problems?



- N=100, 11-17 yo
- Formal vision assessment with a developmental optometrist
- H/o previous concussion not associated with vision disorder

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Master, *Clin Peds*, 2016

POLICY STATEMENT Organizational Principles to Guide and Define the Child Health Care System and/or Improve the Health of all Children

American Academy of Pediatrics

DEDICATED TO THE HEALTH OF ALL CHILDREN™

Vision and Concussion: Symptoms, Signs, Evaluation, and Treatment

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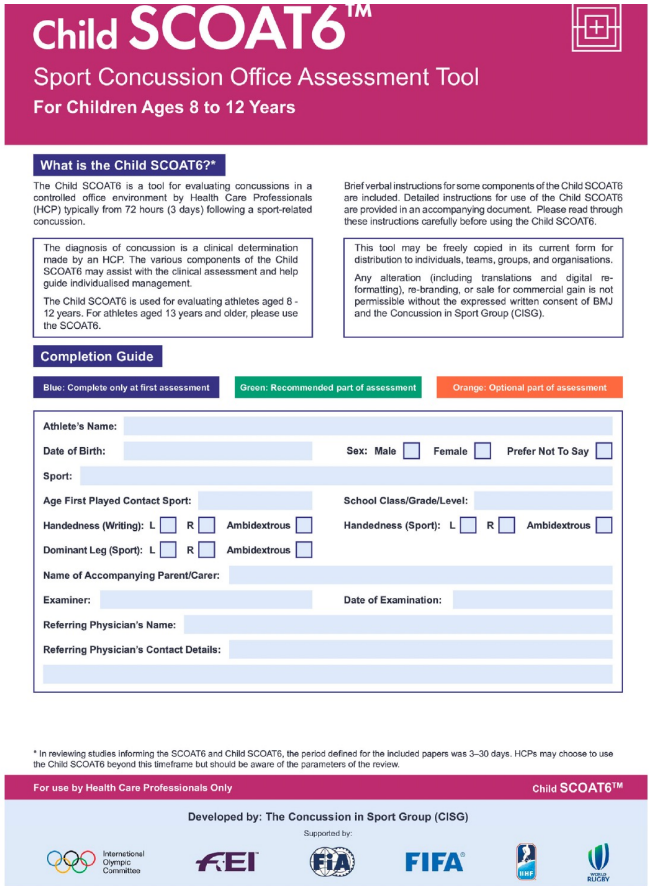

Child SCOAT6™

Sport Concussion Office Assessment Tool

For Children Ages 8 to 12 Years

What is the Child SCOAT6?*

The Child SCOAT6 is a tool for evaluating concussions in a controlled office environment by Health Care Professionals (HCP) typically from 72 hours (3 days) following a sport-related concussion.

The diagnosis of concussion is a clinical determination made by an HCP. The various components of the Child SCOAT6 may assist with the clinical assessment and help guide individualised management.

The Child SCOAT6 is used for evaluating athletes aged 8 - 12 years. For athletes aged 13 years and older, please use the SCOAT6.

Brief verbal instructions for some components of the Child SCOAT6 are included. Detailed instructions for use of the Child SCOAT6 are provided in an accompanying document. Please read through these instructions carefully before using the Child SCOAT6.

Completion Guide

Blue: Complete only at first assessment | Green: Recommended part of assessment | Orange: Optional part of assessment

Athlete's Name:

Date of Birth: Sex: Male ☐ Female ☐ Prefer Not To Say ☐

Sport:

Age First Played Contact Sport: School Class/Grade/Level:

Handedness (Writing): L ☐ R ☐ Ambidextrous ☐ Handedness (Sport): L ☐ R ☐ Ambidextrous ☐

Dominant Leg (Sport): L ☐ R ☐ Ambidextrous ☐

Name of Accompanying Parent/Carer:

Examiner: Date of Examination:

Referring Physician's Name:

Referring Physician's Contact Details:

* In reviewing studies informing the SCOAT6 and Child SCOAT6, the period defined for the included papers was 3–30 days. HCPs may choose to use the Child SCOAT6 beyond this timeframe but should be aware of the parameters of the review.

For use by Health Care Professionals Only — Child SCOAT6™

Developed by: The Concussion in Sport Group (CISG)

Supported by: International Olympic Committee, FEI, FIA, FIFA, IIHF, World Rugby

So what?

- How does this help us help our patients with self-efficacy?
  - Understand their injury?
  - Manage their symptoms?

- How do we support and help them adjust activities?
  - School or work?
  - Sports?

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Implications of visio-vestibular deficits

- Smooth Pursuit - Visual tracking initiated by a moving target
  - Trouble with moving objects, i.e., ball sports, driving
- Saccades - Coordinated jump eye movements, used in scanning
  - Horizontal – trouble with reading
  - Vertical – trouble with smartboard or monitor, note-taking
- Near point of convergence - Coordinated binocular inward movement of eyes in to maintain focus at near distance
  - Contribution from monocular accommodation
  - Trouble with focus at near distance, double vision, visual fatigue with prolonged focus at near, words moving on page, loss of place, slow reading
- Accommodation - Under autonomic control, changes lens shape and pupil size
  - Contributes to convergence and focus at near
  - Blurry vision
- VOR/Gaze stability – maintaining visual target while moving
  - Sensitive to motion or moving visual stimuli

Relevant visio-vestibular accommodations

- Extra time or untimed tasks
- Pacing breaks, especially visual
- Pre-printed notes and hard copy/audio/recorded formats vs. electronic format
- Enlarged font materials (18 point or larger)
- Extra time in hallways

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Master, *Pediatrics*, 2022

Treatment of acute concussion

"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 . . . The exact amount and duration of rest is not yet well defined in the literature and requires further study."

