

# Young Athlete Conference: Concussion Update

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Sponsored by:  
The Sports Medicine Center at Children's Mercy



The official health care provider  
of Sporting Kansas City



## Disclosures

- I have no financial disclosures
- I will disclose there have been an **EXPLOSION** of concussion articles over the past 5 years...I will not be reviewing all 6,654 articles from pubmed
- This will not be comprehensive
- Will be research oriented – clinical decisions beware
- Should have time for questions



## Course Objectives

- Review updates in sports related concussion research
- Review options for sideline/in office work up
- Review sub-symptom threshold exercise and return to learn



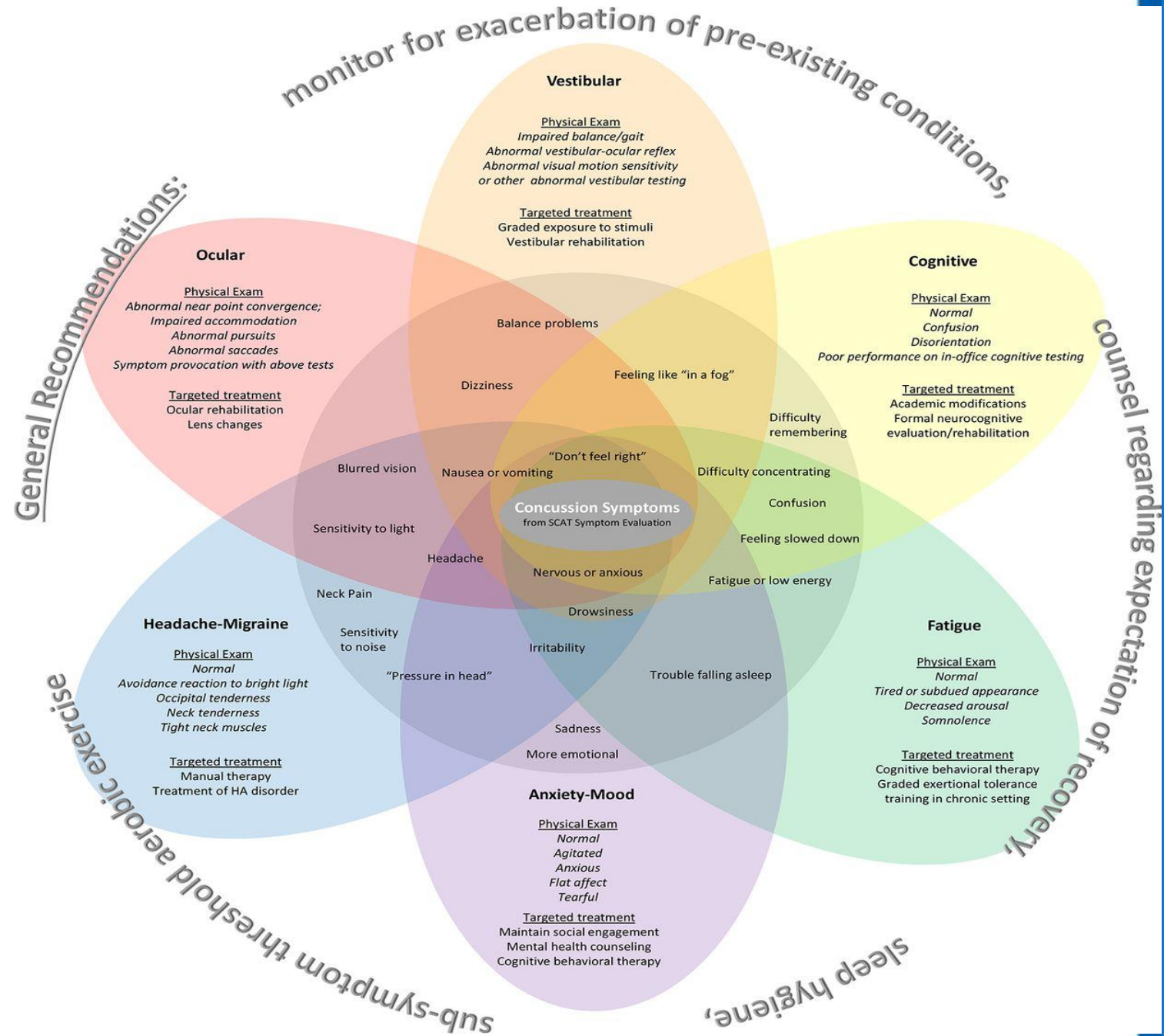
# CONCUSSIONS

- Best thing about COVID...feels like concussions have been down over the past year
- Minus this one!
- Or was it a concussion at all?



# Not a simple condition

- Diagnosis can be hard.....
- Direct/Indirect blow to the head or neck
- Rapid onset of self resolving symptoms
- Functional not structural disturbance
- Cannot be explained by drug, alcohol, medication or other injuries



# Concussion

- Any ONE or ALL of these symptoms is a concussion
- Any of these symptoms may **WORSEN** with mental or physical activity
- May be delayed in presentation

	none	mild		moderate		severe		
Headache	0	1	2	3	4	5	6	
"Pressure in head"	0	1	2	3	4	5	6	
Neck Pain	0	1	2	3	4	5	6	
Nausea or vomiting	0	1	2	3	4	5	6	
Dizziness	0	1	2	3	4	5	6	
Blurred vision	0	1	2	3	4	5	6	
Balance problems	0	1	2	3	4	5	6	
Sensitivity to light	0	1	2	3	4	5	6	
Sensitivity to noise	0	1	2	3	4	5	6	
Feeling slowed down	0	1	2	3	4	5	6	
Feeling like "in a fog"	0	1	2	3	4	5	6	
"Don't feel right"	0	1	2	3	4	5	6	
Difficulty concentrating	0	1	2	3	4	5	6	
Difficulty remembering	0	1	2	3	4	5	6	
Fatigue or low energy	0	1	2	3	4	5	6	
Confusion	0	1	2	3	4	5	6	
Drowsiness	0	1	2	3	4	5	6	
More emotional	0	1	2	3	4	5	6	
Irritability	0	1	2	3	4	5	6	
Sadness	0	1	2	3	4	5	6	
Nervous or Anxious	0	1	2	3	4	5	6	
Trouble falling asleep (if applicable)	0	1	2	3	4	5	6	
Total number of symptoms:								of 22
Symptom severity score:								of 132

# Diagnosis

- **Still a clinical diagnosis**
  - History
  - Symptom check list
  - Physical Exam
- **What are the tools in our tool box?**



# In office eval

- PCSS/SCAT 5
- VOMS
- KD
- BFCTT
- Pupillometry
- EEG
- Balance
- Neurocognitive testing
  - ImPACT
- Lab testing?
  - Blood
  - Saliva
- Dual Task



# SCAT 5/PCSS

**Table 3.** Sport Concussion Assessment Tool-5 Results by Sex (N=462).

Component	Males		Females		U	p
	Mean(SD)	Median[IQR]	Mean(SD)	Median[IQR]		
Symptom Number	1.92 (3.29)	0.50 [3.00]	2.00 (3.47)	0.00 [3.00]	25951.00	.68
Symptom severity	3.14 (6.65)	0.50 [3.00]	3.77 (8.65)	0.00 [4.00]	26008.50	.71
SAC Total	34.72 (5.31)	35.00 [7.00]	35.64 (5.10)	35.00 [7.00]	24444.00	.15
Orientation	4.95 (0.22)	5.00 [0.00]	4.97 (0.18)	5.00 [0.00]	25997.00	.32
Immediate Memory	19.88 (3.43)	20.00 [5.00]	20.53 (3.35)	21.00 [5.00]	23982.00	.08
Concentration	3.63 (1.20)	4.00 [2.00]	3.56 (1.07)	4.00 [1.00]	25001.50	.28
Delayed Recall	6.26 (1.94)	6.00 [3.00]	6.58 (1.94)	7.00 [3.00]	23846.00	.06
mBESS Total Errors	4.35 (3.99)	3.00 [6.00]	4.19 (3.89)	3.00 [5.00]	25974.50	.71
Double Leg Stance	0.00 (0.00)	0.00 [0.00]	0.00 (0.00)	0.00 [0.00]	26500.00	1.00
Single Leg Stance	3.11 (2.97)	2.00 [4.00]	3.06 (2.74)	2.00 [4.00]	26120.50	.79
Tandem Leg Stance	1.24 (2.06)	1.00 [1.00]	1.13 (2.04)	0.00 [2.00]	24519.50	.13

