

Extended Management of the Post-Concussive Athlete: Treatment Strategies for Persistent Symptoms

- ▶ Kim Barron, D.O., CAQSM
- ▶ April 20, 2024

Treatment Strategies for Persistent Post-Concussive Symptoms (PPCS)

Presenter:

Kim Barron, D.O., CAQSM

Primary Care Sports Medicine Physician

- ▶ Clinical Assistant Professor OSU-CHS Osteopathic Manipulative Medicine
- ▶ Faculty OSU-CHS Orthopedic Surgery Residency Program
- ▶ Medical Director OSU-CHS Masters Athletic Training Program
- ▶ Team Physician ECHL Tulsa Oilers Hockey and IFL Tulsa Oilers Football

- ▶ Education:
 - ▶ Medical School: NSU-KPCOM
 - ▶ Residency: OMECO Family Medicine
 - ▶ Fellowship: University of Arizona Primary Care Sports Medicine



Disclosure

I have NO financial disclosure or conflicts of interest with the presented material in this presentation.

Treatment Strategies for PPCS

Objectives: at the conclusion of the program, participants will be able to:

- 1) Understand the risk factors and underlying conditions that are associated with persistent post-concussive symptoms.
- 2) Identify treatment strategies for extended management of symptoms.
- 3) Discuss pharmacological treatment options for the treatment of persistent post-concussive symptoms.
- 4) Develop advanced options in symptom management of persistent post-concussion symptoms utilizing manual therapy and vestibular oculomotor therapy.

“Recovery”

- ▶ Wide variability in clinical time points for definition of “recovery” from Sport Related Concussion (SRC)
- ▶ The following definitions have been adopted by the Amsterdam Consensus Panel:
 1. Symptom resolution at rest: resolution of symptoms associated with the current concussion at rest.
 2. Complete symptom resolution: resolution of symptoms associated with the current concussion at rest with no return of symptoms during or after maximal physical and cognitive exertion.
 3. Return-to-learn (RTL): return to preinjury learning activities with no new academic support, including school accommodations or learning adjustments.
 4. Return-to-sport (RTS): completion of the RTS strategy with no symptoms and no clinical findings associated with the current concussion at rest and with maximal physical exertion.

“Recovery”

- ▶ Large majority of injured athletes recover from sport related concussion, from a clinical perspective, within 4 weeks following injury
- ▶ Neurobiological recovery might extend beyond clinical recovery in some athletes

Post-Concussive Syndrome (PCS)

- ▶ Lack of agreement about the definition of Post-Concussive Syndrome (PCS)
- ▶ ICD-10 requires 3 symptoms or more from a restricted list of symptoms including headache, dizziness, fatigue, irritability, insomnia, concentration difficulty, memory difficulty, and reduced tolerance to stress, emotional excitement, or alcohol
- ▶ In contrast, DSM-IV requires 3 or more symptoms from a different list, including fatigue, sleep disturbance, headache, dizziness, irritability, affective disturbance, personality change, and apathy, and requires symptoms to last 3 or more months following injury
 - ▶ It also requires the presence of cognitive deficits in attention and/or memory and a significant decline in social and/or occupational functioning
- ▶ In DSM-V, PCS was replaced by “Major or Mild Neurocognitive Disorder Due to Traumatic Brain Injury”
 - ▶ In general, DSM-V only recognizes patients with loss of consciousness (LOC), posttraumatic amnesia, disorientation, or focal neurological signs such as hemiparesis or abnormal neuroimaging

Persistent Post-Concussive Symptoms (PPCS):

The term 'persisting symptoms' is used for symptoms that persist > 4 weeks across children, adolescents and adults



Risk Factors for PPCS

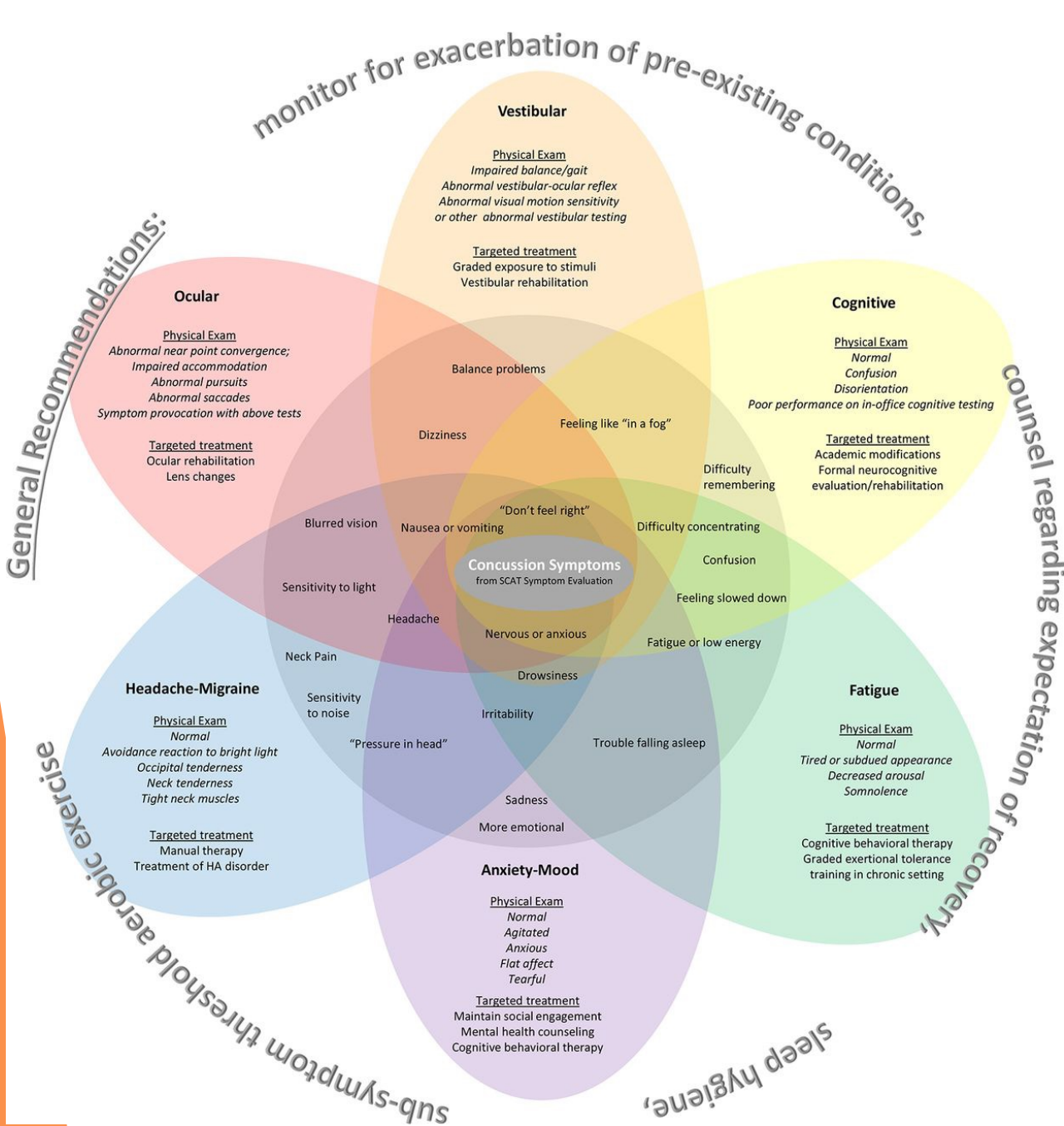
- ▶ **The most consistent predictor of recovery from concussion is the number and severity of acute and subacute symptoms (symptom burden)**
 - ▶ Subacute headache and depression after injury are risk factors for symptoms persisting for >1month
 - ▶ Sleep disturbance in the 10 days after SRC is associated with an increased risk of persisting symptoms
 - ▶ A preinjury history of mental health problems, particularly depression, appears to increase the risk for persistent symptoms
 - ▶ Athletes with learning disabilities or attention deficit/hyperactivity disorder do not appear to be at risk for prolonged recovery