"Relative (not strict) rest, which includes activities of daily living and reduced screen time, is indicated immediately, and for up to the first 2 days after injury. Individuals can return to light-intensity physical activity (PA), such as walking, that does not more than mildly exacerbate

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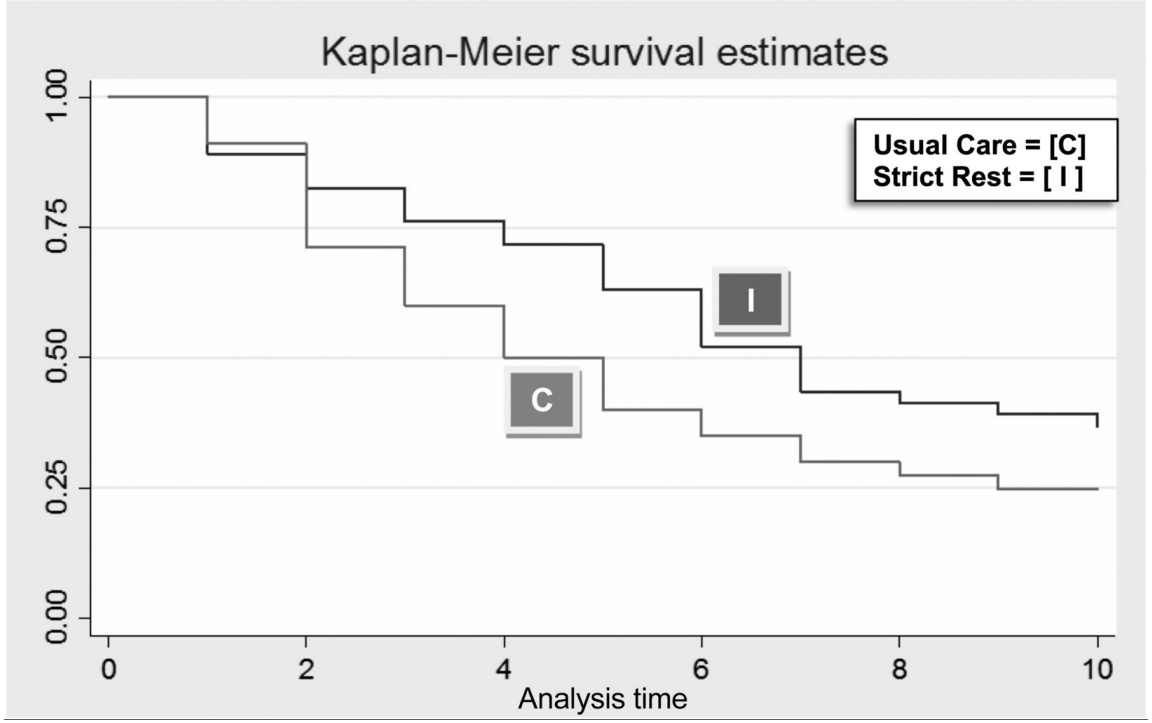
McCrory, *Br J Sports Med*, 2017; Patricios, *Br J Sports Med*, 2023

Physical activity: Evidence for “brief period of rest”

- N = 99; RCT of 11-22 yo from ED
  - 1-2 vs. 5 days rest then gradual return to activity
  - 5 day rest group had greater concussion symptom burden and slower symptom resolution



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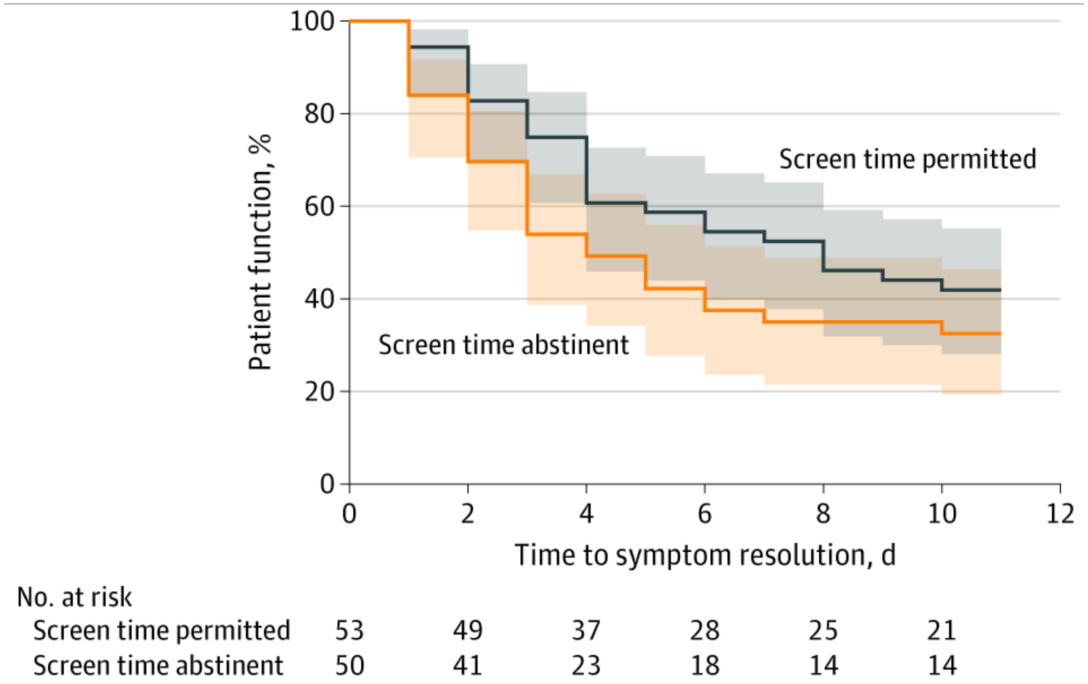
Thomas, *Pediatrics*, 2015

Cognitive activity: Evidence for “brief period of rest”

- N = 125, RCT of 12-25 yo from ED
  - Screen time permitted vs. abstained for 48 hours
  - 620 vs. 130 minutes difference between groups
  - Screen time permitted group took longer to symptom recovery (8 days vs. 3.5 days)



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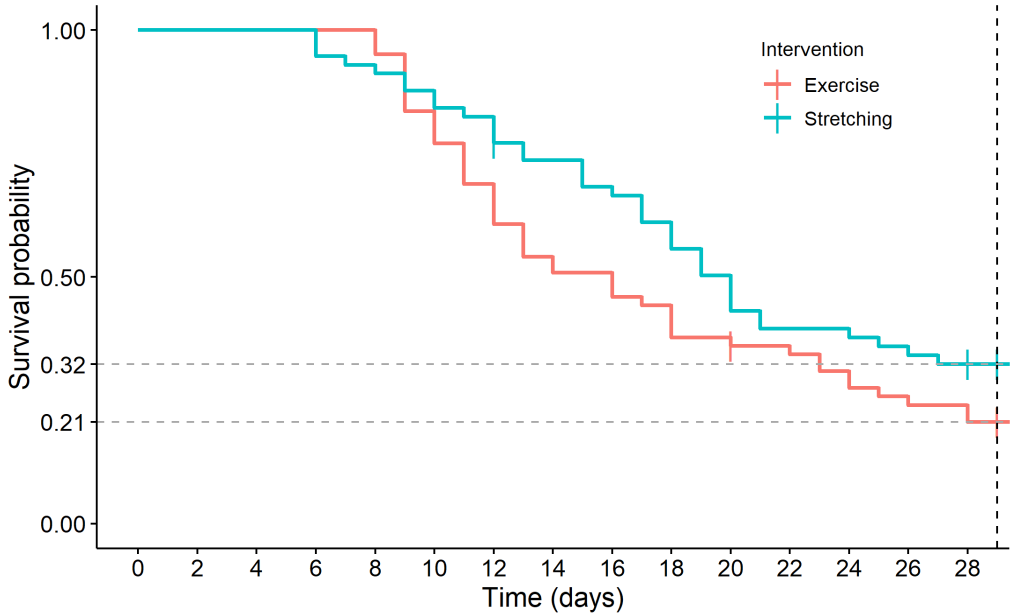
Macnow, *JAMA Pediatr,* 2021

Aerobic exercise prescription prevents persistent symptoms

- RCT heart rate-targeted aerobic exercise vs. placebo stretching
- Fewer participants in the aerobic exercise arm had persistent symptoms at 28 days vs placebo stretching arm (p = 0.042)
- Dotted lines represent percentage of sample not recovered by Day 29 for each intervention.