**Table 5.** Sport Concussion Assessment Tool-5 Results by Sport Type (N=462).

Component	Contact		Non-Contact		U	p
	Mean(SD)	Median[IQR]	Mean(SD)	Median[IQR]		
Symptom Number	2.24 (3.82)	1.00 [3.00]	1.68 (2.85)	0.00 [3.00]	23834.50	.03*
Symptom severity	4.19 (9.54)	1.00 [4.00]	2.69 (5.07)	0.00 [3.00]	23759.00	.03*
SAC Total	34.53 (5.46)	35.00 [7.00]	35.73 (4.94)	36.00 [8.00]	23686.50	.04*
Orientation	4.94 (0.23)	5.00 [0.00]	4.97 (0.17)	5.00 [0.00]	25939.50	.15
Immediate Memory	19.85 (3.55)	20.00 [4.00]	20.49 (3.24)	21.00 [4.00]	24430.50	.12
Concentration	3.57 (1.20)	4.00 [2.00]	3.63 (1.08)	4.00 [2.00]	26292.00	.78
Delayed Recall	6.17 (2.05)	6.00 [3.00]	6.64 (1.81)	7.00 [3.00]	23296.50	.02*
mBESS Total Errors	4.15 (4.11)	3.00 [6.00]	4.40 (3.78)	3.00 [4.00]	24503.50	.13
Double Leg Stance	0.00 (0.00)	0.00 [0.00]	0.00 (0.00)	0.00 [0.00]	26672.50	1.00
Single Leg Stance	2.91 (3.01)	2.00 [5.00]	3.26 (2.71)	3.00 [4.00]	23521.00	.03*
Tandem Leg Stance	1.25 (2.11)	1.00 [1.00]	1.14 (1.99)	0.00 [2.00]	25181.50	.26

\*Significance at p < .05

- On field assessment
- Diagnostic utility diminishes after 3-5 days
- Baseline symptoms score 2-3
- Baseline severity score just over 3-5
- Hx of Contact Sport, ADHD, Anxiety/Depression report more symptoms and greater severity
- Echmendis et al. Br J Sports Med, 2017
- Petit et al, SCAT5: Baseline Assessment in NCAA D1. International Journal of Exercise Science

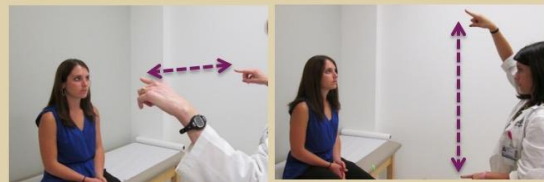
# VOMS

- Addition of VOMS to the SCAT3 improved assessment and diagnostic rates
- Would add 304,000 sports related concussions if used as an assessment tool in conjunction with the SCAT3

## Identifying Vestibular and Ocular Problems after Concussion: UPMC VOMS



Horizontal & Vertical Pursuits



Horizontal & Vertical Saccades



Near Point Convergence



Horizontal & Vertical VOR

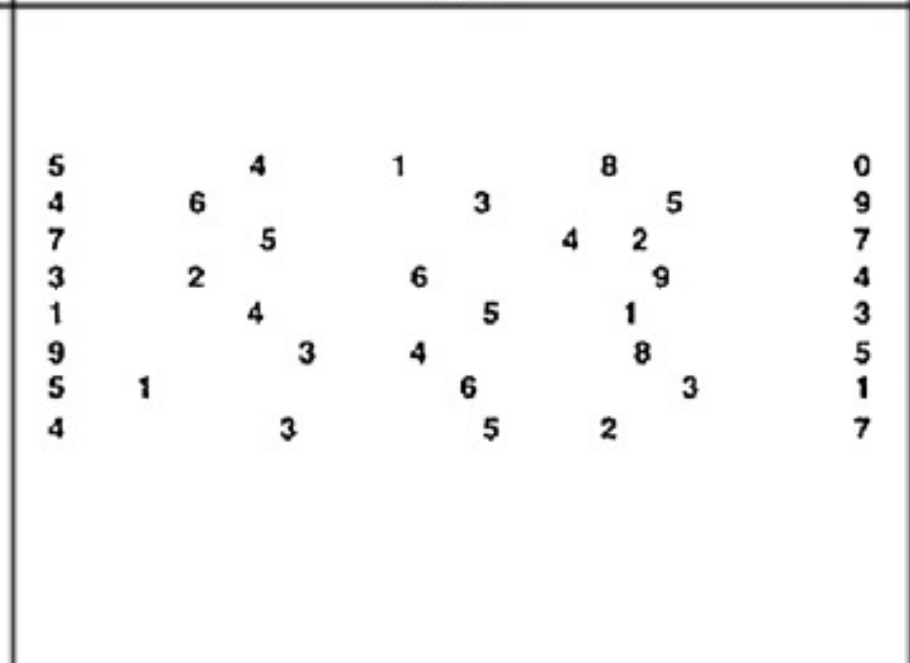
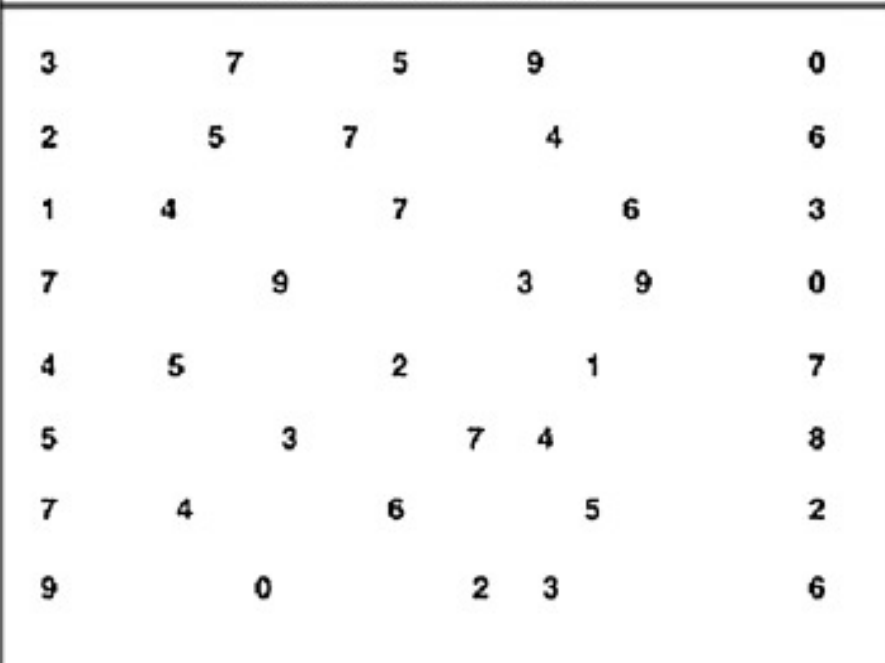
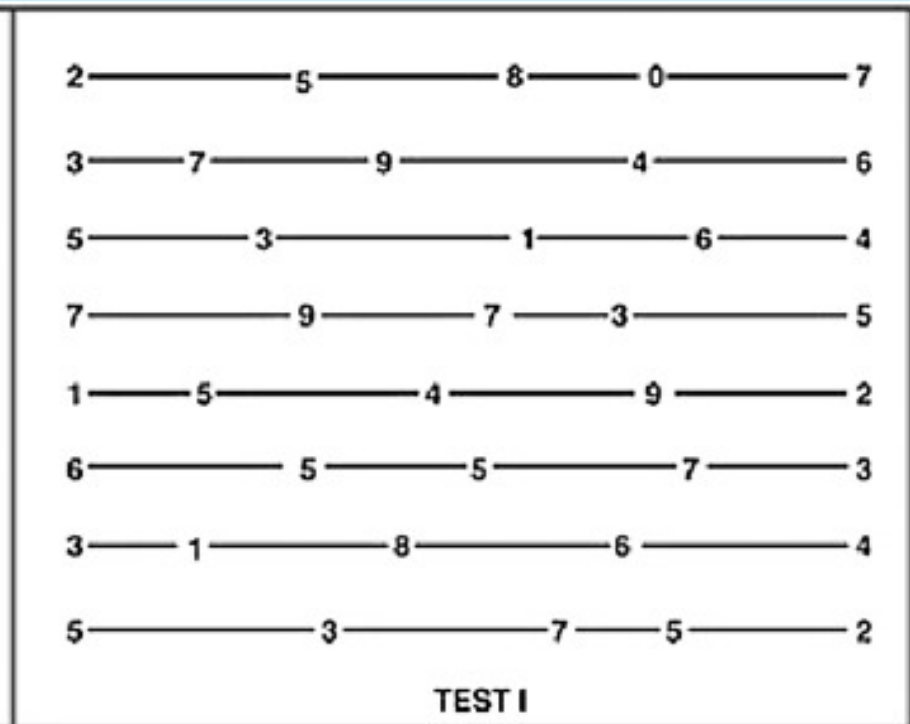
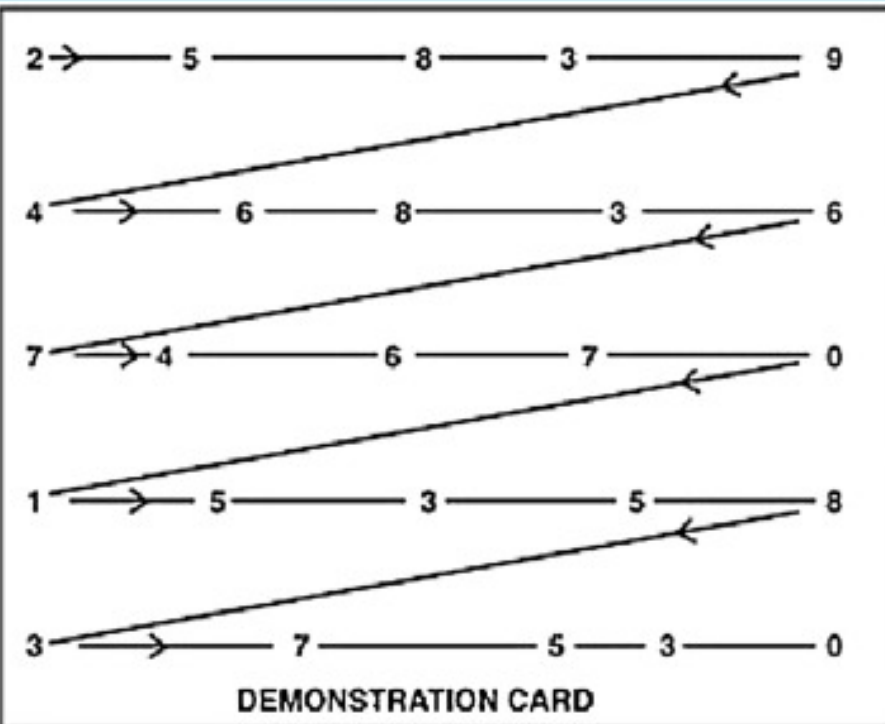