Risk Factors for PPCS

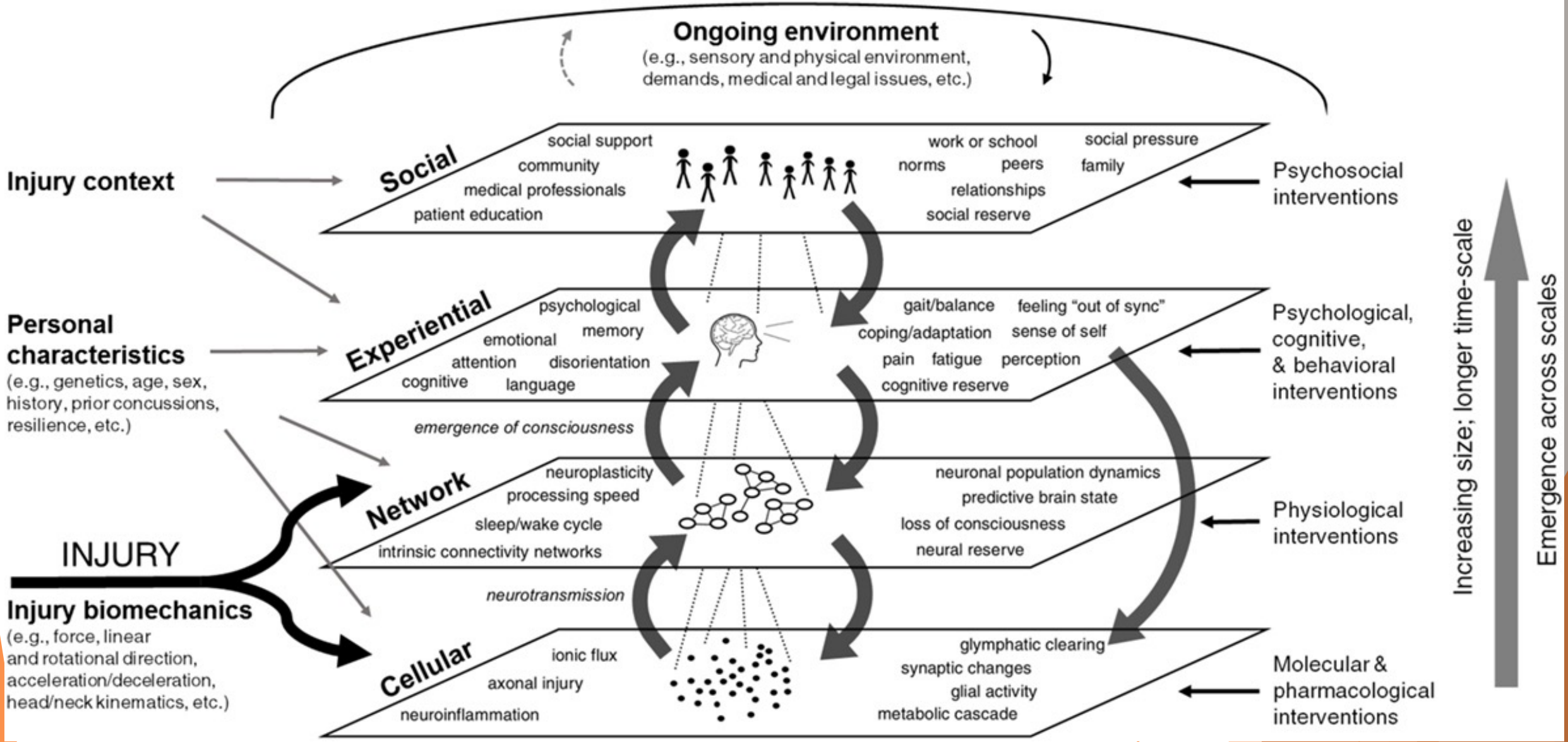
- ▶ Morgan CD et al. “ Predictors of postconcussion syndrome after sports-related concussion in young athletes: a matched case-control study” J Neurosurg Pediatr 2015; 15(6):589-98
 - ▶ Risk for developing PCS: History of previous concussion ($p = 0.010$); Delayed symptom onset (> 3 hours) ($p < 0.001$); History of mood disorders ($p=0.002$) other psychiatric illness ($p=0.039$); History of significant life stressors ($p=0.036$); Family history of mood disorders ($p=0.006$) and other psychiatric illness ($p=0.031$); and Family history of migraine ($p=0.003$)
 - ▶ Development NOT predicted by: race, insurance status, BMI, sport, helmet use, type of symptoms, medication use, learning disability, and ADHD

