

Concussion Management in 2024: *What Does the Evidence Tell Us About the Role of Post-Concussion Rest, Exercise, Sleep, and Beyond?*

David R. Howell, PhD, ATC

Associate Professor & Director of Clinical Research | Department of
Orthopedics | CU Anschutz School of Medicine

Research Director | Sports Medicine Center | Children's Hospital Colorado

Disclosures

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- The Denver Broncos Foundation

Objectives

1. To provide an overall update from the 6th International Consensus Statement on Concussion in Sport.
2. To describe the latest evidence regarding rest, physical activity, and exercise following concussion.
3. To describe the latest evidence regarding sleep after concussion.

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1st (2001)

Concussion in sport

Summary and agreement statement of the first International Conference on Concussion in Sport, Vienna 2001*

M Aubry, R Cantu, J Dvorak, T Graf-Baumann, K Johnston (Chair), J Kelly, M Lovell, P McCrory, W Meeuwisse, P Schamasch (the Concussion in Sport (CIS) Group)

Recommendations for the improvement of safety and health of athletes who may suffer concussive injuries

2nd (2004)

ORIGINAL ARTICLE

Summary and agreement statement of the 2nd International Conference on Concussion in Sport, Prague 2004

P McCrory, K Johnston, W Meeuwisse, M Aubry, J Dvorak, T Graf-Baumann, J Kelly, M Lovell, P Schamasch

See end of article for

Br J Sports Med 2005;39:196–204. doi: 10.1136/bjpm.2005.018614

3rd (2008)

Consensus Statement on Concussion in Sport: The 3rd International Conference on Concussion in Sport Held in Zurich, November 2008

Paul McCrory, MBBS, PhD*; Willem Meeuwisse, MD, PhD†; Karen Johnston, MD, PhD‡; Jiri Dvorak, MD§; Mark Aubry, MD||; Mick Molloy, MD¶; Robert Cantu, MD††#

4th (2012)

Consensus statement on concussion in sport: the 4th International Conference on Concussion in Sport held in Zurich, November 2012

Paul McCrory,¹ Willem H Meeuwisse,^{2,3} Mark Aubry,^{4,5,6} Bob Cantu,^{7,8} Jiri Dvorak,^{9,10,11} Ruben J Echemendia,^{12,13} Lars Engebretsen,^{14,15,16} Karen Johnston,^{17,18} Jeffrey S Kutcher,¹⁹ Martin Raftery,²⁰ Allen Sills,²¹ Brian W Benson,^{22,23,24} Gavin A Davis,²⁵ Richard G Ellenbogen,^{26,27} Kevin Guskiewicz,²⁸ Stanley A Herring,^{29,30} Grant L Iverson,³¹ Barry D Jordan,^{32,33,34} James Kissick,^{6,35,36,37} Michael McCrea,³⁸ Andrew S McIntosh,^{39,40,41} David Maddocks,⁴² Michael Makhlessi,^{43,44} Laura Purcell,^{45,46} Margot Putukian,^{47,48} Kathryn Schneider,⁴⁹ Charles H Tator,^{50,51,52,53} Michael Turner⁵⁴

5th (2016)

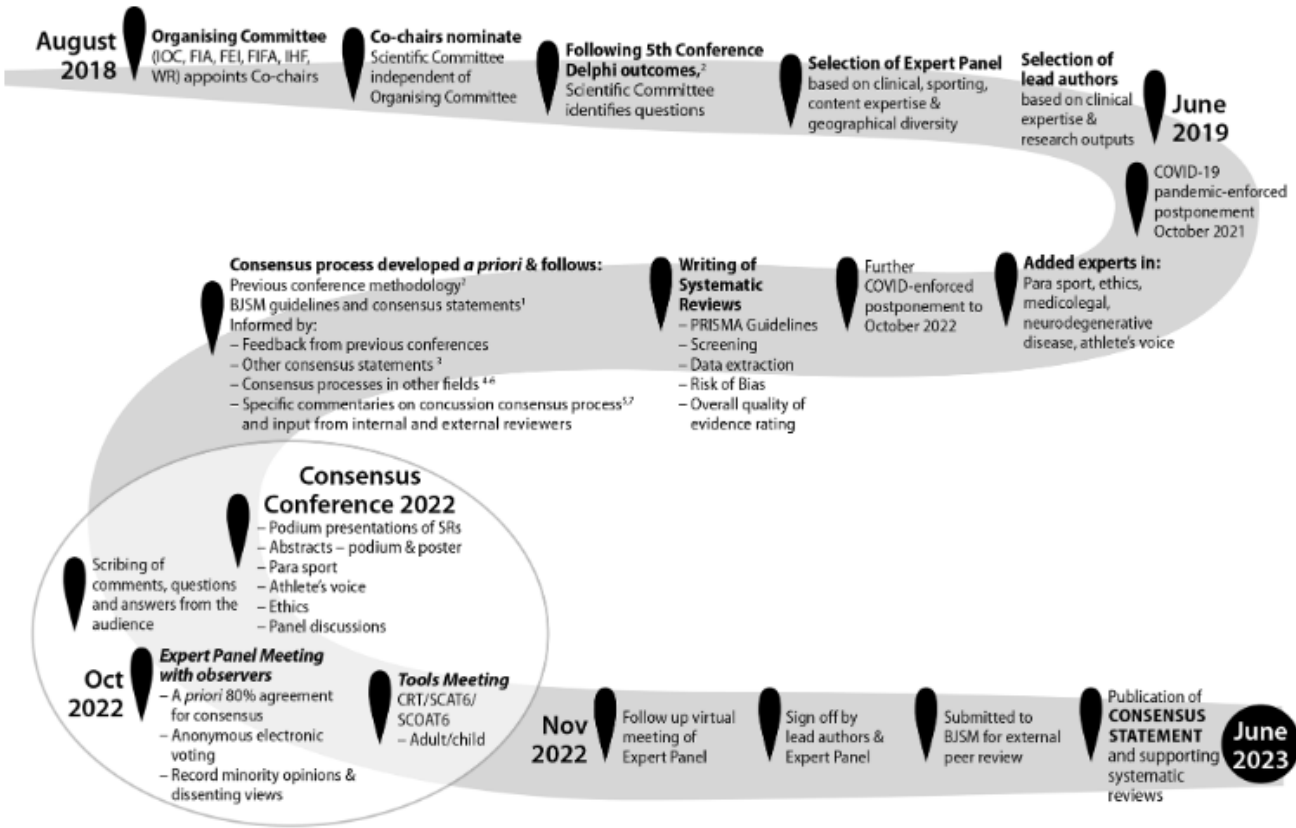
Consensus statement on concussion in sport—the 5th international conference on concussion in sport held in Berlin, October 2016

Paul McCrory,¹ Willem Meeuwisse,² Jiri Dvorak,^{3,4} Mark Aubry,⁵ Julian Bailes,⁶ Steven Broglio,⁷ Robert C Cantu,⁸ David Cassidy,⁹ Ruben J Echemendia,^{10,11} Rudy J Castellani,¹² Gavin A Davis,^{13,14} Richard Ellenbogen,¹⁵ Carolyn Emery,¹⁶ Lars Engebretsen,¹⁷ Nina Feddermann-Demont,^{18,19} Christopher C Giza,^{20,21} Kevin M Guskiewicz,²² Stanley Herring,²³ Grant L Iverson,²⁴ Karen M Johnston,²⁵ James Kissick,²⁶ Jeffrey Kutcher,²⁷ John J Leddy,²⁸ David Maddocks,²⁹ Michael Makhlessi,^{30,31} Geoff Manley,³² Michael McCrea,³³ William P Meehan,^{34,35} Sinji Nagahiro,³⁶ Jon Patricios,^{37,38} Margot Putukian,³⁹ Kathryn J Schneider,⁴⁰ Allen Sills,^{41,42} Charles H Tator,^{43,44} Michael Turner,⁴⁵ Pieter E Vos⁴⁶

6th (2022)

Consensus statement on concussion in sport: the 6th International Conference on Concussion in Sport—Amsterdam, October 2022

Jon S Patricios ¹, Kathryn J Schneider ², Jiri Dvorak ³, Osman Hassan Ahmed ^{4,5}, Cheri Blauwet ^{6,7}, Robert C Cantu ^{8,9}, Gavin A Davis ^{10,11}, Ruben J Echemendia ^{12,13}, Michael Makhlessi^{14,15}, Michael McNamee,^{16,17} Steven Broglio ¹⁸, Carolyn A Emery ², Nina Feddermann-Demont,^{19,20} Gordon Ward Fuller ²¹, Christopher C Giza,^{22,23} Kevin M Guskiewicz,²⁴ Brian Hainline ²⁵, Grant L Iverson ^{26,27}, Jeffrey S Kutcher,²⁸ John J Leddy ²⁹, David Maddocks,³⁰ Geoff Manley ³¹, Michael McCrea ³², Laura K Purcell,³³ Margot Putukian ³⁴, Haruhiko Sato ³⁵, Markku P Tuominen,³⁶ Michael Turner ^{37,38}, Keith Owen Yeates ³⁹, Stanley A Herring,^{40,41} Willem Meeuwisse ⁴²



What is the Result?

