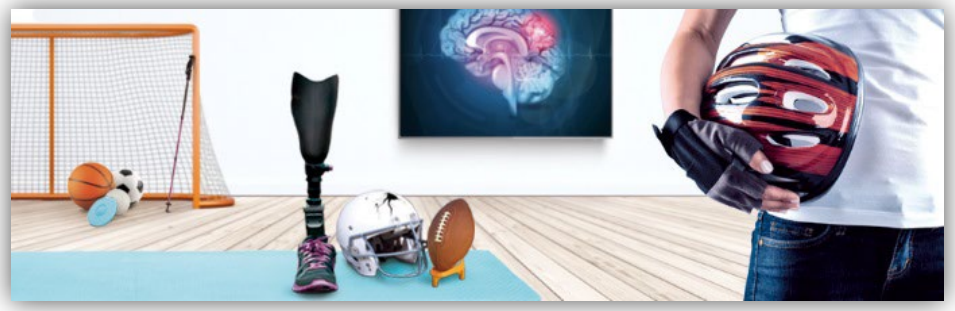
Mass General Brigham



Sports Neurology – is it a man's world?

Claus Reinsberger, M.D., Ph.D.
Division of Sports Neurology and Neurosciences
Mass General Brigham

Email: creinsberger@mgb.org

May, 2025

Learning Objectives

- recognize sport related concussion, be familiar with therapeutic and return-to-activity concepts & be sensitive to peculiarities of female athletes

- understand & use the potential of sport and physical activity to prevent and treat neurological diseases (in women)

Disclosures

I have no actual or potential conflict of interest

in relation to this presentation, but…

… see patients with concussion and neurological disorders in my sports neurology clinic

… use various technologies to assess patients with concussion

… receive scientific funding by the Federal Institute of Sports Sciences (Germany), District of Paderborn & Paderborn County, Westfalian Foundation, Paderborn University

… am a member of the Medical Committee of the German Football Association (DFB) and counsel the Union of European Football Associations (UEFA)

Sports Neurology / Neuroscience

sports and exercise associated (overuse) syndromes

CNS: *dystonias, dysautonomia,* ***PNS****: trauma*

‚cerebral performance' in sports (and training)

ANS control, cognitive-motor training, neuroathletic training

clinical neurology

& neurosciences

sports medicine

& sports physiology

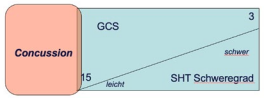
sports and exercise to prevent & treat neurological diseases

‚exercise is medicine'

‚sports is pharmacy'

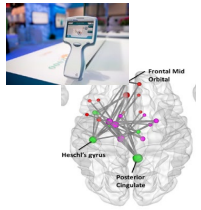
Mass General Brigham

Part 1: Sport Associated Concussion in Women

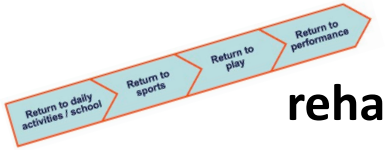


definition and classification

on pitch, in the gym

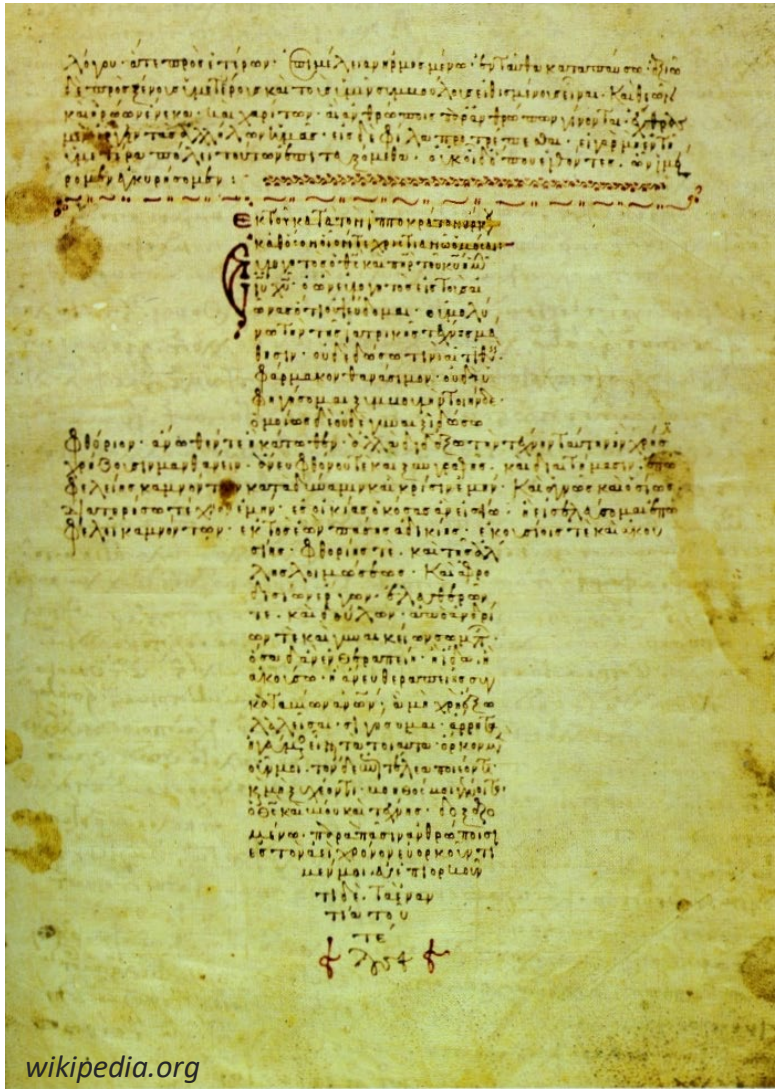


diagnosis: biomarkers, devices etc.



rehabilitation and ‚return-to‘

The Hippocratic Corpus



wikipedia.org

loss of speech, hearing and sight

that can result from

"commotion of the brain"

There is no good animal model for concussion…

…really?

454

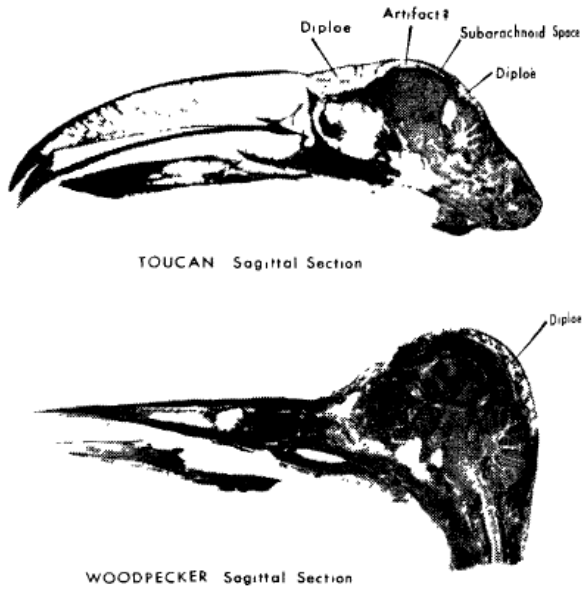
THE LANCET, FEBRUARY 28, 1976

WOODPECKERS AND HEAD INJURY

PHILIP R. A. MAY JOAQUIN M. FUSTER
PAUL NEWMAN ADA HIRSCHMAN

Brentwood Veterans Administration Hospital, Los Angeles, California 90073, and Neuropsychiatric Institute, University of California at Los Angeles, Los Angeles, California 90024, U.S.A.

Summary The woodpecker is an experiment in Nature, a model for the investigation of mechanisms of basic importance for head injury and its prevention. A preliminary anatomical study of the woodpecker's head suggests that it may be fruitful to explore impact protective systems which are radically different from those in common use.



OPEN ACCESS Freely available online

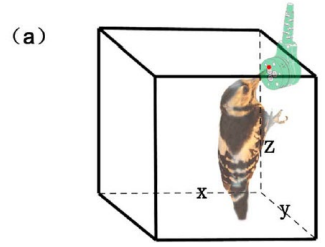
PLoS one

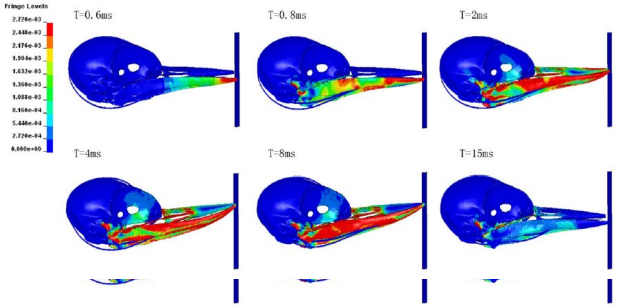
Why Do Woodpeckers Resist Head Impact Injury: A Biomechanical Investigation

Lizhen Wang[1,2], Jason Tak-Man Cheung[3], Fang Pu[1], Deyu Li[1], Ming Zhang[2]*, Yubo Fan[1]*

1 Key Laboratory for Biomechanics and Mechanobiology of Ministry of Education, School of Biological Science and Medical Engineering, Beihang University, Beijing, People's Republic of China, **2** Department of Health Technology and Informatics, the Hong Kong Polytechnic University, Hong Kong, **3** Li Ning Sports Science Research Center, Beijing, People's Republic of China

October 2011 | Volume 6 | Issue 10 | e26490





Is it a man‘s world?

the game of football is quite unsuitable for females and ought not to be encouraged

English FA, 1921, in: Skillen et al., 2022

Is it a man‘s world?

female players are ~ 50% more likely to suffer

from a concussion in soccer

Kontos et al., 2023

80 % of sport concussion research in males

40 % of consensus / position papers without females

D‘Lauro et al., 2022

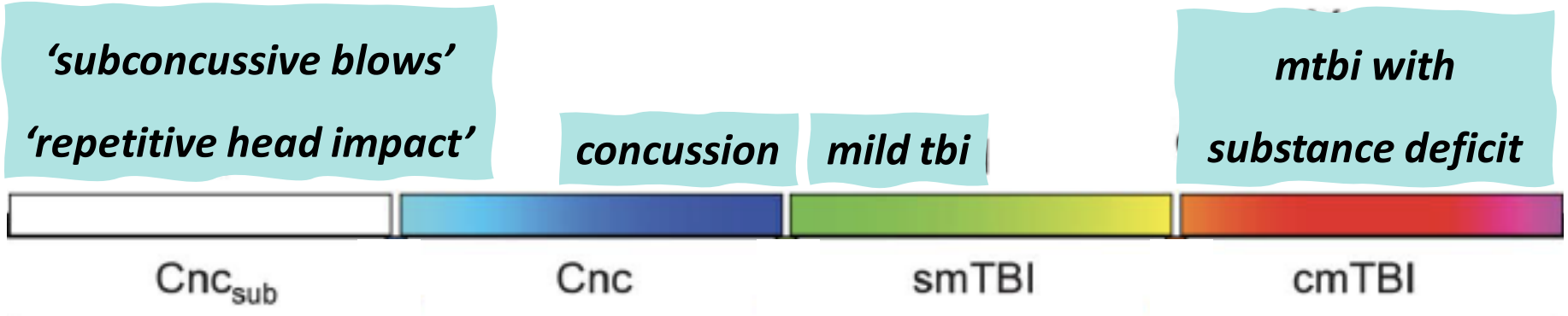
concussion risk in females is not higher in every kind of sport (wrestling)

Van Pelt et al., 2021

?! sex vs. gender !?

Sports associated brain damage is not a clinical entity

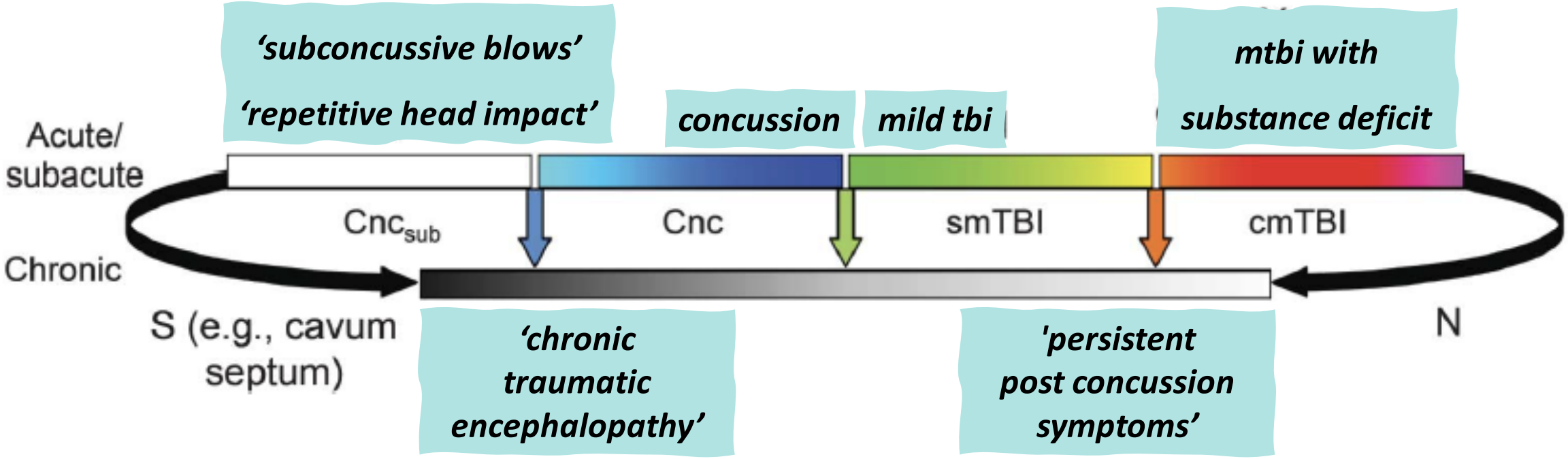
spectrum of mild traumatic brain injury



modified from Mayer et al., 2017

Sports associated brain damage is not a clinical entity

spectrum of mild traumatic brain injury



Mayer et al., 2017

Definition of sport related concussion

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

- initiation of 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 on standard structural neuroimaging (but in research protocols)

- range of clinical signs and symptoms, loss of consciousness may or may not involved

- clinical signs and symptoms cannot be explained by drug, alcohol, or medication use, other injuries (such as cervical injuries, peripheral vestibular dysfunction, etc.) or other comorbidities (e. g., psychological factors or co-existing medical conditions)

Patricios et al., 2023

Research in sport related concussion

- is it a man‘s world?