Treatment for Persistent Post-Concussive Symptoms (PPCS)

A multimodal clinical assessment, ideally by a multidisciplinary team, is indicated to characterize individuals with persisting symptoms, including the types, pattern and severity of symptoms, and any associated conditions or other factors that may be causing or contributing to the symptoms

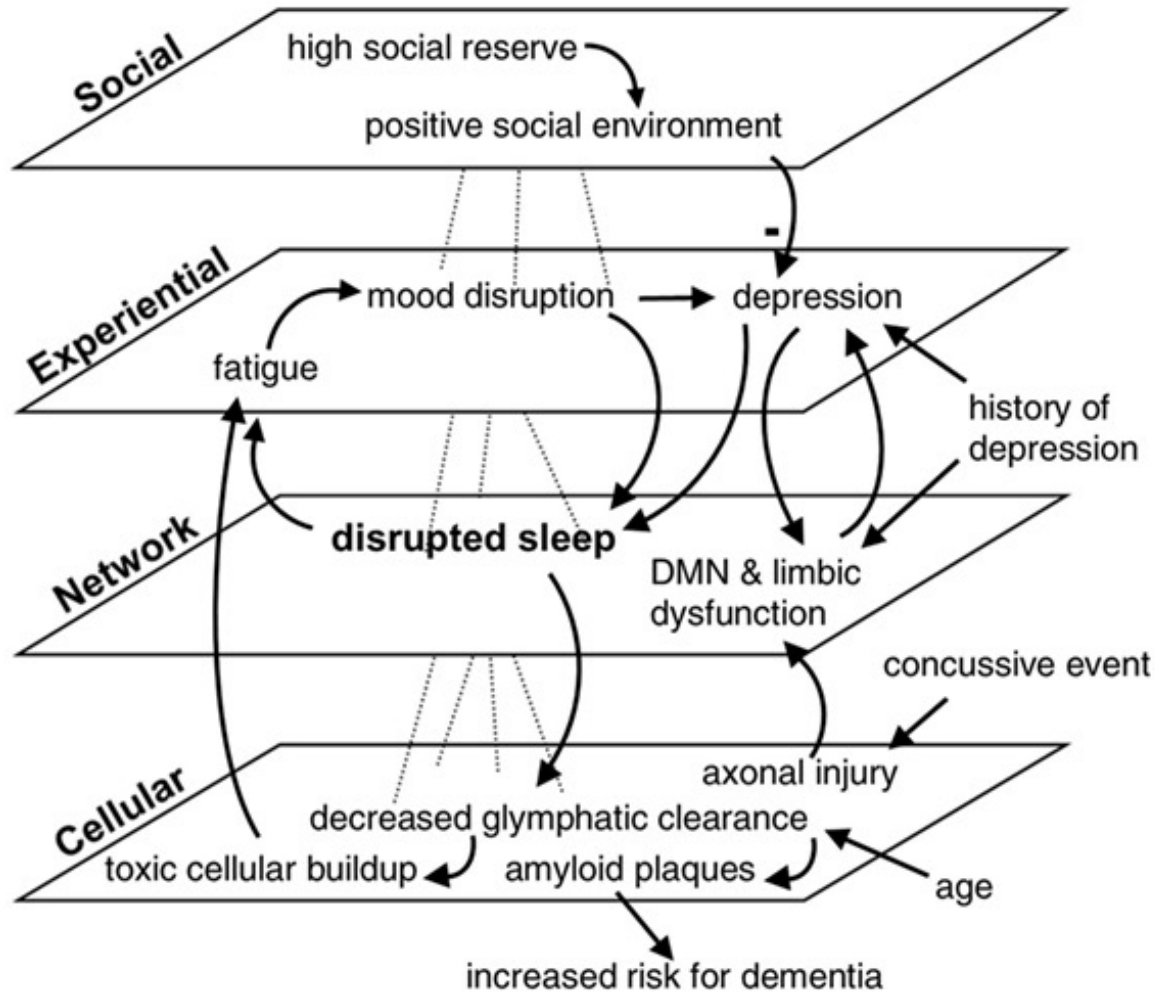


- ▶ Symptoms attributed to concussion are non-specific, commonly also reported by healthy individuals and those with conditions other than concussion and can be exacerbated by a variety of biopsychosocial factors aside from concussion, which should be assessed in the context of persisting symptoms
- ▶ Other problems may exist prior to injury (but can be exacerbated by a concussion), co-occur with persisting symptoms or mimic persisting symptoms but do not arise from concussion



