



Sports-related concussion

What do we now?

Why is it important?



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Conflicts of interest



Disclosures

Member of the Concussion in Sport Group (CISG)



Definition & physiopathology

What is a concussion ?



Multiple definitions with some overlap (CDC, WHO, CISG, ACRM ...)

Common concepts:

- Traumatic event – type of traumatic brain injury (TBI)
- GCS score 13-15 (mild)
- Negative CT scan

Disagreements:

- Loss of consciousness + duration (<15/30/60 min)
- Post-traumatic amnesia + duration (5 min – 24h)
- **Clinical symptoms**

Sports-related concussion definition



Concussion in Sport Group (CISG)

International Sports Federations
Systematic reviews of the literature
Evidence- and expert-based recommendations



Sports-related concussion definition



Concussion in Sport Group (CISG) – 2023

Sport-related concussion is a traumatic brain injury caused by a direct blow to the head, neck or body resulting in an impulsive force being transmitted to the brain that occurs in sports and exercise-related activities. This initiates a neurotransmitter and metabolic cascade, with possible axonal injury, blood flow change and inflammation affecting the brain. Symptoms and signs may present immediately, or evolve over minutes or hours, and commonly resolve within days, but may be prolonged. No abnormality is seen on standard structural neuroimaging studies (computed tomography or magnetic resonance imaging T1- and T2-weighted images), but in the research setting, abnormalities may be present on functional, blood flow or metabolic imaging studies. Sport-related concussion results in a range of clinical symptoms and signs that may or may not involve loss of consciousness. The clinical symptoms and signs of concussion cannot be explained solely by (but may occur concomitantly with) drug, alcohol, or medication use, other injuries (such as cervical injuries, peripheral vestibular dysfunction) or other comorbidities (such as psychological factors or coexisting medical conditions).

Sports-related concussion definition



Concussion in Sport Group (CISG) – 2023

Sport-related concussion is a **traumatic brain injury** caused by a **direct blow to the head, neck or body** resulting in an impulsive force being transmitted to the brain that occurs in sports and exercise-related activities. This initiates a neurotransmitter and metabolic cascade, with possible axonal injury, blood flow change and inflammation affecting the brain. **Symptoms and signs may present immediately, or evolve over minutes or hours, and commonly resolve within days, but may be prolonged.** No abnormality is seen on standard structural neuroimaging studies (computed tomography or magnetic resonance imaging T1- and T2-weighted images), but in the research setting, abnormalities may be present on functional, blood flow or metabolic imaging studies. Sport-related concussion results in a range of clinical symptoms and signs that may or may not involve loss of consciousness. The clinical symptoms and signs of concussion cannot be explained solely by (but may occur concomitantly with) drug, alcohol, or medication use, other injuries (such as cervical injuries, peripheral vestibular dysfunction) or other comorbidities (such as psychological factors or coexisting medical conditions).

Sports-related concussion definition



Symptoms and signs of a concussion

Symptom	
Headaches	“Don’t feel right”
Pressure in head	Difficulty concentrating
Neck pain	Difficulty remembering
Nausea or vomiting	Fatigue or low energy
Dizziness	Confusion
Blurred vision	Drowsiness
Balance problems	More emotional
Sensitivity to light	Irritability
Sensitivity to noise	Sadness
Feeling slowed down	Nervous or anxious
Feeling like “in a fog”	Trouble falling asleep (if applicable)

Observable Signs

- actual or suspected loss of consciousness
- seizure
- tonic posturing
- ataxia
- poor balance,
- confusion
- behavioural changes
- amnesia



Primarily based on neurometabolic cascade of events that involves bioenergetic challenges, cytoskeletal and axonal alterations, impairments in neurotransmission, vulnerability to delayed cell death and chronic dysfunction

1) Acute phase

Biomechanical injury → ionic flux alterations & indiscriminate glutamate (excitatory neurotransmitter) release

→ Need to restore homeostasis → overactivation of ionic pumps (ATP)