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

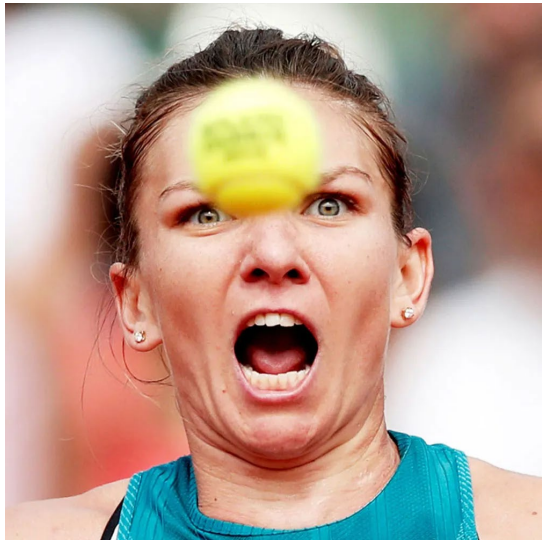
Jon S Patricios [1], Kathryn J Schneider [2], Jiri Dvorak [3], Osman Hassan Ahmed [4,5], Cheri Blauwet [6,7], Robert C Cantu,[8,9] Gavin A Davis [10,11], Ruben J Echemendia [12,13], Michael Makdissi,[14,15] Michael McNamee,[16,17], Steven Broglio [18], Carolyn A Emery [2], Nina Feddermann-Demont,[19,20], 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]

Amsterdam 2022 process: A summary of the methodology for the Amsterdam International Consensus on Concussion in Sport

Kathryn J Schneider [1,2,3], Jon S Patricios [4], Willem Meeuwisse,[5] Geoff M Schneider,[6], K Alix Hayden [7], Zahra Premji [8], Osman Hassan Ahmed [9,10,11], Cheri Blauwet [12,13], Steven Broglio [14], Robert C Cantu,[15,16], Gavin A Davis [17,18], Jiri Dvorak [19], Ruben J Echemendia [20], Carolyn A Emery [1], Grant L Iverson [21,22], John J Leddy [23], Michael Makdissi,[24,25], Michael McCrea [26], Michael McNamee,[27,28], Margot Putukian [29], Keith Owen Yeates [2,3,30], Amanda M Black [1], Joel S Burma [1], Meghan Critchley,[31], Paul H Eliason [31], Anu M Räisänen [32], Jason B Tabor [31], Clodagh Toomey,[1,33], Paul E Ronksley,[34], J David Cassidy[35]

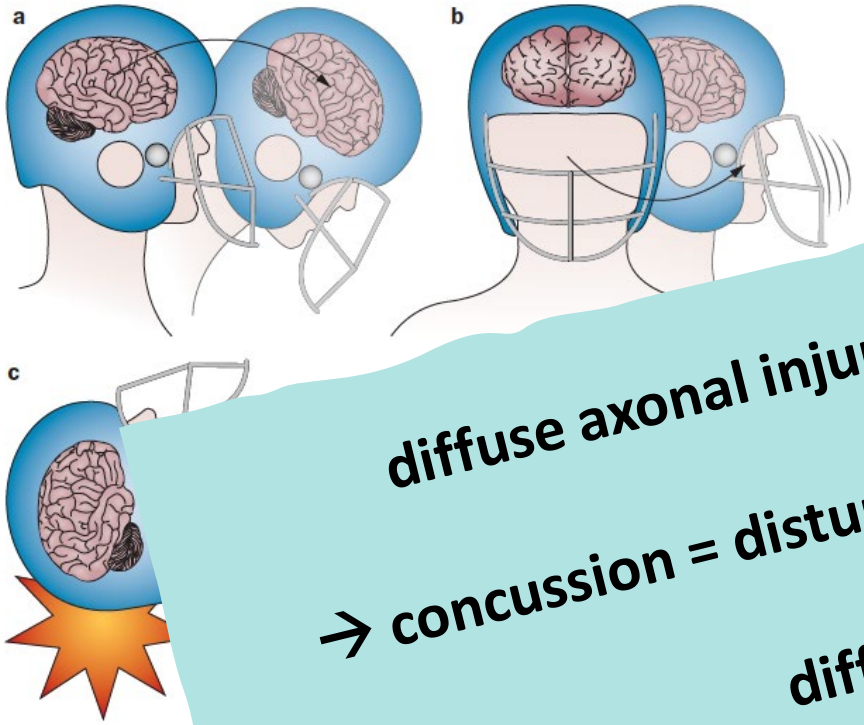
Generalisability

Challenge: Many studies include select samples of high performance male athletes, and are primarily from North America. There are not enough studies of children <12 years, women, non-binary genders and para athletes. *Solution:* Future studies should be inclusive and more studies need to be undertaken that include all age groups, sexes, genders, races and ethnicities, para athletes, and all levels of sport participation, and geographical regions.



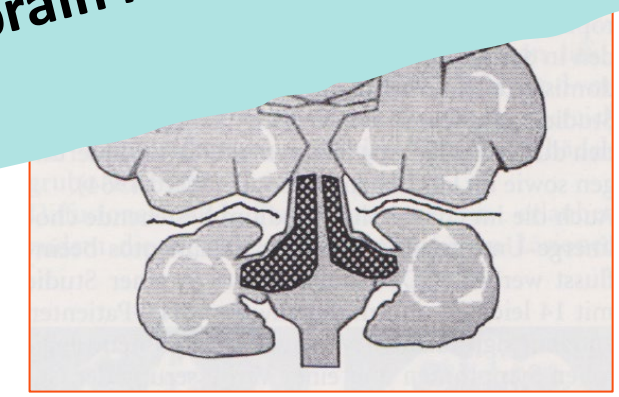
Schneider et al., 2023

What happens during concussion? diffuse axonal injury



diffuse axonal injury (rarely coup / contre-coup)

→ concussion = disturbance of communication between different brain regions



Jordan et al., 2013

Brandt, Dichgans, Diener, 2007
Noble & Hesdorffer, 2013

Clinical Signs / Symptoms

modifiers:

- sleep
- c-spine

vestibular

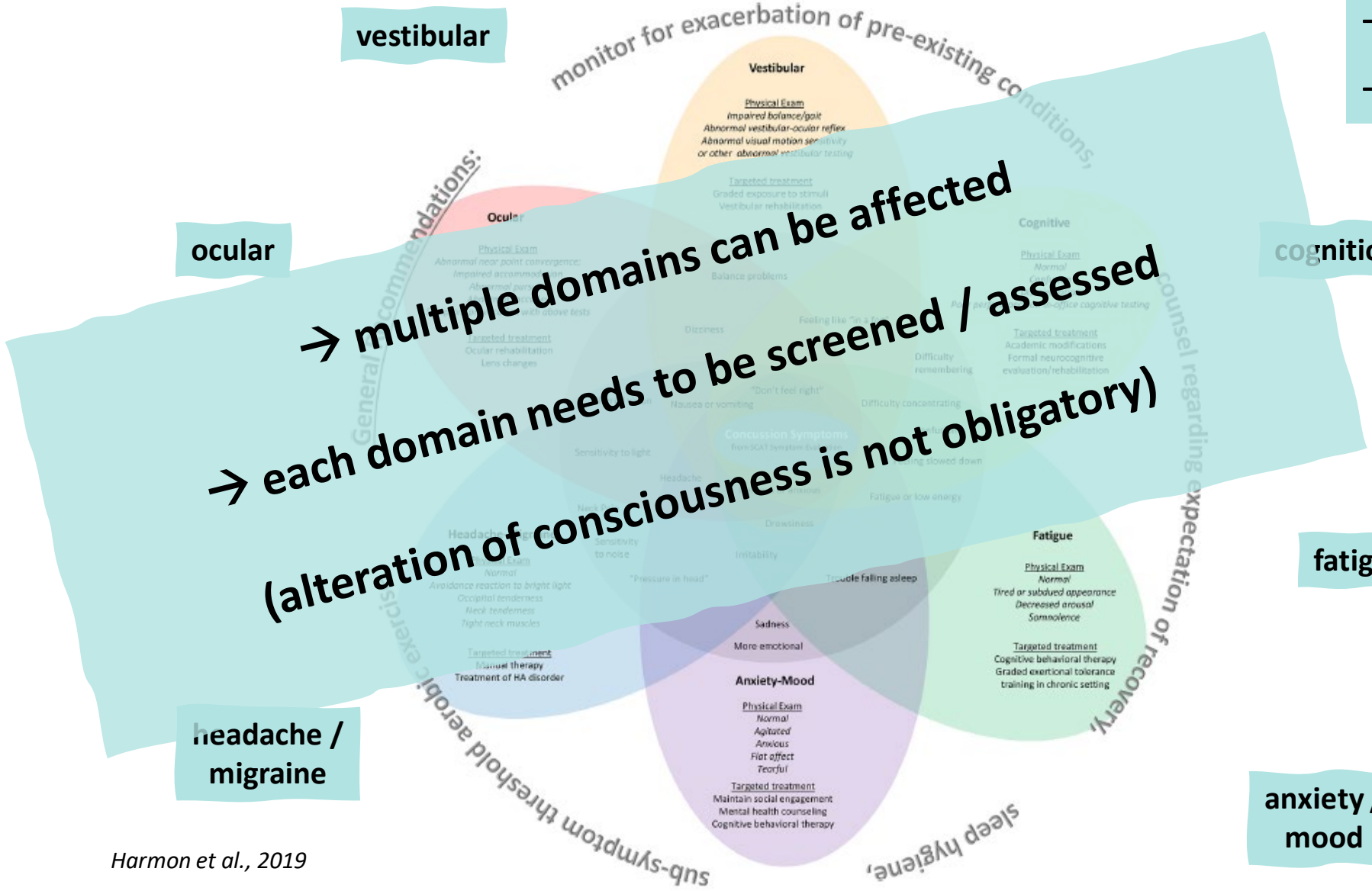
ocular

cognition

fatigue

headache / migraine

anxiety / mood



→ multiple domains can be affected

→ each domain needs to be screened / assessed

(alteration of consciousness is not obligatory)

Harmon et al., 2019

Clinical Signs / Symptoms

modifiers:

- sleep
- c-spine

vestibular

ocular

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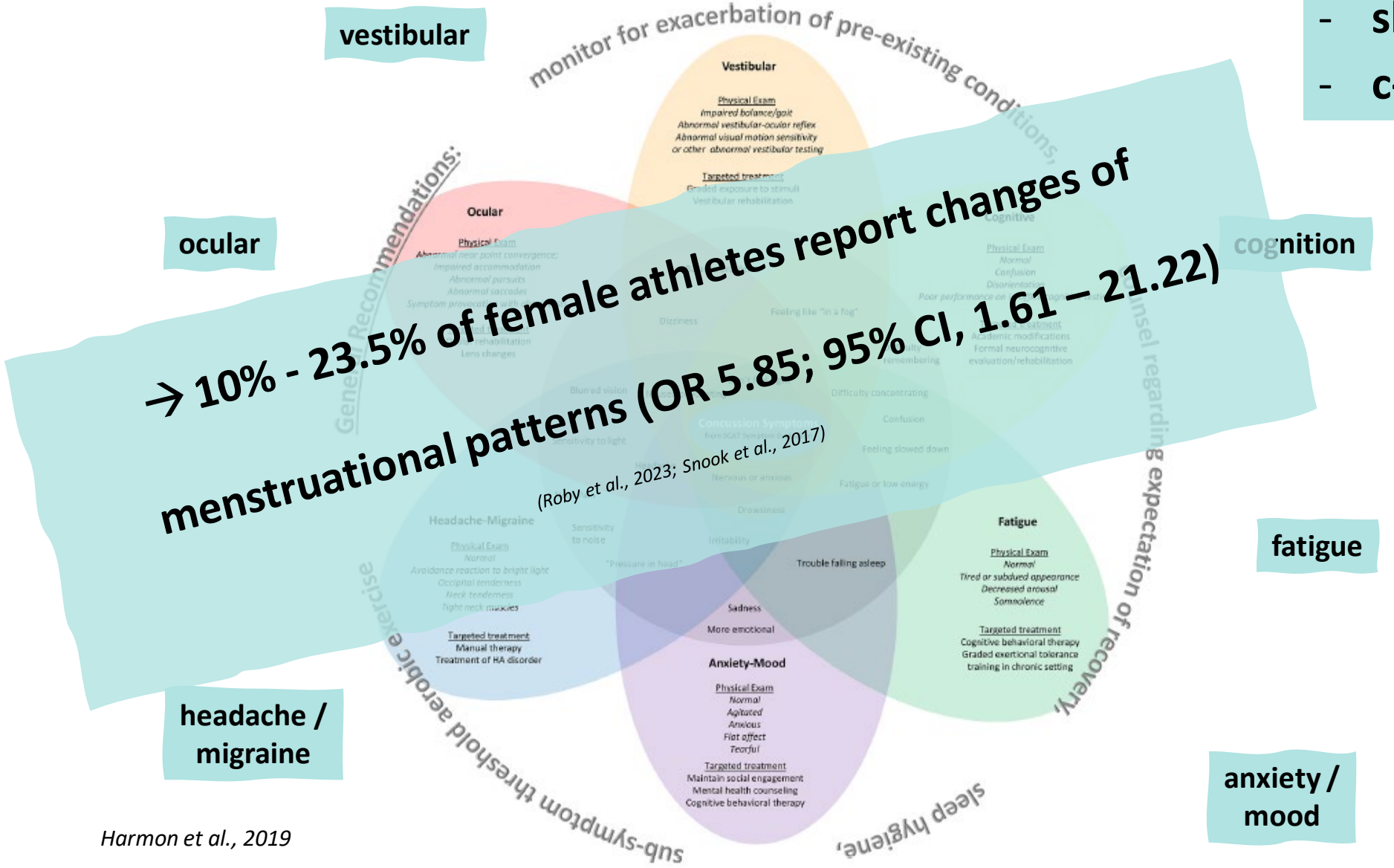
anxiety / mood



→ 10% - 23.5% of female athletes report changes of menstruational patterns (OR 5.85; 95% CI, 1.61 – 21.22)

(Roby et al., 2023; Snook et al., 2017)

Harmon et al., 2019

Initial Assessment (on pitch, in the gym)

Concussion Recognition Tool 6 - CRT6™

CRT6 Concussion Recognition Tool
To Help Identify Concussion in Children, Adolescents and Adults

1: Visible Clues of Suspected Concussion

Visible clues that suggest concussion include:

- Loss of consciousness or responsiveness
- Lying motionless on the playing surface
- Falling unprotected to the playing surface
- Disorientation or confusion, staring or limited responsiveness, or an inability to respond appropriately to questions
- Dazed, blank, or vacant look
- Seizure, fits, or convulsions
- Slow to get up after a direct or indirect hit to the head
- Unsteady on feet / balance problems or falling over / poor coordination / wobbly
- Facial injury

2: Symptoms of Suspected Concussion

Physical Symptoms	Changes in Emotions
Headache	More emotional
"Pressure in head"	More irritable
Balance problems	Sadness
Nausea or vomiting	Nervous or anxious
Drowsiness	**Changes in Thinking**
Dizziness	Difficulty concentrating
Blurred vision	Difficulty remembering
More sensitive to light	Feeling slowed down
More sensitive to noise	Feeling like "in a fog"
Fatigue or low energy	
"Don't feel right"	
Neck Pain	

Remember, symptoms may develop over minutes or hours following a head injury.

3: Awareness

(Modify each question appropriately for each sport and age of athlete)

Failure to answer any of these questions correctly may suggest a concussion:

"Where are we today?"
"What event were you doing?"
"Who scored last in this game?"
"What team did you play last week/game?"
"Did your team win the last game?"

Any athlete with a suspected concussion should be - IMMEDIATELY REMOVED FROM PRACTICE OR PLAY and should NOT RETURN TO ANY ACTIVITY WITH RISK OF HEAD CONTACT, FALL OR COLLISION, including SPORT ACTIVITY until ASSESSED MEDICALLY, even if the symptoms resolve.