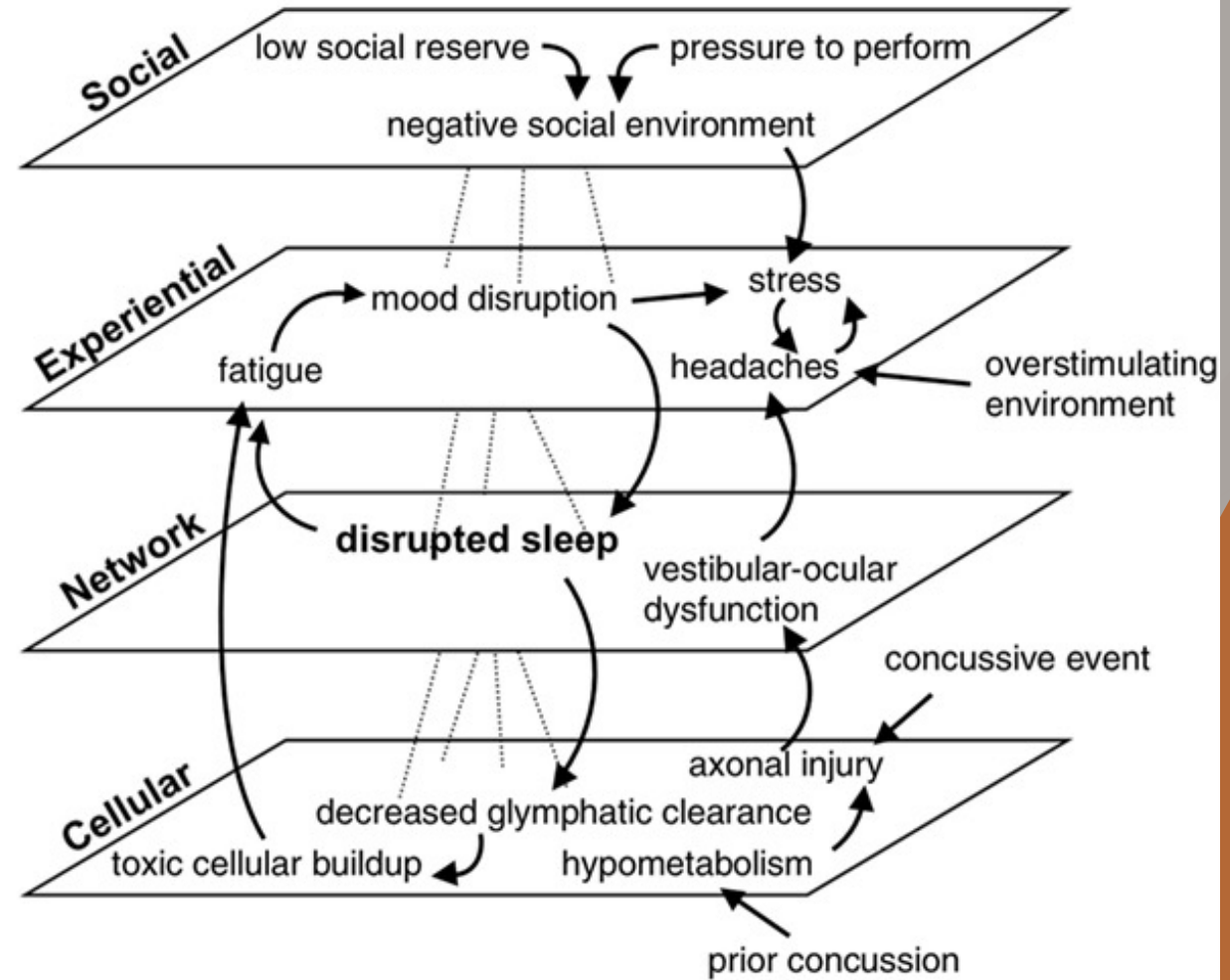
Person A

Elderly female, concussion from fall



Person B

Male college athlete, concussion at football practice



Treatment for PPCS

- ▶ Common considerations in the context of persisting symptoms include:
 - ▶ Mental health issues
 - ▶ Learning or attention difficulties
 - ▶ Visual, oculomotor, cervical and vestibular problems
 - ▶ Headache disorders and migraine
 - ▶ Sleep disturbance
 - ▶ Dysautonomia, including orthostatic intolerance and postural orthostatic tachycardia syndrome (POTS)
 - ▶ Pain

Treatment for PPCS

▶ Subthreshold Aerobic Exercise Training

- ▶ Multicenter prospective randomized clinical trial was conducted at university concussion centers. Male and female adolescent athletes (age 13-18 years) presenting within 10 days of SRC were randomly assigned to aerobic exercise or a placebo-like stretching regimen
- ▶ Recovery was defined as being asymptomatic with exercise treadmill tolerance (vs return to school and/or return to play)
- ▶ Excluded athletes with ADHD, learning disorder, depression, anxiety, and a history of more than 3 prior concussions

Treatment for PPCS

▶ Subthreshold Aerobic Exercise Training

- ▶ Results: those assigned to aerobic exercise recovered faster (13 days) than those assigned to placebo-like stretching (17 days)
- ▶ Conclusion: individualized sub symptom threshold aerobic exercise treatment prescribed to adolescents with concussion symptoms during the first week after SRC speeds recovery and may reduce the incidence of delayed recovery
- ▶ Authors did not measure physical activity objectively, and thus it is impossible to estimate the dose of exercise require to elicit a treatment outcome or what the exercise intervention actually meant
 - ▶ Leddy JJ, Haider MN, Ellis MJ, Mannix R, Darling SR, Freitas MS, Suffoletto HN, Leiter J, Cordingley DM, Willer B. Early Subthreshold Aerobic Exercise for Sport-Related Concussion: A Randomized Clinical Trial. *JAMA Pediatr.* 2019 Apr 1;173(4):319-325. doi: 10.1001/jamapediatrics.2018.4397. PMID: 30715132; PMCID: PMC6450274

Treatment for PPCS

- ▶ Persistent Concussion Symptoms and Cervicovestibular Rehabilitation
 - ▶ Prospective randomized controlled trial of concussed patients with symptoms of dizziness, neck pain, and/or headaches of > 10 days
 - ▶ Patients aged 12-30 with n=15 in treatment group and n=14 in control group
 - ▶ For up to 8 weeks, both groups received postural education, ROM exercises and cognitive and physical rest until asymptomatic followed by a protocol of graded exertion. The intervention group also received cervical spine and vestibular rehabilitation.