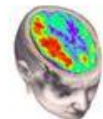
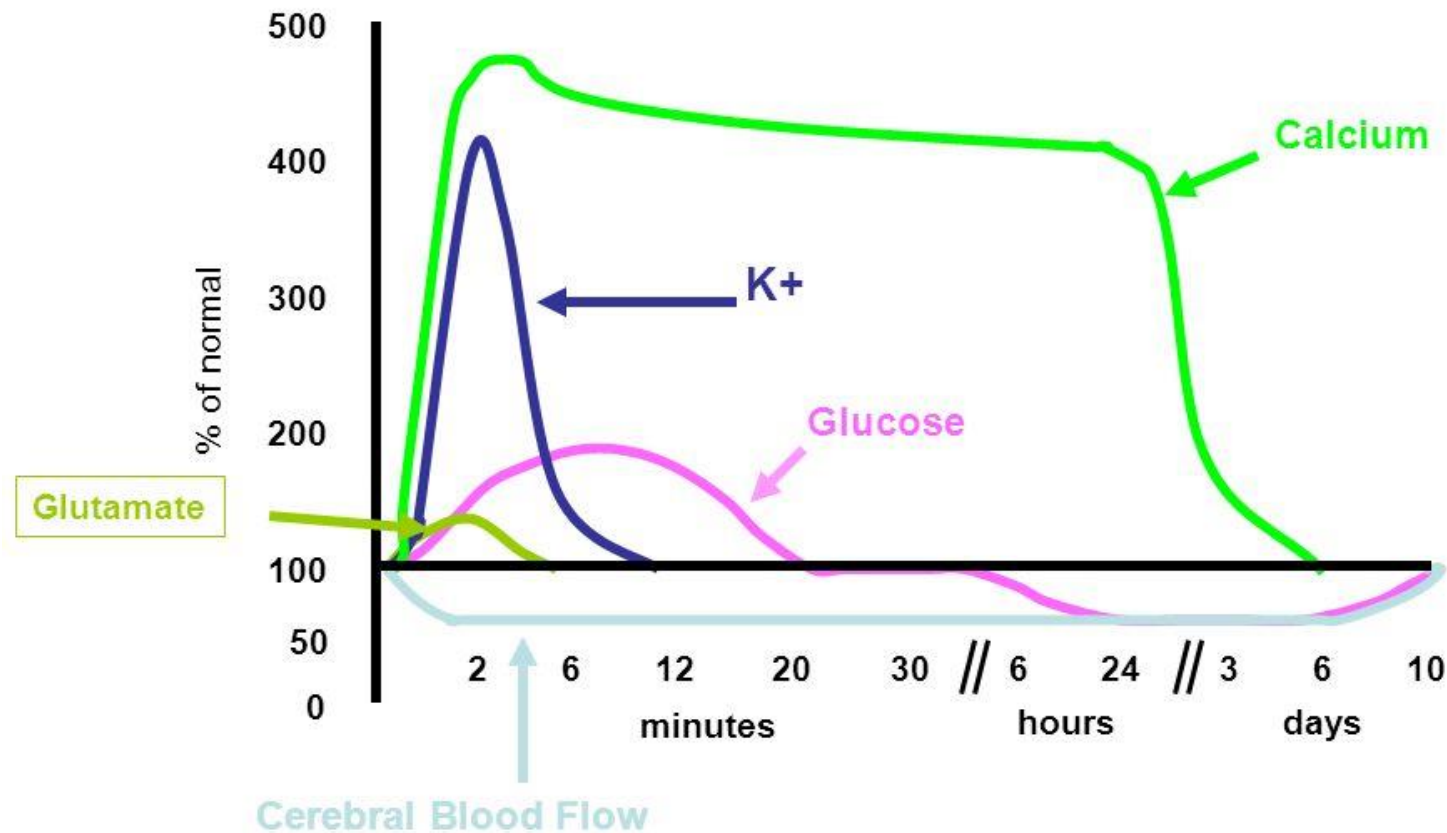
→ Depletion of intracellular energy reserves (hyperglycolysis)

→ Mismatch between energy supply and demand (metabolic uncoupling) = **energy crisis**



Neurometabolic Cascade Following Cerebral Concussion/MTBI

(Giza & Hovda, 2001)





02 **Diagnosis & management**



Concussion is a
CLINICAL DIAGNOSIS

No single tool validated
for diagnosis

1. Observation of the injury
mechanism:

➤ Traumatic

2. Symptoms

3. Physical signs

4. Cognitive impairment

Diagnosis: the new generation of SRC tools (2023)



SCAT6TM 

Sport Concussion Assessment Tool
For Adolescents (13 years +) & Adults

SCOAT6TM 

Sport Concussion Office Assessment Tool
For Adults & Adolescents (13 years +)

Child SCAT6TM 

Sport Concussion Assessment Tool
For Children Ages 8 to 12 Years

Child SCOAT6TM 

Sport Concussion Office Assessment Tool
For Children Ages 8 to 12 Years

CRT6TM 

Concussion Recognition Tool
To Help Identify Concussion in Children, Adolescents and Adults

Freely available: <https://www.concussioninsportgroup.com/scat-tools/>

Sport Concussion Assessment Tool (SCAT) 6

- Standardized, designed for healthcare professionals
- Acute phase (within 3 days – max 7 days post injury)
- Minimum 10-15 minutes

Immediate on-field assessment

Red flags

Consciousness

Cervical, oculomotor, memory

→ Screening for more severe lesions

Off-field assessment

Background

Symptoms

Cognitive assessment

Coordination & balance

→ Concussion identification & acute follow-up

Why is this screening important ?