Visual Motion Sensitivity

- A brief 5 minute ***clinical screening*** tool to identify additional vestibular and ocular motor impairment and symptoms following concussion
- Used in conjunction with symptom reporting, neurocognitive assessment, balance testing, cervical and exertion screening in order to provide more complete clinical picture

# King D

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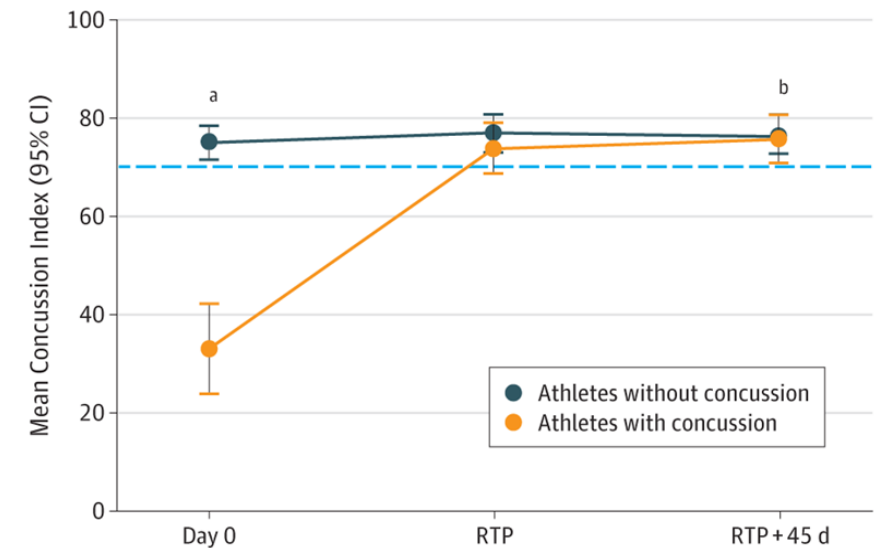
# Concussion treadmill testing

- **Exercise tolerance testing - bike or treadmill**
  - Monitoring heart rate
  - Symptom score
  - Rating of perceived exertion
- **Exercise script based off results**
  - 20 min, 80-90% of HRt, once per day, go to twice per day if tolerating
  - Can increase HRt by 5-10% each week
  
- Leddy, et al. *Curr Sports Med Rep* 2013
- Haider et al. *Sports Health*. 2019



# Pupillometry and EEG

- Pupillometry - Master, JAMA Ophthalmol, 2020
  - 134 healthy controls, 98 with SRC
  - Maximum pupil diameter and peak constriction velocity with AUC = 0.78
  - Getting better research/easier to use
- qEEG - Bazarian, Jama NewtOpen, 2021
  - 207 concussed, 373 controls
  - Concussion Index Sensitivity 86%, specificity 70.8%
  - AUC=0.89
  - Significantly lower on Day 0
  - significant increase to RTP ( $p < 0.001$ )
  - Needs more research



# Balance Testing

- Balance is an important evaluation tool but which one!?
- BESS /mBESS– portions are reliable, total not reliable. Training/learning effect
  - A Change in score of 9(inter) 7(intra) before you can say it is balance issues and not scoring
    - Finnoff, et al. PMR 2009
- Sway Balance/phone gyroscope– early test/retest reliability is good. needs more research, mostly small studies
- Clinical Test of Sensory Interaction on Balance(CTSIB) Sensory Organization test (SOT), Wii Balance Board, Rhomburg
  - Meta-analysis – no current reliability or validity information

# ImPACT testing

- Most widely used neurocognitive test
- Baseline compared to post injury



## ImPACT Clinical Report

SAM SAMPLE

Exam Type	Baseline	Post-Injury 1	Post-Injury 1	Baseline	Post-Injury 1
Age When Tested	15	15	16	19	19
Date Tested	Jan 20, 2016	Sep 02, 2016	Mar 14, 2017	Aug 21, 2020	Aug 24, 2020
Concussion Date					Aug 22, 2020
Exam Language	English	English	English	English	English
Test Version	2.1	2.1	3.2.1	3.12.0	3.12.0
Pointing Device	n/a	n/a	n/a	Mouse	Trackpad

### COMPOSITE SCORE

A indicates old normative data set, B indicates new normative data set.

	A		A		A		B		B	
Memory composite (verbal)	84	56%	95	91%	<b>71</b>	10%	98	88%	<b>85</b>	39%
Memory composite (visual)	46	<1%	59	14%	42	<1%	95	93%	89	79%
Visual motor speed composite	42.6	85%	39.65	74%	42.42	65%	48.28	88%	<b>37.02</b>	45%
Reaction time composite	0.48	96%	<b>0.57</b>	66%	0.49	90%	0.52	87%	<b>0.60</b>	64%
Impulse control composite	11		15		68		14		21	
Total Symptom Score	2		<b>16</b>		4		1		<b>46</b>	

### TWO-FACTOR SCORES

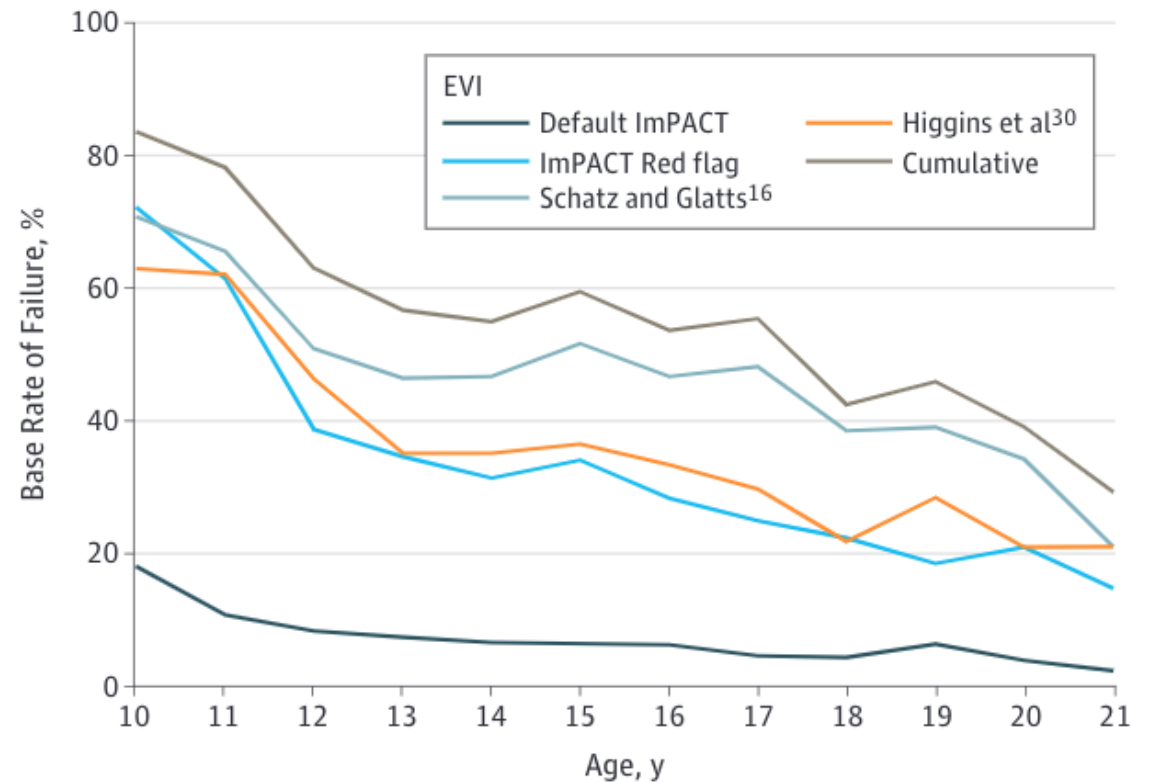
Memory	n/a	n/a	n/a	1.26	0.35
Speed	n/a	n/a	n/a	0.07	-0.35

