CONCUSSIONS?

Can Concussions be Managed?

How Long Before a Concussion Cannot be Rehabilitated?

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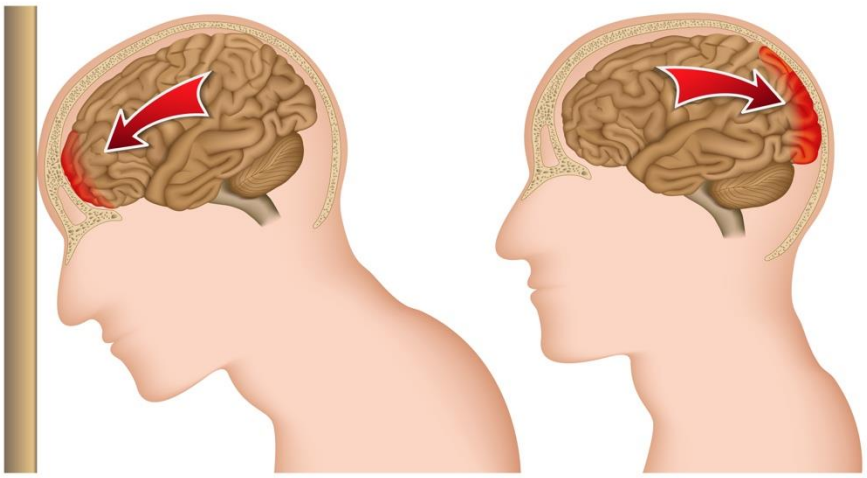
Introduction to Concussion

A concussion is a type of mild traumatic brain injury (TBI) that occurs when the brain is jolted or shaken, causing it to bounce or twist within the skull. This sudden movement can cause damage to the brain cells, leading to a range of symptoms that can vary in severity and duration.



1. Primary Impact - Coup
The brain strikes the skull on the side of impact.

2. Secondary Impact -
Contrecoup Impact posterior area of skull.

Concussions are commonly caused by sports-related injuries, falls, car accidents, or any other sudden impact to the head. They are particularly common in contact sports such as football, soccer, cheerleading, mixed martial arts and boxing, but can occur in any activity that involves the risk of head injury.

Symptoms of a concussion may include headaches, dizziness, confusion, nausea, sensitivity to light or sound, memory problems, difficulty concentrating, etc. In some cases, these symptoms may be mild and resolve within a few days, while in others they can be more severe and last for weeks, months or even years.

It is important to seek medical attention if a concussion is suspected, as the condition can

have serious long-term consequences if left untreated. Treatment for concussions has drastically changed over the last several years. The old “cocoon therapy” previously prescribed for concussion, e.g., extended rest, no cognitive activity, no screen time, has now been replaced with very effective management tools and procedures that will be explained later.

Recognizing Concussion

Concussions are common in contact sports, motor vehicle collisions (MVCs), falls, and other incidents that involve sudden impact or jarring of the head. Recognizing a concussion quickly and accurately is crucial to proper management and prevention of further injury.

Key concepts in recognizing a concussion include:

Mechanism of Injury
In the acute setting, observing and/or understanding the mechanism of injury is important. If an individual experiences a blow to the head, neck, or upper body, observe for concussion-induced symptoms. In sports, this may occur due to a tackle or collision, while in MVCs, it could be due to the head hitting a window or dashboard, or a whiplash-type mechanism.

Observational Assessment
Witnessing changes in behavior, coordination, balance/disequilibrium or physical function can implicate a concussion.

These might include appearing dazed or stunned, clumsiness, slow response to questions, and loss of consciousness (even briefly), changes in mood, behavior, or personality, or an inability to recall events before or after the hit or fall.

Signs and Symptoms

The following symptoms may appear immediately, or may develop minutes, hours, or even within 2-3 days following the concussive event:

- **Physical Symptoms**: These include headaches, nausea or vomiting, balance problems, dizziness, visual problems, fatigue, and sensitivity to light or noise. Patient may report feeling “dazed” or like “in a fog”.
- **Cognitive Symptoms**: Difficulty thinking clearly, feeling slowed down, difficulty concentrating, and memory problems are common cognitive symptoms. Reaction times may be slowed.
- **Emotional Symptoms**: Mood swings, behavior changes, irritability, sadness, nervousness, and emotional lability can be signs of a concussion.
- **Sleep Disturbances**: Sleeping more or less than usual, or having trouble falling asleep can be symptoms, e.g., somnolence, drowsiness.