Sport Concussion Assessment Tool 6 - SCAT6®

Étape 1: Signes Visibles	
Constaté en personne ☐	Observé sur vidéo ☐
Couché-e et immobile sur le terrain	O N
Chute sans protection sur le terrain	O N
Troubles de l'équilibre et de la démarche, manque de coordination motrice, ataxie (trébuchements, mouvements lents ou laborieux)	O N
Désorientation ou confusion, regard fixe ou réactivité limitée, ou incapacité à répondre adéquatement aux questions	O N
Regard vide ou sans expression	O N
Blessure au visage à la suite de l'impact à la tête	O N
Convulsions à la suite de l'impact	O N
Mécanisme de blessure à risques élevés (selon le sport pratiqué)	O N

Étape 2: Échelle de Glasgow	
L'échelle de Glasgow est habituellement utilisée une seule fois. Les colonnes supplémentaires servent à la surveillance au fil du temps, au besoin.	
Heure de l'évaluation: _____	
Évaluation: _____	
A la voix	
Spontanée	1 1 1
	2 2 2
	3 3 3
	4 4 4
Réponse Verbale (V)	
Absente	1 1 1
Sans Incompréhensibles	2 2 2
Mots Inappropriés	3 3 3
Confuse	4 4 4
Orientée	5 5 5
Réponse Motrice (M)	
Absente	1 1 1
Extension à la douleur	2 2 2
Flexion anormale à la douleur	3 3 3
Flexion ou retrait à la douleur	4 4 4
Localisée au site de douleur	5 5 5
Obéit aux ordres simples	6 6 6
Score à l'échelle de Glasgow (Y + V + M)	

Usage réservé exclusivement aux professionnels de santé

Encadré 1: Signaux d'Alarme
• Douleur ou sensibilité au cou • Crise d'épilepsie ou convulsions • Vision double • Perte de connaissance • Faiblesse, picotement ou sensation de brûlure dans plus d'un bras ou d'une jambe • Détérioration de l'état de conscience • Vomissements • Maux de tête sévères ou s'intensifiant • Agitation, agressivité ou combativité grandissante • Échelle de Glasgow <15 • Déformation visible du crâne

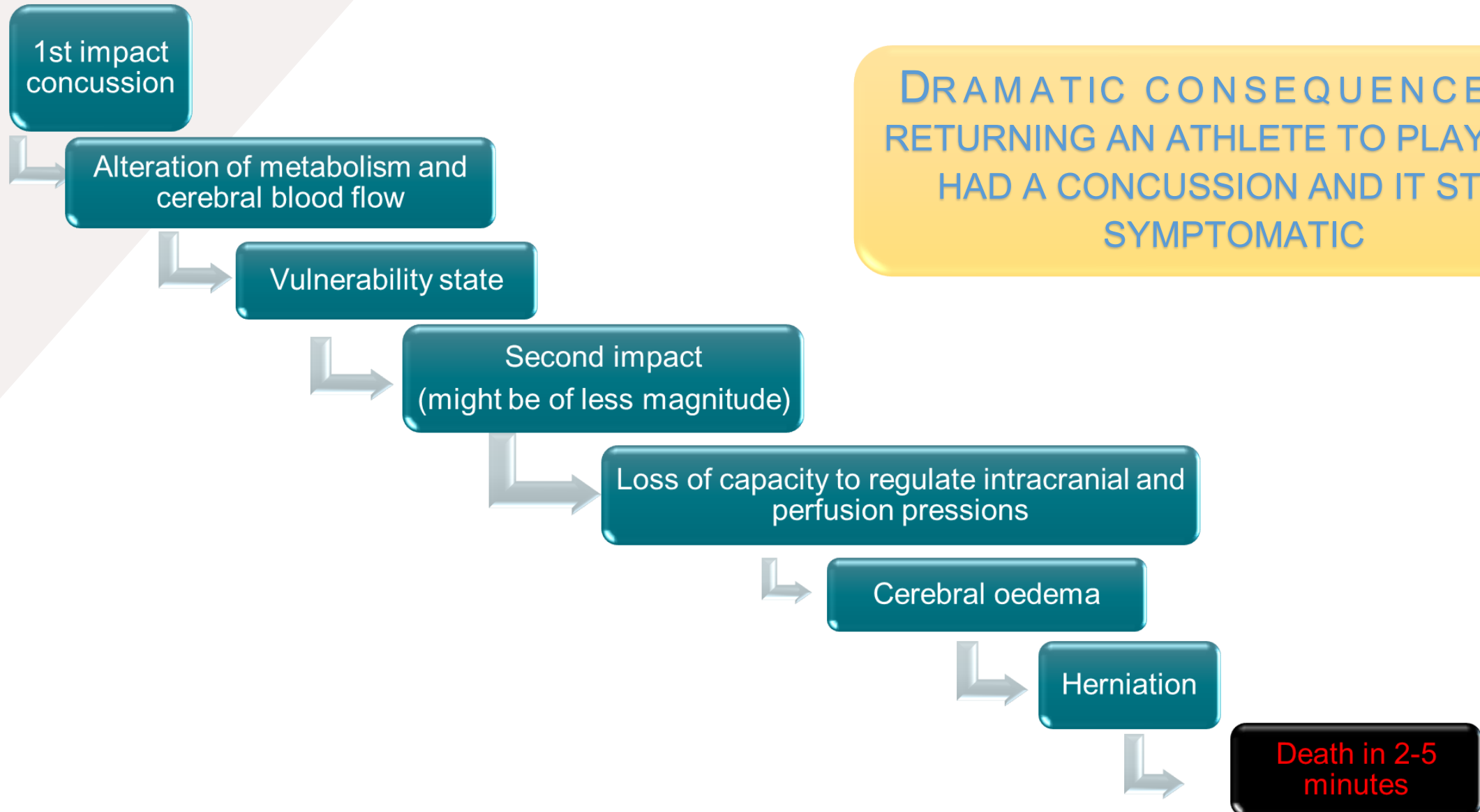
Étape 3: Évaluation de la colonne cervicale	
Si le patient n'est pas lucide ou entièrement conscient, il faut supposer une blessure à la colonne cervicale et des précautions doivent être prises afin de protéger la colonne vertébrale.	
Est-ce que l'athlète ressent de la douleur au cou au repos?	O N
Y a-t-il de la sensibilité à la palpation?	O N
S'il n'y a PAS de douleur au cou et de sensibilité, l'athlète a-t-il une amplitude ACTIVE de mouvement complète et sans douleur?	O N
La force et la sensation des membres sont-elles normales?	O N