A comprehensive consensus statement on concussion in sport

- Standardized tools
 - CRT6
 - SCAT6, Child SCAT6
 - SCOAT6, Child SCOAT6

In depth reviews on:

1. Definition
2. On-field/acute assessment (SCAT)
3. Office assessment (SCOAT)
4. Prevention
5. Rest/exercise
6. Targeted interventions
7. Prognosis
8. Role of biomarkers
9. Clinical recovery- RTS/RTL
10. Late in life risks after concussion
11. Discontinuing participation in contact/collision sports

What Has Changed? Definition

Berlin (2016)

- A TBI induced by biomechanical forces. Common features include:
 - Direct blow to head, face, neck, body
 - Rapid onset of neurological impairment
 - Functional disturbance rather than structural injury
 - Range of clinical signs/symptoms

Modified (2022)

- A TBI caused by direct blow to head, face, neck, or body.
- Initiates metabolic cascade with blood flow change and inflammation affecting the brain
- Symptoms/signs may be present immediately, evolve over hours, and commonly resolve in days but may be prolonged
- No abnormality on standard neuroimaging
- Large range of symptoms/signs
- Not specific diagnostic criteria (can find those in ACRM criteria)

What Has Changed? SCAT6

Immediate Memory

All 3 trials must be administered irrespective of the number correct on Trial 1. Administer at the rate of one word per second.

Trial 1: Say "I am going to test your memory. I will read you a list of words and when I am done, repeat back as many words as you can remember, in any order."

Trials 2 and 3: Say "I am going to repeat the same list. Repeat back as many words as you can remember in any order, even if you said the word before in a previous trial."

Word list used: A B C

List A	Trial			Alternate Lists			
	1	2	3	List B	List C		
Jacket	0	1	0	1	0	Finger	Baby
Arrow	0	1	0	1	0	Penny	Monkey
Pepper	0	1	0	1	0	Blanket	Perfume
Colton	0	1	0	1	0	Lemon	Sunset
Movie	0	1	0	1	0	Insect	Iron
Dollar	0	1	0	1	0	Candle	Elbow
Honey	0	1	0	1	0	Paper	Apple
Mirror	0	1	0	1	0	Sugar	Carpet
Saddle	0	1	0	1	0	Sandwich	Saddle
Anchor	0	1	0	1	0	Wagon	Bubble
Trial Total							

Immediate Memory Score: 0 of 30 Time Last Trial Completed: 00:00

10-word list

Timed Tandem Gait

Place a 3-metre-long line on the floor/firm surface with athletic tape. The task should be timed. Please complete all 3 trials.

Say "Please walk heel-to-toe quickly to the end of the tape, turn around and come back as fast as you can without separating your feet or stepping off the line."

Single Task:

Time to Complete Tandem Gait Walking (seconds)				
Trial 1	Trial 2	Trial 3	Average 3 Trials	Fastest Trial

Dual Task Gait (Optional. Timed Tandem Gait must be completed first)

Place a 3-metre-long line on the floor/firm surface with athletic tape. The task should be timed.

Say "Now, while you are walking heel-to-toe, I will ask you to count backwards out loud by 7s. For example, if we started at 100, you would say 100, 93, 86, 79. Let's practise counting. Starting with 93, count backward by sevens until I say "stop". Note that this practice only involves counting backwards.

Dual Task Practice: Circle correct responses; record number of subtraction counting errors.

Task									Errors	Time
Practice	93	86	72	65	58	51	44	37		

Say "Good. Now I will ask you to walk heel-to-toe and count backwards out loud at the same time. Are you ready? The number to start with is 88. Go!"

Dual-task tandem gait

CHCO Evidence in the SCAT6

Timed Tandem Gait

Place a 3-metre-long line on the floor/firm surface with athletic tape. The task should be timed. Please complete all 3 trials.

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Tandem Gait^{6,7}

Participants are instructed to stand with their feet together behind a starting line (the test is best done with footwear removed). Then, they walk in a forward direction as quickly and as accurately as possible along a 38mm wide (sports tape), 3 metre line with an alternate foot heel-to-toe gait ensuring that they approximate their heel and toe on each step. Once they cross the end of the 3m line, they turn 180 degrees and return to the starting point using the same gait. Athletes fail the test if they step off the line, have a separation between their heel and toe, or if they touch or grab the examiner or an object. A total of 3 trials will be conducted.

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- Guskiewicz KM. Assessment of postural stability following sport-related concussion. Current Sports Medicine Reports. 2003; 2: 24-30.
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- Wingerson, M.J., Seehusen, C.N., Walker, G.A., Wilson, J.C., Howell, D.R. Clinical feasibility and utility of a dual-task tandem gait test for pediatric concussion management. Journal of Athletic Training. 2020. 58(2), 106-111.
- Howell DR, O'Connell LR, Chou LS. Single-task and dual-task tandem gait test performance after concussion. J Sci Med Sport. 2017 Jul;20(7):622-626. doi: 10.1016/j.jsams.2016.11.020. Epub 2017 Jan 24. PMID: 28169147

Concussion Assessment Tools: Children

- **Child SCAT3/5:** Added a Child Version for use in children 5-12 years of age
- **Child SCAT6:** Updated for children 8-12 years of age

Child-SCAT3™ Sport Concussion Assessment Tool for children ages 5 to 12 years

What is a concussion?
A concussion is a mild traumatic brain injury (MTBI) caused by a blow to the head or a violent shaking of the head and neck. It is a temporary disturbance of the normal function of the brain. Concussion is a clinical diagnosis and cannot be confirmed by any test. It is a clinical diagnosis and cannot be confirmed by any test. It is a clinical diagnosis and cannot be confirmed by any test.

Prevalent signs of concussion?
The child should be observed for the following signs of concussion. If any of these signs are present, the child should be removed from play and assessed for concussion. If any of these signs are present, the child should be removed from play and assessed for concussion.

Superior Assessment - mild-Moderate Injury?
This assessment is used to determine if a child has a mild to moderate injury. It consists of a series of questions that are answered by the child and the parent/guardian. If the child answers "yes" to any of the questions, the child should be removed from play and assessed for concussion.

SIDELINE ASSESSMENT Indications for Emergency Management
If you observe any of the following signs or symptoms, the child should be removed from play and transported to a medical facility for further evaluation.

BACKGROUND
This tool may be freely copied in its current form for distribution to individuals, teams, groups and organizations. It should not be altered in any way, re-branded or sold for commercial gain. Any revision, translation or reproduction in a digital form requires specific approval by the Concussion in Sport Group.

Child SCAT5™ SPORT CONCUSSION ASSESSMENT TOOL FOR CHILDREN AGED 5 TO 12 YEARS FOR USE BY MEDICAL PROFESSIONALS ONLY

Patient details
Name: _____
DOB: _____
Address: _____
ID number: _____
Examiner: _____
Date of injury: _____ Time: _____

WHAT IS THE CHILD SCAT5?
The Child SCAT5 is a standardized tool for evaluating concussion designed for use by physicians and licensed healthcare professionals.