These symptoms may not always appear immediately after the injury and may develop hours or even 2-3 days later.

What is an mTBI?

Mild Traumatic Brain Injury (mTBI) and concussion are terms that are often used interchangeably, but there are subtle differences between the two. Both conditions involve a traumatic injury to the brain caused by an external force, such as a blow to the head or a violent shaking of the head or body. They share many similarities in symptoms and outcomes, but the main difference lies in the classification and scope of the injuries.

Mild Traumatic Brain Injury (mTBI)

- mTBI is a broader term that refers to any mild traumatic injury to the brain, which can result from various causes, such as a fall, car accident, sports injury, or assault.
- mTBI is classified based on the severity of the injury using the Glasgow Coma Scale (GCS), with scores ranging from 13 to 15 (out of 15). A score of 15 indicates a mild injury, while a lower score denotes a more significant injury.
- mTBI can result in temporary or permanent physical, cognitive, emotional, and behavioral changes. These symptoms may resolve within hours or days, or they may persist for months or even years.
- Common symptoms of mTBI include headache, dizziness, fatigue, memory problems, difficulty concentrating, irritability, and sleep disturbances.
- Diagnosis of mTBI typically involves a thorough medical evaluation, including a detailed history of the injury, physical

examination, and, in some cases, imaging studies like CT scans or MRIs to rule out more moderate or severe injuries.

Concussion

- A concussion is a specific type of mTBI, characterized by a temporary disturbance in brain function following a traumatic injury.
- The term "concussion" is more commonly used in the context of sports medicine and public awareness campaigns, but it is essentially a subset of mTBI.
- Concussions can result from a direct blow to the head or from an indirect impact transmitted through the body (e.g., a whiplash injury).
- Symptoms of a concussion are similar to those of mTBI and may include headache, dizziness, confusion, memory loss, and balance problems. However, they are generally milder and more transient, with most individuals recovering fully.
- Diagnosing a concussion typically involves a clinical examination, evaluation of signs and symptoms, and, in some cases, neurocognitive testing. Imaging studies are usually not required unless there is a concern for a more moderate or severe injury.

Are the Terms Interchangeable?

As an expert in Concussion/mTBI, the above information is offered in the interest of completeness. However, for the most part and throughout the remainder of this brochure, the terms will be considered interchangeable. The vast majority of healthcare providers are using these terms interchangeably now.

Missed Diagnosis vs. Misdiagnosis

The lack of comprehensive knowledge about concussion management prior to the 2017 Consensus statement impacted the ability of healthcare providers to identify and treat concussions effectively. It is difficult to determine the exact number of missed or untreated concussions due to knowledge gaps, as the under diagnosis of concussions is a complex issue influenced by several factors, such as athletes not reporting their symptoms, inadequate sideline assessments, or a lack of awareness among coaches, parents, and athletes.

Unfortunately, the gap in knowledge surrounding concussion management persists. The following review will focus on several studies evaluating the knowledge base of medical students and HCPs (Health Care Providers) relative to concussion management. Remember, prior to the 2017 Consensus on SRC(Sports Related Concussion), treatment was essentially bed rest with a “wait and see” for symptom resolution. Due to the fact there were really no specific treatment parameters, medical education did not spend a lot of time on concussions.

Concussion Recovery Misinformation

Recovery from mild traumatic brain injury (mTBI), also known as concussion, generally refers to the process through which an individual returns to their pre-injury cognitive, emotional, and

functional state. Recovery can vary significantly between individuals, but there are some common elements that may be involved that include the reduction of symptoms, restoration of cognitive activities, physiologic recovery, emotional and psychological recovery, return to daily activities, return to learning and return to play status for competitive sports. The recovery process is complicated and unique to each injured individual. Information from the internet shows a wide path of misinformation stating recovery times from 2-3 days or 7 days or an average of 10 days. The correct recovery time is based on the injury sustained, the condition and ability of the patient to follow rehabilitation protocols and the avoidance of secondary injuries that are very common with concussions.