Étape 4: Coordination et Examen Oculomoteur	
Coordination: Les résultats de l'épreuve doigt-nez sont-ils normaux pour les deux mains, avec les yeux ouverts et fermés?	O N
Oculomoteur: Sans bouger la tête ni le cou, l'athlète peut regarder d'un côté à l'autre et de haut en bas sans voir double?	O N
Les mouvements extraoculaires observés sont-ils normaux? Sinon, décrire:	O N

Étape 5: Questionnaire Maddocks et Évaluation de la Mémoire	
Dire "Je vais vous poser quelques questions. Écoutez attentivement et répondez du mieux que vous le pouvez. D'abord, pouvez-vous me dire ce qui s'est produit?"	
Questionnaire Maddocks modifié (À modifier selon chaque sport; attribuer 1 point pour chaque bonne réponse)	
Dans quel stade sommes-nous aujourd'hui?	0 1
À quelle période du jeu sommes-nous?	0 1
Qui a marqué le dernier but de ce match?	0 1
Contre quelle équipe avez-vous joué la semaine dernière/le dernier match?	0 1
Votre équipe a-t-elle gagné le dernier match?	0 1
Résultat au questionnaire Maddocks	/5

Remarque: Il convient d'adapter les questions selon le sport pratiqué.

Second impact syndrome



Second impact syndrome



1st impact
concussion

Al

DRAMATIC CONSEQUENCE OF
RETURNING AN ATHLETE TO PLAY WHO
N AND IT STILL
MATIC

**IF IN DOUBT,
SIT THEM OUT**

Death in 2-5
minutes



Acute phase (24-48h)

- Relative rest
- Primarily cognitive rest (avoid screens)
- Brain under stress (neurometabolic cascade) → any stimulation/treatment requires more energy (= fatigue)



Complete & prolonged rest (“cocooning”) → deleterious





Acute phase (24-48h)

- Relative rest
- Primarily cognitive rest (avoid screens)
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Controlled resumption of physical activity → beneficial