Scores in **bold red** type exceed the Reliable Change Index (RCI) when compared to the baseline score. However, scores that do not exceed the RCI index may still be clinically significant. Percentile scores if available are listed in small type.

# ImPACT

- **Alsalaheen et al. Sports Med 2016**
  - Systematic review (5968 studies, 69 met criteria)
  - Convergent Validity supported
  - Discriminant/predictive validity, diagnostic and responsiveness was inconclusive
- **Abeare et al. JamaNeuro. 2018**
  - 7897 participants
  - baseline rate of failure 6.4-47%
  - 55.7 failed at least 1/4 indicators

Figure. Base Rate of Failure for 7897 Athletes by Age and Embedded Validity Indicator (EVI)



ImPACT indicates Immediate Postconcussion and Cognitive Testing.



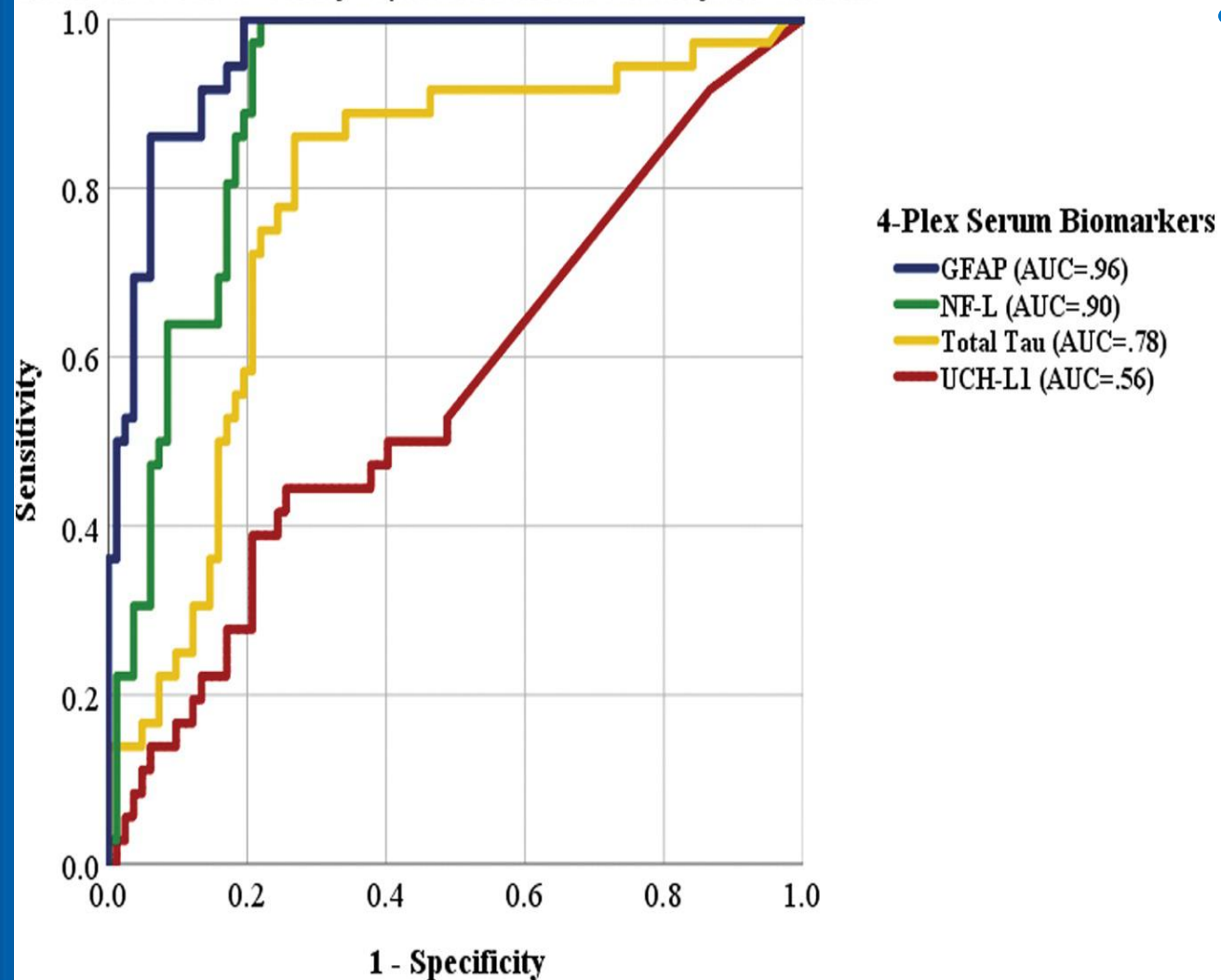
**WELCOME TO THE FUTURE!!**



# Blood work

## Asken, J Neurotrauma, 2020

Quanterix 4-Plex "B" Assay - Sport Concussion vs. Uninjured Controls



- N=110 preinjury; mostly football, W soccer, W Lax; 56% F
  - 36 SRC – blood within 48 hours, (Quanterix)
  - GFAP, T-Tau, and NF-L elevated after SRC
  - GFAP and NF-L distinguish concussed from controls, not UCH-L1
  - Did not correspond to clinical assessments (SCAT 3, KD, ImPACT) or length of recovery

# Blood work

Papa, JAMA Neurol, 2016; Yue Lancet Neurol, 2019

- **N=1947**
- **Point-of-care, handheld**
- **15 minutes to results for plasma; whole blood in development**
  - UCH-L1 and GFAP – correlate with intracranial lesions on CT
  - Elevated GFAP with positive MRI neg CT in adults
  - 97.5 sensitivity, 99.6 specificity
  - Previously approved 2018 Banyan Brain Trauma Indicator