Athletes with suspected concussion should **NOT**:

- Be left alone initially (at least for the first 3 hours). Worsening of symptoms should lead to immediate medical attention.
- Be sent home by themselves. They need to be with a responsible adult.
- Drink alcohol, use recreational drugs or drugs not prescribed by their HCP
- Drive a motor vehicle until cleared to do so by a healthcare professional

? continue to play

? substitution & outpatient care

? substitution & inpatient care

SCAT6™
Sport Concussion Assessment Tool
For Adolescents (13 years +) & Adults

- protect… …upport)
- Glasgow Coma Scale
- neurological assessment
- …

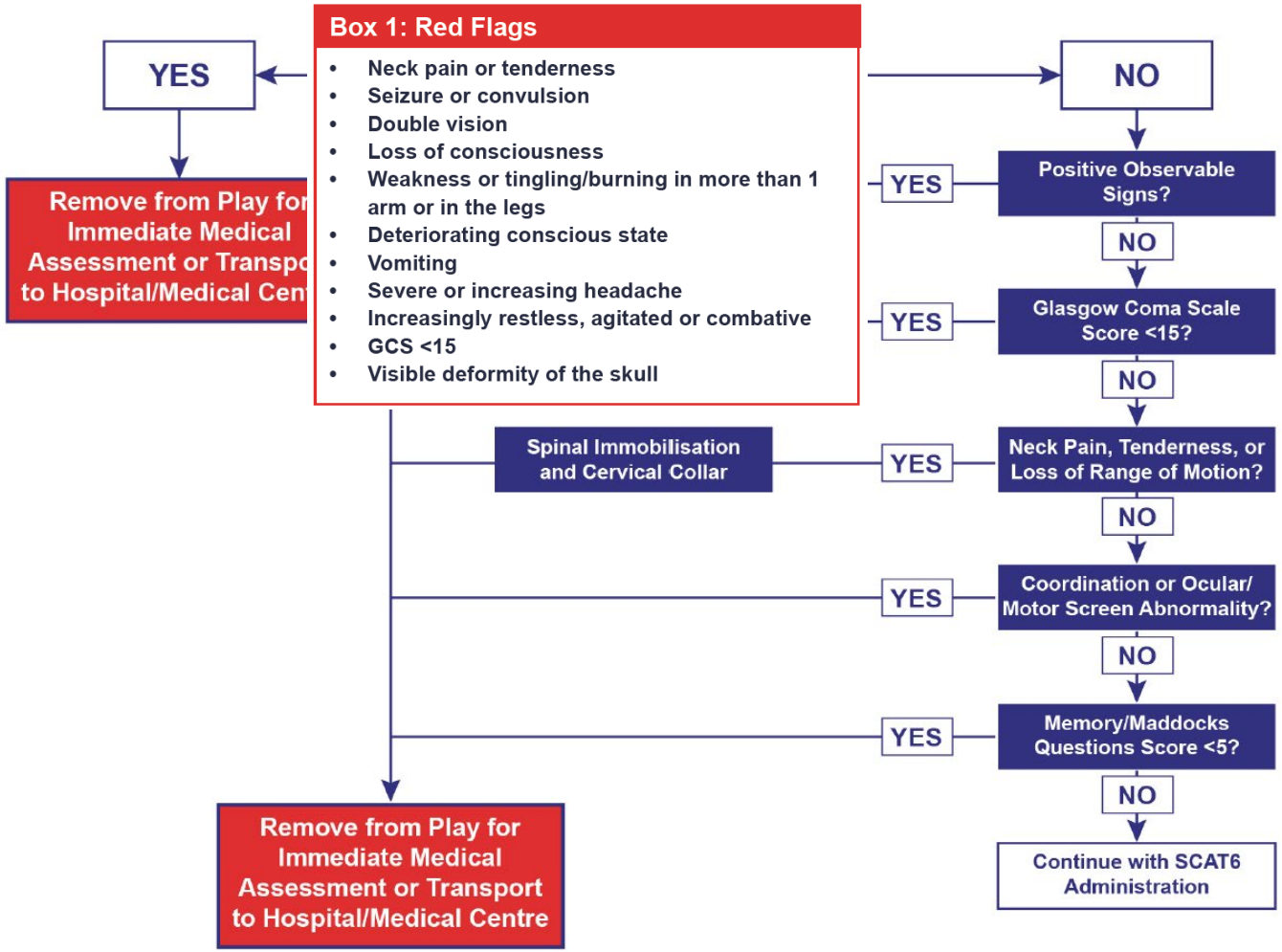
! screening ≠ diagnosing !

SCAT6™

Sport Concussion Assessment Tool

For Adolescents (13 years +) & Adults

Immediate Assessment/Neuro Screen



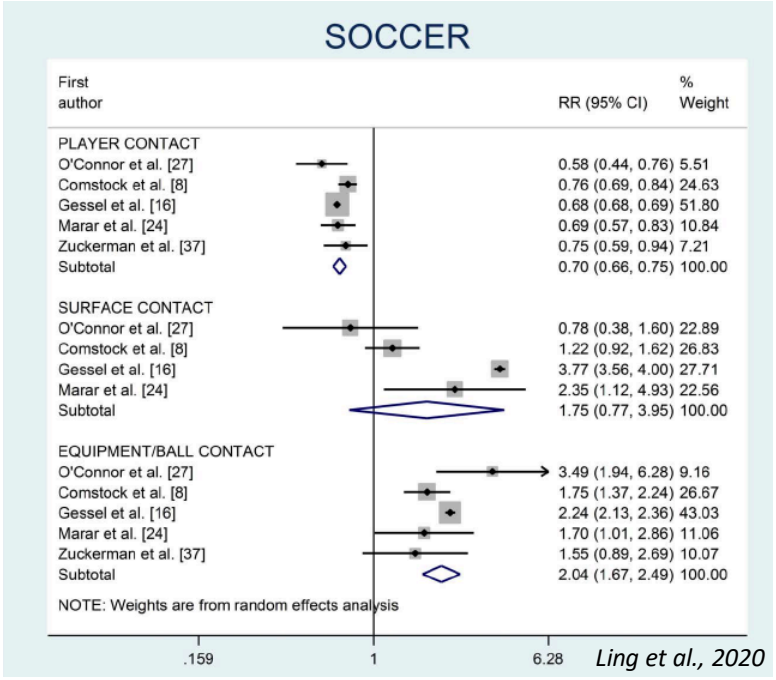
Mechanisms leading to Concussion are different in women

women report more symptoms than men

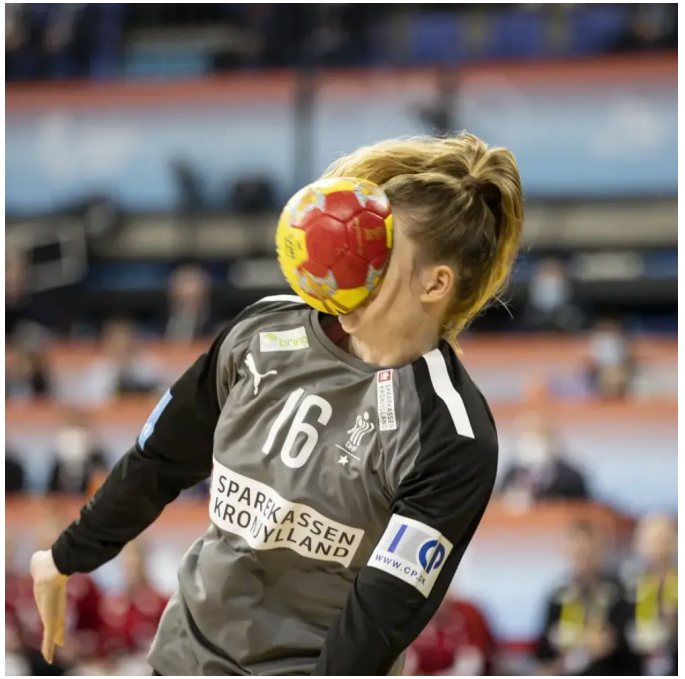
(Blyth et al., 2021)

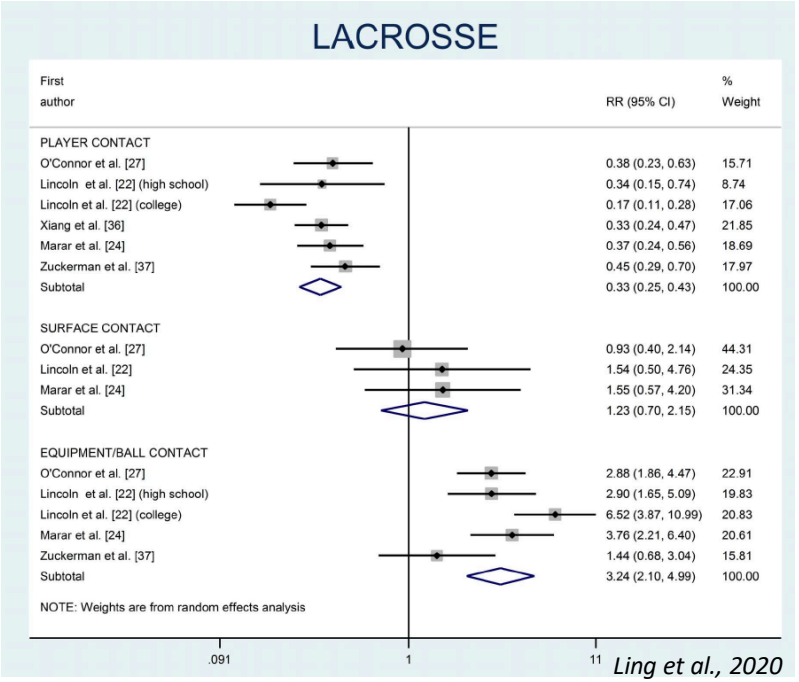
football: head/ball contact rather than head/body (or head) contact

(Blyth et al., 2021; Dave et al., 2022)



Ling et al., 2020





Ling et al., 2020

Mechanisms leading to Concussion are different in women

different reporting behavior

(Van Pelt et al., 2021)

access to medical support

(Bretzinet al., 2021)

training of heading technique

(Parsanejad et al., 2021)

eyes closed during headers?

(Clark et al., 2017)

Sports Medicine (2023) 53:1335–1358
https://doi.org/10.1007/s40279-023-01852-x

REVIEW ARTICLE

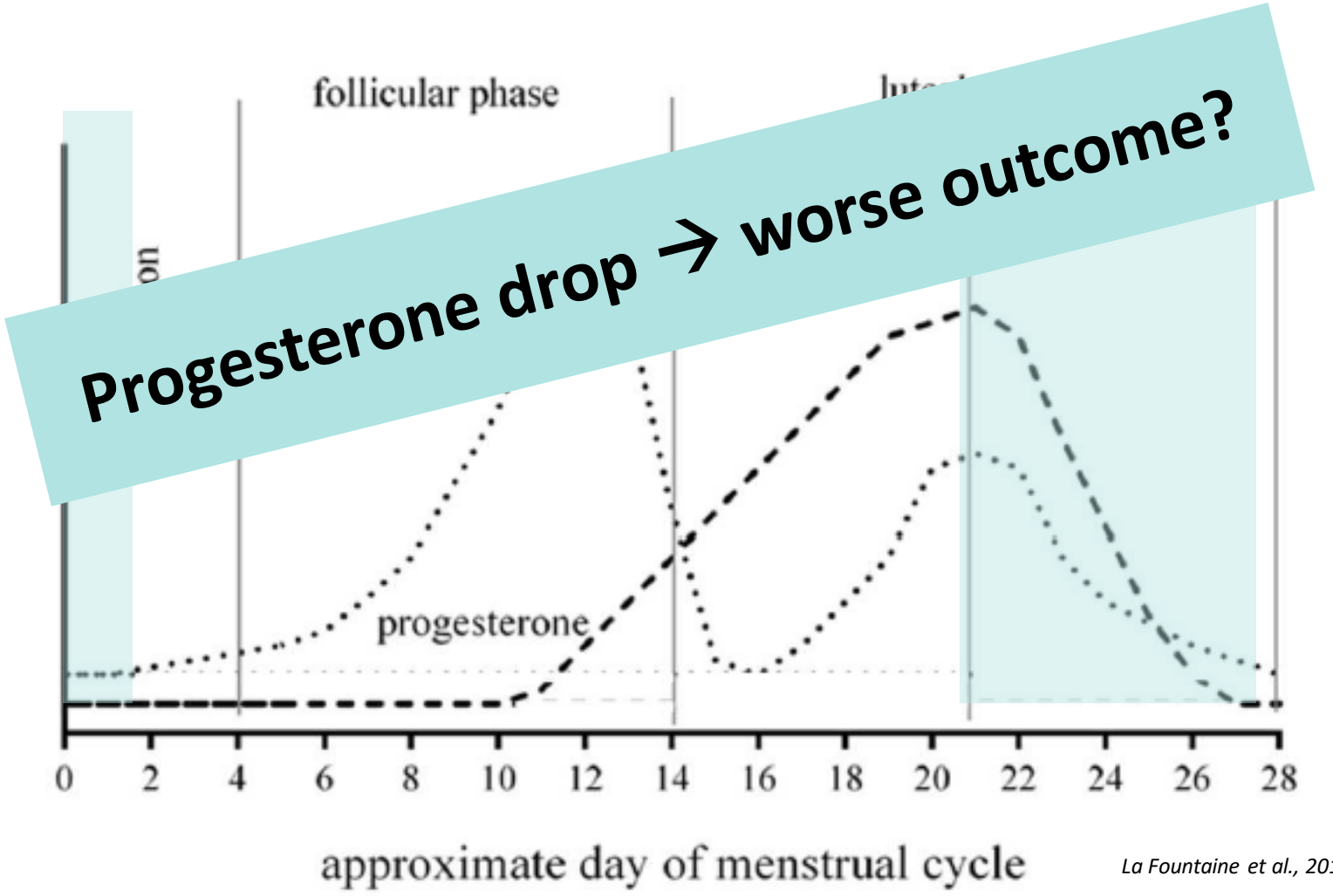
Check for updates

Where are We Headed? Evidence to Inform Future Football Heading Guidelines

Kerry Peek[1] · Rob Duffield[2,3] · Ross Cairns[4,5] · Mark Jones[3] · Tim Meyer[8] · Alan McCall[2,3] · Vincent Oxenham[6,7]

The Female cycle – not a man's world!

concussion risk depending on cycle? *(Blyth et al., 2021; Musko & Demetriades, 2023))*



Progesterone drop → worse outcome?

concussion during follicular phase

→ lower symptom endorsement

Roby et al., 2023

(not sports associated) concussion during luteal phase

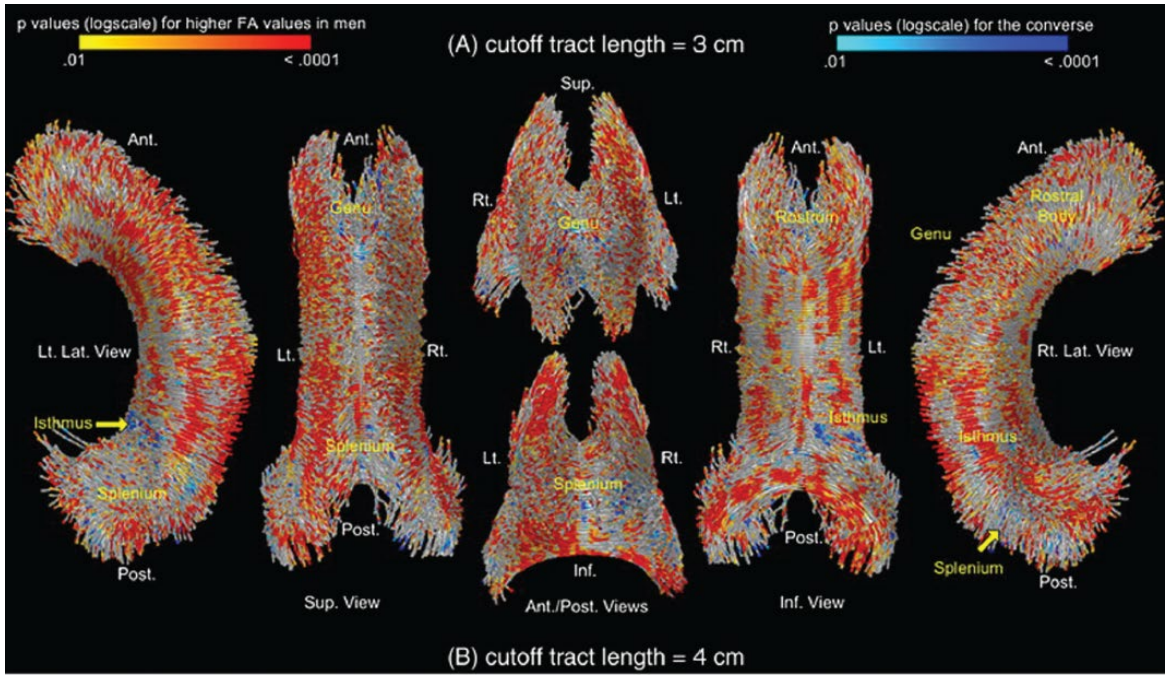
→ worse symptoms

Wunderle et al., 2014

La Fountaine et al., 2019

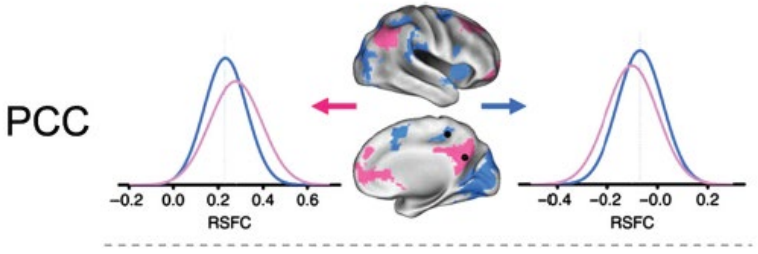
The Female brain – not a man's world?

female corpus callosum more vulnerable? *(Solomito et al., 2019, Gong et al., 2011)*



females:

- less fibers & cross sectional areas (parasaggital & midsaggital)
- more utilization of both hemispheres
- less functional connectivity (e.g. posterior cingulate)



Anterior cruciate ligament injury: towards a gendered environmental approach

Joanne L Parsons [1], Stephanie E Coen [2], Sheree Bekker [3]

To cite: Parsons JL, Coen SE, Bekker S. *Br J Sports Med* 2021;**55**:984–990.