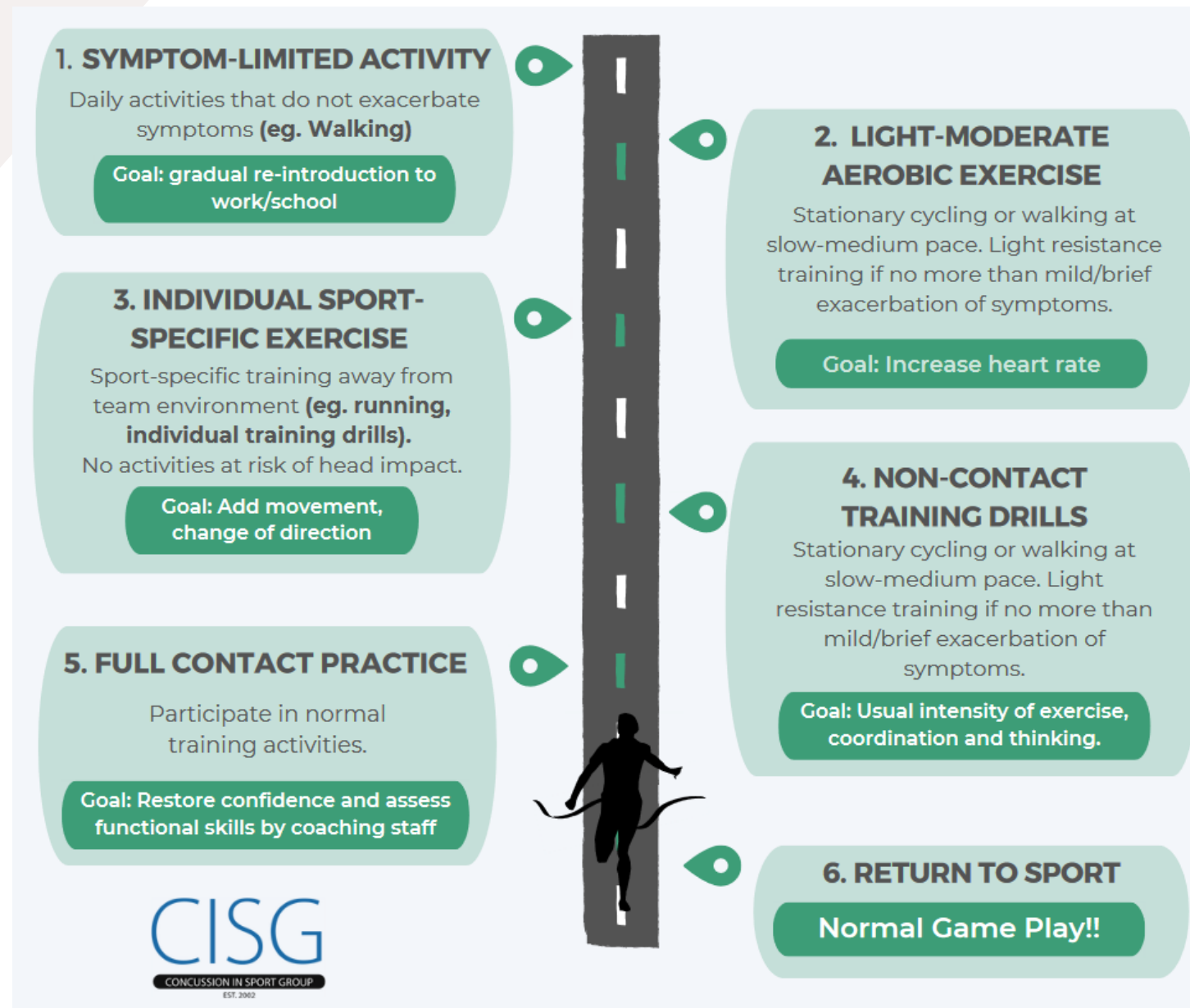




Management : return to play (RTP) protocols

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).			

Management : return to learn (RTL) / play (RTP) protocols



Adopted by international sports federations



Returning to play after concussion or suspected concussion



FIFA®

Return to play guidelines





03

Physiological effects of sports-related concussions

An observational study

Sport-related concussion: head impact exposure

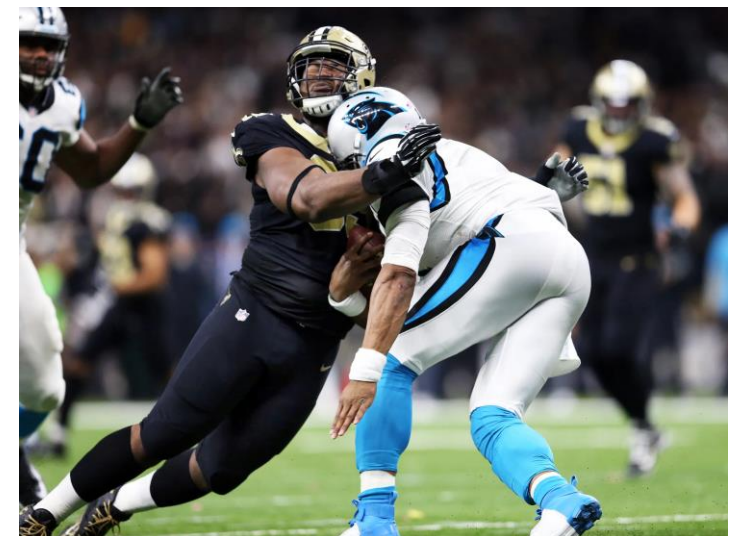


Context: American/Canadian football = contact sport++

High risk of **concussive** (= diagnosed concussion) or **subconcussive** (= altered brain functioning without visible clinical signs) impacts

Affects short-term and long-term brain health (e.g., motor control and memory performance)

→ Monitoring head impact exposure (HIE)