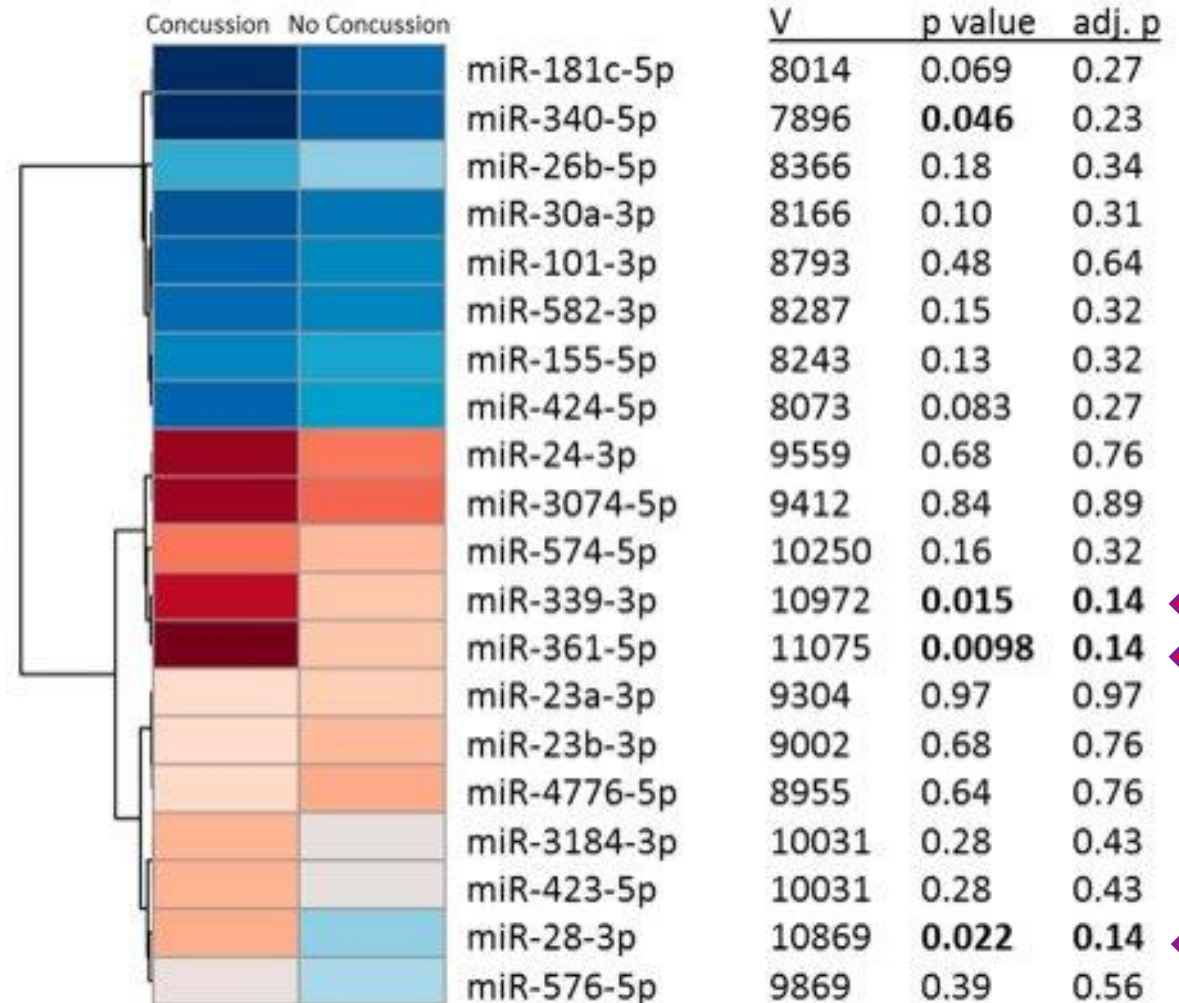
## Blood Work

- Research is coming
- Not for primetime in diagnosis of concussion
- Point of care may be useful in ruling out head bleed

# Saliva

## Hicks, Int J Mol Sci, 2020

- Group 1 (male, mean age 73)
  - N=13 retired professional football
  - 18 matched controls
- Group 2 (76% male, age 20+/- 5)
  - N=56 single concussion, N=24 recurrent
  - N=230 controls
- Neurocognitive testing did not distinguish
- 20 miRNAs distinguish
- 2 correlate with # of concussions



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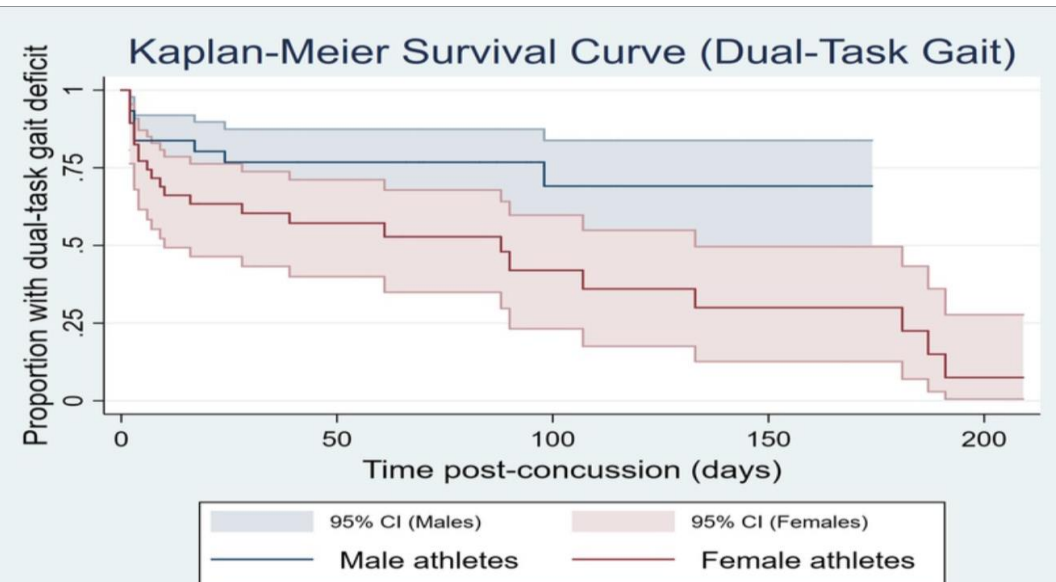
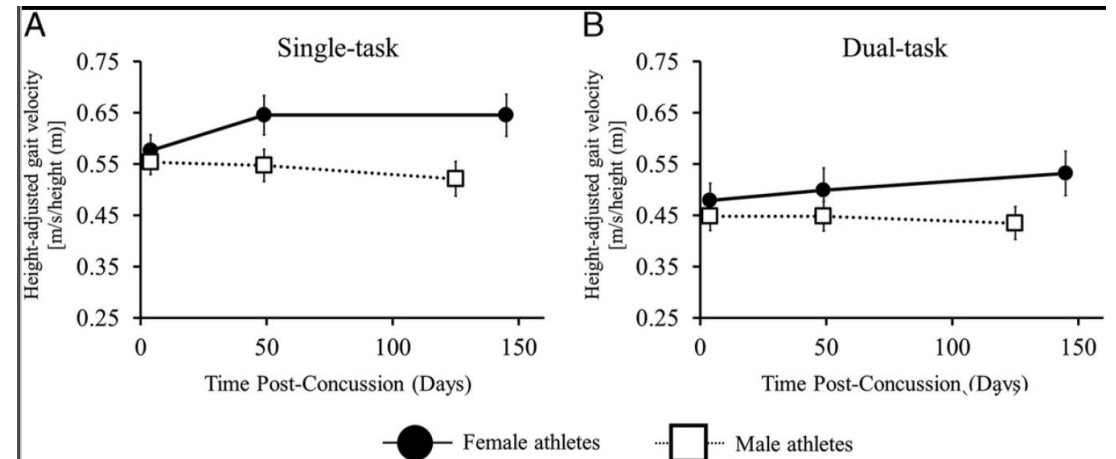
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# Saliva

- Promising new results with microRNA technology
- Not for primetime – lots of work left to do

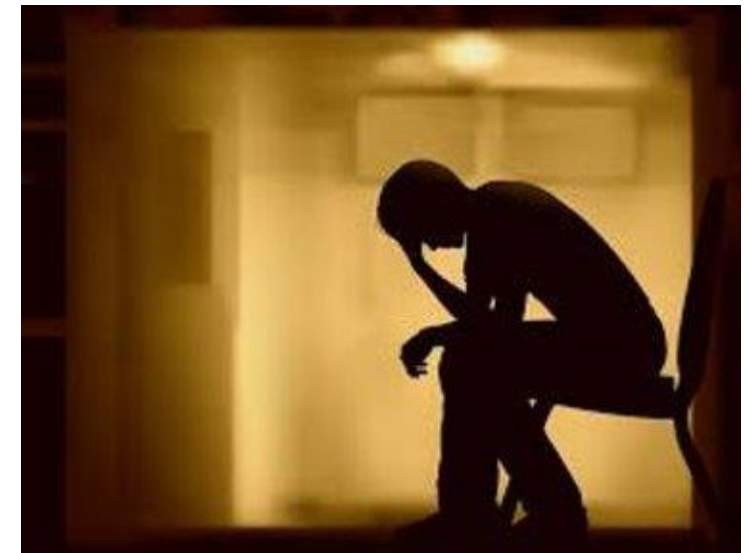
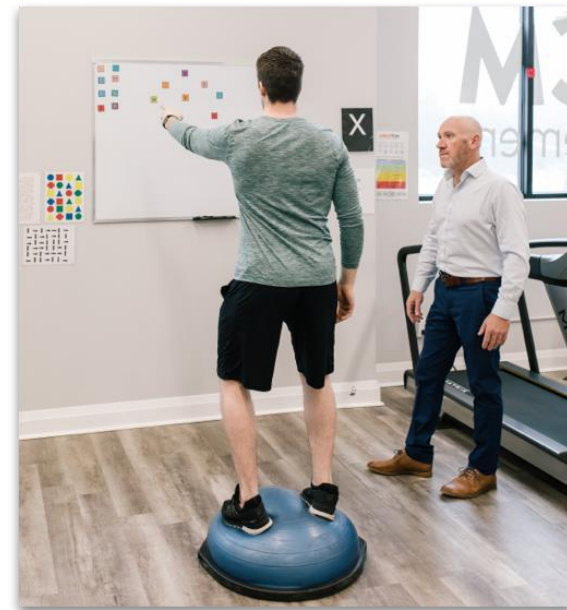
# Dual Task - Howell et al. Med Sci Sports Exerc. 2020 May