Treatment for PPCS

▶ Persistent Concussion Symptoms and Cervicovestibular Rehabilitation

▶ Results: For adolescents and adults with dizziness, neck pain and/or headaches >10 days following concussion, individualized cervicovestibular rehabilitation may decrease time to return to sport compared with rest followed by gradual exertion (HR 3.91 (95% CI 1.34 to 11.34)) and when compared with a subtherapeutic intervention (HR 2.91 (95% CI 1.01 to 8.43)). For adolescents with vestibular symptoms/impairments, vestibular rehabilitation may decrease time to medical clearance (vestibular rehab group 50.2 days (95% CI 39.9 to 60.4) compared with control 58.4 (95% CI 41.7 to 75.3) days).

▶ Conclusion: “Cervicovestibular rehabilitation is recommended for adolescents and adults with dizziness, neck pain and/or headaches for >10 days. Vestibular rehabilitation (for adolescents with dizziness/vestibular impairments >5 days) and active rehabilitation and/or collaborative care (for adolescents with persisting symptoms >30 days) may be of benefit.”

▶ Schneider KJ, Critchley ML, Anderson V, *et al.* Targeted interventions and their effect on recovery in children, adolescents and adults who have sustained a sport-related concussion: a systematic review. *British Journal of Sports Medicine* 2023;57:771-779

Treatment for PPCS

▶ Collaborative Care for PPCS

- ▶ Prospective randomized controlled trial of patients with persistent symptoms >1 month following sports-related concussion
- ▶ Patients aged 11-17 received collaborative care (n=25) or care as usual (n=24)
 - ▶ Collaborative care: care management, cognitive behavioral therapy (CBT), and psychopharmacological consultation (in cases of severe or recalcitrant symptoms that did not respond to psychotherapy when warranted at any time in treatment)
- ▶ Patients assessed prior to randomization and after 1, 3, and 6 months. 2 groups compared over time using linear mixed effects regression models

Treatment for PPCS

▶ Collaborative Care for PPCS

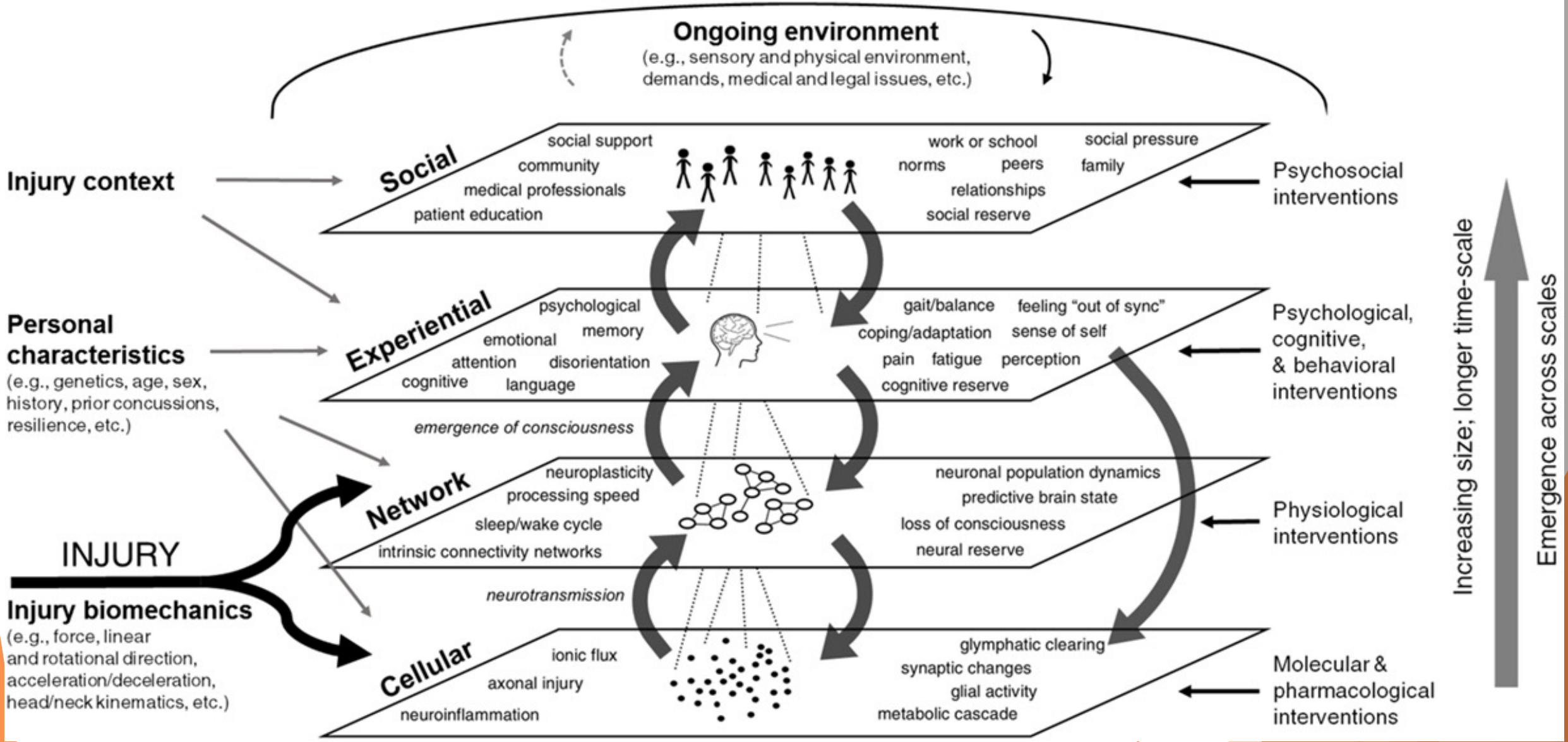
▶ Results:

- ▶ Adolescents assigned to collaborative care experienced clinically and statistically significant improvements in postconcussive symptoms in addition to functional gains at 6 months compared with controls
- ▶ Six months after the baseline assessment, 13.0% of intervention patients and 41.7% of control patients reported high levels of postconcussive symptoms ($P = .03$), and 78% of intervention patients and 45.8% of control patients reported $\geq 50\%$ reduction in depression symptoms ($P = .02$)
- ▶ No changes between groups were demonstrated in anxiety symptoms

- ▶ McCarty CA, Zatzick D, Stein E, Wang J, Hilt R, Rivara FP; Seattle Sports Concussion Research Collaborative. Collaborative Care for Adolescents With Persistent Postconcussive Symptoms: A Randomized Trial. *Pediatrics*. 2016 Oct;138(4):e20160459. doi: 10.1542/peds.2016-0459. Epub 2016 Sep 13. PMID: 27624513; PMCID: PMC5051206

Treatment for PPCS

- ▶ Studies:
 - ▶ Leddy
 - ▶ Exercise
 - ▶ Schneider
 - ▶ Vestibular/Cervical Spine
 - ▶ McCarty
 - ▶ Mental Health
- ▶ ALL studies showed valid outcomes with interventions
- ▶ What are we treating? Which treatment do we use?



Pharmacological Intervention



Role of Nutraceuticals

- ▶ **There is no human evidence that nutraceuticals prevent or ameliorate concussion in athletes**
 - ▶ This is an area that requires significantly more research to guide future recommendations
- ▶ **There is emerging evidence in animal models of concussion that some supplements may protect or speed recovery from concussion, specifically focused on:**
 - ▶ Certain B vitamins, omega-3 fatty acids, vitamin D, progesterone, N-Methyl-D-aspartate, exogenous ketones and dietary manipulations (eg, ketogenic diet)
 - ▶ Is a gap between experimentally produced injury in an animal model and the heterogeneous mechanisms that cause human concussion during sports activities

Pharmacological Management

- ▶ **Evidence equivocal**

- ▶ Most of the data is of low quality, without large, double-blind, randomized controlled trials
- ▶ Many of the studies include patients with more severe injuries than are typically seen in sports
- ▶ In many cases, the therapies described are off-label

- ▶ Each therapy is associated with potential adverse effects

- ▶ **No effective pharmacologic treatment has been shown to speed recovery from traumatic brain injury**

- ▶ **As a result, no standard approach exists**

- ▶ **Medications used in treating the signs and symptoms of PPCS** (sleep disturbance, headaches, mood disorders, cognitive symptoms, etc)

Referrals



Referrals

- ▶ Case Management
- ▶ Vision and Vestibular Rehabilitation Physical Therapist
- ▶ Osteopathic Neuromusculoskeletal Medicine Specialist
- ▶ Neuropsychiatrist
- ▶ Psychologist

Vision and Vestibular Rehabilitation Physical Therapist

- ▶ If dizziness, neck pain and/or headaches persist for more than 10 days, cervicovestibular rehabilitation is recommended
 - ▶ Cervical, vestibular AND oculomotor rehabilitation
- ▶ The goal of vestibular rehab is to improve symptoms of dizziness and improve the patient's balance
- ▶ Principles of vestibular rehabilitation are to facilitate neural plasticity within healthy neural systems to help overcome the deficits experienced from a concussion
- ▶ Vestibular rehab helps overcome deficits in the ability to keep focus on an object with the head in motion
 - ▶ This process, known as dynamic gaze stability, relies on the vestibular ocular reflex, cervical ocular reflex, and the visual system

Vision and Vestibular Rehabilitation Physical Therapist

- ▶ ECHO in the future featuring:
 - ▶ Holly Thompson, PT, NCS
 - ▶ Balance and Vestibular Specialist
 - ▶ Certification in vestibular rehabilitation
 - ▶ Specialty certification as a neurodevelopment treatment therapist
 - ▶ Board certification as a Neurological Clinical Specialist (NCS)

Physician Referral

- ▶ Physicians in United States
 - ▶ Medical School Options:
 - ▶ Allopathic: Doctor of Medicine (MD)
 - ▶ Osteopathic: Doctor of Osteopathic Medicine (DO)
 - ▶ Additional training in Osteopathic Manual Treatment (OMT)
 - ▶ Single Match into Residency
 - ▶ All Residency and Fellowship Programs accredited by Accreditation Council for Graduate Medical Education (ACGME)

Osteopathic Neuromusculoskeletal Medicine Specialist

- ▶ Doctor of Osteopathic Medicine (DO)
 - ▶ Osteopathic Manipulative Treatment (OMT)
 - ▶ Is the generic term used to refer to many different hands-on techniques
 - ▶ Can be used to treat structural and functional issues in the bones, joints, tissues and muscles of the body
 - ▶ Uses the relationship between the neuromusculoskeletal system and the rest of the body to restore functionality and/or remove barriers to motion and healing
- ▶ Additional Fellowship in Neuromusculoskeletal Medicine / Osteopathic Manual Medicine
 - ▶ Involves the development of skills in the use of visual, palpatory, and biomechanical evaluation techniques for improved physical assessment of body disturbances expressed clinically in the neuromusculoskeletal system and in other fundamentally related systems

Osteopathic Manipulative Treatment

- ▶ As a general principle, do not use any OMT procedure within the first 24 hours from concussion
- ▶ Treatment may be performed within the first 24 hours if:
 - ▶ Symptoms are improving
 - ▶ Symptoms are rated as mild
 - ▶ There is only one reported symptom (headache)
- ▶ Initial application of procedures is ideally 24-36 hours after injury
- ▶ Indications for OMT
 - ▶ Headache, Dizziness, Visual Disturbances, Balance Issues, Depression, Fatigue, Neck Pain