N = 118

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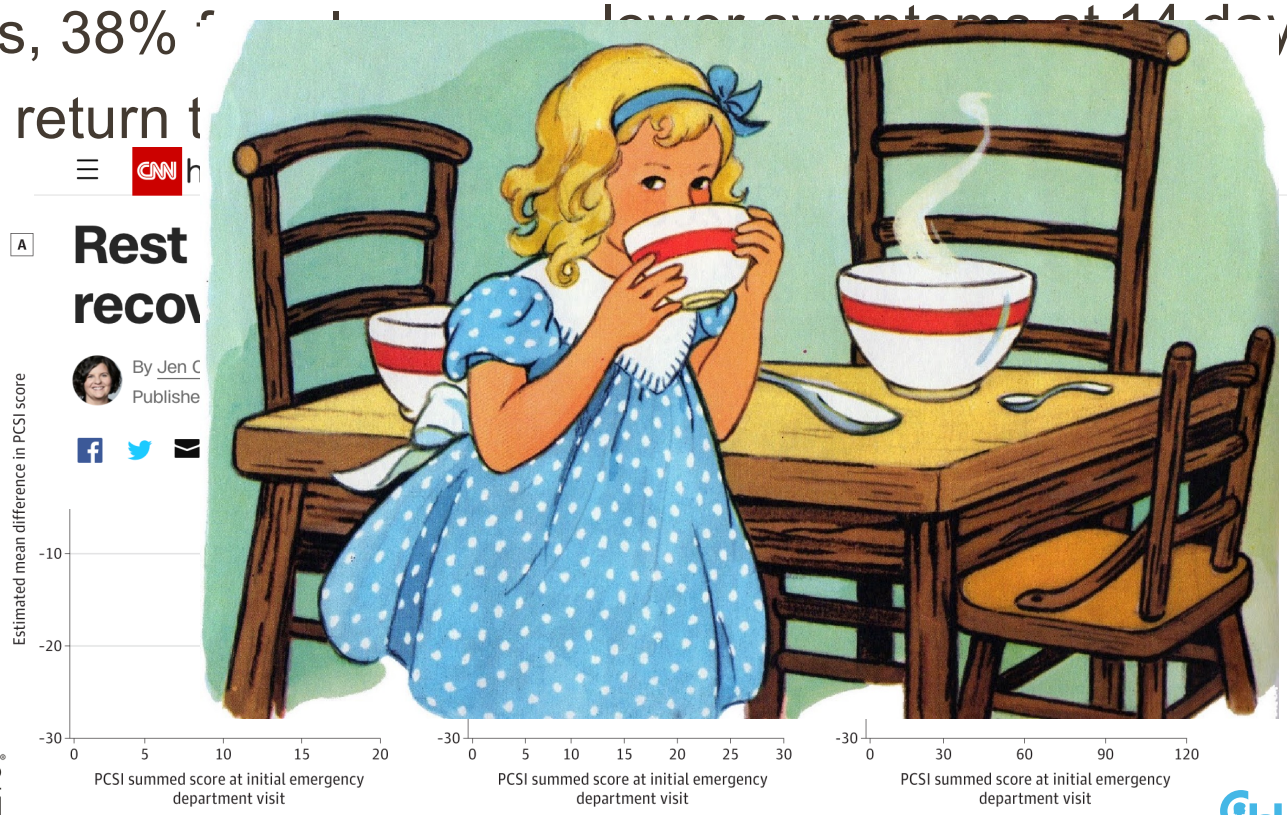
Leddy, *Lancet Child Adolesc. Health,* 2021

Return to School

- N = 1630, 5-18 yo, mean age 11.8 years, 38% f
- 875 early return t days)
- Early return associated with lower symptoms at 14 days for



Vaughan, *JAMA Open*, 2023

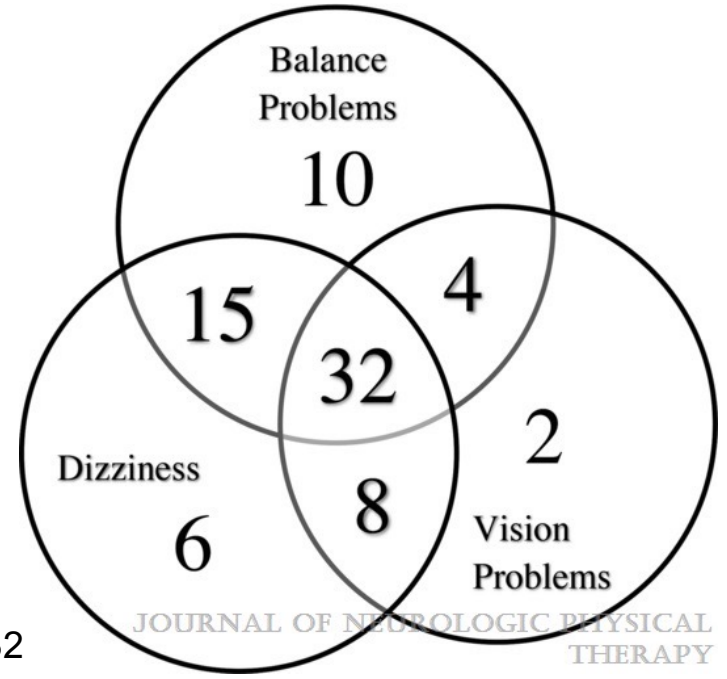
Active rehabilitation strategies for persistent symptoms

- Vestibular
  - Habituation and desensitization
  - Increase motion tolerance
  - Improve balance
- Exercise
  - Safe and beneficial
  - Timing? Acute and chronic
- Cognitive
  - School as therapy with adequate accommodations
  - Formal speech/OT with executive function training
- Vision
  - Address specific visual symptoms
  - Increase visual stamina