Key points
• Any athlete with suspected concussion should be REMOVED FROM PLAY, medically assessed and monitored for deterioration. The athlete diagnosed with concussion should be returned to play on the day of injury.
• If the child is suspected of having a concussion and medical personnel are not immediately available, the child should be referred to a medical facility for urgent assessment.
• Concussion signs and symptoms evolve over time and it is important to consider repeat evaluation in the assessment of concussion.
• The diagnosis of a concussion is a clinical judgment, made by a medical professional. The Child SCAT5 should NOT be used by itself to make or exclude the diagnosis of concussion. An athlete who has a concussion even if the Child SCAT5 is "normal".

Remember:
• The best prognostic of final outcome, response, return, healing, (re-)participation should be followed.
• Do not attempt to give the athlete (other than that required for a) any management unless trained to do so.
• Assessment for a spinal cord injury is a critical part of the initial field assessment.
• Do not remove a helmet or any other equipment unless trained to do so.

What Has Changed? Child-specific

- Pediatric populations have less access to medical personnel
 - Use the **Concussion Recognition Tool** for any adult (non-HCP) supervising child sport
- Return-to-Learn (RTL) is a priority, and should be prioritized over return-to-sport (RTS)
- Child SCAT6
 - Different symptom scale than SCAT6
 - Parent symptom evaluation
 - Dual-task tandem gait: subtract by 3s

Dual Task Gait (Optional)

Only perform if the child successfully completes complex tandem gait.

Place a 3-metre-long line on the floor/firm surface with athletic tape. The task should be timed.

Say "Now, while you are walking heel-to-toe, I will ask you to count backwards out loud by 3s. Starting at 100, you would say 100, 97, 94, 91. Let's practise counting. Starting with 95, count backwards by 3s until you reach 77. Say 'stop'." Note that this practice only involves counting backwards.

Dual Task Practice: Circle correct responses; record number of subtraction counting errors.

Task							
Practice	95	92	89	86	83	80	77

What Has Changed? Tools

Sport Concussion Office Assessment Tool (SCOAT6)

New tool, designed for
assessment 7-30 days post-
concussion

Assessment Domains

- Medical history
- Symptoms
- Immediate/delayed memory
 - *(10 / 15-word list optional)*
- Orthostatic vital signs
- Cervical spine assessment
- Balance (BESS, tandem gait)
- VOMS
- Anxiety and depression screen
- Sleep screen
- Computerized cognitive testing
- Graded aerobic testing

What Has Changed? Biomarkers

Table 1 Fluid biomarkers to detect and monitor recovery

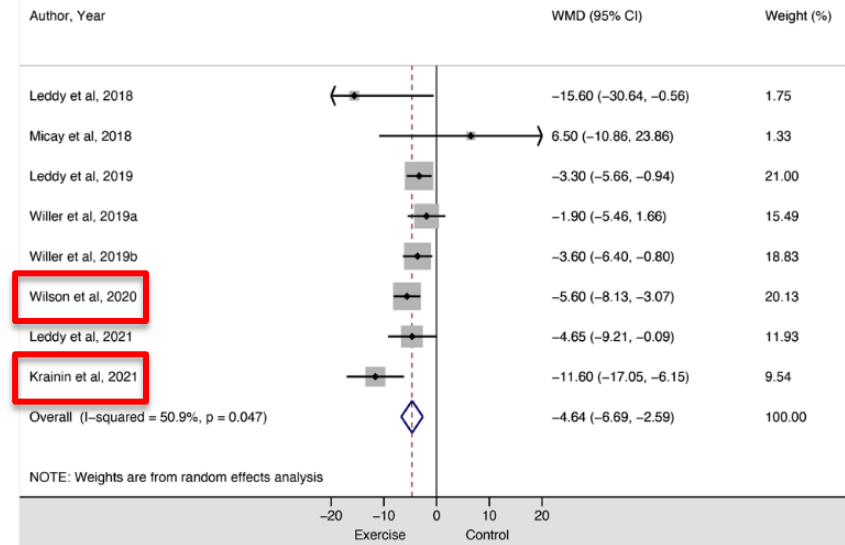
Biomarkers demonstrating ability to discriminate between SRC and controls	<ul style="list-style-type: none"> ▶ AMPAR¹⁹ ▶ Aβ-42^{20 21} ▶ BLBP²² ▶ C-proteins²³ ▶ Extracellular-vesicle associated and depleted cytokines³² ▶ GFAP²⁴⁻²⁷ ▶ IgA autoantibodies⁴⁹ 	<ul style="list-style-type: none"> ▶ Inflammatory chemokines MCP-4^{28 29}, MIP-1β²⁹ ▶ Inflammatory cytokines IL-6^{21 30 31}, IL-1RA^{30 31} ▶ Matrix metalloproteinases MMP-2 and MMP-3³³ ▶ Metabolomic^{34-36 51} and proteomic^{37 52} panels ▶ miRNAs^{38 39 50} ▶ Neuron-derived and astrocyte-derived exosome cargo proteins²¹ ▶ NF-L^(24 25 27 40 53 54) 	<ul style="list-style-type: none"> ▶ PRDX-6^{28 41} ▶ QUIN and KYNA⁴²⁻⁴⁴ ▶ s100B^{20 31 40 45} ▶ SNTF^{18 31} ▶ T-tau^{20 24-28 41 45-47} and tau-C⁴⁸ ▶ UCH-L1^{21 26 31 40}
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Useful research tools, but require validation for use in clinical practice

What Has Changed? Rest/Exercise

Complete rest is not recommended!

- 24-48 hours of rest after concussion, followed by physical activity
- Exercise testing can be done safely 2-10 days after injury under supervision
- Advance duration/intensity if no symptom exacerbation
>2 points on 0-10 scale compared to rest



What Has Changed? Persisting Symptoms

- **Definition of persisting symptoms (PPCS)**
>4 weeks for all ages
- Use of standardized symptom scales
- Diagnosis of PPCS depends solely on symptom severity (limitation)