Information from a health care provider board certified in concussion management is critical and necessary to recover.

The Neurometabolic Cascade

The neurometabolic cascade is a series of complex, interconnected biochemical reactions and cellular events that occur in the brain following a traumatic brain injury (TBI). This cascade can lead to secondary injury, which exacerbates the initial damage caused by the trauma.

The neurometabolic cascade following a concussion or traumatic brain injury (TBI) involves a series of complex cellular and molecular events that contribute to the development of secondary injury. The excitatory phase and the spreading depression phase

are two components of this cascade that contribute to the overall pathophysiology of the injury.

Usual Symptoms and Signs

Signs and symptoms of concussion are important to recognize and assess. This section will explore the best ways to assess patient symptomatology.

Concussions can have a wide range of symptoms, which may appear immediately or develop over time. Here are 22 common signs and symptoms of a concussion as proposed by the Acute Concussion Evaluation (ACE) form available from the Center for Disease Control (CDC):

Physical (10)

1. **Headache**: A persistent or worsening headache is a common symptom of a concussion.
2. **Nausea**: Nausea can be a common symptom following concussion.
3. **Vomiting**: Vomiting may occur shortly after the injury.
4. **Balance Problems**: The person may have difficulty maintaining balance or coordinating movements.
5. **Dizziness**: Feelings of unsteadiness or lightheadedness may occur.

6. **Blurred or Double Vision**: Vision problems are common after a concussion.
7. **Fatigue**: The injured person may feel excessively tired or have difficulty staying awake.
8. **Sensitivity to Light:** Bright lights may cause discomfort or worsen other symptoms.
9. **Sensitivity to Noise**: Loud sounds may cause discomfort or worsen other symptoms.
10. **Numbness/Tingling**: The person may complain of numbness or tingling sensations.

Cognitive (4)

1. **Fogginess**: Feeling mentally foggy.
2. **Feeling Slowed Down**: The injured person may feel slowed down.
3. **Difficulty Concentrating**: The person may have trouble focusing on tasks or following conversations.
4. **Memory**: Difficulty remembering new information or recalling previously learned information may occur.

Emotional (4)

1. **Irritability**: The person may be more irritable or have mood swings.
2. **Depression or Anxiety**: Feelings of sadness, hopelessness, or worry may develop after a concussion.
3. **Emotional**: The person may experience increased levels of emotion.
4. **Nervousness**: The person may have a feeling of ongoing nervousness.

Sleep (4)

1. **Drowsiness**: Due to less sleep, drowsiness is a common symptom.
2. **Sleeping Less than Usual**: Difficult to stay asleep.
3. **Sleeping More than Usual**: In contrast, some people will sleep excessively.
4. **Trouble Falling Asleep**: Difficult to fall asleep.

Second Impact Syndrome

Second impact syndrome (SIS) is a rare but potentially life-threatening condition that can occur when an individual sustains a second concussion before the first concussion has fully healed.

This condition can cause rapid and severe swelling of the brain, leading to severe neurological impairment or even death.

This is one of the primary reasons Health Care Practitioners (HCPs) need to understand the concept of the neurometabolic cascade and appropriate evaluation procedures to determine when a patient is ready to Return-to-Play (RTP). Remember, managing concussions simply cannot be “symptom-driven”, particularly in youth sports.

Initial Visit

Mild Traumatic Brain Injury (mTBI)/Concussion is a common injury, especially in motor vehicle collisions, contact sports, and

falls. Concussions can lead to a variety of symptoms, such as headache, dizziness, confusion, memory problems, etc., significantly affecting a patient's activities of daily living (ADLs). The initial visit history and evaluation are essential to properly diagnose and manage the injury, as well as to determine whether emergent referral and/or diagnostic imaging are indicated.

The importance of the initial visit history and evaluation with mTBI lies in several factors.