Gagnon, *Brain Inj*, 2009; Schneider, *Br J Sports* Med, 2014; Storey, *J Neurol Phys Ther*, 2018; Leddy, *JAMA* Peds, 2019; Thiagarajan, *Brain Inj,* 2015

Vestibular therapy improves symptoms and signs in children with persistent symptoms

- Mean age 11.8 years, 46% F
- Presented to sports med office median = 24 days
- Referred/started vestibular PT median = 55 days, completed median 7 visits/56 days
- 80% symptomatic with saccades, ~50% symptomatic with gaze stability, 77.6% with abnormal complex tandem gait, 26% receded NPC, 34.7% abnormal accommodation
- Concussion symptoms, visio-vestibular clinical assessment and BESS improved
- NPC did not



N=432

N = 109

Storey, *J Neurol Phys Therapy*, 2018

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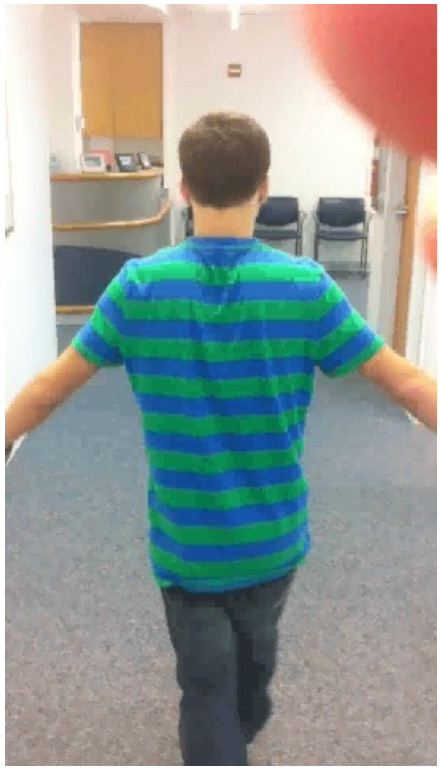
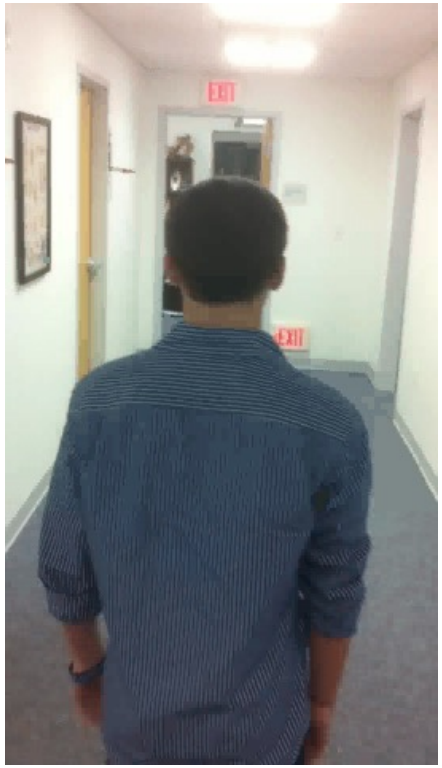
Before and after vestibular therapy





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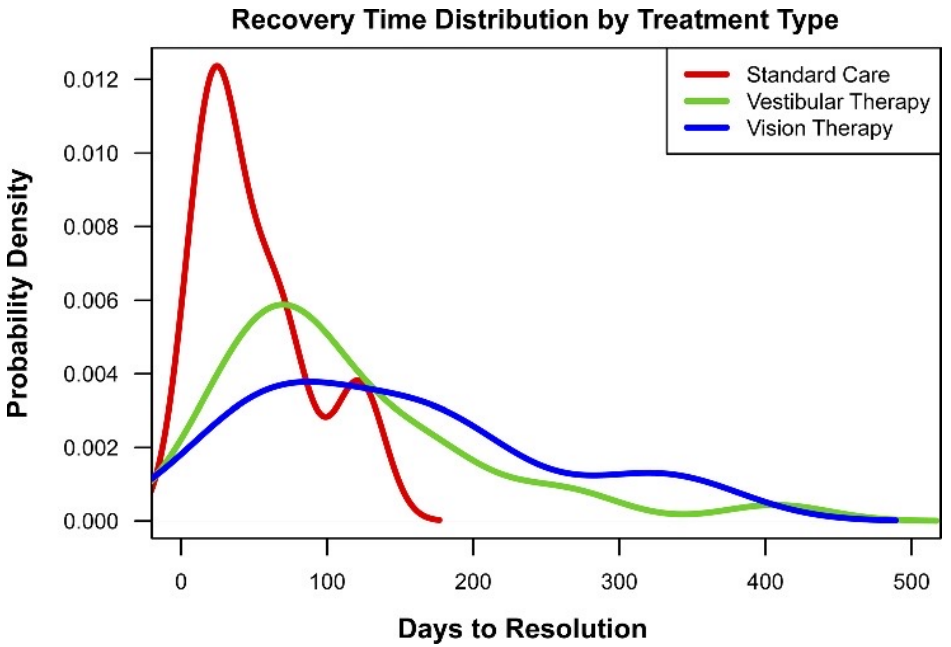
Vision rehabilitation for receded near point of convergence

- Of 275 concussions, 67 had receded NPC
- 46% resolved spontaneously median 4.5 weeks
  - 65% of these received visio-vestibular home exercise program
- 41% with vestibular therapy
  - Referred median = 30 days post-injury
  - Recovered median = 11 weeks after injury
- 13% with vestibular and vision therapy
  - Referred to vision therapy median = 52 days
  - Recovered median = 23 weeks post-injury



N = 67

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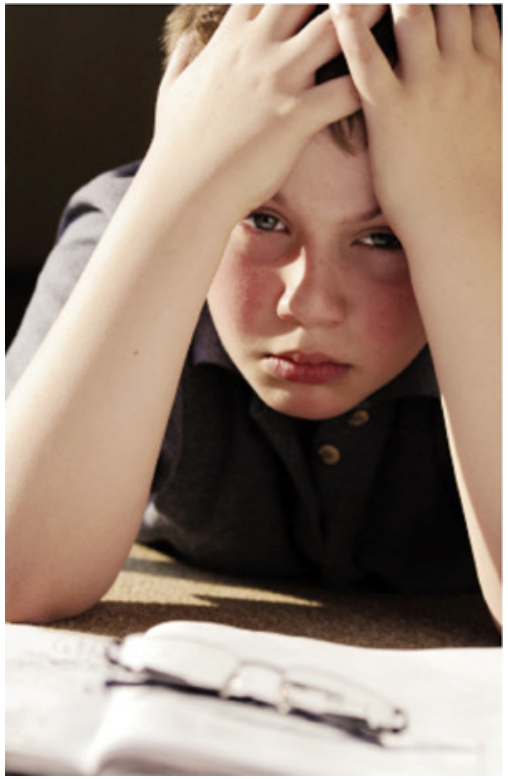
Storey, *Optom Vis Sci*, 2017

Before vision rehabilitation

After vision rehabilitation

What about mental health and well-being?