How to Diagnose a Concussion

SCHRITT 2: SYMPTOM BEURTEILUNG

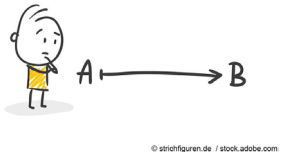
Dem Sportler sollte der Symptombogen gegeben werden mit der Aufforderung, diesen Instruktionssatz laut vorzulesen und danach die Symptomskalen zu beantworten. Bei einer Basisuntersuchung sollte der Sportler seine Symptome danach bewerten, wie er sich typischerweise fühlt. Bei einer Untersuchung nach einer Verletzung sollte der Sportler seine Symptome zu diesem Zeitpunkt bewerten.

Bitte ankreuzen: ☐ Basistestung ☐ nach Verletzung

Bitte geben Sie das Formular dem Sportler

	kein		leicht		mäßig		stark
Kopfschmerzen	0	1	2	3	4	5	6
„Druck im Kopf"	0	1	2	3	4	5	6
Nackenschmerzen	0	1	2	3	4	5	6
Übelkeit oder Erbrechen	0	1	2	3	4	5	6
Schwindelgefühl / Benommenheit	0	1	2	3	4	5	6
Verschwommenes Sehen	0	1	2	3	4	5	6
Gleichgewichtsprobleme	0	1	2	3	4	5	6
Lichtempfindlichkeit	0	1	2	3	4	5	6
Geräuschempfindlichkeit	0	1	2	3	4	5	6
Gefühl „verlangsamt / langsam zu sein"	0	1	2	3	4	5	6
Gefühl „wie im Nebel" / „benebelt" zu sein	0	1	2	3	4	5	6
„Etwas stimmt nicht mit mir"	0	1	2	3	4	5	6
Schwierigkeiten, sich zu konzentrieren	0	1	2	3	4	5	6
Schwierigkeiten, sich zu erinnern	0	1	2	3	4	5	6
Erschöpfung, Ermüdung oder wenig Energie	0	1	2	3	4	5	6
Verwirrtheit	0	1	2	3	4	5	6
Schläfrigkeit	0	1	2	3	4	5	6
Emotionaler als gewohnt	0	1	2	3	4	5	6
Reizbarkeit	0	1	2	3	4	5	6
Traurigkeit	0	1	2	3	4	5	6
Nervös oder ängstlich	0	1	2	3	4	5	6
Schwierigkeiten einzuschlafen (wenn zutreffend)	0	1	2	3	4	5	6
Gesamtzahl der Symptome:							von 22

→ history



→ 'physical' exam

→ additional exams / workup

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

Off-Field Assessment

Step 1: Athlete Background

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Notes

Step 2: Symptom Evaluation

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Step 3: Cognitive Screening (Based on Standardized Assessment of Concussion; SAC)[2]

Orientation | **Immediate Memory** | **Concentration**

All 3 trials must be administered

Months in Reverse Order:

What mo

What is t

What is t

What yea

What tim

Orientati

urately as possible. Start with the last

Step 4: Coordination and Balance Examination

Modified Balance Error Scoring System (mBESS)[3] testing

(see detailed administration instructions)

Foot Tested: **Left** ☐ **Right** ☐ (i.e. test the **non-dominant** foot)

Testing Surface (hard floor, field, etc.):

Footwear (shoes, barefoot, braces, tape etc.):

OPTIONAL (depending on clinical presentation and setting resources): For further assessment, the same 3 stances can be performed on a surface of medium density foam (e.g., approximately 50cm x 40cm x 6cm) with the same instructions and scoring.

	April	March	February	January
Head				
Pres				
Neck				
Naus				
Dizzi				
Blur				
Balance problems	N			
Sensitivity to light	N			
Sensitivity to noise	N			

Arrow	3-8-1-4	1-7-9-5	6-8-3-1	Y	N	0 1
Pepper	3-2-7-9	4-9-6-8	3-4-8-1	Y	N	

Patricios et al., 2023

SCAT6™

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

Off-Field Assessment

Step 4: Coordination and Balance Examination (Continued)

Modified BESS

(20 seconds each)

Double Leg Stance:		**of 10**
Tandem Stance:		**of 10**
Single Leg Stance:		**of 10**
Total Errors:		**of 30**

Note: If the **mBESS** yields normal findings then proceed

If the **mBESS** reveals abnormal findings or clinically sign

Timed Tandem Gait

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***

Step 5: Delayed Recall

The Delayed Recall should be performed after **at least 5 minutes** have elapsed since the end of the Immediate Memory section:
Score 1 point for each correct response.

number of subtraction counting errors.

Task													Errors	Time (circle fastest)
Trial 1	88	81	74	67	60	53	46	39	32	25	18	11	4		

Patricios et al., 2023

SCOAT6™

Sport Concussion Office Assessment Tool

For Adults & Adolescents (13 years +)

SCAT6™
Sport Concussion Assessment Tool
For Adolescents (13 years +) & Adults

+

Completion Guide

Blue: Complete only at first assessment

Green: Recommended part of assessment

Orange: Optional part of assessment

Orthostatic Vital Signs	Supine	Standing (after 1 minute)
Blood Pressure (mmHg)		
Heart Rate (bpm)		
Symptoms[1]		
• Dizziness or light-he		
• Fainting		
• Blurred or fading vis		
• Nausea		
• Fatigue		
• Lack of concentratio		
Results		

Cervical Spine Palpation	Signs and Symptoms
Muscle Spasm	
Midline Tenderne	
Paravertebral Ter	
C	
Flexion (50-70°)	
Extension (60-85	
Right Lateral Flex	
Left Lateral Flexi	
Right Rotation (6	
Left Rotation (60-	

Cranial Nerves

Normal ☐ A

Notes:

Other Neurological

Limb Tone: N

Strength: N

Deep Tendon Reflexes: N

Sensation: N

Cerebellar Function: N

Comments:

Modified Vestibular/Ocular-Motor Screening (mVOMS) for Concussion

For detailed instructions please see the Supplement.

mVOMS	Not Tested	Headache	Dizziness	Nausea	Fogginess	Comments
Baseline symptoms	N/A					
Smooth pursuits (2 horizontal and 2 vertical, 2 seconds to go full distance right-left and back; up-down and back)						
Saccades – Horizontal (10 times each direction)						
VOR – Horizontal (10 repetitions) (metronome set at 180 beats per minute – change direction at each beep, wait 10 secs to ask symptoms)						
VMS (x 5, 80° rotation side to side) (at 50 bpm, change direction each beep, wait 10 secs to ask symptoms)						

Patricios et al., 2023

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+

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Anxiety Screen

Not Done ☐

Assign score
days," and "

Over the
bother

1. Feeling r
2. Not bein
3. Worrying
4. Trouble r
5. Being so
6. Becomin
7. Feeling a

Anxiety Screen Score:

Depression Screen

Not Done ☐

The purpose is
the PHQ-9 to d

Over the la
bothered

1. Little intere
2. Feeling dov

Depression Sc

Sleep Screen

Not Done ☐

5 to 6 hours
6 to 7 hours
7 to 8 hours
8 to 9 hours
More than 9

2. How satisfied/diss

Very dissatisfied
Somewhat dissatisfied
Somewhat satisfied
Satisfied
Very satisfied

3. During the recent past, how long has it usually taken you to fall asleep each night?

Computerised Cognitive Test Results (if used)

Not Done ☐

Test Battery Used:

Recent Baseline - if per

Post-Injury Result (Res

Post-Injury Result (Pos

Graded Aerobic Exercise Test

Not Done ☐

Exclude contra-indications: cardiac condition, respiratory disease, significant vestibular symptoms, motor dysfunction, lower limb injuries, cervical spine injury.

Protocol Used:

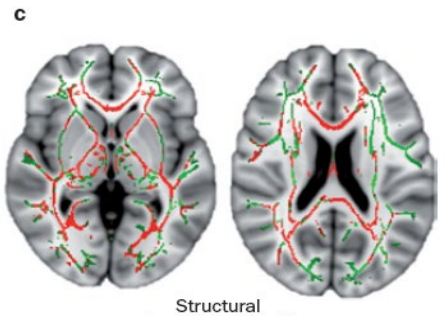
Patricios et al., 2023

The Quest for Biomarkers

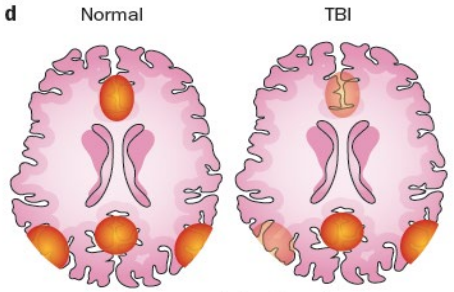
→ concussion is a clinical diagnosis

→ workup may be needed to assess for higher degree tbi or other pathology

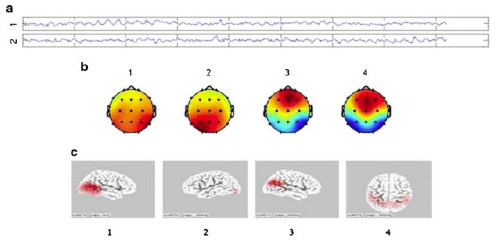
"He's clear, coach!"

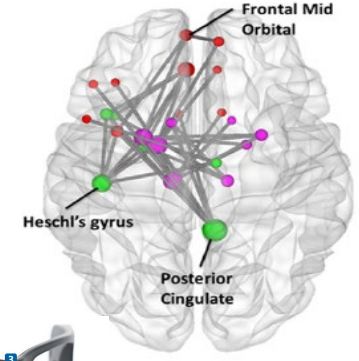


Structural network disconnection

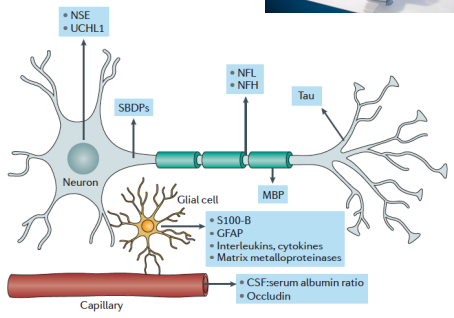


Large-scale functional network disruption





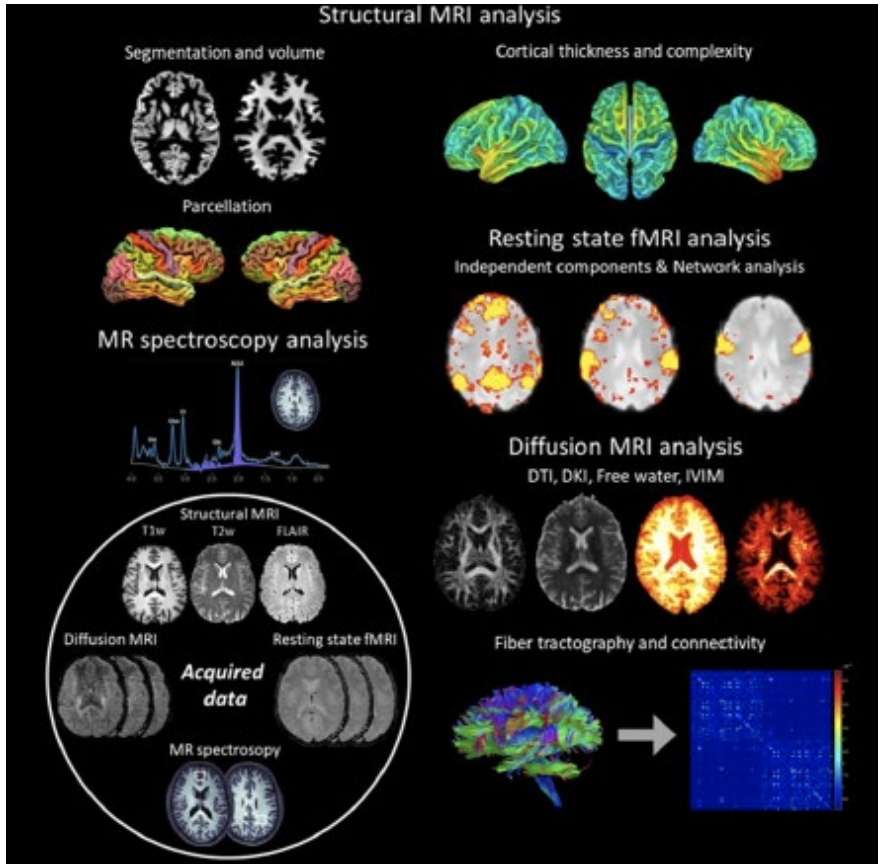
KING-DEVICK TEST



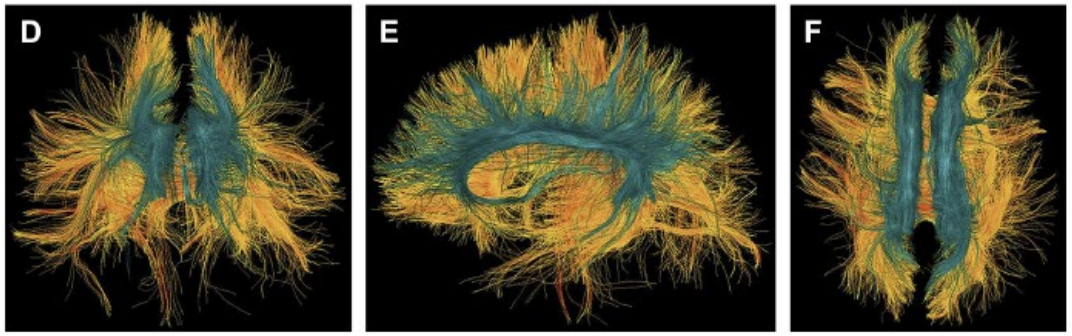
SCAT6™
Sport Concussion Assessment Tool
For Adolescents (13 years +) & Adults

Sharp, Nature Rev Neurol, 2014, Slobounov et al., 2012, Dunkley et al., 2015, Zetterberg, Nature Rev Neurol, 2016

Neuroimaging



Koerte et al., 2021



Guenette et al., 2017

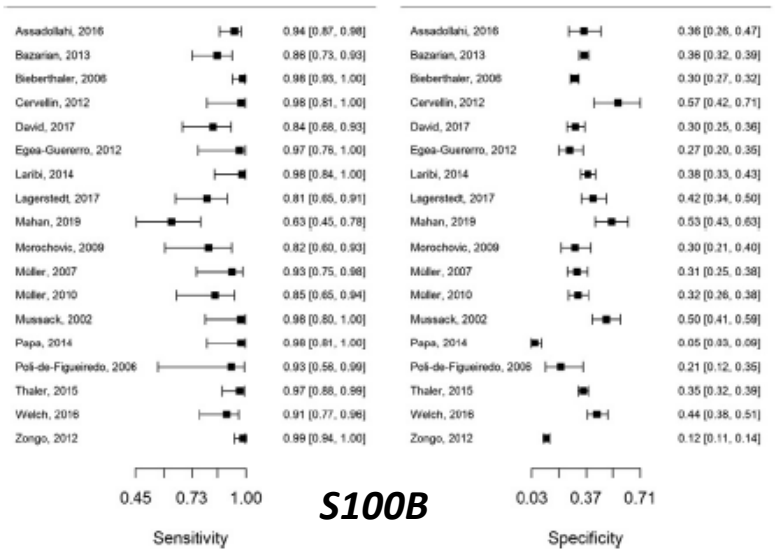
- *group vs. individual level*
- *diagnostic sensitivity*

  & specificity not clear

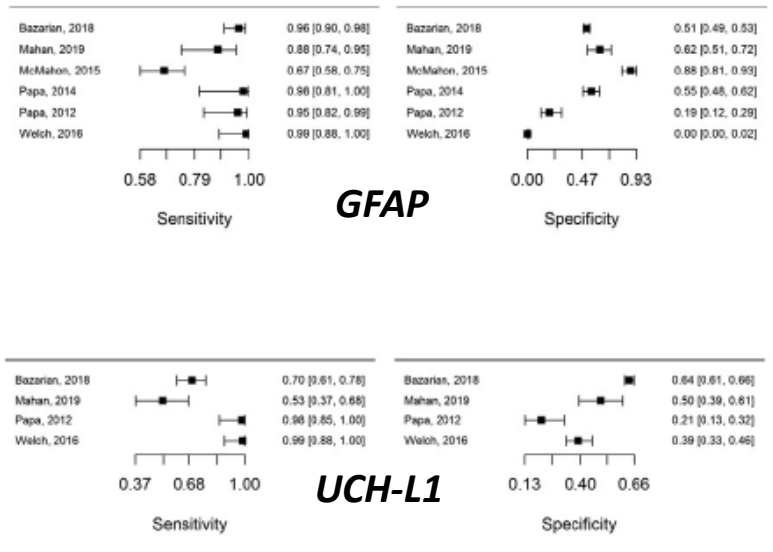
→ not (yet) ready for clinical use to dx concussion !

