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

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Colorado Program for Musculoskeletal Research UNIVERSITY OF COLORADO ANSCHUTZ MEDICAL CAMPUS

Disclosures

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Children's Hospital Colorado Sports Medicine Center





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, R Cantu, 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/bjsm.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 \parallel ; Mick Molloy, MD \P ; Robert Cantu, MD††#

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4th (2012)

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

Paul McCroy,¹ Willem H Meeuwisse,^{2,3} Mark Aubry,^{4,5,6} Bob Cantu,^{7,8} Jiří Dvořák,^{9,(0,1)} 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,⁵⁵ Richard G Ellenboegn,^{26,27} Kevin Guskiewicz,²⁸ Stanley A Herring,^{29,30} Grant L Iverson,³¹ Barry D Jordan,^{32,33,34} James Kissick,^{6,35,8,33} Michael McCrea,³⁸ Andrew S McIntosh,^{39,40,41} David Maddocks,⁴² Michael Makdisi,^{45,44} Aura Purcell,^{45,46} Margot Putukian,^{47,48} Kathyn Schneider,⁴⁹ Charles H Tator,^{50,51,52,53} Michael Turrer⁵⁴

5th (2016)

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

Paul McCrory, ¹Willem Meeuwisse,² Jiří Dvorak,^{3,4} Mark Aubry,⁵ Julian Bailes,⁶ Steven Broglio,⁷ Robert C Cantu,¹ David Cassidy, ² Ruben J Echemendia,^{10,11} Rudy J Castellani,¹² Gavin A Davis,^{13,14} Richtan Ellenbogen,¹⁵ Zarolyn Emery,¹⁶ Lars Engebretsen,¹⁷ Nina Feddermann-Demont,^{18,19} Christopher C Giza,^{30,21} Kevin M Guskiewicz,²² Stanley Herring,²³ Grant L Verson,²⁴ Karen M, Johnston,²⁵ James Kissić,²⁴ Bifferiy Kutcher,²⁷ John J Leddy,³² David Maddock,³⁹ Michael Makdissi,^{30,31} Geoff Manley,³² Michael McCrea,³³ William P Meehan,^{34,35} Sinji Nagahiro,³⁵ Jon Patricios,^{37,38} Margot Putukian,³⁹ Kathryn J Schneider,⁴⁰ Allen Sills,^{41,42} Charles H Tarot,^{34,44} Michael Turnef,⁴⁷ Pieter E Vos ⁶⁶

6th (2022)

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

Jon S Patricios ⁹, ¹ Kathnyn J Schneider ⁹, ² Jin Dvorak ⁹, ³ Osman Hassan Ahmed ⁴, ⁴S Cheri Blauwet ⁹, ⁶R Obbert C Cantu, ^{8,9} Gavin A Davis ^{9,101} Ruben J Echemendia ^{9,12,13} Michael Makdissi, ^{14,15} Michael McNamee, ^{16,17} Steven Broglio ^{9,18} Carolyn A Emery ^{9,2} Nina Feddemann-Demont, ^{13,20} Gordon Ward Huller ^{9,17} (hnistopher C Giza, ^{22,23} Kevin M Guskiewicz, ²⁴ Brian Hainline ^{9,25} Grant Liverson ^{9,8,27} Jeffrey S Kutcher,⁷⁸ John J Leddy ^{9,20} David Maddocks, ³⁰ Geoff Manley ^{9,31} Michael McCrea ^{9,12} Laux K Purcell,²⁴ Margot Putukian ^{9,41} Haruhiko Sato ^{9,35} Markku P Tuominen,⁸⁴ Michael Turner ^{9,31,38} Keith Oven Yeates ^{9,39}





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What is the Result?

A comprehensive <u>consensus</u> <u>statement</u> on concussion in sport

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

In depth <u>reviews</u> 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)







Concussion Assessment Tools

Initial goal: develop a uniform method to diagnose concussion on the sideline SCAT5: Used in contexts outside of this original goal Need for an office-based assessment (SCOAT6)

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5th (2016)

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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 📃]				Alternat	Alternate Lists		
List A	Tri	al 1	Tri	al 2	Tria	al 3	List B	List C		
Jacket	0	1	0	1	0	1	Finger	Baby		
Arrow	0	1	0	1	0	1	Penny	Monkey		
Pepper	0	1	0	1	0	1	Blanket	Perfume		
Cotton	0	1	0	1	0	1	Lemon	Sunset		
Movie	0	1	0	1	0	1	Insect	Iron		
Dollar	0	1	0	1	0	1	Candle	Elbow		
Honey	0	1	0	1	0	1	Paper	Apple		
Mirror	0	1	0	1	0	1	Sugar	Carpet		
Saddle	0	1	0	1	0	1	Sandwich	Saddle		
Anchor	0	1	0	1	0	1	Wagon	Bubble		
Trial Total										
Immediate Memory Score		of 30 Time Las				t Trial Completed:				

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	93	86	72	65	58	51	44	37	Errors	Tir

Dual-task tandem gait





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CHCO Evidence in the SCAT6

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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!"

Tandem Gait^{5,6,7}

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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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

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Child SCA	T5 .	FOR CH	SPORT CONCUSSION ASSESSMENT TOOL FOR CHILDREN AGES 5 TO 12 YEARS FOR USE BY MEDICAL PROFESSIONALS ONLY		
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Patient details					

DOB:	
Address:	
ID number:	
Examiner	

WHAT IS THE CHILD SCAT5?