1. First, it allows healthcare providers to assess the severity of the injury and the risk of complications, such as second-impact syndrome or post-concussion syndrome.
2. Second, it helps to establish a baseline for the patient's neurological function, which can be used to monitor their recovery over time.
3. Third, it enables healthcare providers to provide appropriate recommendations for activity modification, future evaluation and, if necessary, mTBI/PCS rehab, as well as Return-to-Work (RTW)/Return-to-Learn (RTL)and/or Return-to-Play (RTP) decisions.
4. Fourth, it provides an opportunity to identify any other injuries or conditions that may require emergent/additional treatment or referral.

Whether emergent referral or diagnostic imaging is indicated in the evaluation of an mTBI depends on several factors. Generally, emergent referral and special imaging is not necessary in most cases of mTBI, as the diagnosis is based primarily on the patient's symptoms and physical examination findings. However, emergent referral or advanced imaging may be recommended if there is

concern for a more serious injury, such as a skull fracture, intracranial hemorrhage, neurologic deficits, or brain swelling. These situations would transfer the diagnosis from mTBI to a Moderate/Severe TBI. In such cases, a CT scan or MRI may be performed to assess the extent of the injury and determine the appropriate course of treatment.

Co-Management

The treatment of concussion, a mild form of traumatic brain injury, often calls for a multifaceted, interdisciplinary approach. Ensuring the provision of optimal care may require the integration of various healthcare professionals. However, given the neurological implications of a concussion, the co-management approach with a neurologist may often be indicated.

As stated by Dr. Jeffrey Kutcher, neurologist:

> “Neurologists are physicians (MD or DO), with specific training in the diagnosis and management of the entire spectrum of neurological injury and disease. This expertise is essential in the evaluation and management of patients with a suspected concussion. This is both because the diagnosis itself is often difficult to confirm, and when concussion is present, other neurological injuries and processes are almost always present as well. Neurologists are also able to utilize a wide array of treatment options, including medications, procedures, and various physical modalities. As well, they will be able to efficiently direct patient evaluation with diagnostic testing, such as MRI, CT scan, and blood work.”

Concussions often present with a wide array of symptoms, from physical manifestations such as headaches and dizziness to cognitive disruptions like memory loss and slowed processing speed. Equally important are the emotional symptoms, which can range from irritability to depression. Concussion-trained HCPs, equipped with a broad understanding of health and disease, are often the first point of contact in managing these diverse symptoms. Their knowledge of the patient's overall health, their continuity of care, and their expertise in addressing multiple concurrent health issues make them invaluable in the early identification, diagnosis, and management of concussions.

Various Evaluations

For decades, the standard approach to treating a concussion has been to prescribe rest, both physical and cognitive, until symptoms subside. The rationale behind this approach was to give the brain time to heal and reduce the risk of further injury or complications.

However, there is now growing evidence that prolonged rest following a concussion may actually be harmful and can delay recovery. Studies have found that prolonged rest can lead to physical deconditioning, which can make it harder for a patient to return to their normal activities once they are cleared to do so. In addition, prolonged rest can lead to psychological issues such as depression and anxiety, as well as social isolation.

The dilemma of concussion treatment, specifically regarding the role of rest versus exercise, is a complex and evolving topic. As discussed above, rest has been considered the primary treatment recommendation for concussion, with the aim of allowing the brain

to heal by minimizing physical and cognitive activity. Current research has not supported this treatment plan, e.g., “do-nothing cocoon therapy”.

On the contrary, exercise has also been shown to exacerbate concussion symptoms. This creates a dilemma – should the patient rest or should the patient be allowed to exercise?

Fortunately, research has challenged the “rest” approach and provided a method to instigate exercise safely without worsening concussion symptoms.

Treatment of Concussion and Post-Concussion Syndrome

The Importance of Concussion Education

- Patient education is critical in the management of concussion. In the context of mTBI/concussion is a functional injury, which means that there is no structural damage to the brain, but the way it functions is altered. This can result in a wide range of physical, cognitive, and emotional symptoms. Patients and their families need to understand that concussion is a treatable injury, and that there are steps they can take to help manage the symptoms and promote recovery.
- In simple terms, the neurometabolic cascade and resultant energy crisis occurs as a result of concussion. There is a normal physiologic recovery pattern of concussion – understanding that "normal" has been primarily derived from sports-related concussions (SRC) with predominately young, healthy, athletic males. Symptoms are shown to peak within 2-

3 days, with symptom resolution typically between 7-10 days. If the patient is still symptomatic after 10 days, they are not exhibiting a "normal physiologic recovery pattern".