What Has Changed? RTS/RTL

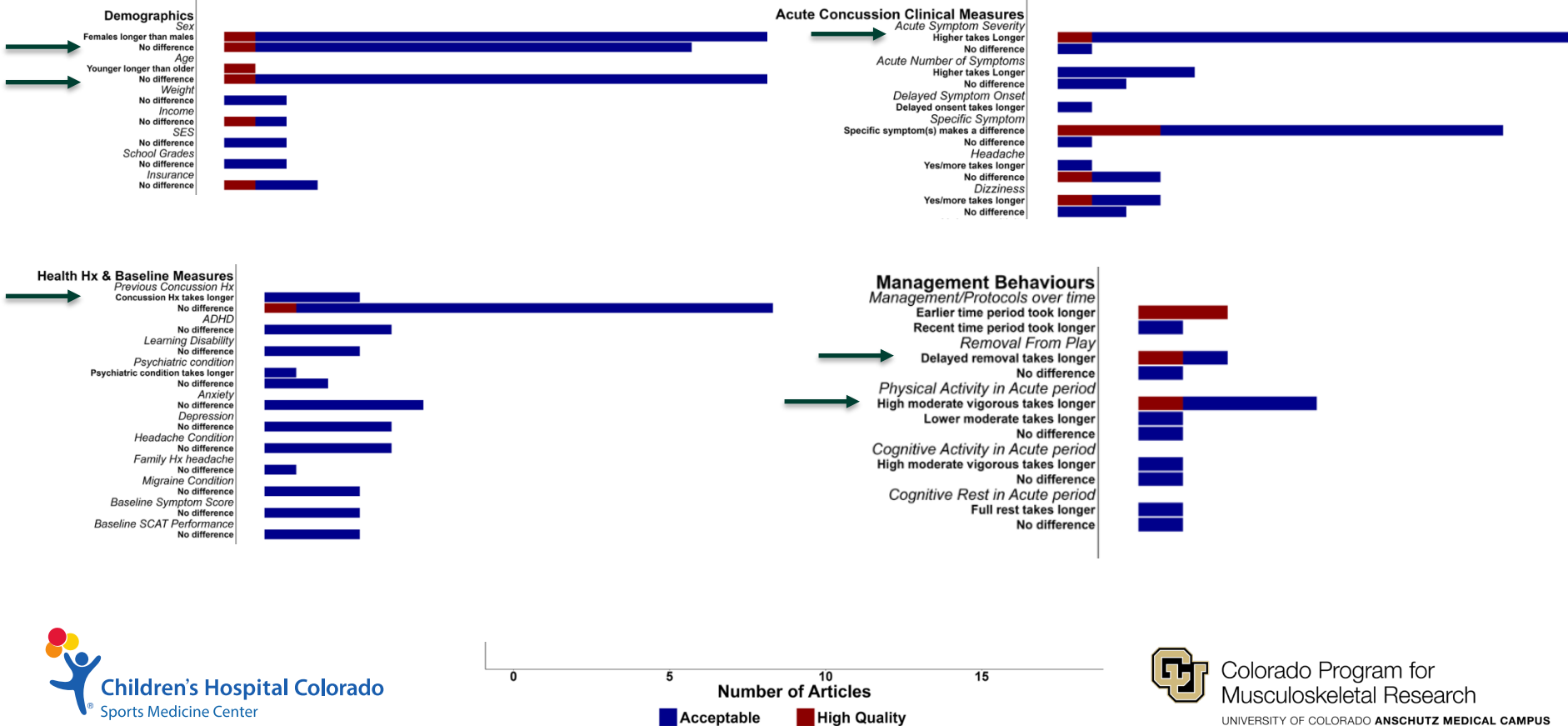
Return to Sport

Step	Exercise Strategy	Activity at Each Step	Goal
1	Symptom-limited activity.	Daily activities that do not exacerbate symptoms (e.g., walking).	Gradual reintroduction of work/school.
2	Aerobic exercise 2A – Light (up to approx. 55% max HR) then 2B – Moderate (up to approximately 70% max HR)	Stationary cycling or walking at slow to medium pace. May start light resistance training that does not result in more than mild and brief exacerbation* of concussion symptoms.	Increase heart rate.
3	Individual sport-specific exercise NOTE: If sport-specific exercise involves any risk of head impact, medical determination of readiness should occur prior to step 3.	Sport-specific training away from the team environment (e.g., running, change of direction and/or individual training drills away from the team environment). No activities at risk of head impact.	Add movement, change of direction.
Steps 4-6 should begin after resolution of any symptoms, abnormalities in cognitive function, and any other clinical findings related to the current concussion, including with and after physical exertion.			
4	Non-contact training drills.	Exercise to high intensity including more challenging training drills (e.g., passing drills, multiplayer training). Can integrate into team environment.	Resume usual intensity of exercise, coordination, and increased thinking.
5	Full contact practice.	Participate in normal training activities.	Restore confidence and assess functional skills by coaching staff.
6	Return to sport.	Normal game play.	

Return to Learn

Step	Mental Activity	Activity at Each Step	Goal
1	Daily activities that do not result in more than a mild exacerbation* of symptoms related to the current concussion.	Typical activities during the day (e.g., reading) while minimizing screen time. Start with 5–15 min at a time and increase gradually.	Gradual return to typical activities.
2	School activities.	Homework, reading, or other cognitive activities outside of the classroom.	Increase tolerance to cognitive work.
3	Return to school part time.	Gradual introduction of schoolwork. May need to start with a partial school day or with greater access to rest breaks during the day.	Increase academic activities.
4	Return to school full time.	Gradually progress school activities until a full day can be tolerated without more than mild* symptom exacerbation.	Return to full academic activities and catch up on missed work.

What Has Changed? Prognosis



What Has Changed? Prognosis

- Most established predictors of prolonged recovery:
 - **Continuing to play after the injury**
 - **Delayed access to healthcare**
- Consider pre-morbid and post-morbid factors that may affect recovery (depression, anxiety, migraine)
- Most athletes will return to learn (93%) within 10 days with no academic support
- Over the past two decades, athletes have taken longer to become symptom free and return to sport

CHCO SMC: Evidence

36 original data publications cited in Amsterdam consensus/review documents emanating from Children's Hospital Colorado

- SCAT6 / Child SCAT6
- Discontinuing participation in contact/collision sports
- Clinical recovery- RTS/RTL
- Role of biomarkers
- Rest/exercise
- Prevention
- On-field/acute assessment
- Office assessment



Summary

- The SCAT6 should be used within 72 hours of injury, SCOAT6 in the following weeks
- Return-to-learn and return-to-sport strategies have been updated based on evolving evidence.
- Strong evidence exists regarding the benefits of physical activity as an early intervention.
- Limited evidence exists on SRC in patients aged 5–12 years.

Objectives

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- 2. To describe the latest evidence regarding rest, physical activity, and exercise following concussion.**
3. To describe the latest evidence regarding sleep after concussion.

Exercise/Physical Activity: Not Harmful

Table 2 Return-to-sport (RTS) strategy—each step typically takes a minimum of 24 hours

Step	Exercise strategy	Activity at each step	Goal
1	Symptom-limited activity	Daily activities that do not exacerbate symptoms (eg, walking).	Gradual reintroduction of work/school
2	Aerobic exercise 2A—Light (up to approximately 55% maxHR) then 2B—Moderate (up to approximately 70% maxHR)	Stationary cycling or walking at slow to medium pace. May start light resistance training that does not result in more than mild and brief exacerbation* of concussion symptoms.	Increase heart rate
3	Individual sport-specific exercise Note: If sport-specific training involves any risk of inadvertent head impact, medical clearance should occur prior to Step 3	Sport-specific training away from the team environment (eg, running, change of direction and/or individual training drills away from the team environment). No activities at risk of head impact.	Add movement, change of direction
Steps 4–6 should begin after the resolution of any symptoms, abnormalities in cognitive function and any other clinical findings related to the current concussion, including with and after physical exertion.			
4	Non-contact training drills	Exercise to high intensity including more challenging training drills (eg, passing drills, multiplayer training) can integrate into a team environment.	Resume usual intensity of exercise, coordination and increased thinking
5	Full contact practice	Participate in normal training activities.	Restore confidence and assess functional skills by coaching staff
6	Return to sport	Normal game play.	

*Mild and brief exacerbation of symptoms (ie, an increase of no more than 2 points on a 0–10 point scale for less than an hour when compared with the baseline value reported prior to physical activity). Athletes may begin Step 1 (ie, symptom-limited activity) within 24 hours of injury, with progression through each subsequent step typically taking a minimum of 24 hours. If more than mild exacerbation of symptoms (ie, more than 2 points on a 0–10 scale) occurs during Steps 1–3, the athlete should stop and attempt to exercise the next day. Athletes experiencing concussion-related symptoms during Steps 4–6 should return to Step 3 to establish full resolution of symptoms with exertion before engaging in at-risk activities. Written determination of readiness to RTS should be provided by an HCP before unrestricted RTS as directed by local laws and/or sporting regulations.
HCP, healthcare professional; maxHR, predicted maximal heart rate according to age (ie, 220-age).

Patricios et al., BJSM, 2023

Exercise Can Help Accelerate Recovery (Group-Level)

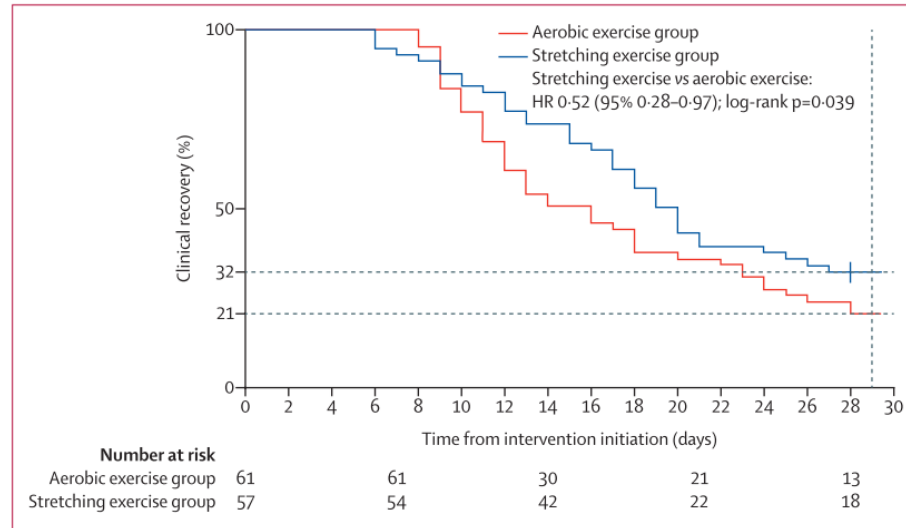


Figure 2: Kaplan-Meier survival curves stratified by intervention group
Dashed lines represent percentage of sample not recovered by day 29 for each intervention. HR=hazard ratio.