Osteopathic Manipulative Treatment

- ▶ Integration of OMT into Concussion Management
 - ▶ Retrospective chart review of cross-sectional medical information
 - ▶ 26 patient charts met selection criteria which included those that had a diagnosis of concussion sustained during athletics and required that the patient had completed the symptom checklist found on SCAT2 prior to the visit as well as completing another SCAT2 symptom checklist following OMT. Scores from each patient's pre-treatment SCAT2 assessment were then compared to their post-treatment scores
 - ▶ OMT improved each of the 22 self-reported symptoms listed on the SCAT2, with 10 symptoms (45.4%) demonstrating statistically significant improvement ($p < .05$). These symptoms included: headache, pressure in head, blurred vision, sensitivity to light, feeling in a fog, don't feel right, difficulty concentrating, fatigue or low energy, irritability, and sadness

Osteopathic Manipulative Treatment

▶ Integration of OMT into Concussion Management

- ▶ OMT was effective at reducing overall symptoms related to concussion. A substantial subset of concussive symptoms on the SCAT2 had significant reduction with the use of OMT. The integration of OMT into concussion management appears to immediately reduce symptom burden

- ▶ Chappell, DO, C., E. Dodge, BS, and G. Y. Dogbey, PhD. “Assessing the Immediate Effect on Osteopathic Manipulation on Sports Related Concussion Symptoms”. *Osteopathic Family Physician*, Vol. 7, no. 4, 1, <https://ofpjournal.com/index.php/ofp/article/view/398>

Osteopathic Manipulative Treatment

▶ OMT and Cervical Pain

- ▶ Chila AG. **Chapter 38-Cervical Region; Chapter 66-Acute Neck Pain.** In: *Foundations of Osteopathic Medicine*, 3rd ed. Baltimore: Wolters Kluwer, 2011, pp. 513-527 & 979-989
- ▶ Karageanes SJ. **Chapter 16-Head & Neck.** In: *Principles of Manual Sports Medicine*. Philadelphia: Lippincott Williams & Wilkins, 2005, pp. 124-158
- ▶ A randomized clinical trial in the ED by McReynolds T and Sheridan B found that, at one hour posttreatment, OMT is as efficacious as IM ketorolac in providing pain relief and significantly better in reducing pain intensity
- ▶ A single-blinded randomized controlled trial by Cholewicki et al found that OMT is relatively safe and effective in reducing pain and disability along with improving sleep, fatigue, and depression in patients with chronic NP immediately following treatment delivered over approximately 4 to 6 weeks

Osteopathic Cranial Manipulative Medicine (OCMM)

- ▶ OCMM is based on the idea that the anatomy of the cranium reflects the human body as a whole. Often described as Primary Respiratory Mechanism
 - ▶ The brain and spinal cord have an inherent motion to them that is separate to any breathing respiration and the pulse of the cardiovascular system
 - ▶ CSF has an ebb and flow rhythmic fluctuation
 - ▶ Dural membrane reciprocal tension
 - ▶ Mobility of cranial bones
 - ▶ Involuntary motion of the sacrum between ilia
- ▶ “Craniosacral therapy” is not the same as OCMM
 - ▶ Craniosacral Therapy comes from OCMM

Osteopathic Cranial Manipulative Medicine (OCMM)

- ▶ Kashyap et al. in 2021 studied 11 traumatic brain injury (TBI) patients who received an Osteopathic treatment with OCMM.
 - ▶ This study demonstrates that OMT may help optimize glial lymphatic clearance of CSF and improve brain edema, interstitial waste product removal, Neurological Pupil Index, ICP, CSF volume, and optic nerve sheath diameter.
- ▶ A study by P.E. Greenman et al. showed that 95 % of patients who have had a TBI showed at least one pattern of cranial strain and 87 % had at least one or more bony motion restrictions
- ▶ A study by Patel et al. showed approximately 71 % of the participants who completed the two treatment sessions of OCMM showed improvements in their post-concussive symptoms with no adverse effects in one small study.
- ▶ OCMM has been shown to be safe and may be an option for patients suffering from PPCS

OMT and Concussion Literature Review

▶ Case Reports

- ▶ Castillo, I, Wolf, K, Rakowski, A. Concussions and Osteopathic Manipulative Treatment: An Adolescent Case Presentation. *J Am Osteop Assoc*. March 2016, Vol. 116, 178-181
- ▶ Guernsey, D, Leder, A, Yao, S. Resolution of Concussion Symptoms After Osteopathic Manipulative Treatment: A Case Report. Leder, A, Yao, S. *J Am Osteop Assoc*, March 2016, Vol. 116, e13-e17

Neuropsychiatrist

- ▶ Neurologist or Psychiatrist that completed additional fellowship/training and board certification* in Behavioral Neurology & Neuropsychiatry
 - ▶ Fellowships at Stanford, Indiana University, Univ of Nebraska, Univ of Toronto, Univ Hospitals Cleveland Medical Center, Univ of Alabama Birmingham, Barrow Neurological Institute at St Joseph's Hospital
- ▶ How do I find a neuropsychiatrist?
 - ▶ United Council of Neurological Subspecialties

Psychologist

- ▶ Individualized choice
 - ▶ Neuropsychology – additional training/fellowship
 - ▶ The Sports Neuropsychology Society
 - ▶ The American Academy of Clinical Neuropsychology
 - ▶ Child & Adolescent Psychology
 - ▶ Couple and Family Psychology
 - ▶ Adult Psychology
 - ▶ Sport Psychology

Questions? Comments?

Thank you!