→ but important to assess for higher degree tbi!

Serological Biomarkers



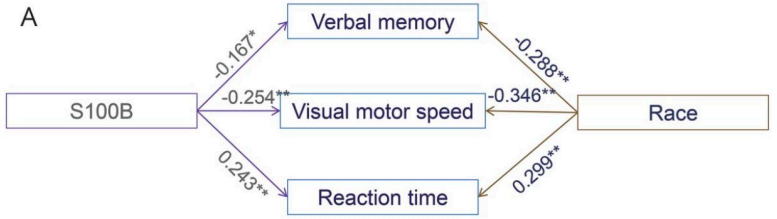
S100B



GFAP

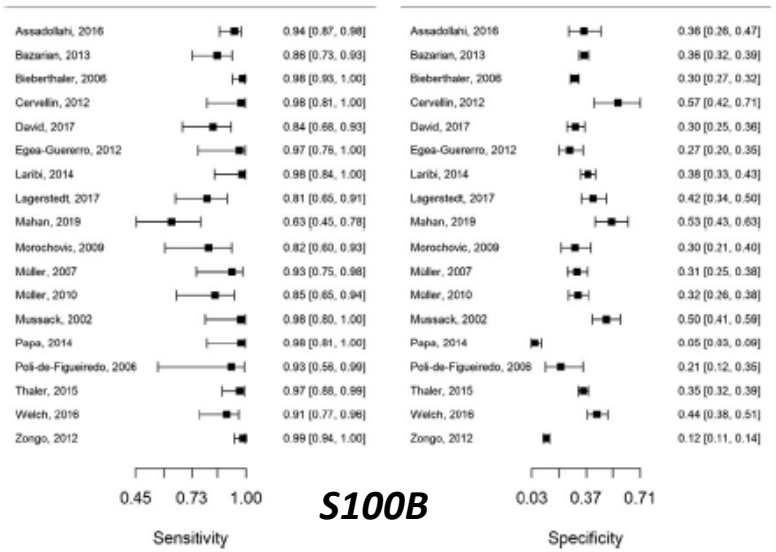
UCH-L1

Rogan et al., 2022

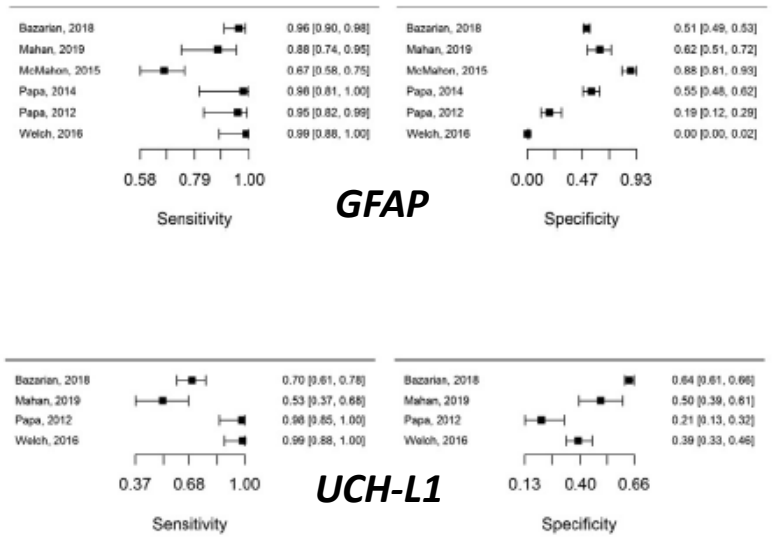


Asken et al., 2018

Serological Biomarkers

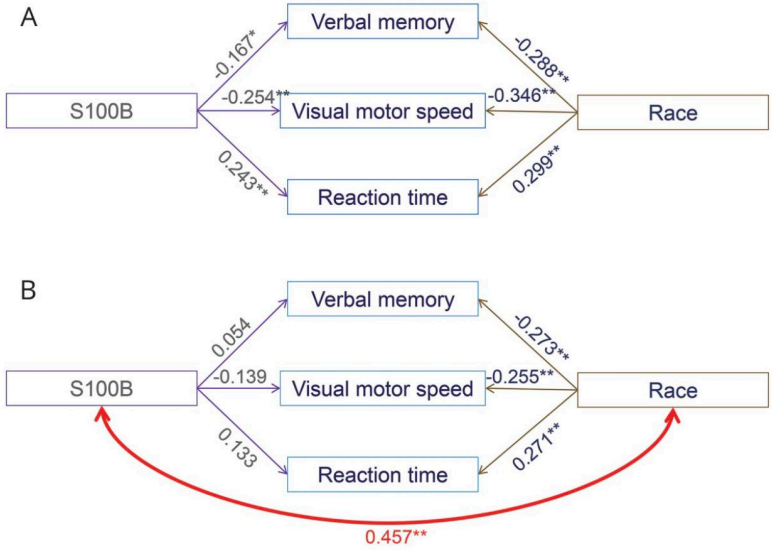


S100B



GFAP ***UCH-L1***

Rogan et al., 2022



Asken et al., 2018

Guidelines

1.) concussion diagnosed / suspected:

→ no return to play/practice

on the same day

2.) after initi

earlier access to specialized care → faster and better recovery!

…wise return to play / practice

→ 80-90%: favorable prognosis with complete remission of symptoms after 2 week

…if diagnosed and managed correctly!

Patricios et al., 2023

‚Return-to'-activity

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.	

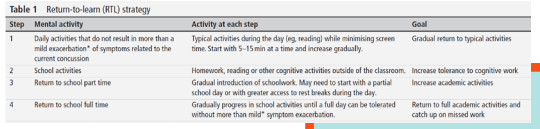
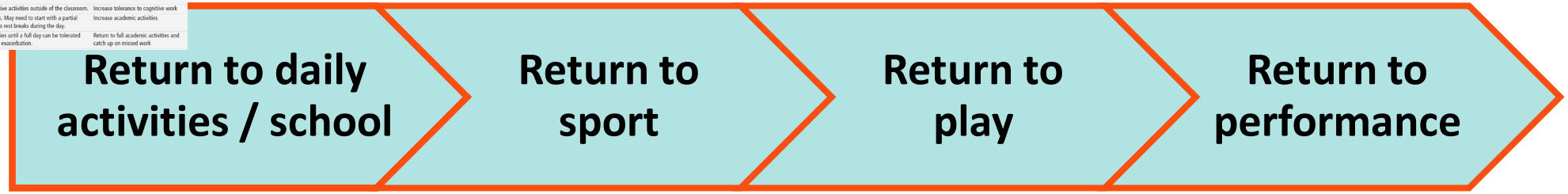


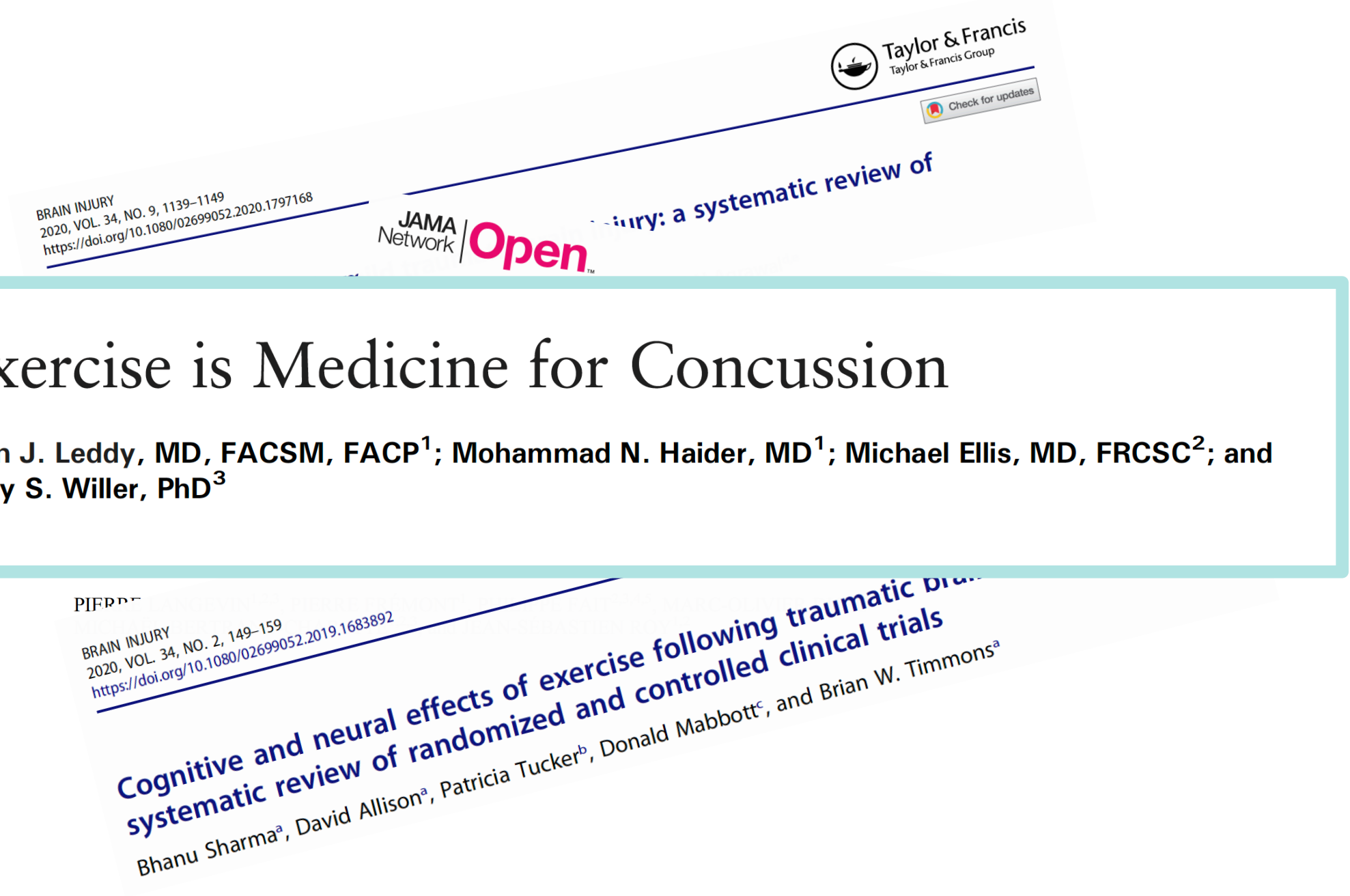
Table 1 Return-to-learn (RTL) strategy

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 (eg, reading) while minimising 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 in 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



Patricios et al., 2023

Treatment / Rehabilitation



BRAIN INJURY
2020, VOL. 34, NO. 9, 1139–1149
https://doi.org/10.1080/02699052.2020.1797168

Taylor & Francis
Taylor & Francis Group

Check for updates

JAMA Network Open

Exercise is Medicine for Concussion

John J. Leddy, MD, FACSM, FACP[1]; Mohammad N. Haider, MD[1]; Michael Ellis, MD, FRCSC[2]; and Barry S. Willer, PhD[3]

BRAIN INJURY
2020, VOL. 34, NO. 2, 149–159
https://doi.org/10.1080/02699052.2019.1683892

Cognitive and neural effects of exercise following traumatic brain injury: a systematic review of randomized and controlled clinical trials

Bhanu Sharma[a], David Allison[a], Patricia Tucker[b], Donald Mabbott[c], and Brian W. Timmons[a]

Different Outcome in females ?

more neck pain *(King et al., 2024)*

A prospective investigation of the effects of soccer heading on cognitive and sensorimotor performances in semi-professional female players

Jan Kern*, Philipp Gulde and Joachim Hermsdörfer

Chair of Human Movement Science, Department Health and Sport Sciences, TUM School of Medicine and Health, Technical University of Munich, Munich, Germany

frontiers | Frontiers in Human Neuroscience

TYPE Original Research
PUBLISHED 09 February 2024
DOI 10.3389/fnhum.2024.1345868

Received: 23 February 2022 | Revised: 3 January 2023 | Accepted: 31 January 2023

DOI: 10.1111/sms.14324

ORIGINAL ARTICLE

WILEY

Cortical thickness and neurocognitive performance in former high-level female soccer and non-contact sport athletes

Franziska Katharina Haase[1] | Annika Prien[2,3] | Linda Douw[4,5] | Nina Feddermann-Demont[6] | Astrid Junge[2] | Claus Reinsberger[1]

Therapeutic principles of Concussion

Systematic review

Rest and exercise early after sport-related concussion: a systematic review and meta-analysis

John J Leddy ,[1] Joel S Burma ,[2] Clodagh M Toomey,[3] Alix Hayden,[4] Gavin A Davis ,[5] Franz E Babl ,[6] Isabelle Gagnon,[7,8] Christopher C Giza,[9,10] Brad G Kurowski,[11] Noah D Silverberg ,[12] Barry Willer,[13] Paul E Ronksley,[14] Kathryn J Schneider [15]

To cite: Leddy JJ, Burma JS, Toomey CM, *et al*. *Br J Sports Med* 2023;**57**:762–770.

Conclusion Early PA, prescribed aerobic exercise and reduced screen time are beneficial following SRC. Strict physical rest until symptom resolution is not effective, and sleep disturbance impairs recovery after SRC.

1.) brief (!) protection from stimuli, reduction of screen time

2.) interventions to enhance the regeneration of the cerebral metabolism

RESTORATION OF CEREBRAL ENERGY METABOLISM

Exercise is Therapy!

- aerobic / cardio exercise
- monitoring: hr, RPE, symptom scores
- no significant worsening of symptoms
- careful with resistance training (initially)
- consider cognitive motor training

(Restoration of Healthy) Sleep is Therapy!