The Child SCATS is a standardized tool for evaluating concussions designed for use by physicians and licensed restlincare professionals'.

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 Concussion signs and symptoms evolve over time and is important to concider repeat evaluation in the assessment of concussion.
 The diagnosis of a concussion is a clinical judgment, made by a metical professional. The CNI SCATS should

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averting post-injury lest scores, but not required for the petrolegies of the Child SCATS and

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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 b at 100, you would say 100, 97, 94, 91. Let's practise counting. Starting with 95, count l "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 (<u>SCOAT6</u>)

New tool, designed for assessment 7-30 days postconcussion

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





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What Has Changed? Biomarkers

Table 1 Fluid biomarkers to detect and monitor recovery

Biomarkers demonstrating ability to discriminate between SRC and controls

- AMPAR¹⁹
 Aβ-42^{20 21}
- Ap-42
 BLBP²²
- BLBP
- C-proteins²³
- Extracellular-vesicle associated and depleted cytokines³²
- ► GFAP^{24–27}
- IgA autoantibodies⁴⁹

- 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})

- PRDX-6^{28 41}
- ► QUIN and KYNA⁴²⁻⁴⁴
- \$100B^{20 31 40 45}
- SNTF^{18 31}
- ► T-tau^{20 24-28 41 45-47} and tau-C⁴⁸
- ► UCH-L1^{21 26 31 40}

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

Return to Learn

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.	Step	Mental Activity	Activity at Each Step	Goal
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.	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.
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.	2	School activities.	Homework, reading, or other cognitive activities outside of the classroom.	Increase tolerance to cognitive work.
Steps 4-6 should begin after resolution of any symptoms, abnormalities in cognitive function, and any other clinical findings related to th current concussion, including with and after physical exertion.		clinical findings related to the			Gradual introduction of schoolwork. May		
4	Non-contact training drills.	Exercise to high intensity including more challenging training drills (e.g., passing drills, multiplayer training). Can integrate	Resume usual intensity of exercise, coordination, and increased thinking.	3	Return to school part time.	with greater access to rest breaks during the day.	Increase academic activities.
5	Full contact practice.	into team environment. Participate in normal training activities.	Restore confidence and assess functional skills by coaching staff.	4	Return to school full time.	Gradually progress school activities until a full day can be tolerated without more than mildt sumptom ovacorbation	Return to full academic activities and catch up on missed work.
6	Return to sport.	Normal game play.				mild symptom exacerbation.	







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 <u>Children's Hospital</u> <u>Colorado</u>

- 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







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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

- 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.







Exercise/Physical Activity: Not Harmful

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			
C	Return to sport	Normal game play.				

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).





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Patricios et al., BJSM, 2023



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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





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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?





Colorado Concussion Research Laboratory UNIVERSITY OF COLORADO ANSCHUTZ MEDICAL CAMPUS Howell et al., Med Sci Sport Exer 2019



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Adolescents and Adherence

Rest



в

First 4 weeks of study





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

700 700 mins/week) 200 200 ₹600 SC 500 0 (mean ueau 400 400 0 8 0 volume volume 300 300 Exercise 002 Exercise 100 200 100 00 0 0 Exercise Standard-of-care Exercise Standard-of-care Intervention Intervention

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

Root et al., Clin Peds, 2019

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Howell et al., Am J Sports Med, 2021

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Second 4 weeks of study

Exercise Volume

Outcome	Control (n = 171)	Intervention (n = 178)	∆ 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 <u>30 min daily light exercise</u> vs. <u>gradual return to exercise</u> after symptom resolution

Varner et al., Acad Emer Med, 2020





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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





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Moderate-to-Vigorous Physical Activity (MVPA)

Smulligan et al, In Review

Colorado Program for





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



Not All Physical Activity is Equal

	Activity Added	
	Moderate-to-Vigorous Activity	
Activity Replaced	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 <u>sedentary behavior</u> with **10-min/day** of <u>MVPA</u> was associated with a 6.5 day decrease in symptom resolution time and 5.1 day decrease in RTP time (N=41)





Wingerson et al, In Review



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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





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Fatigue and Mobility Limit MVPA



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





Hemmerle et al., In development



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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	Р
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**.





Potter et al., Clin Peds, 2019



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





Howell et al., CJSM, 2020

Magliato et al., J Child Neurol, 2023



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Poor Sleep Quality After Concussion



Adolescents with concussion (N=147) reported <u>worse sleep quality</u> than uninjured controls (N=129).

PSQI ratings adjusted for age, sex, concussion and anxiety/depression history were diagnostically useful.

A <u>clinical cutoff of 4</u> was most appropriate in this sample (not 5, as previously used).





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Insomnia as a Prognostic Measure

Less <u>time in bed awake at</u> <u>night</u> associated with significantly faster symptom resolution time

C. Time in Bed Awake– Symptom Resolution Time Kaplan-Meier survival estimates







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Physical Activity and Insomnia



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)





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MVPA and Sleep After Concussion





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



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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





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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)







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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.







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Colorado Clinical and Translational Sciences Institute (CCTSI)







Colorado Concussion Research Laboratory Website





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