- N 94 participants
- Evaluated Concussed Participants
  - <7 d postinjury, 1.5 months post injury , 3.5 months postinjury.
  - Participants completed a single/dual-task gait evaluation and symptom inventory.
- Sex not independently associated with single task gait velocity recovery
- Male sex WAS independently associated with longer dual task gait recovery time
- Dual task abnormalities may persist beyond symptom resolution, further investigation is required



# Treatment

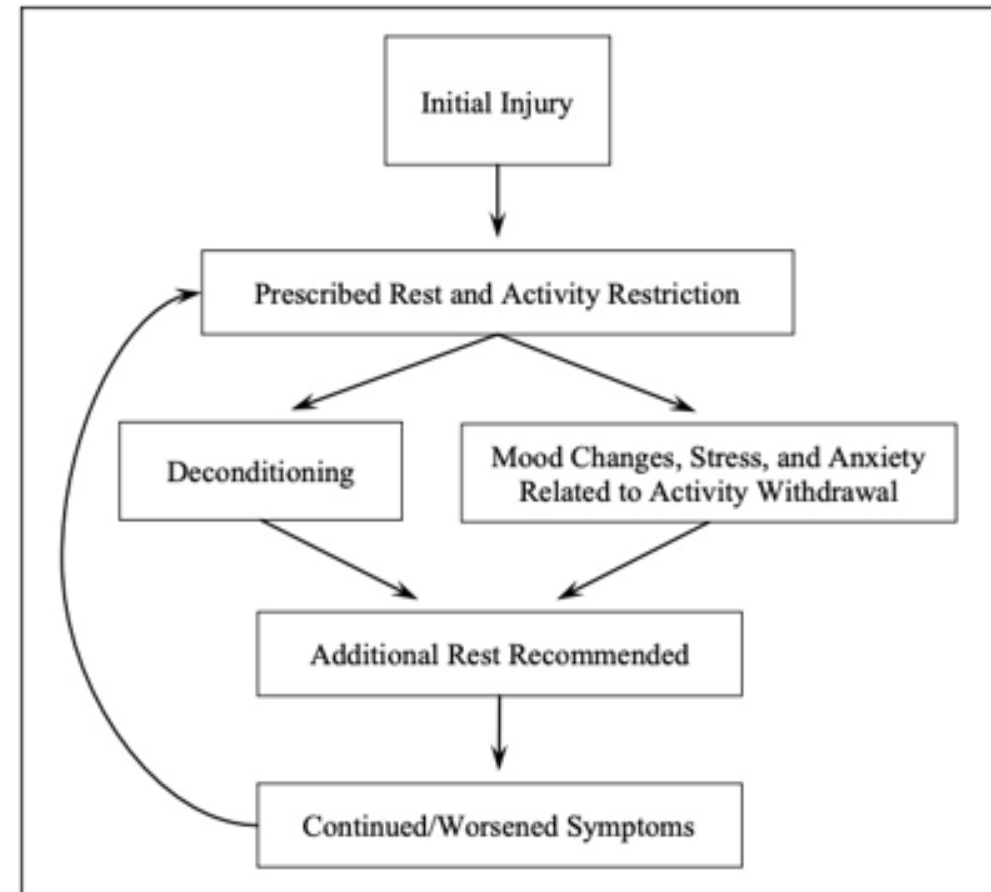
- Physical and Mental Rest
- Exercise
- Vestibular therapy - when
- Sleep
- Mental Health
- Return to Learn
- Medications
  
- Can we prevent LE injuries





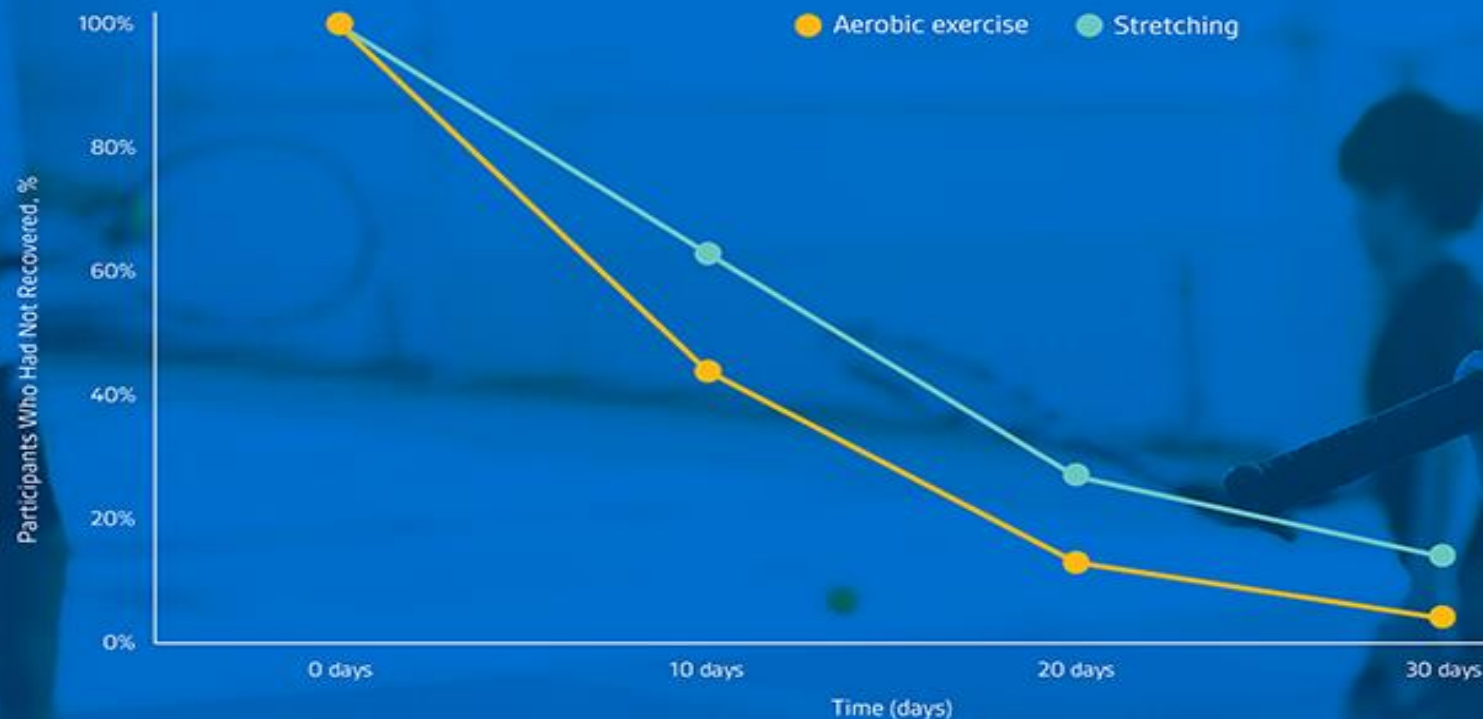
# Mental and Physical Rest

- Prolonged inactivity in a previously active patient may lead to:
  - Depression
  - Anxiety
  - Physical Deconditioning
  - Mood dysregulation
- Recommend 24-72 hours of rest



– DiFazio M, et al, 2016; Clin Peds  
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On average, **aerobic exercise participants recovered** in 13 (interquartile range [IQR], 10-19) days, **significantly faster** than stretching participants who recovered in 17 (IQR, 13-23) days ( $P = .009$ ).