- In a retrospective administrative database cohort in Canada (N = 448,803)
  - Those with sustained a concussion were 40% more likely to develop a mental health issue than orthopedic controls (aHR 1.38; 95% CI,1.37-1.40)[1]
- In our prospective CHOP Minds Matter registry (N = 3105)
  - Those with pre-injury history of mental health issues had greater post-injury emotional symptom burden (M>F),visio-vestibular dysfunction, later return to exercise, and longer recovery in a dose-response fashion[2]



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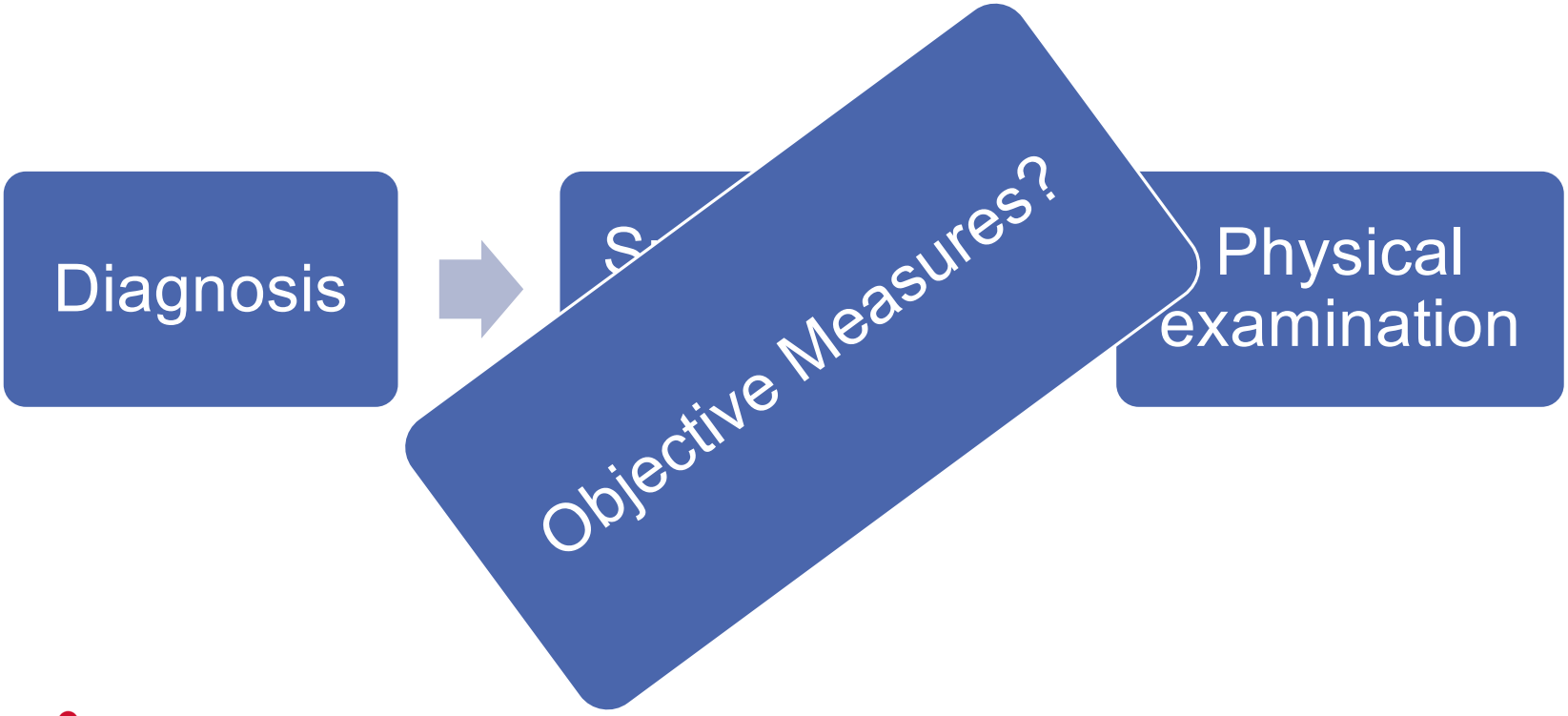
[1]Ledoux, *JAMA Netw Open,* 2022;, [2]Master, *Sports Health*, 2024

Can we do even better?



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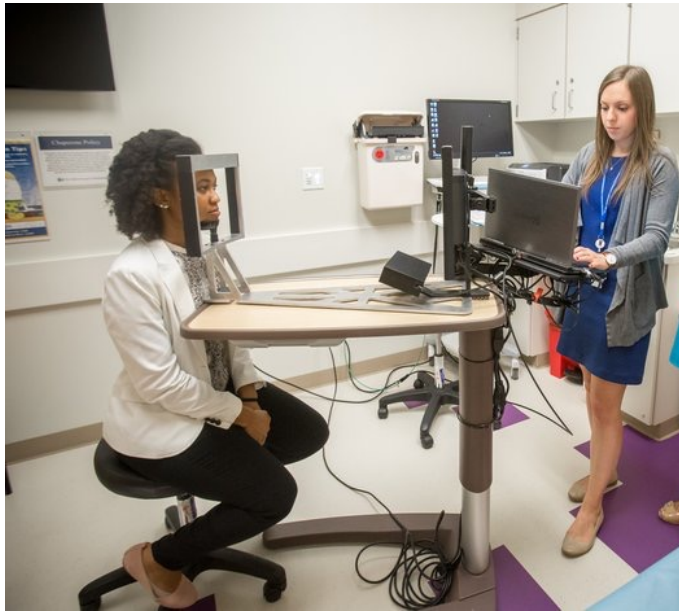
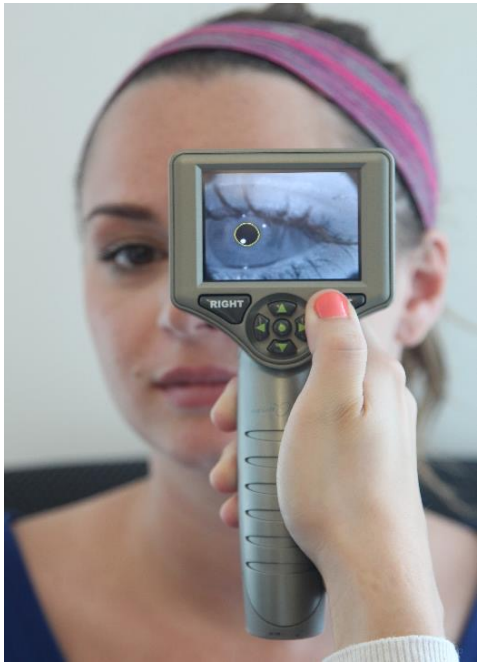
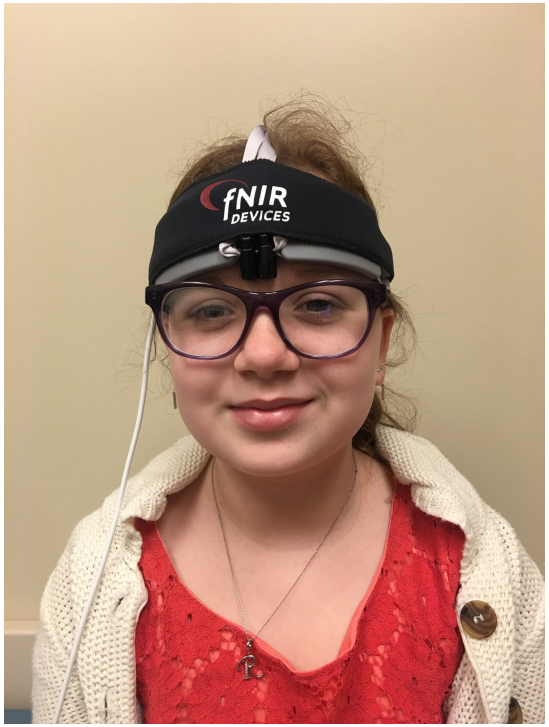
Think outside the box: more than just blood biomarkers