References

1. Patricios JS, Schneider KJ, Dvorak J, *et al.* Consensus statement on concussion in sport: the 6th International Conference on Concussion in Sport—Amsterdam, October 2022. *British Journal of Sports Medicine* 2023;**57**:695-711.
2. Harmon KG, Clugston JR, Dec K, *et al.* American Medical Society for Sports Medicine position statement on concussion in sport. *British Journal of Sports Medicine* 2019;**53**:213-225.
3. Tator CH, Davis HS, Dufort PA, Tartaglia MC, Davis KD, Ebraheem A, Hiploylee C. Postconcussion syndrome: demographics and predictors in 221 patients. *J Neurosurg*. 2016 Nov;**125**(5):1206-1216. doi: 10.3171/2015.6.JNS15664. Epub 2016 Feb 26. PMID: 26918481.
4. Chappell, DO, C., E. Dodge, BS, and G. Y. Dogbey, PhD. "Assessing the Immediate Effect on Osteopathic Manipulation on Sports Related Concussion Symptoms". *Osteopathic Family Physician*, Vol. 7, no. 4, 1, <https://ofpjournal.com/index.php/ofp/article/view/398>
5. Guernsey, D, Leder, A, Yao, S. Resolution of Concussion Symptoms After Osteopathic Manipulative Treatment: A Case Report. Leder, A, Yao, S. *J Am Osteop Assoc*, March 2016, Vol. 116, e13-e17
6. Castillo, I, Wolf, K, Rakowski, A. Concussions and Osteopathic Manipulative Treatment: An Adolescent Case Presentation. *J Am Osteop Assoc*. March 2016, Vol. 116, 178-181
7. Chila AG. Chapter 38-Cervical Region; Chapter 66-Acute Neck Pain. In: *Foundations of Osteopathic Medicine*, 3rd ed. Baltimore: Wolters Kluwer, 2011, pp. 513-527 & 979-989.
8. Karageanes SJ. Chapter 16-Head & Neck. In: *Principles of Manual Sports Medicine*. Philadelphia: Lippincott Williams & Wilkins, 2005, pp. 124-158.
9. McReynolds T, Sheridan B. Intramuscular ketorolac vs. osteopathic manipulative treatment in the management of acute neck pain in the emergency department: a randomized clinical trial. *J Am Osteopath Assoc*. 2005;**105**:57-67.
10. Schneider KJ, Critchley ML, Anderson V, *et al.* Targeted interventions and their effect on recovery in children, adolescents and adults who have sustained a sport-related concussion: a systematic review. *British Journal of Sports Medicine* 2023;**57**:771-779.
11. Morgan CD *et al.* " Predictors of postconcussion syndrome after sports-related concussion in young athletes: a matched case-control study" *J Neurosurg Pediatr* 2015; **15**(6):589-98
12. Leddy JJ, Kozlowski K, Donnelly JP, Pendergast DR, Epstein LH, Willer B. A preliminary study of subsymptom threshold exercise training for refractory post-concussion syndrome. *Clin J Sport Med*. 2010 Jan;**20**(1):21-7. doi: 10.1097/JSM.0b013e3181c6c22c. PMID: 20051730.

References

13. Leddy JJ, Haider MN, Ellis MJ, Mannix R, Darling SR, Freitas MS, Suffoletto HN, Leiter J, Cordingley DM, Willer B. Early Subthreshold Aerobic Exercise for Sport-Related Concussion: A Randomized Clinical Trial. *JAMA Pediatr.* 2019 Apr 1;173(4):319-325. doi: 10.1001/jamapediatrics.2018.4397. PMID: 30715132; PMCID: PMC6450274.
14. Schneider KJ, Critchley ML, Anderson V, *et al.* Targeted interventions and their effect on recovery in children, adolescents and adults who have sustained a sport-related concussion: a systematic review. *British Journal of Sports Medicine* 2023;57:771-779.
15. McCarty CA, Zatzick D, Stein E, Wang J, Hilt R, Rivara FP; Seattle Sports Concussion Research Collaborative. Collaborative Care for Adolescents With Persistent Postconcussive Symptoms: A Randomized Trial. *Pediatrics.* 2016 Oct;138(4):e20160459. doi: 10.1542/peds.2016-0459. Epub 2016 Sep 13. PMID: 27624513; PMCID: PMC5051206.
16. Meehan WP 3rd. Medical therapies for concussion. *Clin Sports Med.* 2011 Jan;30(1):115-24, ix. doi: 10.1016/j.csm.2010.08.003. PMID: 21074086; PMCID: PMC3359788.
17. Gurley JM, Hujsak BD, Kelly JL. Vestibular rehabilitation following mild traumatic brain injury. *NeuroRehabilitation.* 2013;32(3):519-28. doi: 10.3233/NRE-130874. PMID: 23648606.
18. Aligene K, Lin E. Vestibular and balance treatment of the concussed athlete. *NeuroRehabilitation.* 2013;32(3):543-53. doi: 10.3233/NRE-130876. PMID: 23648608.
19. Kashyap S, Brazdzionis J, Savla P, Berry JA, Farr S, Patchana T, Majeed G, Ghanchi H, Bowen I, Wacker MR, Miulli DE. Osteopathic Manipulative Treatment to Optimize the Glymphatic Environment in Severe Traumatic Brain Injury Measured With Optic Nerve Sheath Diameter, Intracranial Pressure Monitoring, and Neurological Pupil Index. *Cureus.* 2021 Mar 11;13(3):e13823. doi: 10.7759/cureus.13823. PMID: 33859888; PMCID: PMC8038899.
20. Sutherland WG. *The cranial bowl.* W. G. Sutherland, Mankato, MN;1939. (Reprinted by the Osteopathic Cranial Association, Meridian, ID, 1948).
21. Greenman PE, McPartland JM. Cranial findings and iatrogenesis from cranosacral manipulation in patients with traumatic brain syndrome. *J Am Osteopath Assoc.* 1995 Mar;95(3):182-8; 191-2. PMID: 7751168.
22. Patel KG, Sabini RC. Safety of Osteopathic Cranial Manipulative Medicine as an Adjunct to Conventional Postconcussion Symptom Management: A Pilot Study. *J Am Osteopath Assoc.* 2018 Jun 1;118(6):403-409. doi: 10.7556/jaoa.2018.061. PMID: 29710088.
23. Cholewicki, J, Popovich Jr, JM, Reeves, NP, et al. The effects of osteopathic manipulative treatment on pain and disability in patients with chronic neck pain: A single-blinded randomized controlled trial. *PM&R.* 2022; 14(12): 1417-1429. doi:10.1002/pmrj.12732