Sport-related concussion: head impact exposure



Monitoring head impact exposure – accelerometry



Skin patch



Instrumented helmets



Instrumented mouthguards

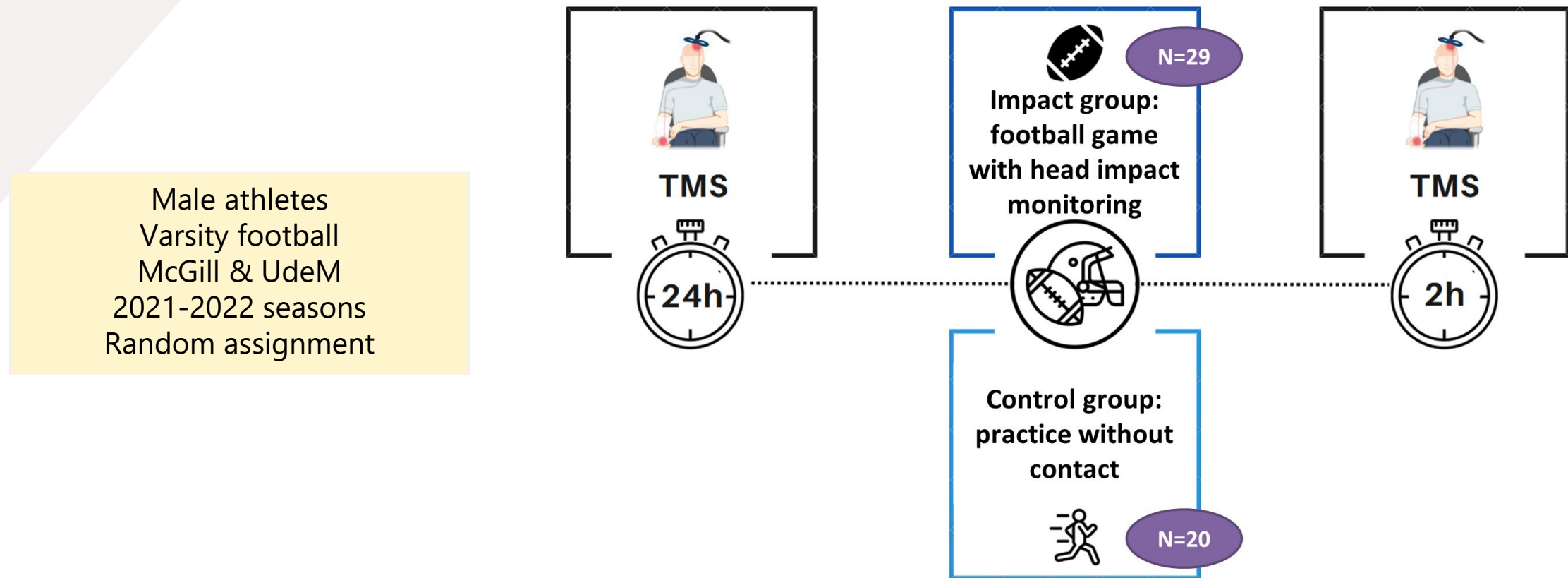


Head impact exposure: acute effects – transcranial magnetic stimulation (TMS)



Example of altered brain functioning without clinically diagnosed concussion (= subconcussive impacts)

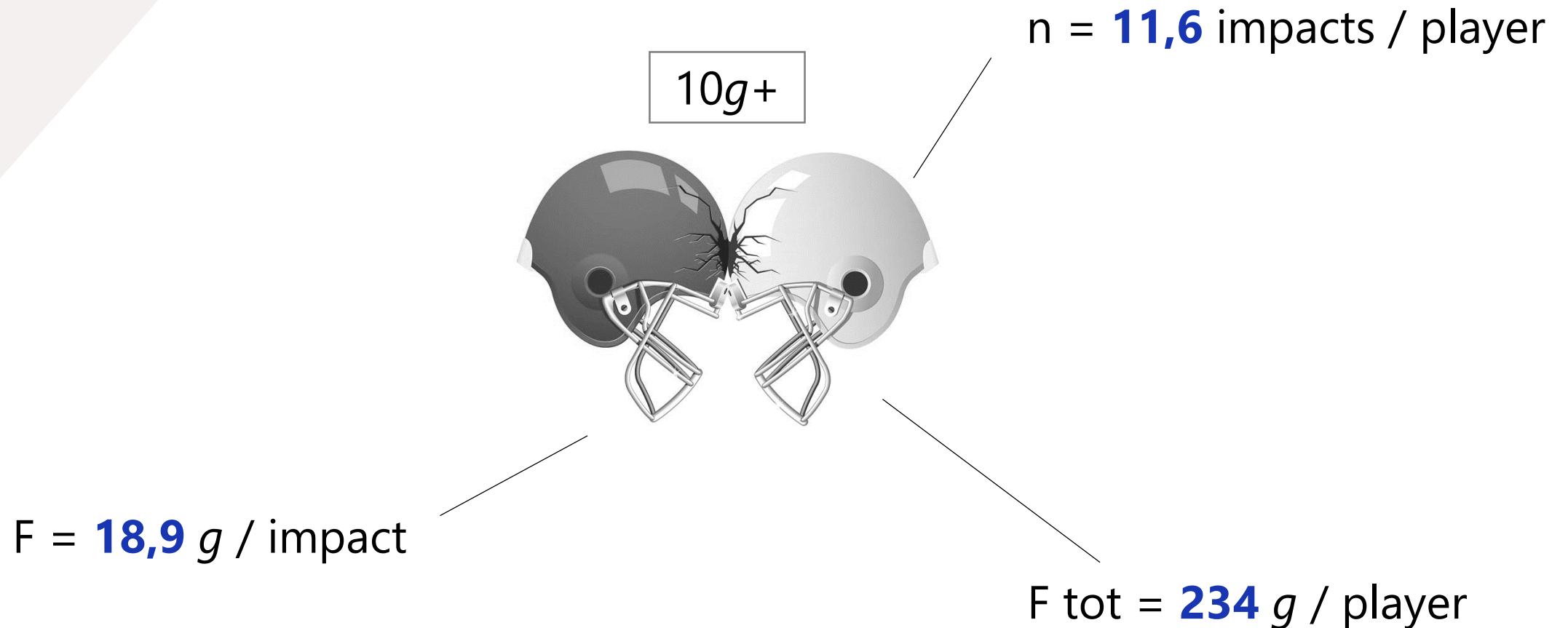
head impact exposure (HIE) vs. brain excitability (intracortical inhibition M1)