Multi-site study: early treatment with individualized targeted heart rate, subsymptom threshold aerobic exercise **accelerated recovery** and **reduced the risk** of persistent post-concussive symptoms

Leddy et al., 2021, Lancet Child Adoles Health

Exercise/Activity Recommendations

What do we do with this information?

Concussion  Recovery

Physical Activity/Exercise Recommendation

What type?

How much?

When to stop?

What to tell patients?

Is it working?

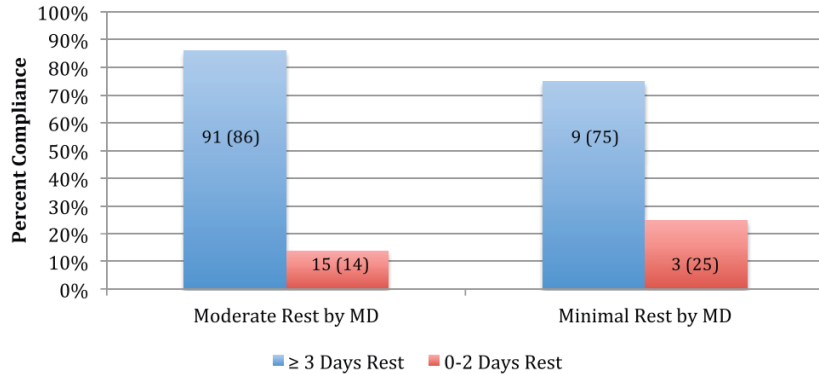
When to adjust?

How to ensure adherence?

Howell et al., Med Sci Sport Exer 2019

Adolescents and Adherence

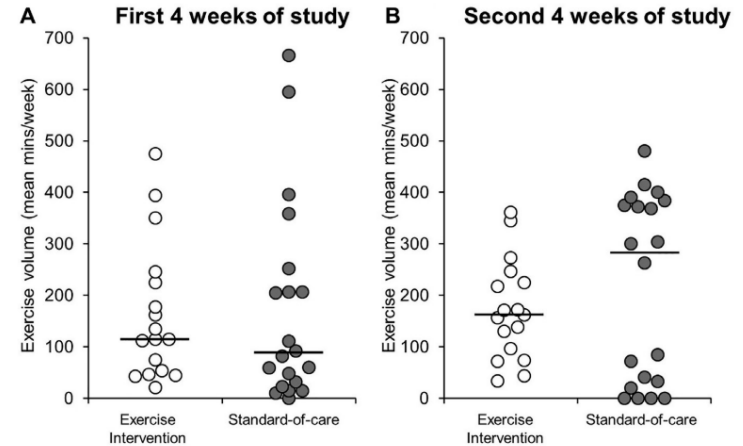
Rest



Patients take a similar amount of rest regardless of what their treating ED physician prescribes

Root et al., Clin Peds, 2019

Exercise



Patients randomized to an individualized exercise recommendation (100 min/week) exercised at a similar volume as those not provided a recommendation.

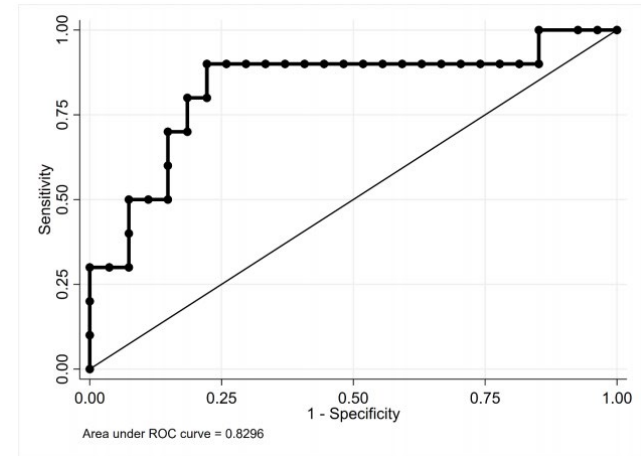
Howell et al., Am J Sports Med, 2021

Exercise Volume

Outcome	Control (n = 171)	Intervention (n = 178)	Δ 95% CI
PCS at 30 days (n,%)	23 (13.4%)	26 (14.6%)	1.2% (-6.2% to 8.5%)
Median (IQR) RPCQ at 7 days	20 (12 to 30)	19 (10 to 30)	1 (-3 to 4)
Median (IQR) RPCQ at 14 days	16 (6 to 23)	16 (6.8 to 22.3)	0 (-4 to 2)
Median (IQR) RPCQ at 30 days	14 (4.5 to 19)	13 (3 to 21)	1 (-1 to 4)
Median (IQR) number of missed days of school or work within 30 days	2 (0 to 6)	2 (0 to 5)	0 (0 to 1)

RCT: No symptom or recovery differences among those prescribed 30 min daily light exercise vs. gradual return to exercise after symptom resolution

Varner et al., Acad Emer Med, 2020



Symptom resolution after 4 weeks of study: optimal cut point =

160 min/week aerobic exercise

Classification accuracy = 81%

Sensitivity: 90%

Specificity: 78%

Howell et al., Am J Sports Med, 2021

Early Intervention in High-Risk Patients

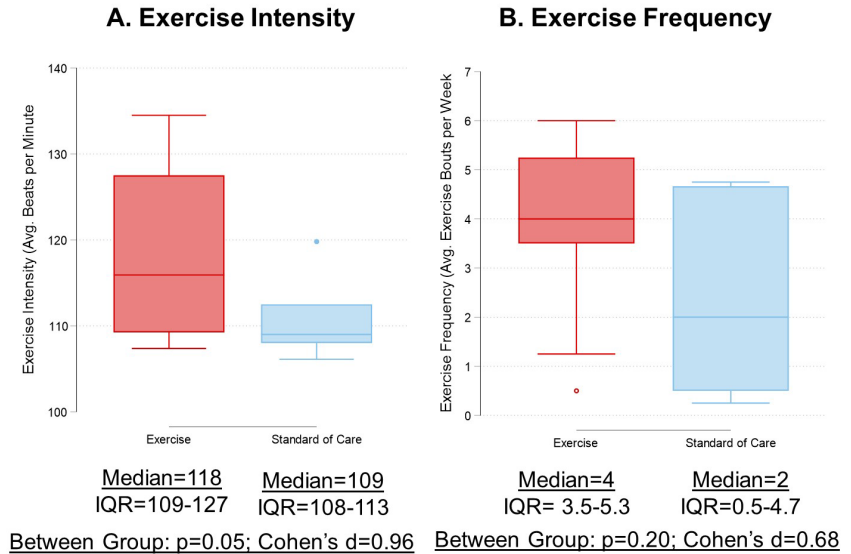
Can early aerobic exercise reduce PPCS risk for those who present at moderate-high risk?
(5P Risk Score ≥ 6)

86% (6/7) – SOC \rightarrow PPCS

44% (4/9) – Exercise Rx \rightarrow PPCS

Relative risk = 0.52 (0.34 – 1.36)

Number needed to treat = 2.4



Intervention led to behavioral change

Howell et al., PT in Sport, 2022



Moderate-to-Vigorous Physical Activity (MVPA)

An easily understood patient target?