Leddy JJ, Haider MN, Ellis MJ, et al. Early Subthreshold Aerobic Exercise for Sport-Related Concussion: A Randomized Clinical Trial. *JAMA Pediatr*. Published online February 04, 2019. doi:10.1001/jamapediatrics.2018.4397

# Vestibular Therapy

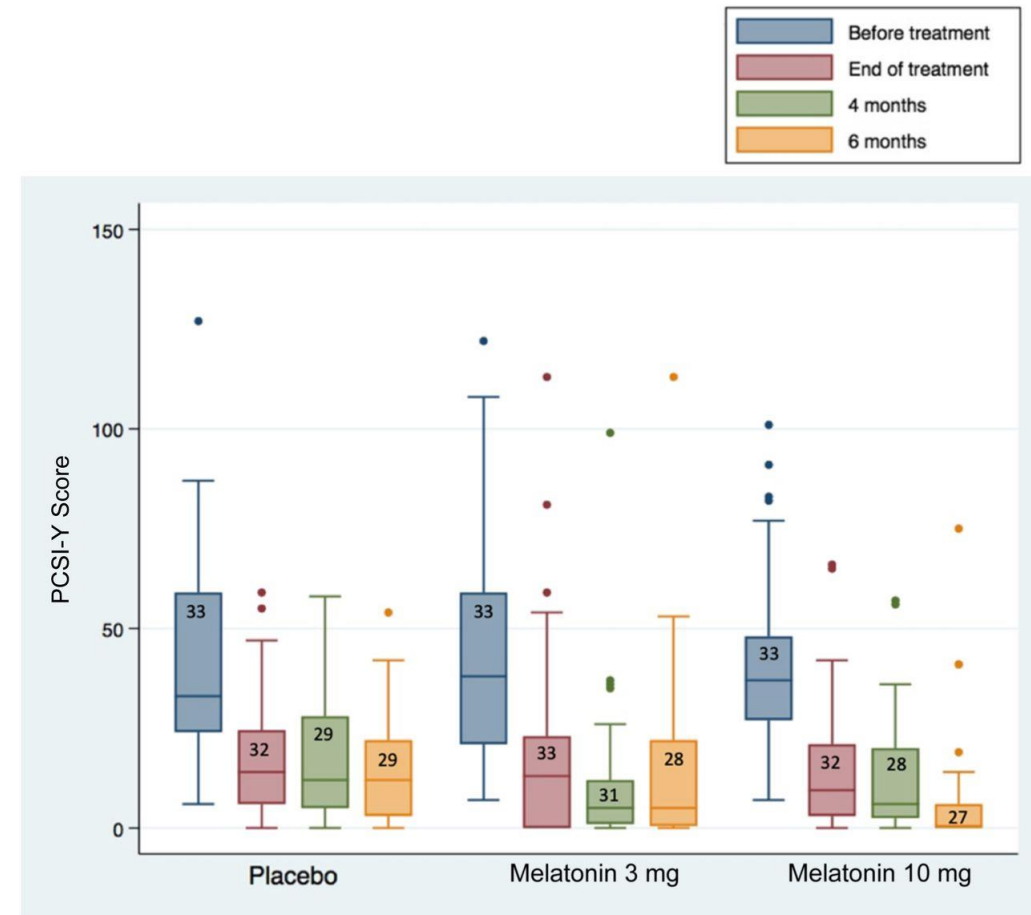
- Retrain the eyes, ears and brain
- Balance, coordination, cognitive function, dual task
- Pilot study
  - 5-23 years of age with sport related concussion, 23 total patients
  - Compared entry into Vestibular therapy at <30 days post injury to >30 days post injury
  - Suggests early entry into vestibular therapy recover quicker than late

Ahluwalia R, Miller S, Dawoud FM, et al. A Pilot Study Evaluating the Timing of Vestibular Therapy After Sport-Related Concussion: Is Earlier Better? *Sports Health*. March 2021



# Sleep - Barlow, Pediatrics, 2020

- RCT - 8-18 yo, PPCS, 92 kids, 4-6 weeks post injury
  - Placebo vs 3 mg melatonin vs 10 mg
  - Goal symptom reduction in PPCS using Post Concussion Symptom Inventory
  - All participant symptoms decreased over time - melatonin had no significant effect



# Sleep – a close look.

## Barlow, J Neurotrauma 2020

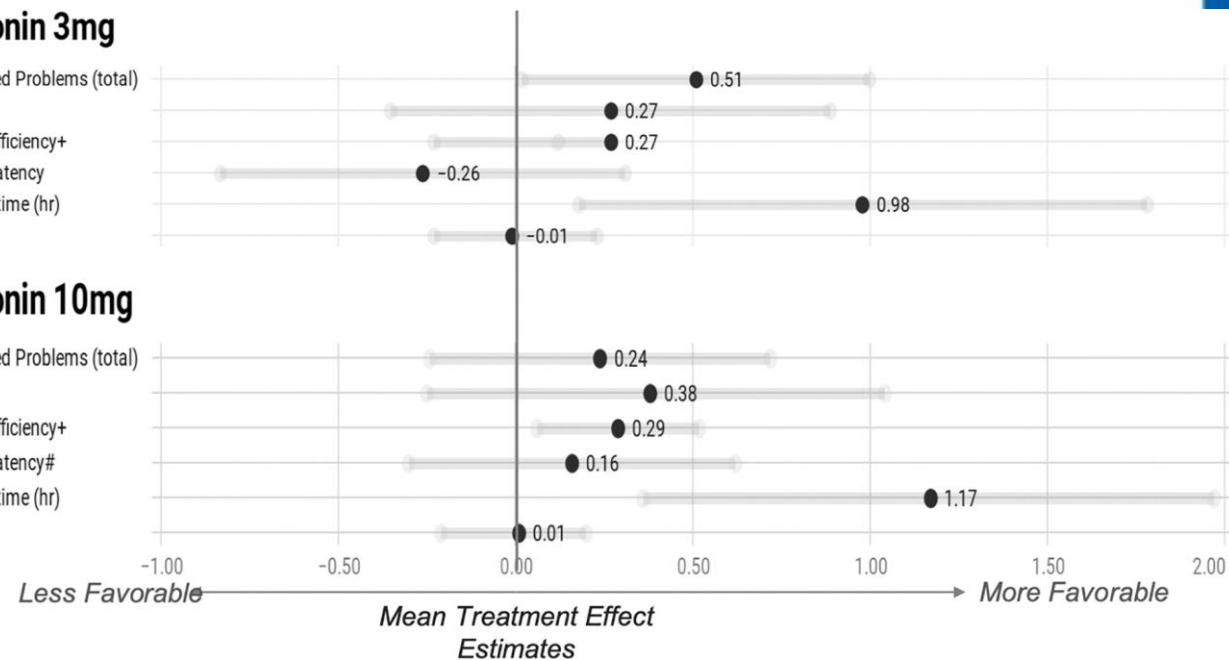
- Secondary analysis of prior study
- 72 participants having sleep related problems in the PCSI
  - Sleep-related problems decreased, sleep duration increased with a significant effect of melatonin at 3 and 10 mg compared with placebo
  - Depressive symptoms significantly decreased with melatonin 3 mg, but not with melatonin 10 mg compared with placebo

### Melatonin 3mg

Sleep Related Problems (total)  
PCSI-Y  
Log Sleep efficiency+  
Log Onset latency  
Total sleep time (hr)  
WASO (hr)

### Melatonin 10mg

Sleep Related Problems (total)  
PCSI-Y  
Log Sleep efficiency+  
Log Onset latency#  
Total sleep time (hr)  
WASO (hr)



## Sleep - Tomfohr-Madsen, J Head Trauma Rehabil, 2020

- 6 wks CBT-I for insomnia
- PPCS in 24 adolescents resulted in improvements in:
  - Insomnia ratings
  - sleep quality
  - better sleep efficiency
  - shorter sleep-onset latency
  - longer sleep time
  - fewer dysfunctional beliefs about sleep compared with those with usual treatment
  - Modest reduction in post-concussion symptoms

## Mental Health – Sandel et al. Sport Exerc Perform Psychol 2018

- Pre-injury history of mental health prolongs recovery
- Diagnosed mental health conditions/mental health treatment prior to concussion predicts larger overall symptom burden
- Avoidance may result in loss of coping, emotional disturbances, secondary distress
- Co-existing vestibular changes may trigger anxiety/mood changes

## Mental Health - Hunt, Brain Inj , 2020

- 6 wk program, 40 adolescents, >2 weeks post injury
  - Individualized low intensity aerobic exercise
  - Sport specific drills
  - Relaxation techniques
  - Comprehensive education and support
- Reduction anger anxiety, greater anger reduction in girls



## Return to Learn

- Interventions in the first 1-4 weeks should be applied generously and weaned away as weeks progress
- Cognitive recovery is not linear and symptoms can flare at certain/different points in the day and not all day
- Low level symptoms are OK to have in the classroom
- The supports aren't intended to be prescriptive. Based on:
  - Symptoms of that student
  - Time of day and the fatigue level
  - Type of class being taught
- **THERE IS NO SUCH THING AS 'MEDICAL CLEARANCE' FOR ACADEMIC INTERVENTIONS.**
  - The classroom is the domain of the teacher, not the doctor.



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**Specific Care Question**

In adolescent and teenagers with concussion does fish oil supplement versus no fish oil supplement improve concussion recovery speed, improve brain healing, decrease inflammation, or decrease severity of concussion?