Consensus statement

Sleep and the athlete: narrative review and 2021 expert consensus recommendations

Neil P Walsh [1], Shona L Halson,[2] Charli Sargent,[3] Gregory D Roach,[3] Mathieu Nédélec,[4] Luke Gupta,[5] Jonathan Leeder,[6] Hugh H Fullagar,[7] Aaron J Coutts,[7] Ben J Edwards,[1] Samuel A Pullinger [1,8], Colin M Robertson,[9] Jatin G Burniston,[1] Michele Lastella,[3] Yann Le Meur,[4] Christophe Hausswirth,[10] Amy M Bender,[11] Michael A Grandner,[12] Charles H Samuels[13]

Tool Box for Athletes:

- Sleep Education for athletes
- Screen for sleep problems
- Encourage power naps
- Bank sleep

Therapeutic principles of Concussion

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Rest and exercise early after sport-related concussion: a systematic review and meta-analysis

John J Leddy [1], Joel S Burma [2], Clodagh M Toomey [3], Alix Hayden [4], Gavin A Davis [5], Franz E Babl [6], Isabelle Gagnon [7,8], Christopher C Giza [9,10], Brad G Kurowski [11], Noah D Silverberg [12], Barry Willer [13], Paul E Ronksley [14], Kathryn J Schneider [15]

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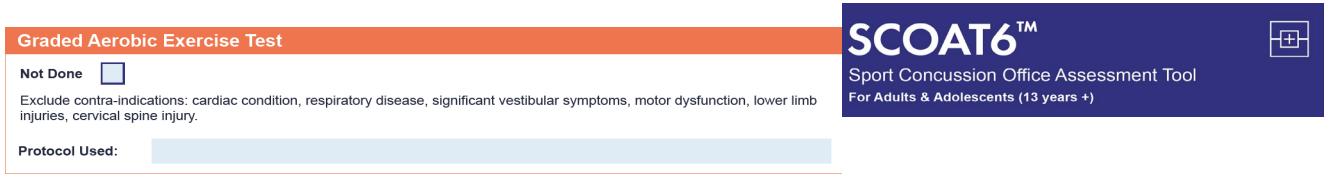
1.) brief (!) protection from stimuli, reduction of screen time

2.) interventions to enhance the regeneration of the cerebral metabolism

3.) interventions to improve symptoms



INDIVIDUALIZED SYMPTOMATIC TREATMENT

Assessment of affected clinical domains

ocular | vestibular | headaches/ migraine | cognition | fatigue | anxiety / mood | sleep

need for further diagnostic work-up?

sympt… …lling

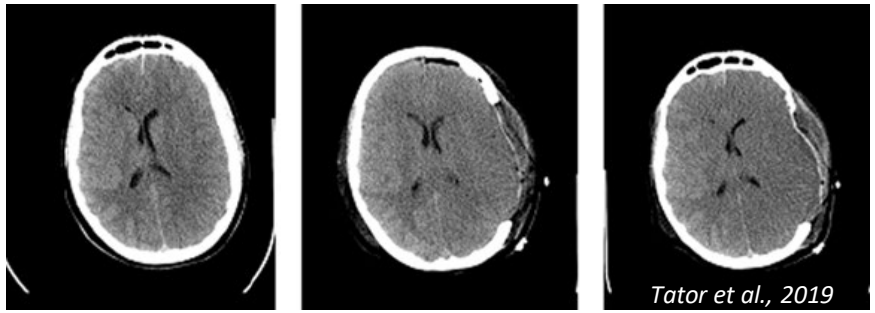
Concussion Therapy is Teamwork!

…pecific pharmacological and/or non-pharmacological therapy

Individualize return-to protocol according to affected clinical domain

Second Impact Syndrom

Rowan Stringer, 17, R.I.P
Rugby



Jake Snakenberg, 14, R.I.P
American Football

ELSEVIER

Neurochirurgie
Available online 10 March 2020
In Press, Corrected Proof

Original article

Second Impact Syndrome. Myth or reality?

J. Engelhardt [a], D. Brauge [b], H. Loiseau [c]

44 cases

1 : 205.000 athlete seasons

male, <20 years

? Postconcussion Syndrome
better: Persistent Postconcussion Symptoms

Elena Myers Taylor

Definitions for postconcussion syndrome and related disorders

	ICD-10	DSM-IV	DSM-V	5th International Consensus Conference on Concussion in Sport
Terminology	Postconcussion syndrome	Postconcussional disorder	Major or mild neurocognitive disorder: traumatic brain injury	Sports-related concussion: symptoms and signs
Trauma	History of head trauma	History of head injury	Impact to head or rapid movement/displacement of brain	Impulsive force transmitted to the head
Loss of consciousness (LOC)	"Usually sufficiently severe to result in loss of consciousness"	Suggested criterion: > 5 minutes	Not required	Not required
Altered consciousness / cognitive impairment	Yes	Relative attention or memory impairment on neuropsychologic testing	Yes, or (+) imaging/ neurologic exam	"Impairment of neurologic functioning"
Maximum symptom delay for attribution to trauma	4 weeks	N/A	Immediate or when conscious	Minutes to hours
Minimum duration	N/A	3 months	"Past the acute injury phase"	Adults: 10–14 days Children: 4 weeks
Objective evidence	Not required	Required	Not required	Not required

DSM-IV, *Diagnostic and Statistical Manual of Mental Disorders*, fourth edition; DSM-V, *Diagnostic and Statistical Manual of Mental Disorders*, fifth edition; ICD-10, *International Statistical Classification of Diseases and Related Health Problems*, 10th revision.

Dwyer and Katz, 2018

risk factors

pre-existing:

- prior tbi
- psychiatric disease
- headache syndrome
- genetic predisposition
- female ….

mechanism of injury:

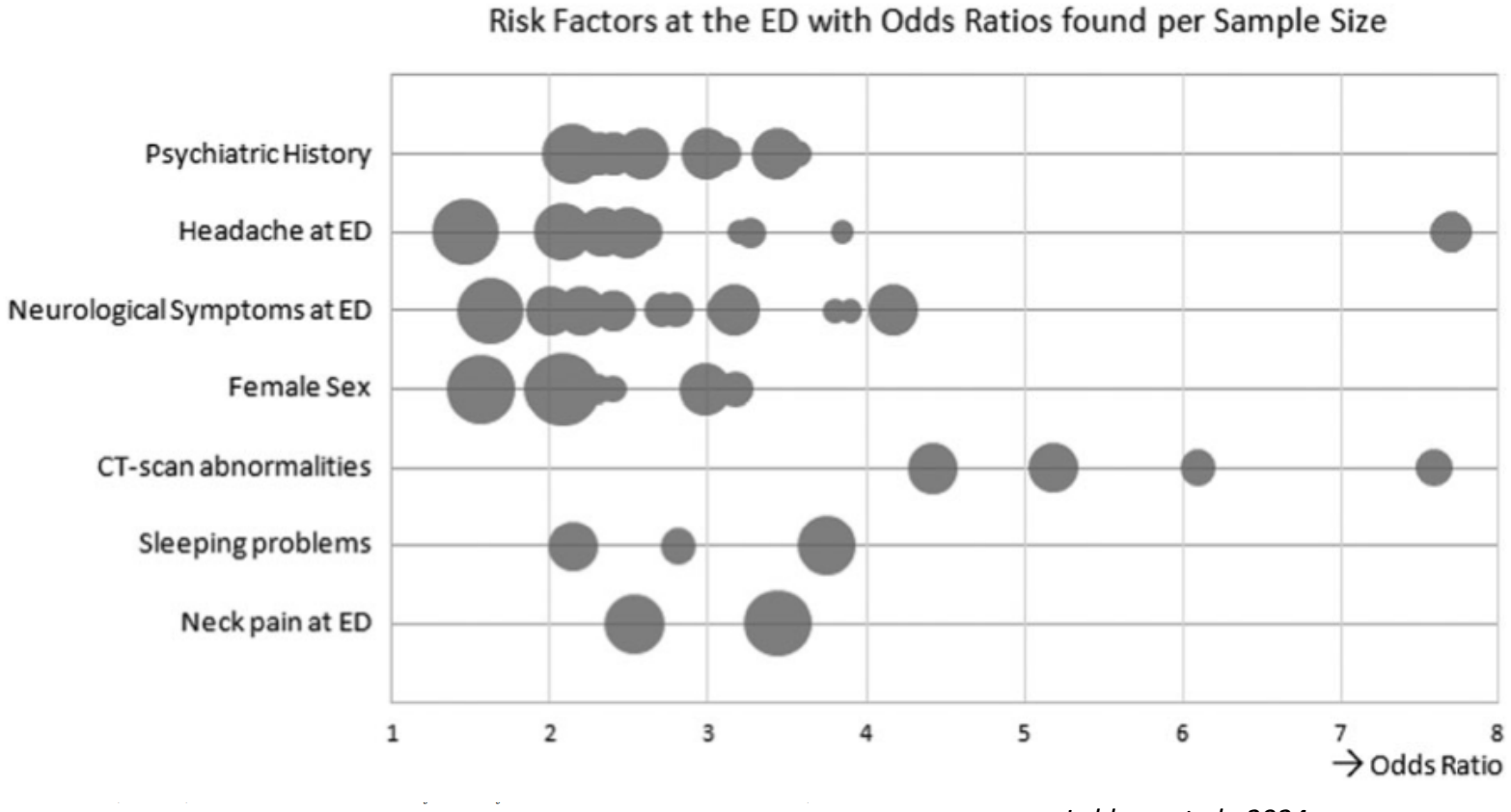
- quick onset of symptoms
- *outside of sport*

after injury:

- adjustment disorders, secondary gain
- bad compliance

Persistent Postconcussion Symptoms

Elena Myers Taylor



Lubbers et al., 2024

risk factors

pre-existing:

- prior tbi
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- headache syndrome
- genetic predisposition
- female ….

mechanism of injury:

- quick onset of symptoms
- *outside of sport*

after injury:

- adjustment disorders, secondary gain
- bad compliance

Long Term Health of Athletes after Concussion

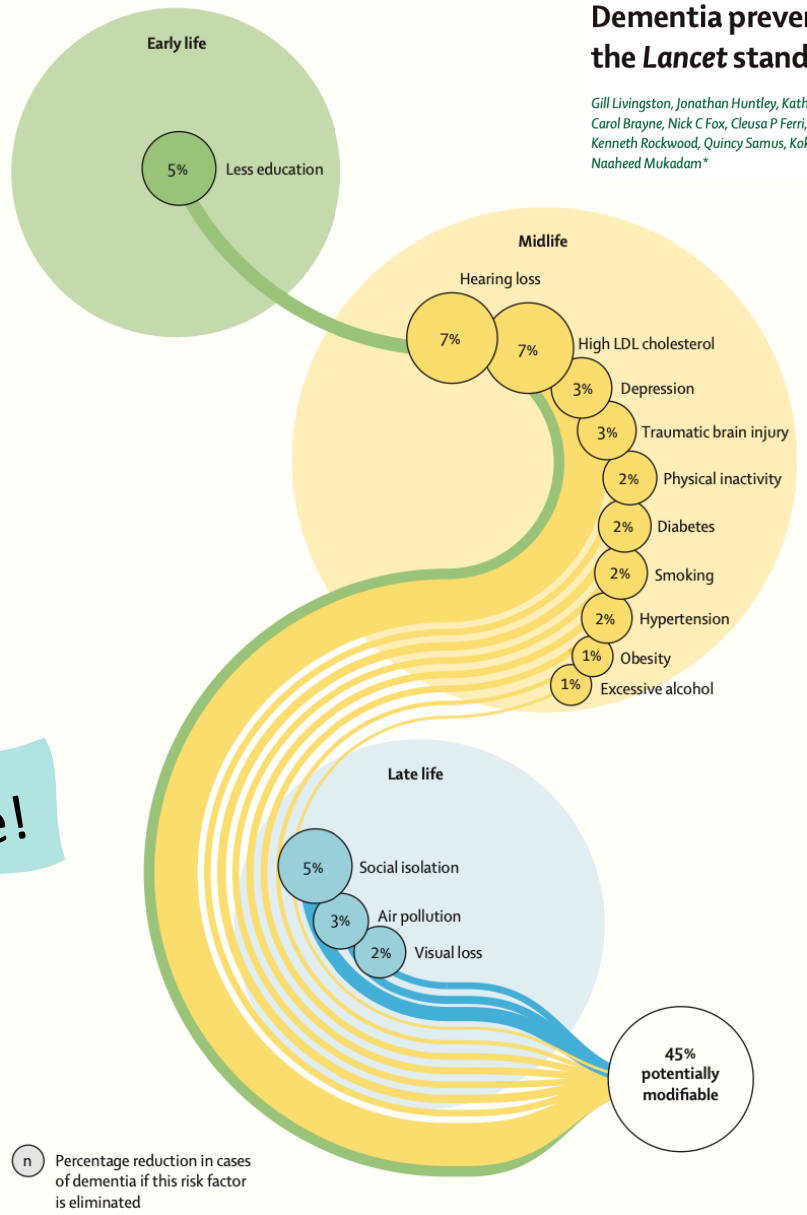
14 potentially modifiable

risk factors

account for ~45%

of worldwide dementias

early specialized care improves outcome!



Dementia prevention, intervention, and care: 2024 report of the *Lancet* standing Commission

Gill Livingston, Jonathan Huntley, Kathy Y Liu, Sergi G Costafreda, Geir Selbæk, Suvarna Alladi, David Ames, Sube Banerjee, Alistair Burns, Carol Brayne, Nick C Fox, Cleusa P Ferri, Laura N Gitlin, Robert Howard, Helen C Kales, Mika Kivimäki, Eric B Larson, Noeline Nakasujja, Kenneth Rockwood, Quincy Samus, Kokoro Shirai, Archana Singh-Manoux, Lon S Schneider, Sebastian Walsh, Yao Yao, Andrew Sommerlad, Naaheed Mukadam**

Lancet 2024; 404: 572–628

Mass General Brigham

Exercise is Medicine

or

Sports is Pharmacy for Patients with Neurological Diseases

Exercise is Medicine ?

stroke

preventative effects
by sports/PA on mortality
larger than by medications

Naci et al., 2013

Exercise is Medicine ?