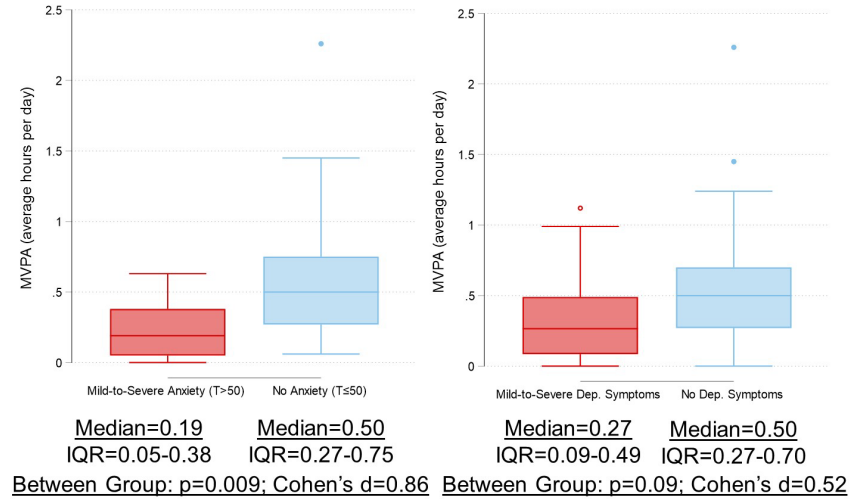
**Global health: ~30 mins
MVPA/day**

Applied to concussion recovery:

- **>30 minutes/day of MVPA/day = faster symptom recovery**
- **More MVPA/Day → Less Anxiety**

A. Anxiety

B. Depressive Symptoms



Smulligan et al, In Review



Not All Physical Activity is Equal

<i>Activity Replaced</i>	<i>Activity Added</i>	
	Moderate-to-Vigorous Activity	
	β	95% CI
Sedentary Behavior		
Time to symptom resolution (days)	-6.46	-10.71, -2.20
Time to RTP clearance (days)	-5.14	-9.53, -0.74

Replacing **10-min/day** of sedentary behavior with **10-min/day** of MVPA was associated with a 6.5 day decrease in symptom resolution time and 5.1 day decrease in RTP time (N=41)



Barriers to Physical Activity

- Initial dizziness ratings predicted physical activity in the subsequent 2 weeks after initial evaluation
- Patients may self-limit PA due to specific symptoms
- Treating dizziness may allow patient to exercise more

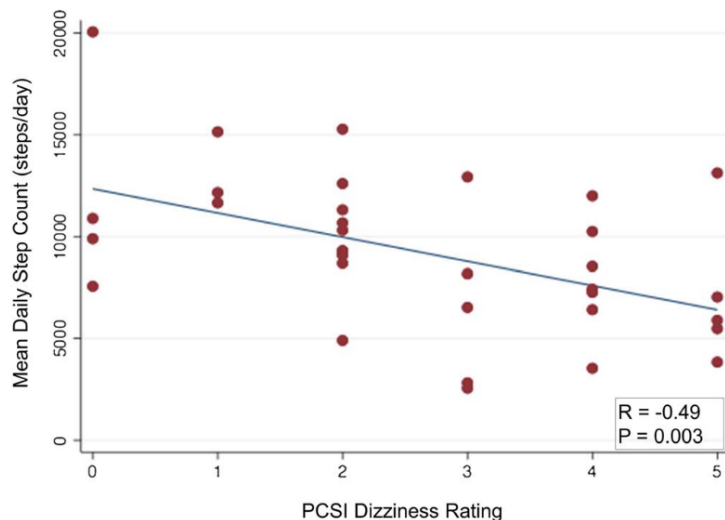
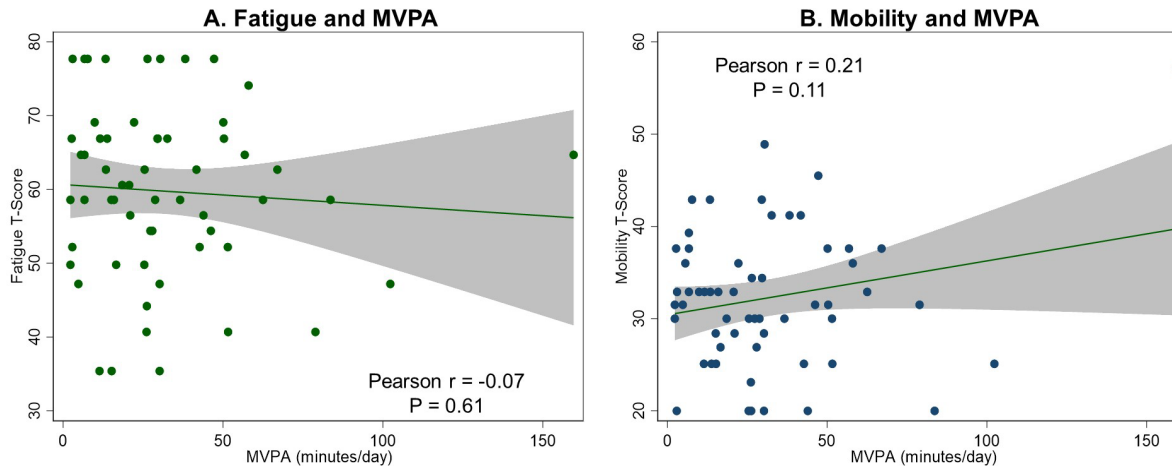


FIGURE 1—Scatterplot and line of best fit of the relationship between PCSI dizziness rating obtained at the initial evaluation (≤ 14 d after concussion) and mean daily step count in the subsequent 2 wk after the initial evaluation. PCSI rating range is 0–6. The highest participant dizziness rating was 5 out of 6.

Smulligan et al., Med Sci Sport Exer, 2022



Fatigue and Mobility Limit MVPA



After adjusting for sex, time, adherence, and symptom severity, **more severe fatigue** and **worse mobility** predicted **less MVPA time/day** over the following two weeks

Clinical Takeaways

- Understand patient adherence and potential barriers or motivations to exercise
 - What are patients doing in real life?
- Early physical activity and exercise goals should consider:
 - Patient preference (adherence/motivation)
 - Feasibility
 - Stage of injury
 - Clinical goals
 - Balancing frequency/intensity

Objectives

1. To provide an overall update from the 6th International Consensus Statement on Concussion in Sport.
2. To describe the latest evidence regarding rest, physical activity, and exercise following concussion.
3. **To describe the latest evidence regarding sleep after concussion.**



Sleep Influences Quality of Life

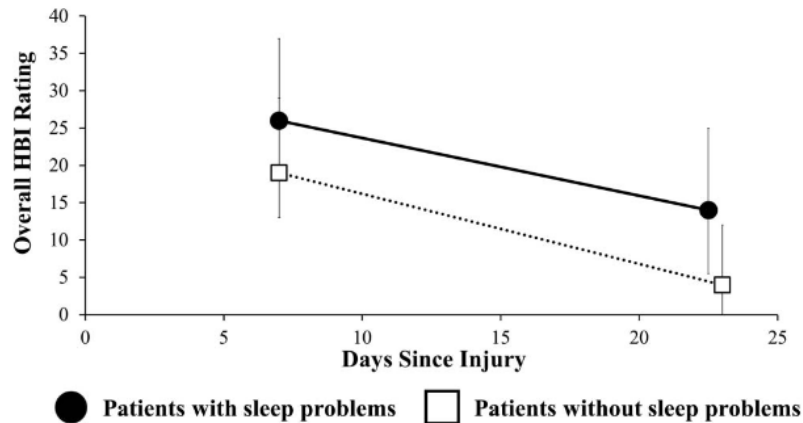
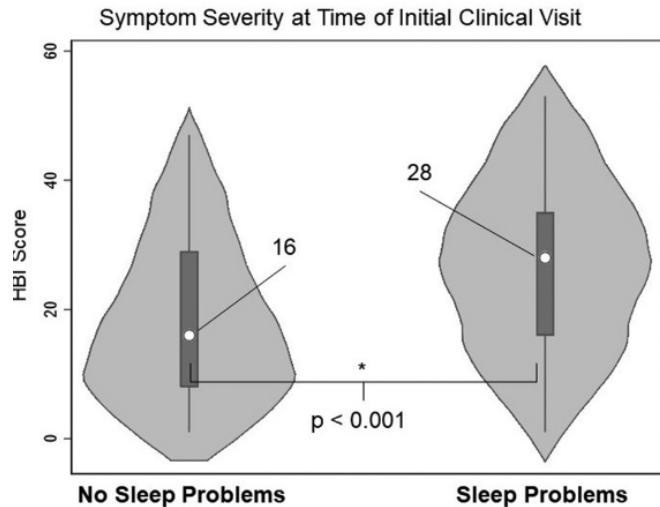
Table 5. Multivariable Results for the Effect of Sleep Quality (Predictor Variable) on Quality of Life (Outcome Variable) When Adjusting for Age and Sex.