Sport-related concussion: head impact exposure & TMS



Results: impacts



Sport-related concussion: head impact exposure & TMS



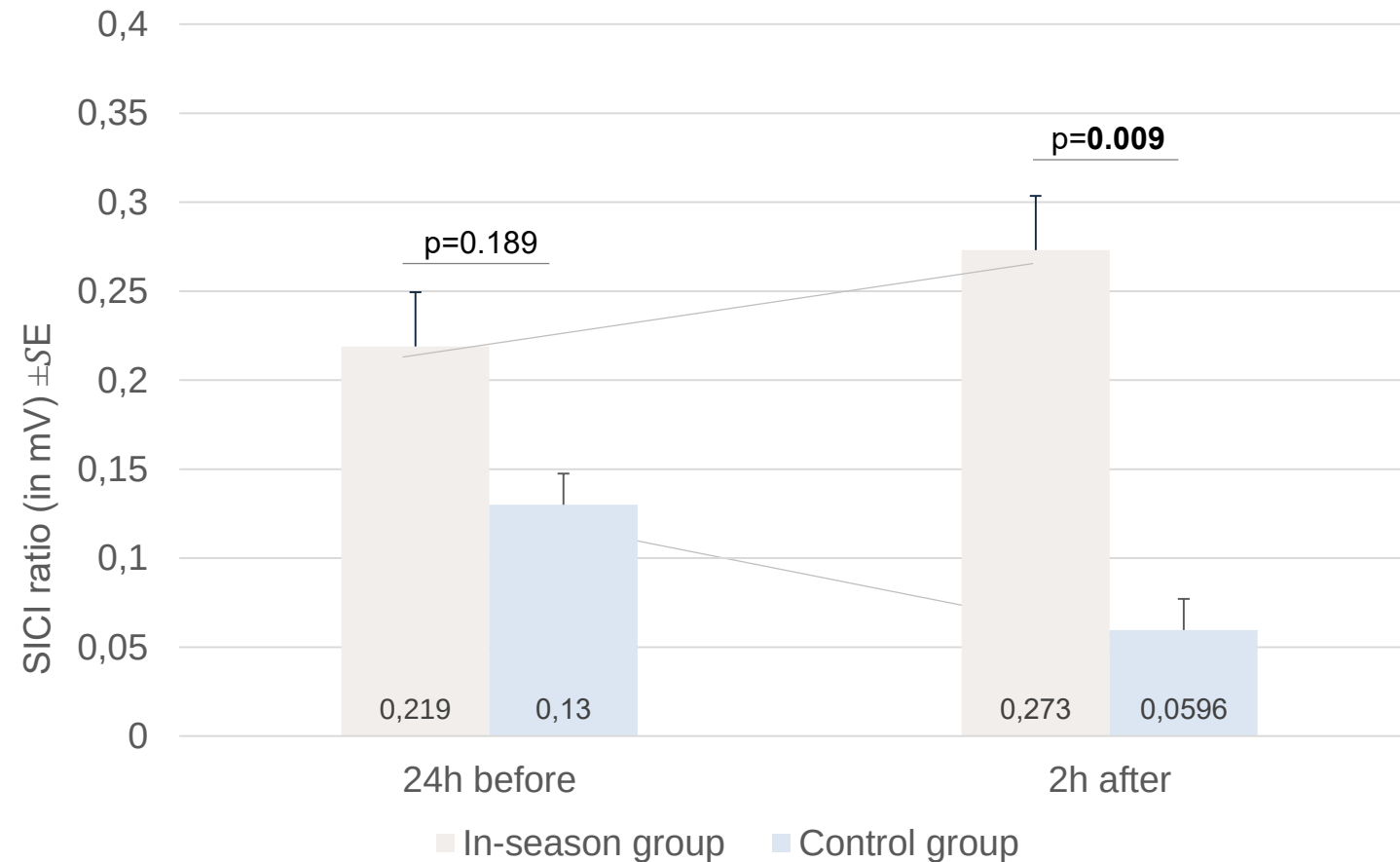
Results: impacts categories

Impact category	N players	N impacts
10 – 24 <i>g</i>	29	9
25 – 39 <i>g</i>	25	2
40 – 59 <i>g</i>	14	1
≥ 60 <i>g</i>	5	1

Head impact exposure & TMS



Results: intracortical inhibition (TMS)