- It is very important that you not sustain another concussion during the metabolic recovery process. The treatment plan is designed to graduate the patient's return to learn/work and return to play in a safe and evidence-based manner.

The following rehabilitation prescriptions should be considered based on clinical examination findings:

1. Sub-Symptom Threshold Cognition
2. Sub-Symptom Threshold Exercise
3. Accommodation Insufficiency Rehabilitation
4. Convergence Insufficiency Rehabilitation

What to Expect

If you begin today to follow the protocol contained herein, you can expect that we will manage your concussion quite well within a week or two. Next, you can expect to begin all the rehabilitation protocols gradually as your injury recovers. After two weeks of that, you should expect to be able to do most of the approved activities without any increase in symptoms. Your time off work should be limited to 1-10 days if all goes well. After one month on the protocol, you can expect to further reduce the treatment frequency, increase activities and exercise and move to complete recovery. It is critical that your care be managed consistently as explained.

The Right Provider

Many people have questions about the treatment protocol and finding the right provider. If you have read the information above, you should have a pretty good understanding of what needs to happen. But that is only half the battle. Finding the right provider to deliver these procedures, monitor your progress and co-manage your concussion with the right neurologist is critical. To obtain the successful results we reference above, one must be managed by a physician, board certified in neuromusculoskeletal medicine with a fellowship in concussion management who has the attention and commitment to detail necessary to insure the correct application of the treatment modalities. Medicine is an art and physical medicine is an acquired skill and art.

What does it mean to be board certified in neuromusculoskeletal medicine with a fellowship in concussion management?

The practitioner who is board certified by The International Academy of Neuromusculoskeletal Medicine (NMSM) is a physician holding a license by the state to practice allopathic, osteopathic or chiropractic medicine. He has extensive, specialized training in physical examination and treatment procedures emphasizing primarily the neuromusculoskeletal structures of the body including the spine and the extremity joints. This involves conditions affecting bones, joints, muscles, tendons, ligaments, cartilage and related nerve structures.

The board certified specialist handles both acute health problems such as automobile accidents and sports injuries as well as more

chronic conditions including disc disease, arthritis, scoliosis, and fibromyalgia. Advanced procedures of x-ray, magnetic resonance imaging (MRI) and computed tomography imaging (CT), electro diagnostic studies, diagnostic ultrasound, nerve conduction studies (EMG) and clinical laboratory procedures are used to assist in the diagnostic process when indicated.

In the course of treatment, this specialist applies manipulative /adjustive procedures along with other treatment options such as computerized axial distraction, ozone injection, physiologic therapeutic modalities, nutritional counseling, structural supports, corrective devices, exercise and rehabilitation regimens, preventive care advice and home therapy programs for patient health.

The fellowship in concussion management is quite rare and most providers in all professions do not have up-to-date skills in managing concussions. It is crucial to have a provider with these skills and credentials.

Is this protocol better than seeing a regular chiropractor, physical therapist or medical doctor?

The Berlin Consensus of 2016 and the Amsterdam Consensus of 2022 dramatically changed how concussions are to be managed successfully. Providers with training prior to 2023 who have not taken current, advanced training in concussion management will not be aware of the shift in management protocols and will not be of much help in managing your case. In most cases, seeing a specialist, board certified in NMSM is better than seeing a regular chiropractor, physical therapist or medical doctor because the NMSM specialist is well trained and certified as having the necessary skills for appropriate concussion management. He has

the diagnostic skills not possessed by the physical therapist, has the manipulative skills not possessed by the medical specialist, has the diagnostic and management skills not generally possessed by the regular chiropractor and he has the skill and experience to enlist the skills of each of these others should the need arise.

If I've already seen a chiropractor, physical therapist or medical doctor, can I still see the board certified NMSM specialist?

Starting with any of these providers or having been to the Emergency Department at the hospital only makes your visit to the NMSM specialist that much easier. He will request your records and simplify your intake process so that you can get on the path to recovery and prevention of disc disease. He will work well with any of these other providers to take advantage of everything they provided for you and increase the effectiveness and outcome of any program you may have already started.