Outcome Variable	β Coefficient	Standard Error	95% Confidence Interval	P
Physical function mobility ^a	0.034	0.013	0.007 to 0.060	.01
Anxiety ^a	0.391	0.065	0.263 to 0.520	<.001
Depressive symptoms ^a	0.456	0.056	0.346 to 0.565	<.001
Fatigue ^a	0.537	0.050	0.438 to 0.636	<.001
Peer relationships	-0.159	0.098	-0.352 to 0.033	.10
Pain interference ^a	0.247	0.065	0.119 to 0.375	<.001
Pain intensity ^a	0.103	0.038	0.029 to 0.177	.006

^a95% confidence interval does not cross zero.

Among adolescent athletes (uninjured), poor sleep quality was associated with worse **mobility, anxiety, depressive symptoms, fatigue, and pain interference.**

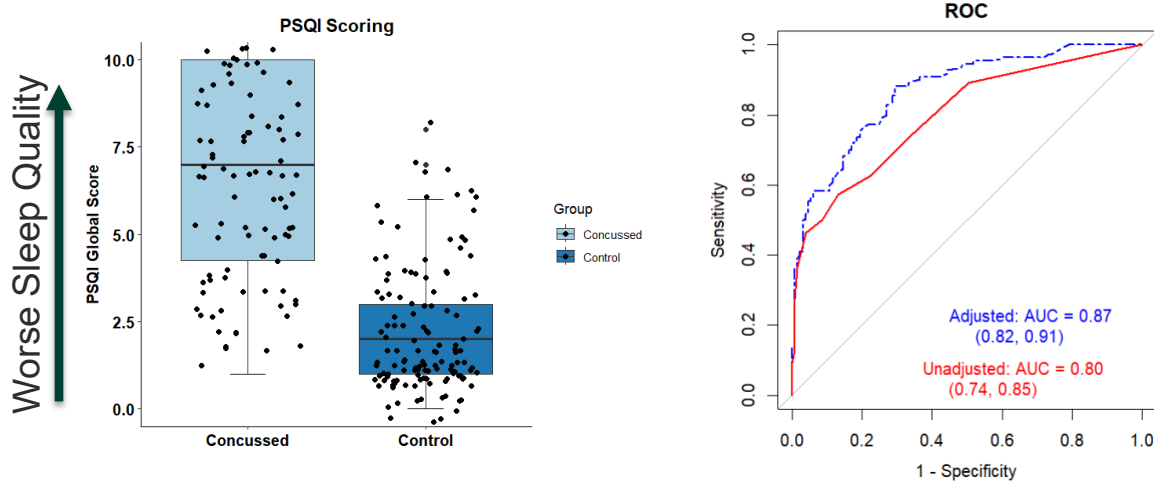
Post-Concussion Sleep Problems



Self-reported sleep problems after concussion are associated with **higher symptom severity**, **worse postural stability**, and **longer symptom duration**.



Poor Sleep Quality After Concussion



Adolescents with concussion (N=147) reported worse sleep quality than uninjured controls (N=129). PSQI ratings adjusted for age, sex, concussion and anxiety/depression history were diagnostically useful. A clinical cutoff of 4 was most appropriate in this sample (not 5, as previously used).

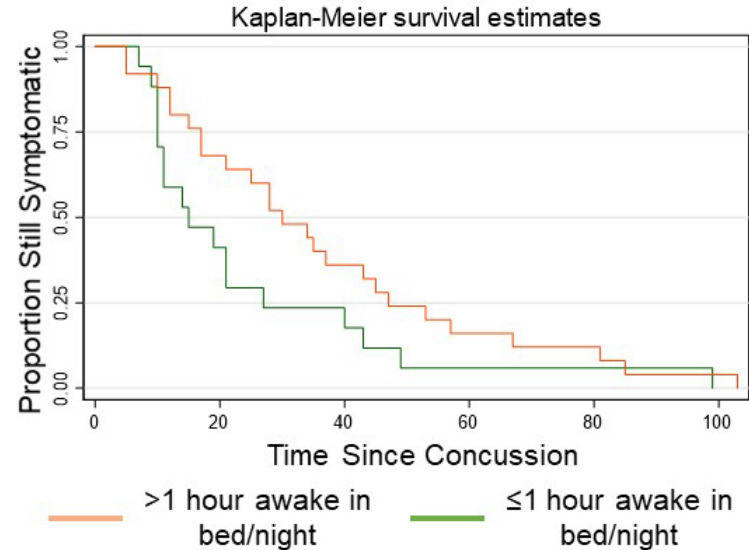


Insomnia as a Prognostic Measure

Less time in bed awake at night associated with significantly faster symptom resolution time

Hazard Ratio = 0.35 [0.12, 0.99]

C. Time in Bed Awake– Symptom Resolution Time

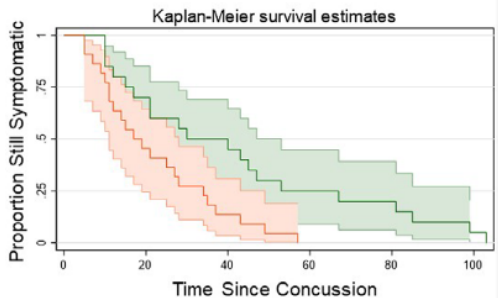


Neely et al., PMR, 2023



Physical Activity and Insomnia

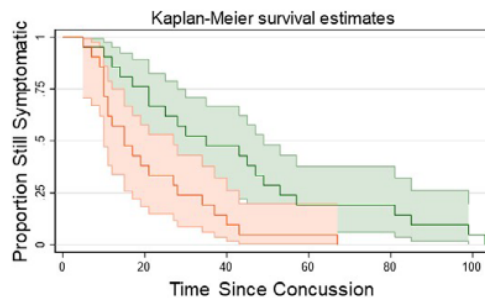
(A) Physical Activity – Symptom Resolution Time



— ≥ 8.96 1K steps/day — < 8.96 1K steps/day

Hazard Ratio= 1.12, 95% CI= 1.02, 1.22; $p = .019$

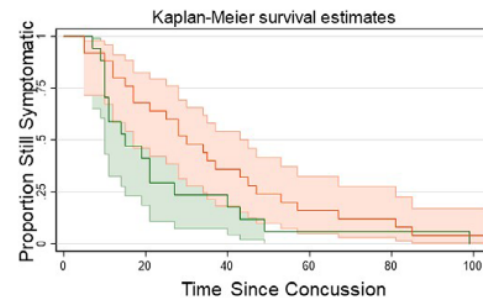
(B) Exercise Frequency – Symptom Resolution Time