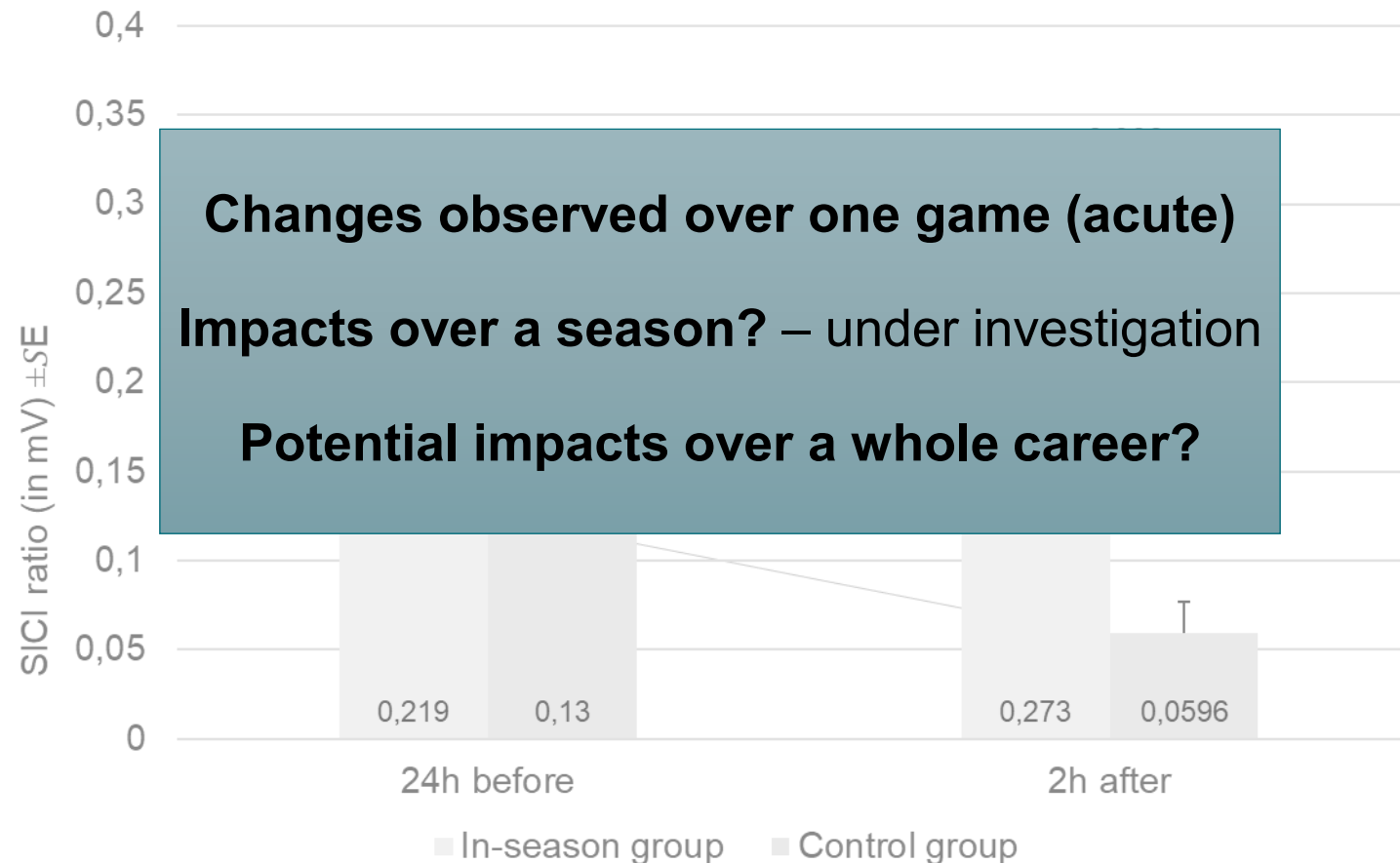


2x2 mixed ANOVA
Time * Group
 $F(1, 44) = 5.19$
 $p = \mathbf{0.028}$
 $\eta^2 = 0.106$

Head impact exposure & TMS



Results: intracortical inhibition (TMS)



2x2 mixed
ANOVA
Time * Group
 $F(1, 44) = 5.19$
 $p = 0.028$
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Short-term changes in the physiology of the primary motor cortex following head impact exposure during a Canadian football game

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* S.A.V. and G.M. contributed equally to this work.



Head impact exposure: acute autonomic effects – heart rate dynamics



Original research

Effects of head impact exposure on in-game heart rate dynamics in Canadian varsity football athletes

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<https://doi.org/10.1016/j.jsams.2026.05.001>

Conclusions



- SRC remains a functional (>< structural) TBI and relies on a **clinical diagnosis**
- The neurometabolic cascade + energy crisis explain why the brain is more **vulnerable** to insult during the acute phase → the biological rationale for management
- Brief relative rest (24–48h, mainly cognitive) followed by *controlled, graded* return to activity (>< cocooning) gives the best recovery
- Standardized RTP protocols and tools are now widely adopted by international federations, but premature return to play carries a real risk
- Subconcussive impacts alter brain excitability (TMS) and autonomic function (HR) even without a clinically diagnosed concussion → **impacts don't need to produce symptoms to have physiological effects**
- These acute changes are measurable after a single game

Conclusions



- SRC remains a functional (>< structural) TBI and relies on a **clinical diagnosis**
- The neurometabolic cascade + energy crisis explain why the brain is more **vulnerable** to further insult during the acute phase → the biological rationale for management
- Concussion management has moved from "rest and wait" to evidence-based, active, graded protocols – but our understanding of the *cumulative* and *subclinical* burden of head impacts is still emerging, which is where current research is headed
- Status epilepticus (SE) is a medical emergency that can occur after a concussion (HR) even without a clinically diagnosed concussion → **impacts don't need to produce symptoms to have physiological effects**
- These acute changes are measurable after a single game



Thank you for your attention

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