Literature Review

1. Burke MJ, Chundamala J, Tator CH. Deficiencies in concussion education in Canadian medical schools. Canadian Journal of Neurological Sciences. 2012;39(6):763-766. DOI:10.1017/s0317167100015584.
2. Choe, M. The pathophysiology of concussion. Curr Pain Headache Rep (2016)20:42, p. 1-10. DOI:10.1007/s11916-016-0573-9.
3. Donaworth MA, Grandhi RK, et al. Is current medical education adequately preparing future physicians to manage concussion: An initial evaluation. Physician and Sports Medicine. 2016;44(1):1-7. DOI:10.1080/00913847.2016.1135039.
4. Guskiewicz KM, Mihalik JP. Biomechanics of sport concussion: quest for the elusive injury threshold. Neurosurgery, 2011 Jan;39(1):4-11. DOI: 10.1097/JES.0b013e318201f53e.
5. Kazemi M, Bogumil ME, et al. Concussion assessment and management knowledge among chiropractic fourth year interns and residents. The Journal of the Canadian Chiropractic Association. 2016;60(3):212-220.
6. Mann A, Tator CH, Carson JD. Concussion diagnosis and management: knowledge and attitudes of family medicine residents. Canadian Family Physician. 2017 Jun;63(6);e310-e315.
7. Mathieu F, Ellis MJ. Concussion education in Canadian medical schools: a 5-year follow-up survey. Canadian Journal of Neurological Sciences. 2018;45(3):281-286. DOI:10.1186/s12909-018-1416-7.
8. Patrick, P. Sean. Emergency Physician Training on Mild Traumatic Brain Injury: A Systematic Review. National Library of Medicine. 2017 Oct;1(4):346–356. DOI:10.1002/aet2.10053.
9. Romeu-Mejia R, Giza CC. Concussion Pathophysiology and Injury Biomechanics. Current Reviews in Musculoskeletal Medicine, 2019;12(2):105-116. DOI:10.1007/s12178-019-09536-8.