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Eyes are a window to the brain?

- More than just visual acuity
  - Eye movement
  - Pupillary light response
  - Visual workload

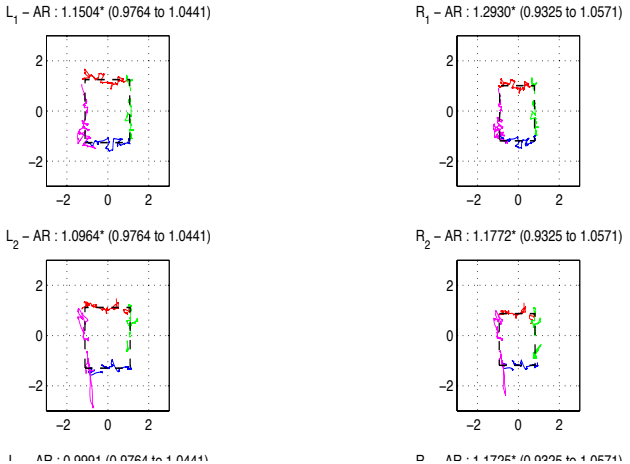
Objective infrared eye tracking

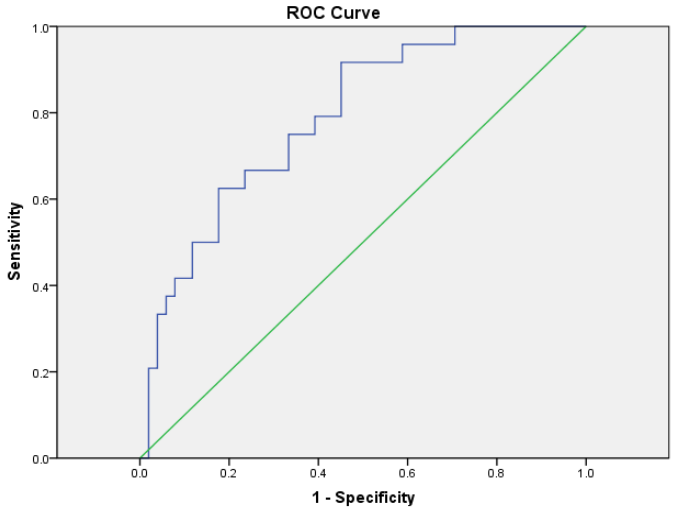
- Binocular eye movements are recorded with an eye tracker
  - Infrared camera captures each pupil
  - Subjects watch a 220-second video traveling around aperture of the monitor
  - FDA-clearance for concussion

Bin Zahid, *Clin J Sports Med*, 2018

Eye tracking as a biomarker of concussion

- 12 metrics to differentiate concussed from healthy :
  - AUC = 0.854 in derivation cohort (N = 64)
  - AUC = 0.789 in validation cohort (N = 75)
- 6 metrics appear specific to pediatric populations





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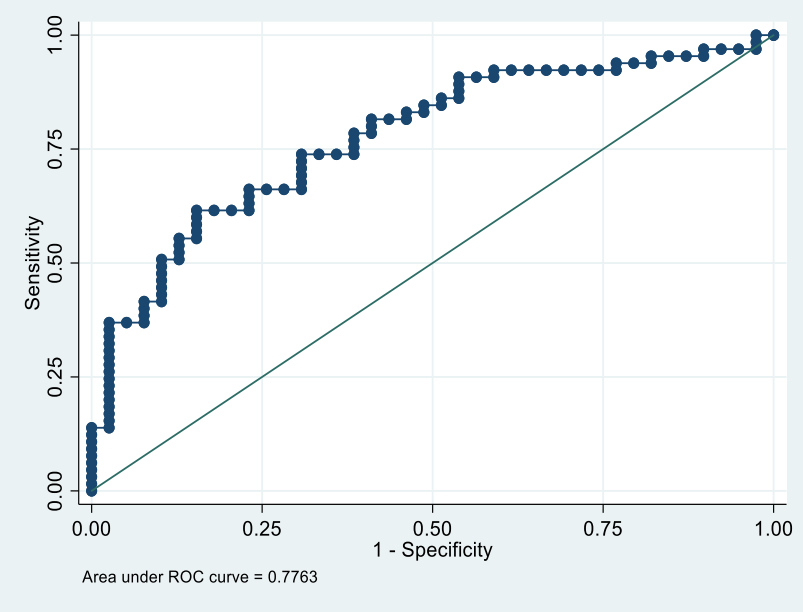
Bin Zahid, *Clin J Sports Med*, 2018

Objective eye tracking distinguishes concussion-related vision disorder (CRVD)

- N=108, 12 weeks after injury with PPCS
- 62% with vision disorder (CI, AI, SD)
  - Higher CISS scores
  - Symptomatic with eye tracking
  - Receded NPC
  - Greater symptoms with horizontal saccades and gaze stability
  - More balance errors on complex tandem gait, forward eyes closed
  - BOX score higher
  - Multivariable model with 8 eye tracking variables discriminate CRVD with AUC = 0.78
- Clinical VVE AUC=0.73; VVE+BOX score AUC=0.81