— ≥ 4 days/week exercising — < 4 days/week exercising

Hazard Ratio= 1.29, 95% CI= 1.11, 1.51; $p = .001$

(C) Time in Bed Awake – Symptom Resolution Time



— > 1 hour awake in bed/night — ≤ 1 hour awake in bed/night

Hazard Ratio= 0.35, 95% CI= 0.12, 0.99; $p = .049$

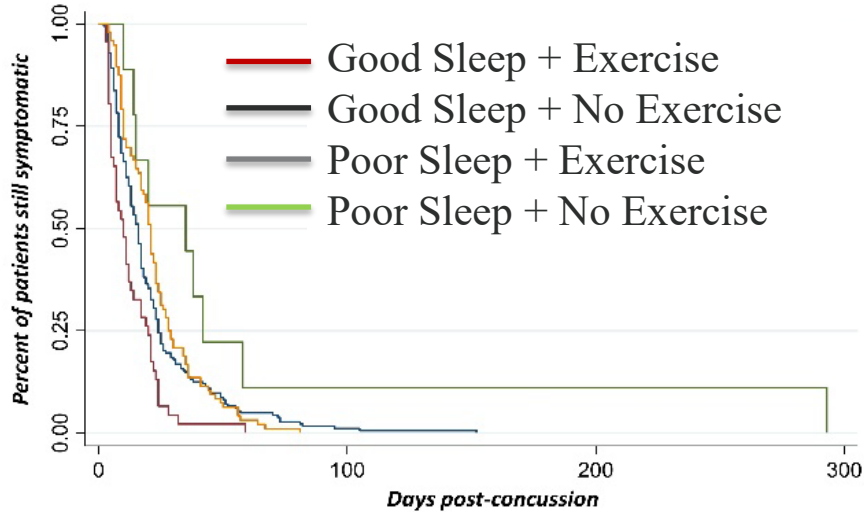
When modeled together, **only greater exercise frequency** was independently associated with faster concussion symptom resolution time.

(Hazard ratio = 1.31, 95% confidence interval [CI] = 1.08, 1.59, $p = 0.006$)

Neely et al., PMR, 2023



MVPA and Sleep After Concussion



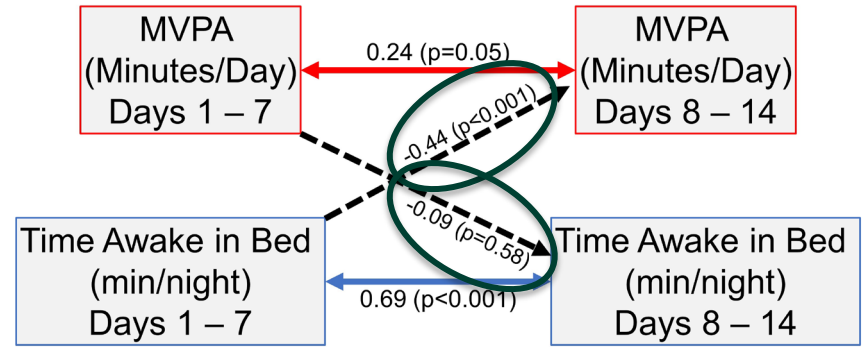
Those who reported **exercising + sleeping well** after concussion recovered **faster** compared to those exhibiting **one or neither behavior**.

Hazard ratios (relative to good sleep + exercise)=

Good Sleep + No Exercise = 1.76 (1.27-2.44)

Poor Sleep + Exercise = 2.02 (1.42-2.88)

Poor Sleep + No Exercise = 3.89 (1.81-8.33)

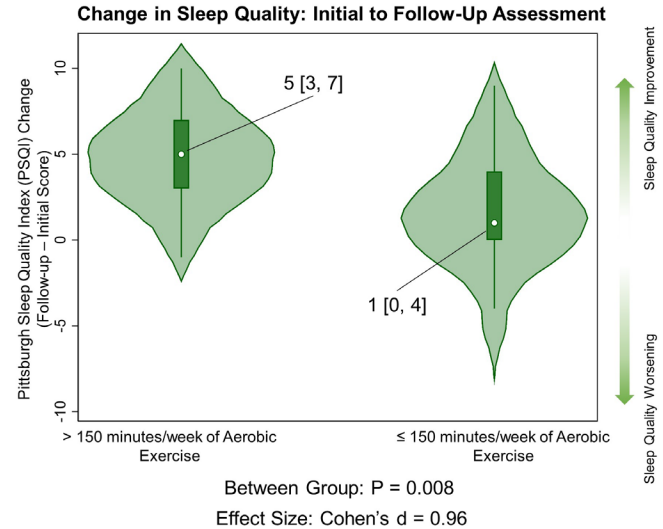
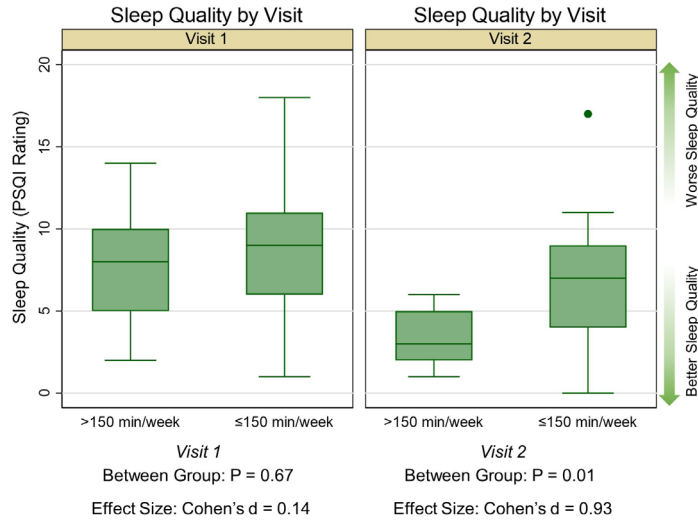


Cross-lagged panel model describing cross-lagged effects (dashed arrows) and auto-regressive effects (solid arrows)

More insomnia (time in bed awake) during Days 1-7 predicted less subsequent MVPA time

Wingerson et al, In Review

Exercise Volume and Sleep Quality



Exercising at a volume that exceeds 150 min/week after concussion was associated with significant sleep quality improvements across time, with a large effect size

Howell et al, JHTR, 2023

Take Home: Sleep After Concussion

- Sleep quality is associated with various domains of quality of life
- Sleep disruptions can lead to worse/prolonged symptoms and/or functional disturbances
- Sleep and exercise have a unique but likely complementary role in concussion recovery
- Specific recommendations for sleep health after concussion are vague and undefined (encourage healthy lifestyle habits)

Overall Summary

The latest evidence and management recommendations are summarized in the Amsterdam Consensus documents.

Many limitations in our understanding still exist.

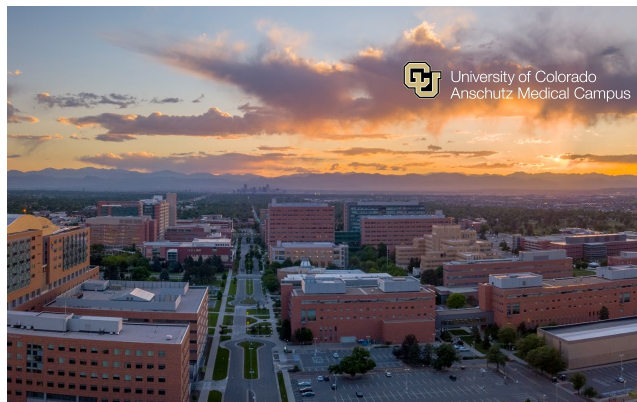
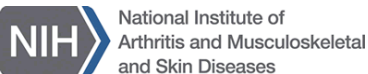
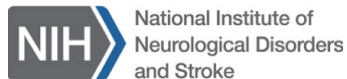
Aerobic exercise volume/intensity should be individualized to treatment goals.

Adherence likely plays a key role in treatment response.

Sleep problems after concussion are common, influence other domains, and interact with physical activity/exercise.

Sleep health should be a priority in acute concussion management.

FUNDING SOURCES



**Colorado Concussion
Research Laboratory
Website**



Lab Team Members (L to R)

- Makenna Hemmerle, MS
- Madison Brna, BS
- Mathew Wingerson, MS
- Samuel Messenger, MS, ATC
- Josh Kniss, PT, DPT
- Kate Smulligan, PT, DPT
- Lindsey Kemp, BS
- David Howell, PhD, ATC
- Julie Wilson, MD
- Cat Donahue, PhD, ATC
- Not Pictured*
- Lindsey Kemp, BS