10. Ellis MJ, Leddy, JJ, Willer, B. Multi-disciplinary management of athletes with post-concussion syndrome: an evolving pathophysiological approach. Frontiers in neurology, 2016 Aug;7:136. DOI:10.3389/fneur.2016.00136.
11. Ellis, JM. Leddy, JL, Willer, B. Physiological, vestibulo-ocular and cervicogenic post-concussion disorders: an evidenced-based classification system with directions for treatment. Brain Injury, 2015;29(2):238-248. DOI:10.3109/02699052.2014.965207.
12. Giza CC, Kutcher JS, Ashwal S, et al. Summary of evidence-based guideline update: evaluation and management of concussion in sports. Neurology. 2013 Jun;80(24):2250-7. DOI:10.1212/WNL.0b013e31828d57dd.
13. Madhok DY, Rodriguez RM, et al. Outcomes in patients with mTBI without acute intracranial traumatic injury. JAMA Network Open, 2022 Aug;5(8):1-13. DOI:10.1001/jamanetworkopen.2022.23245.
14. Patricio JS, Scheider KJ, et al. Consensus statement on concussion in sport: the 6th international conference on concussion in sport – Amsterdam, October 2022. Br J Sports Med 2023;57:695-711. DOI:10.1136/bjsports-2023-106898.
15. McCrory P, Meeuwisse W, et al. Consensus statement on concussion in sport—the 5th international conference on concussion in sport held in Berlin, October 2016. British Journal of Sports Medicine. 2017 Apr;51(11):838-847. DOI:10.1136/bjsports-2017-097699.
16. Echemendia RJ, Brett BL, et al. Sport concussion assessment tool – 6 (SCAT6). Br J Sports Med. 2023 Jun;57(11): 622-631. DOI: 10.1136/bjsports-2023-107036.
17. DuPrey et al. Convergence insufficiency identifies athletes at risk of prolonged recovery from sport-related concussion. Am J of Sports Med (2017) 45(10):2388-2393.
18. Ellis, JM. Leddy, JL, Willer, B. Physiological, vestibulo-ocular and cervicogenic post-concussion disorders: an evidenced-based classification system with directions for treatment. Brain Injury, 2015;29(2):238-248. DOI:10.3109/02699052.2014.965207.
19. Leddy JJ, Haider MN, Noble JM, Rieger B, Flanagan S, McPherson JI, Shubin-Stein K, Saleem GT, Corsaro L, Willer B. Clinical assessment of concussion and persistent post-concussive symptoms for neurologists. Current Neurology and Neuroscience Reports. 2021 Nov;21(70):1-14. DOI: 10.1007/s11910-021-01159-2.
20. Leddy JJ, Haider MN, Noble JM, Rieger B, Flanagan S, McPherson JI, Shubin-Stein K, Saleem GT, Corsaro L, Willer B. Management of concussion and persistent post-concussive symptoms for neurologists. Current Neurology and Neuroscience Reports. 2021 Nov;21(72):1-7. DOI: 10.1007/s11910-021-01160-9.
21. Mata-Mbemba D, Mugikura S, et al. Canadian CT head rule and New Orleans Criteria in mild traumatic brain injury: comparison at a tertiary referral hospital in Japan. Springerplus. 2016 Feb 25;5:176. DOI:10.1186/s40064-016-1781-9. PMID: 27026873; PMCID: PMC4766169.
22. Pearson K, Poltavskiy E, et al. Post-concussive orthostatic tachycardia is distinct from postural orthostatic tachycardia syndrome in children and adolescents. Child Neurol Open, 2022 Mar;2;9:2329048X221082753. DOI:10.1177/2329048X221082753
23. DiFazio M, Silverberg ND, et al. Prolonged activity restriction after concussion: are we worsening outcomes? Clinical Pediatrics, 2016 May;55(5):443-51. DOI:10.1177/0009922815589914.
24. Haider MN, Johnson SL, et al. The buffalo concussion bike test for concussion assessment in adolescents. Sports Health Nov/Dec;11(8):492-497. DOI:10.1177/1941738119870189.
25. Lawrence DW, Richards D, et al. Earlier time to aerobic exercise is associated with faster recovery following acute sport concussion. PLOS ONE 2018 Apr;13(4):e0196062. DOI:10.1371/journal.pone.0196062.
26. Leddy JJ, Haider MN, Noble JM, Rieger B, Flanagan S, McPherson JI, Shubin-Stein K, Saleem GT, Corsaro L, Willer B. Management of concussion and persistent post-concussive symptoms for neurologists. Current Neurology and Neuroscience Reports. 2021 Nov;21(72):1-7. DOI: 10.1007/s11910-021-01160-9.
27. Leddy JJ, Haider MN, Ellis M, Willer BS. Exercise is Medicine for Concussion. Curr Sports Med Rep. 2018 Aug;17(8):262-270. DOI:10.1249/JSR.0000000000000505. PMID: 30095546; PMCID: PMC6089233.
28. Miutz LN, Burma JS, et al. Physical activity following sport-related concussion in adolescents: a systematic review. J Appl Physiol (1985). 2022 May 1;132(5):1250-1266. DOI:10.1152/japplphysiol.00691.2021. Epub 2022 Mar 24. PMID: 35323056.
29. Pertab JL, Merkley TL, et al. Concussion and the autonomic nervous system: An introduction to the field and the results of a systematic review. NeuroRehabilitation. 2018;42(4):397-427. DOI:10.3233/NRE-172298. PMID: 29660949; PMCID: PMC6027940.
30. Silverberg ND, Iaccarino MA, et al. Management of concussion and mild traumatic brain injury: a synthesis of practice guidelines. Archives of Physical Medicine and Rehabilitation. 2020 Feb;101:382-93. DOI:10.1016/j.apmr.2019.10.179.
31. Elbin RJ, Sufrinko A, et al. Prospective Changes in Vestibular and Ocular Motor Impairment After Concussion. J Neurol Phys Ther. 2018 Jul;42(3):142-148. DOI: 10.1097/NPT.0000000000000230. PMID: 29864101; PMCID: PMC6005756.