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Preliminary data, Master, 2022

Pupillometry

- Obtained in response to a brief step-input, white light stimulus
  - 154 msec duration
  - 180 micro watts power
- Performed prior to the athlete's sport season and after concussion
- Examine 9 parameters
- Min/max pupil diameter, latency, %constriction, Avg/peak constriction/dilation velocity, T75
- Concussed = 134, Healthy = 98

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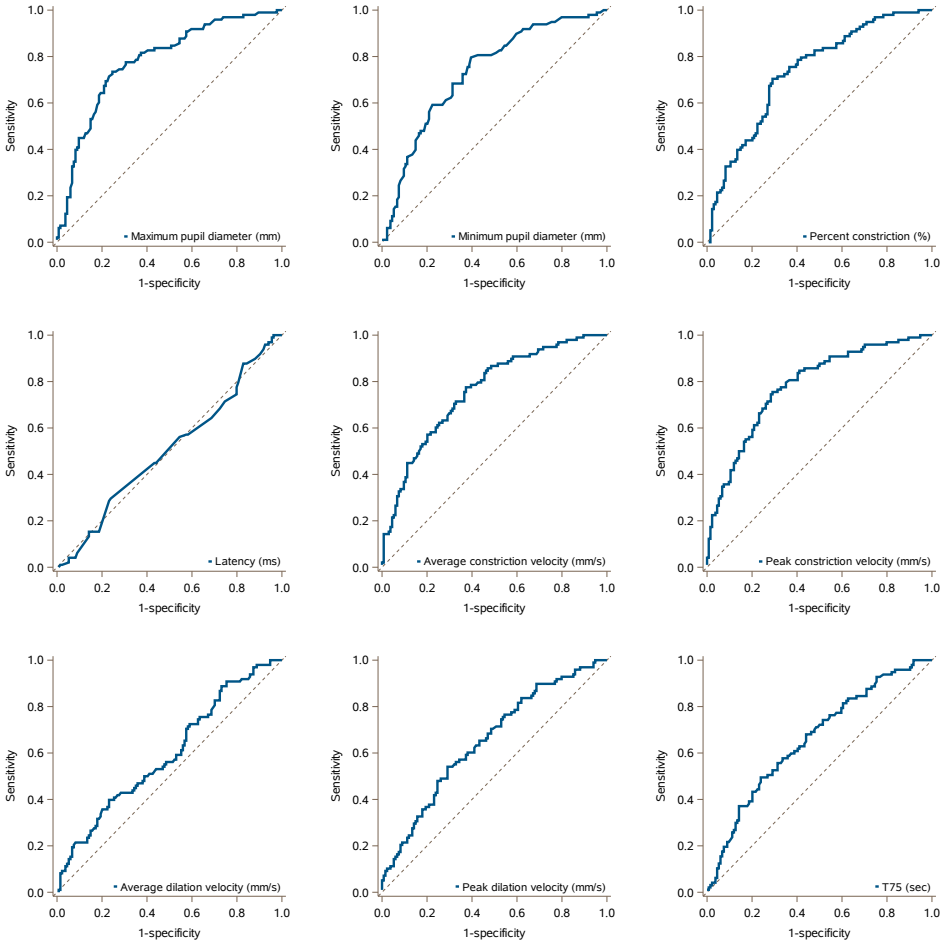
Master, *JAMA Ophthalmol,* 2020

Enhancement of pupillary response in concussion

- All parameters discriminatory except for latency
- Maximum pupil diameter and peak constriction velocity with highest AUC = 0.78
- Preliminary data from ED cohort (N = 33)
  - Enhancement within 12 hours of injury
  - Latency predicts prolonged symptoms



Master, *JAMA Ophthalmol,* 2020

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PLR Metrics remained enhanced at clinical recovery

PLR Metric	Recovered concussed	Healthy control	Difference	99.4% CI
Min. pupil diam	2.96 mm	2.66 mm	0.31	0.17-0.44
Percent constriction	37.84%	32.91%	4.93	2.98-6.88
Avg. constriction velocity	3.09 mm/s	2.50 mm/s	0.59	0.38-0.79
Avg. dilation velocity	1.34 mm/s	1.24 mm/s	0.11	0.01-0.20
Peak dilation velocity	1.86 mm/s	1.66 mm/s	0.20	0.08-0.31
T75	1.73 s	1.46 s	0.27	0.10-0.44

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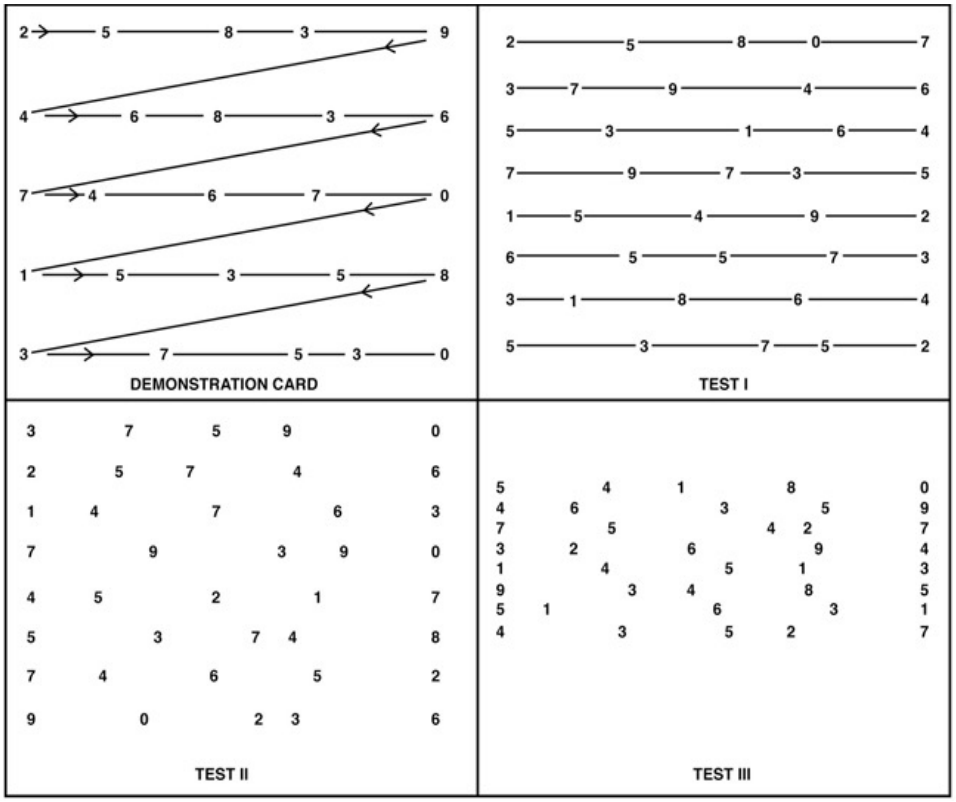
Preliminary data, Master, 2023