Comparative effectiveness of exercise and drug interventions on mortality outcomes: metaepidemiological study

Huseyin Naci *researcher*[1] *fellow*[2], John P A Ioannidis *director*[3]

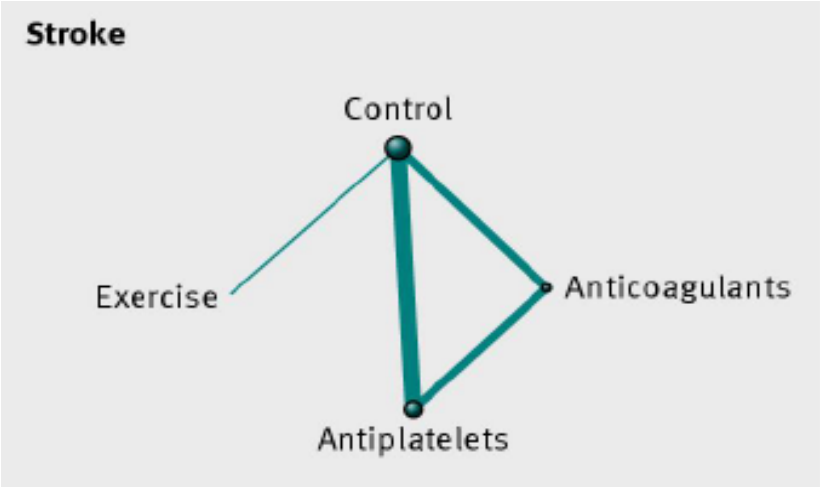
BMJ

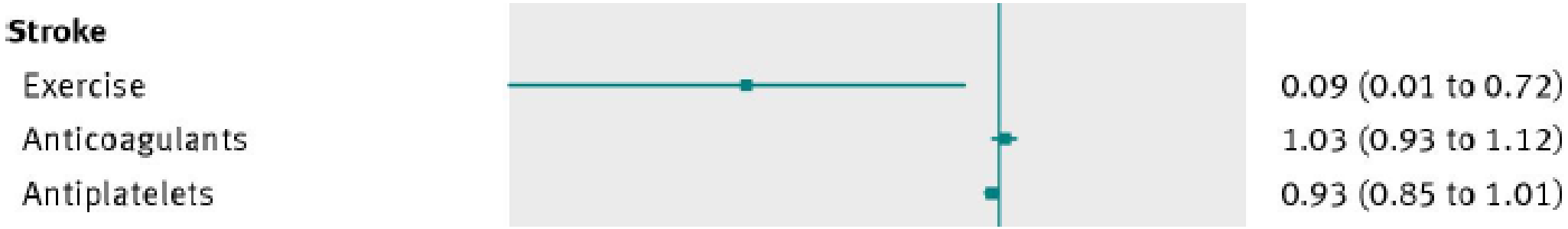
BMJ 2013;347:f5577 doi: 10.1136/bmj.f5577 (Published 1 October 2013)

16 meta analyses

305 studies

~ 340.000 patients





Exercise is Medicine ?

stroke

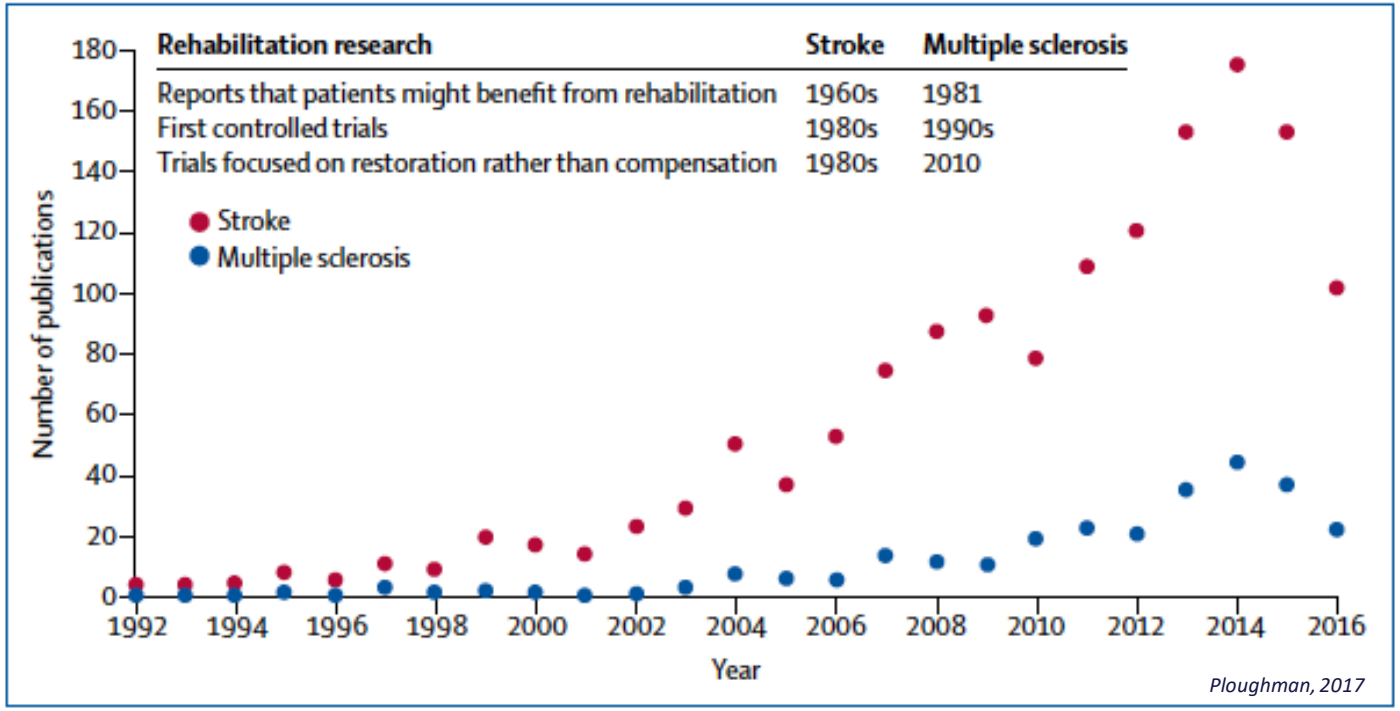
preventative effects
by sports/PA on mortality
larger than by medications

Naci et al., 2013

multiple sclerosis

relapses reduced by 27%
through sports/physical activity

Pelutti et al., 2014

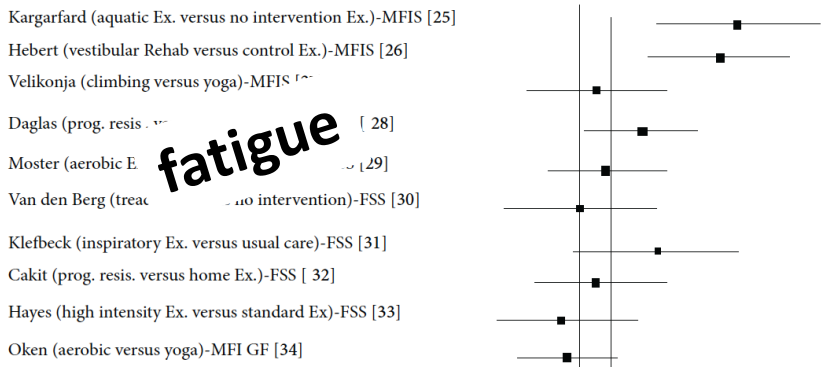


Ploughman, 2017

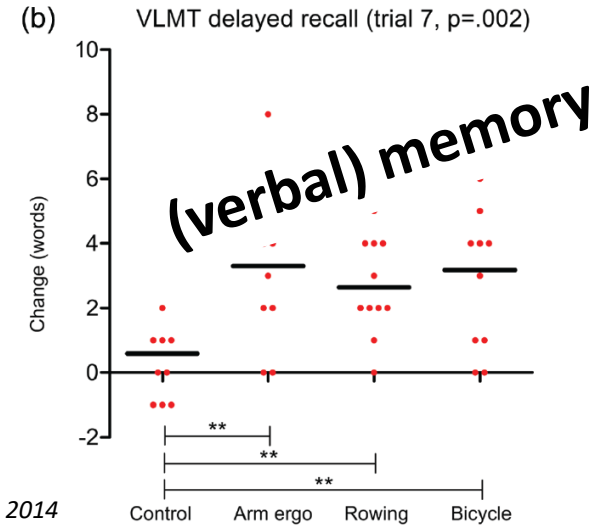
Multiple Sclerosis and Sports & Exercise

effects on…:

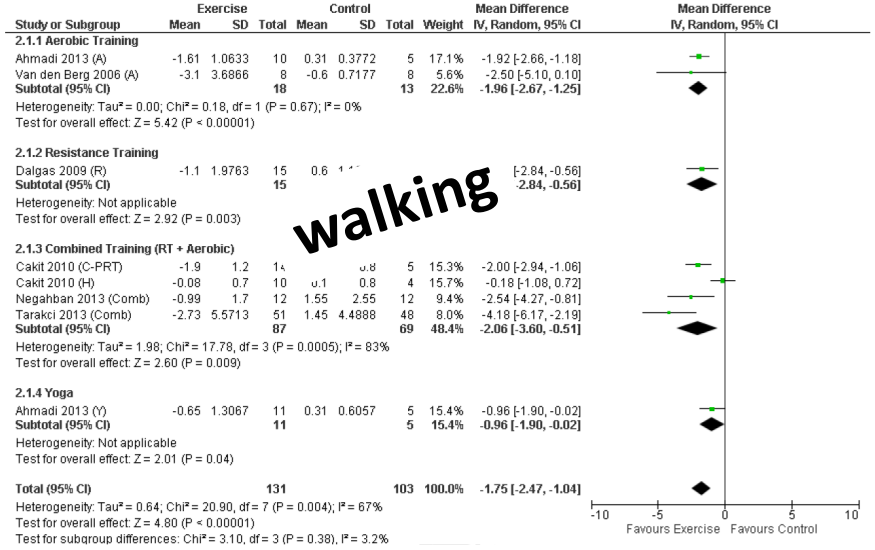
effect size: 0.57



Asano & Finlayson, 2014



Briken et al., 2014



Pearson et al., 2015

→ 2mWT ~ 19% improved

→ 10mWT ~ 16.5% improved

etc…

Multiple Sclerosis and Sports & Exercise

is it safe ?

no study has ever demonstrated worsening of disease (progression) by physical exercise / exercise

‚side effects': 1.2% (ctrl.) vs. 2.0 % (sports), RR 1.67

→ identical rates in healthy subjects

→ mostly musculo-sceletal

relapse rate: 6.3% (Ctrl.) vs. 4.6 % (Sport), RR 0.73

→ 27% exercise induced risk reduction

Pelutti et al., 2014

Exercise is Medicine ?

stroke

preventative effects
by sports/PA on mortality
larger than by medications

Naci et al., 2013

multiple sclerosis

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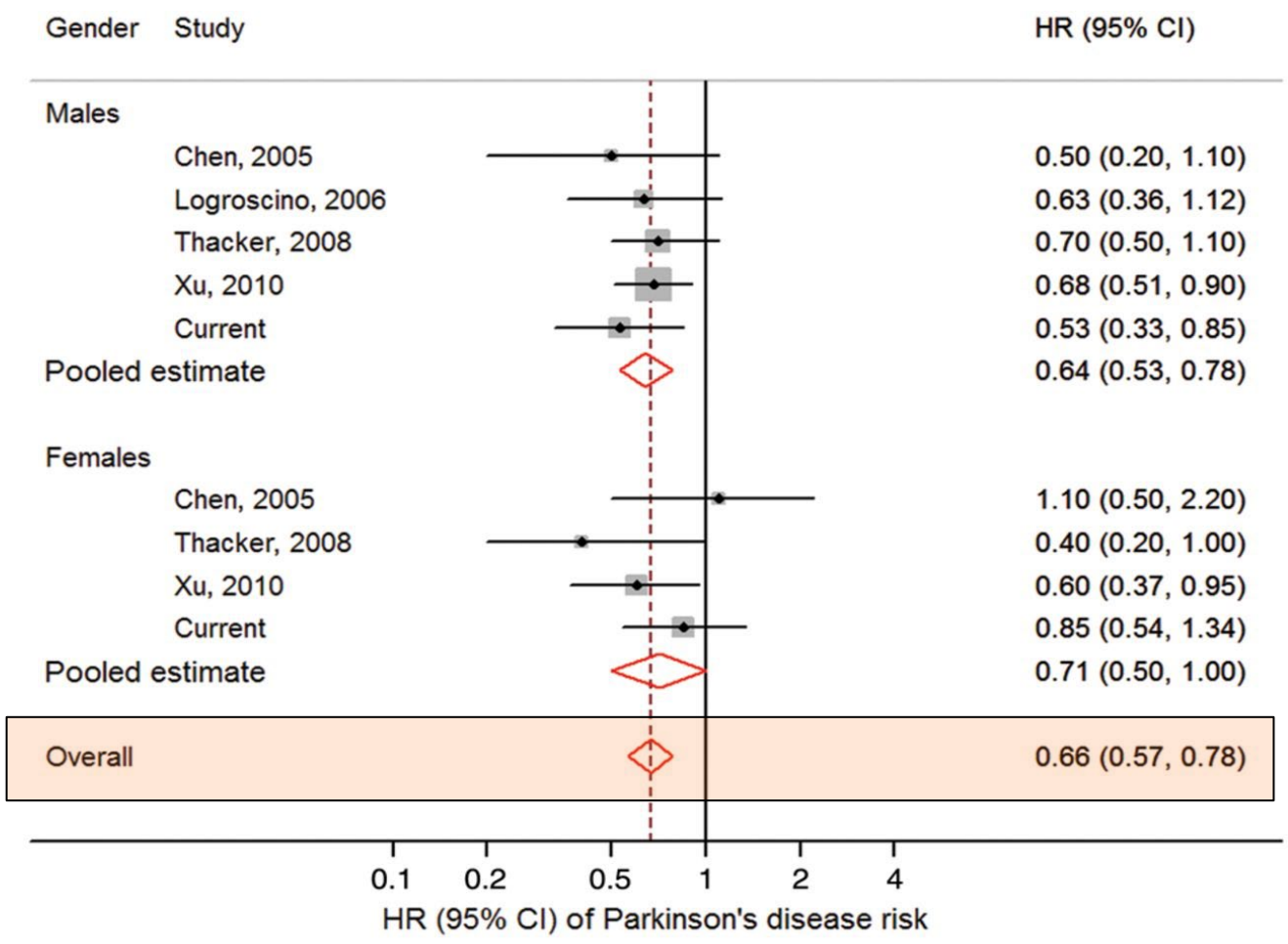
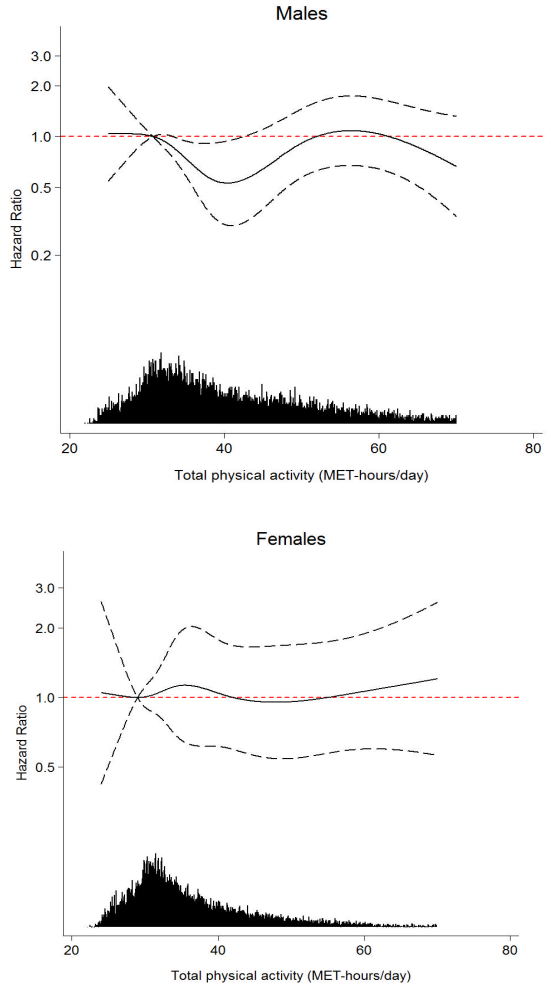
parkinson‘s disease

prevention by sports/PE:
~34% (predominantly males)

Yang et al., 2015, Fang et al., 2018

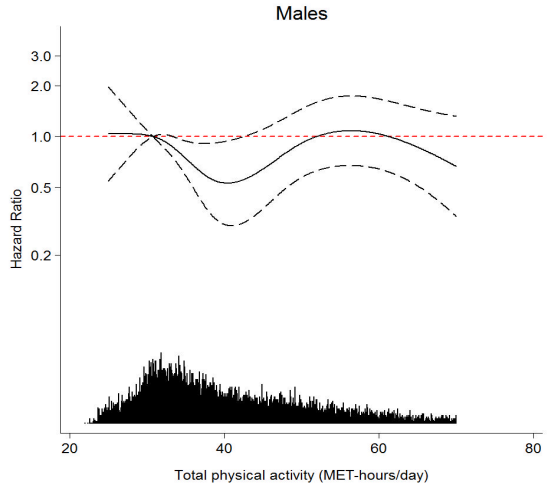
Parkinson's Disease and Sports & Exercise