**Recommendations Based on Current Literature (Best Evidence) Only**

*No recommendation can be made for or against the use of fish oil supplement, based on expert review of current literature by the Department of EBP. No human studies were found that answered the specific care question. When there is a lack of scientific evidence, standard work should be developed, implemented, and monitored.*

**Literature Summary**

**Background.** The Centers for Disease Control and Prevention (CDC) (2020) defines concussions or a mild traumatic brain injury (mTBI) as “a complex pathophysiologic process affecting the brain, induced by traumatic biomechanical forces secondary to direct or indirect forces to the head.” Concussions are a significant public health concern affecting 1.6 to 3.8 million youth annually (Gay, 2016). However, the true concussion incidence may be higher due to underreporting (McGeown et al., 2020).

An area of interest for concussion treatment and recovery is nutrition therapy and omega-3 fatty acids (McGeown et al., 2020). Omega-3 polyunsaturated fatty acids (n-3FA) are part of the cell membrane, and particularly docosahexaenoic acid (DHA) (Lewis, 2016). It is generally believed that the supplementation of n-3FA may be beneficial in the treatment and recovery of concussions. Most of the evidence in this area is based on animal studies (McGeown et al., 2020) and a few case studies (Lewis et al., 2013; Trojian & Jackson, 2011). The pre-clinical evidence of the animal studies has shown promise (McGeowen et al., 2020), but the use of n-3FAs has not been demonstrated in rigorous human studies. To date, there are no head-to-head intervention studies on the use of n-3FA to treat concussions or mTBI in humans; however, there are four trials underway (National Library of Medicine [NLM], NCT01814527; NLM, NCT01903525; NLM, NCT03582267; NLM, NCT03345550). The CDC guidelines for the management of mild brain injury among children makes no mention of n-3FAs or fish oil supplementation in their guideline (Lumba-Brown et al., 2018).

On the topic of usage in patients, in a survey response of 257 active physician members of the American Medical Association of Sports Medicine, 25% reported prescribing n-3FA to athletes that had suffered concussions (Kent et al., 2020). Of the 25% that reported prescribing n-3FAs, 40% believed their use was effective in improving recovery, while 57% were unsure.

Due to the lack of human studies, the EBP Department is unable to review the current literature on this topic.

**Study characteristics.** The search for suitable studies was completed on November 30, 2020. L. Edwards MEd, RD, LD, CSSD reviewed the 95 titles and/or abstracts found in the search and identified<sup>a</sup> 24 single studies believed to answer the question. After an in-depth review, no human studies were found that answered the question.

## Return to play – are athletes still at risk?

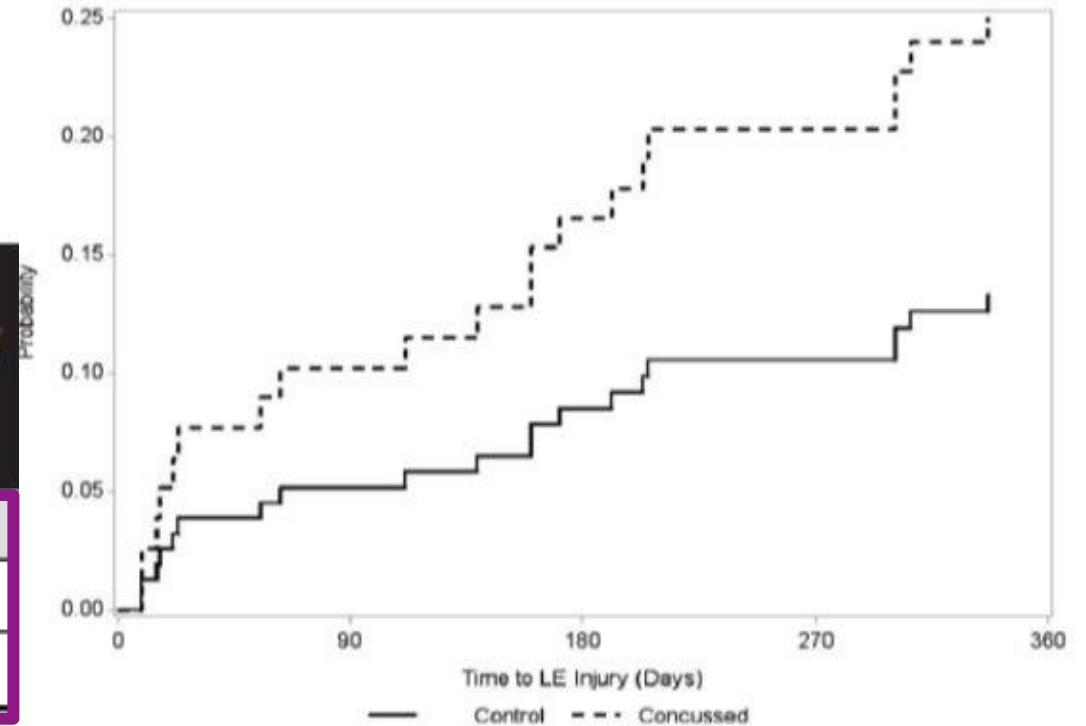
- 110 concussed athletes and 110 matched controls
- Retrospective chart analysis 365 days prior/after concussion
- ↑ relative risk of LE injury (w/in 1 year)  
HR 1.67 (95% CI 1.11-2.53)

**TABLE 4. HRs and CIs for the Instantaneous Relative Risk of Subsequent LE Injury Based on Recent Concussion and Previous LE Injury**

N = 220	HR	P	95% CI
Recent concussion	1.67	0.02	1.11–2.53
Previous LE injury	1.15	0.51	0.76–1.72

(Clin J Sport Med 2019;29:218–223)

### Effects of Recent Concussion and Injury History on Instantaneous Relative Risk of Lower Extremity Injury in Division I Collegiate Athletes



**Figure 2.** Cumulative incidence curve of ipsilateral injury for both concussed and control groups after adjusting for the competing risk of contralateral injuries and censored values. Time 0 indicates the time of the concussion event.

# Return to play – are athletes still at risk?

## Musculoskeletal Injury Risk After Sport-Related Concussion

A Systematic Review and Meta-analysis

The American Journal of Sports Medicine  
2019;47(7):1754–1762

- Concussed athletes 2 times greater odds of musculoskeletal injury than non-concussed

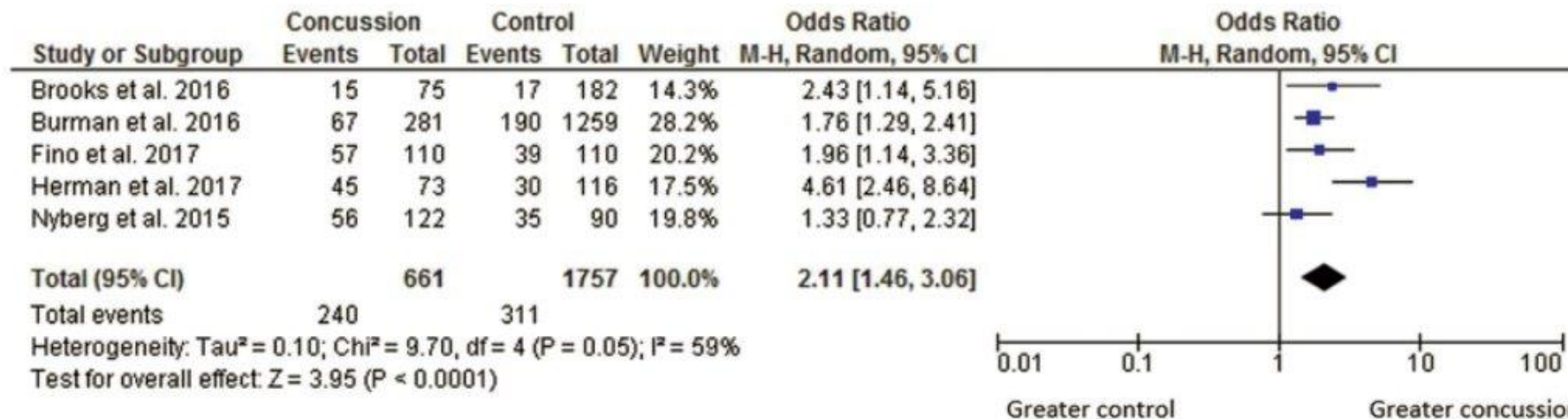


Figure 2. Forest plot of odds ratio of injury after concussion. The mean odds ratio and 95% CI data from individual studies in addition to the pooled data are shown. Odds ratio (OR) > 1 indicates greater odds of injury for athletes with concussion compared with control athletes.

## Conclusion

- Early recognition and appropriate referral are important in recovery after sport-related concussion
- Multi-disciplinary treatment approach focusing on mental health, sleep physical therapy and exercise
- Individuals may be at increased risk of lower extremity injury after a concussion