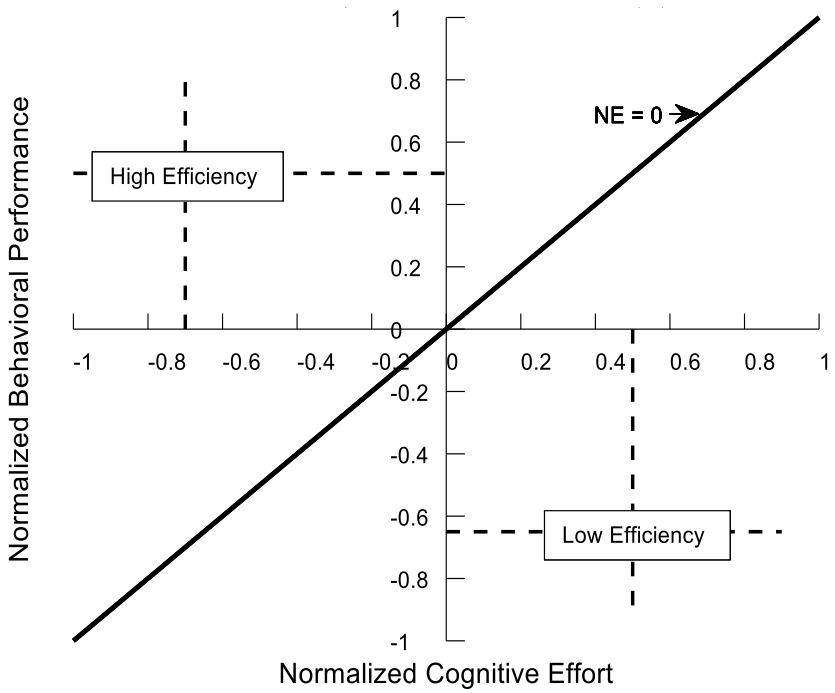
Functional near infrared spectroscopy

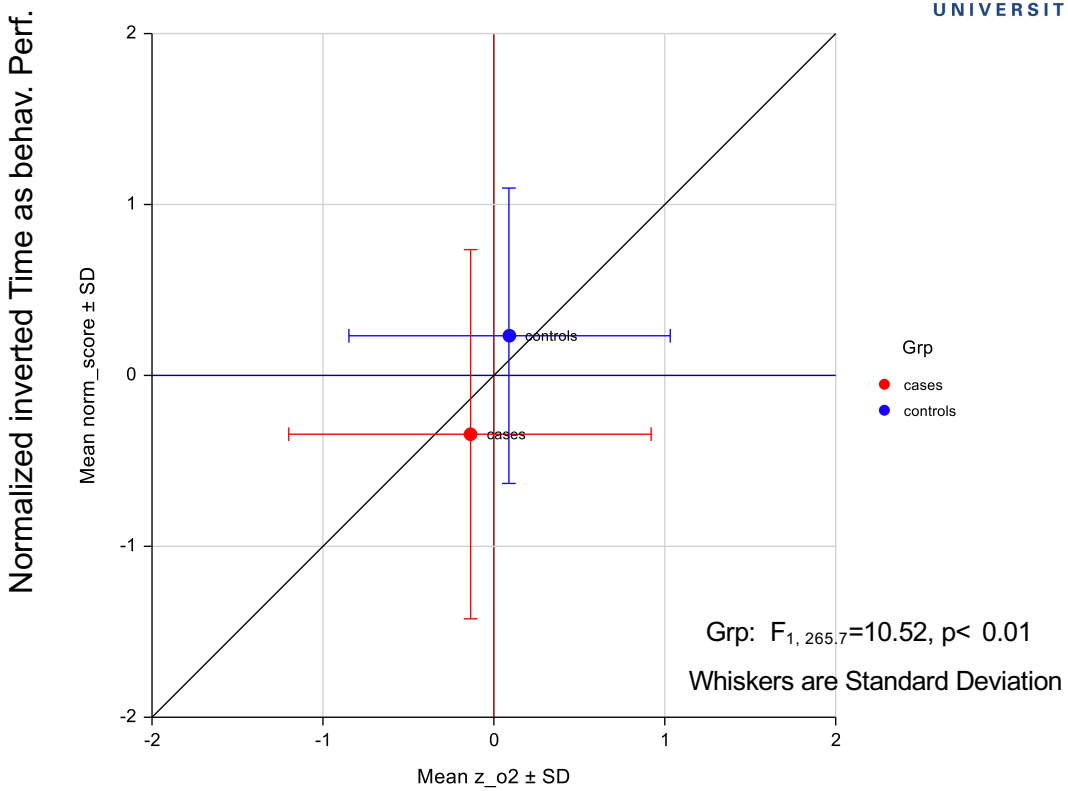


- Low-cost, noninvasive, portable
- Uses low levels of near-infrared light to measure changes in blood oxygenation in the brain
- Measures cortical activation related to hemodynamic changes

Neural Efficiency

Efficiency = (Performance – Effort) / √2





Grp: $F_{1,\ 265.7}$=10.52, p< 0.01

Whiskers are Standard Deviation

Normalized Oxygenation Changes at Optode 2

Master, *Neuroergonomics*, 2021

Take home

- Vision and vestibular deficits are common after concussion so conducting a visio-vestibular examination is important
- Implement active recovery (symptom-limited aerobic activity and gradual return to cognitive activity) for acute phase after concussion
- Consider targeted rehabilitation (vestibular, vision, aerobic) for persistent concussion symptoms
- Be aware of implicit biases that may affect how we diagnose and provide care to our patients with concussion
- Keep an eye on new developments that may help us understand what is happening in the brain after concussion and may also serve as physiologic biomarkers for diagnosis, monitoring, and determining recovery in the future

Minds Matter Concussion Resources

- Practical Content
  - Families
  - Schools
  - Coaches
  - Clinicians
  - Video FAQ

- Downloads
  - Infographics
  - Posters
  - Fact sheets

www.chop.edu/concussion

IRONMAN WORLD CHAMPIONSHIP MEDICAL SYMPOSIUM
October 20-24,2024
Outrigger Kona Resort, Kailua-Kona Hawai'i

Children's Hospital of Philadelphia
Minds Matter Concussion Program

Minds Matter Concussion Program

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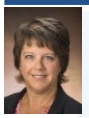

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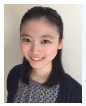

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Thank you!

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