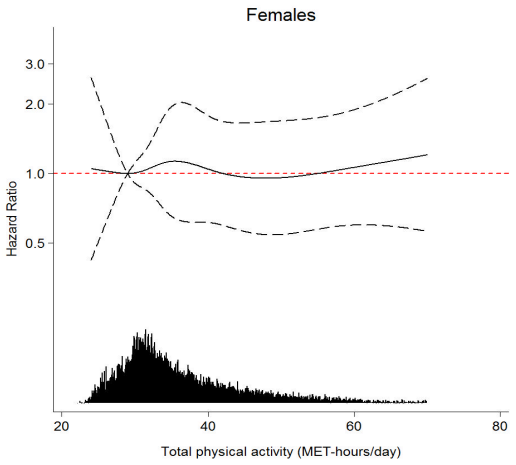




Yang et al., Brain, 2015

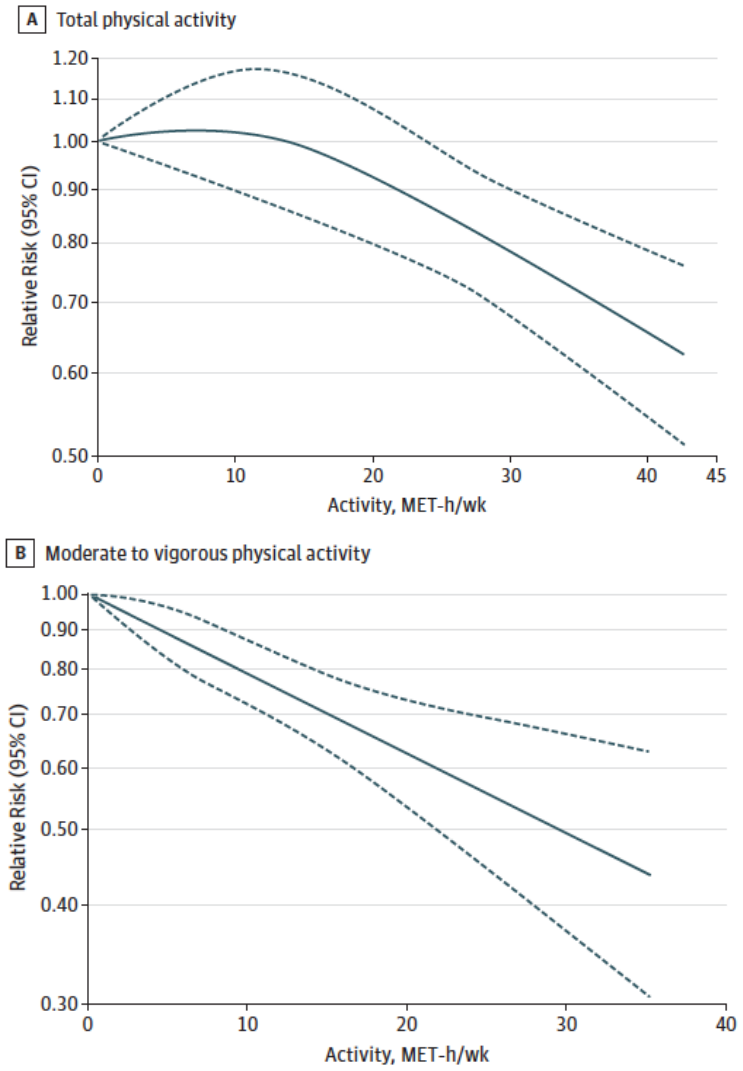
Parkinson's Disease and Sports & Exercise





Yang et al., Brain, 2015

Parkinson's Disease and Sports & Exercise



increase of physical activity by

20 MET-h / week

→ risk reduction by:

-10% (total)

- 35% (vigorous)

... only in males ...

Fang et al., JAMA Netw open, 2018

Parkinson's Disease and Sports & Exercise

	Muscle strength	Balance	Gait	Endurance	Function	UPDRS motor	Fall reduction
Gait training with cues			✓				
Brisk walking		✓		✓			
Nordic walking			✓	✓			
Gait training using treadmill		✓	✓	✓			
Balance training		✓	✓		✓	✓ (on-med)	✓
Progressive resistive exercise	✓					✓ (off-med)	
Virtual-reality therapy		✓	✓		✓		
Tai Chi		✓	✓		✓		✓
Dance		✓		✓		✓ (off-med)	

Abbreviation: UPDRS, United Parkinson Disease Rating Scale.

Mak et al., 2019

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epilepsies

well described effects in animals
only few (but not neg.) clinical studies

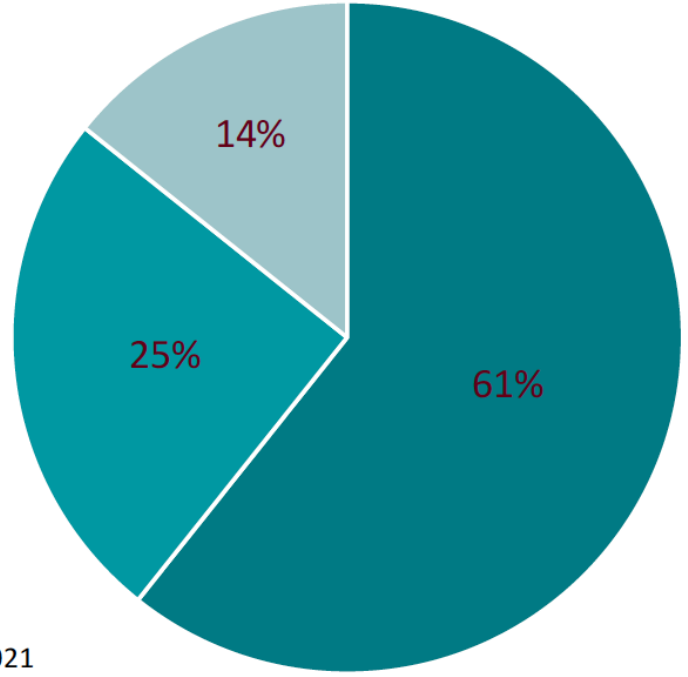
Van den Bongard et al., 2020

Epilepsies and Sports & Exercise

studies investigating the relationship

between exercise & seizure frequency

- reduction (3 studies, n=51)
- no change (2 studies, n=21)
- increase (1 study, n=12)



Van den Bongard et al., 2021

type of exercise …	>/= 1 sympt. sz	single unprov. sz	> / = 12 months sz free	sleep ass. sz	no loc	with loc	cured epilepsy	AED reduction
1								
2								
3								

Capovila et al., 2016

Exercise is Medicine ?

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epilepsies

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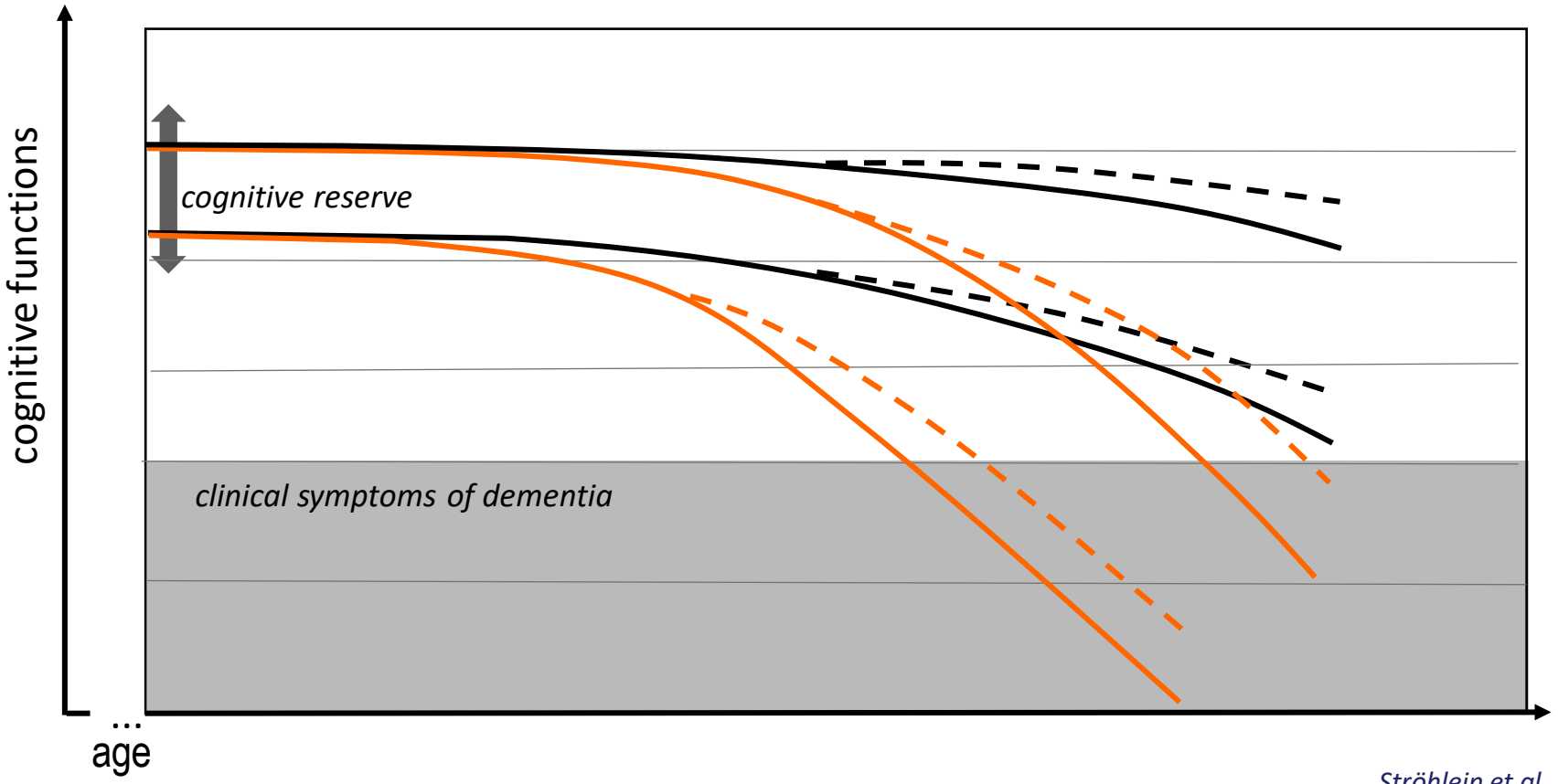
Van den Bongard et al., 2020

dementias

risk reduction by sports/PE:
up tp ~45% (Alzheimer's)

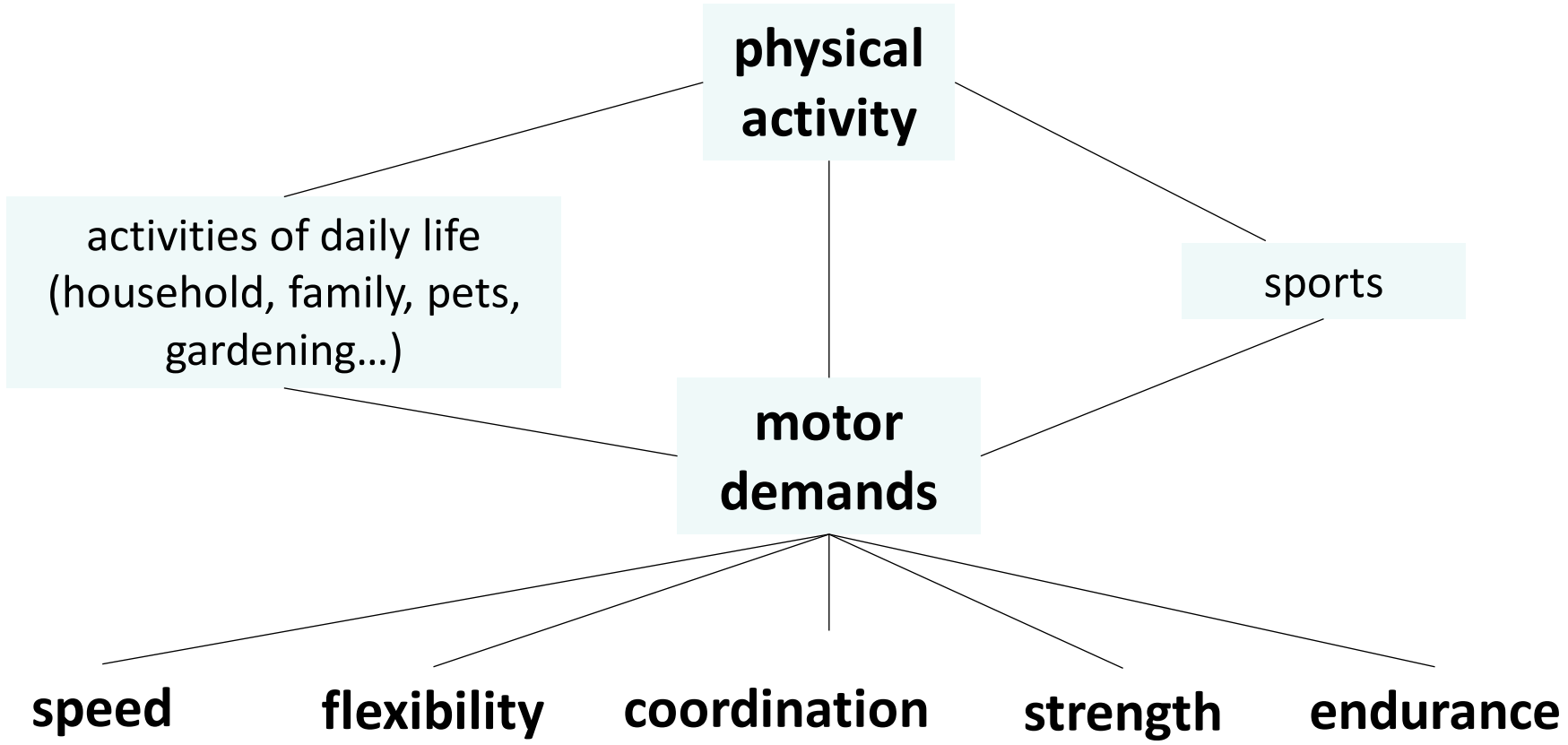
Williams et al., 2010, Erickson et al., 2012

Dementias and Sports & Exercise



Ströhlein et al., 2019
modified from Sperling et al., 2011

Which Exercise is (the best) Medicine ?



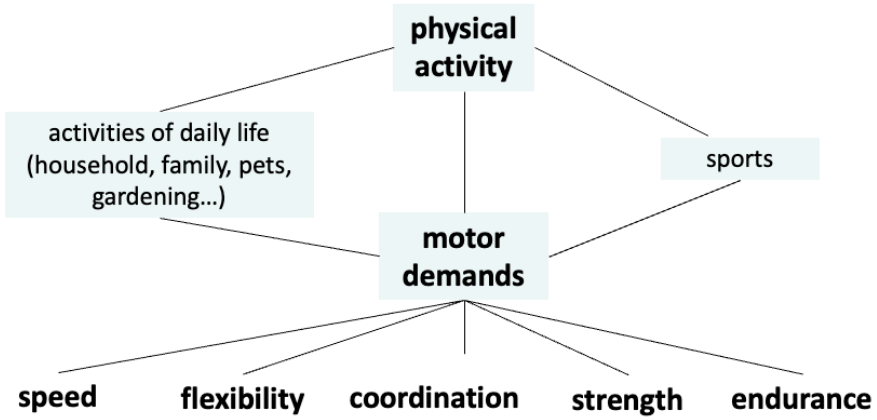
cognition, social interaction, memory, decision making…?

NEUROLOGY 2002;58:1139–1140

Editorial

Does training change the brain?

Peter B. Rosenberger, MD; and David A. Rottenberg, MD



cognition, social interaction, memory, decision making…?

does variability make training more effective for the brain?

influence of joy and pleasure?

Mass General Brigham

Mass General Brigham

Sports Neurology & Neurosciences

it's not a man's world!

Claus Reinsberger, MD PhD
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Mass General Brigham