32. Ellis MJ, Leddy JJ, Willer B. Physiological, vestibulo-ocular and cervicogenic post-concussion disorders: an evidence-based classification system with directions for treatment. Brain Injury, 2015 Oct;29(2):238-248. DOI:10.3109/02699052.2014.965207.
33. Mucha A, Collins MW, et al. A brief vestibular/ocular motor screening (VOMS) assessment to evaluate concussions: preliminary findings. Am J Sports Med. 2014 Oct;42(10):2479-2486. DOI:10.1177/0363546514543775.
34. Cheever K, Kawata K, et al. Cervical injury assessments for concussion evaluation: a review. J Athl Train. 2016 Dec;51(12):1037-1044. DOI: 10.4085/1062-6050-51.12.15.
35. Ellis MJ, Leddy JJ, Willer B. Physiological, vestibulo-ocular and cervicogenic post-concussion disorders: an evidence-based classification system with directions for treatment. Brain Injury, 2015 Oct;29(2):238-248. DOI:10.3109/02699052.2014.965207.
36. Hammerle M, Swan AA, et al. Retrospective Review: Effectiveness of Cervical Proprioception Retraining for Dizziness After Mild Traumatic Brain Injury in a Military Population With Abnormal Cervical Proprioception. J Manipulative Physiol Ther. 2019 Jul;42(6):399-406. doi: 10.1016/j.jmpt.2018.12.002. Epub 2019 Jul 27. PMID: 31362829.
37. Leddy JJ, Haider MN, et al. Clinical assessment of concussion and persistent post-concussive symptoms for neurologists. Current Neurology and Neuroscience Reports, 2021 Nov;21(70):1-14. DOI: 10.1007/s11910-021-01159-2.
38. Treleaven J, Jull G, et al. Smooth pursuit neck torsion test in whiplash-associated disorders: relationship to self-reports of neck pain and disability, dizziness and anxiety. J Rehabil Med 2005;37:219-223.
39. Treleaven J, Jull G, et al. Dizziness and unsteadiness following whiplash injury: characteristic features and relationship with cervical joint position error. J Rehabil Med. 2003 Jan;35(1):36-43. DOI:10.1080/16501970306109. PMID: 12610847.
40. Schneider KJ, Meeuwisse WH, et al. Cervicovestibular rehabilitation in sport-related concussion: a randomised controlled trial. Br J Sports Med. 2014 Sep;48(17):1294-8. DOI:10.1136/bjsports-2013-093267. Epub 2014 May 22. PMID: 24855132.
41. Yaseen K, Hendrick P, et al. The effectiveness of manual therapy in treating cervicogenic dizziness: a systematic review. J Phys Ther Sci. 2018 Jan;30(1):96-102. DOI:10.1589/jpts.30.96. Epub 2018 Jan 27. PMID: 29410575; PMCID: PMC5788784.
42. Azad AM, Al Juma S, Bhatti JA, Delaney JS. Modified Balance Error Scoring System (MBESS) test scores in athletes wearing protective equipment and cleats. BMJ Open Sport Exerc Med. 2016 May 13;2(1):e000117. DOI:10.1136/bmjsem-2016-000117. PMID: 27900181; PMCID: PMC5117076.
43. Bell DR, Guskiewicz KM. Systematic review of the balance error scoring system. Athletic Training. 2011;3(3):287-295.
44. Dizziness Handicap Inventory (DHI).
45. DuPrey KM, Webner D, et al. Convergence Insufficiency Identifies Athletes at Risk of Prolonged Recovery From Sport-Related Concussion. Am J Sports Med. 2017 Aug;45(10):2388-2393. DOI:10.1177/0363546517705640. Epub 2017 May 16. PMID: 28511593.
46. Leddy JJ, Haider MN, et al. Clinical assessment of concussion and persistent post-concussive symptoms for neurologists. Current Neurology and Neuroscience Reports. 2021 Nov;21(70):1-14. DOI:10.1007/s11910-021-01159-2.
47. Leddy JJ, Haider MN, et al. Management of concussion and persistent post-concussive symptoms for neurologists. Current Neurology and Neuroscience Reports. 2021 Nov;21(72):1-14. DOI:10.1007/s11910-021-01160-9.
48. Mata-Mbemba D, Mugikura S, et al. Canadian CT head rule and New Orleans Criteria in mild traumatic brain injury: comparison at a tertiary referral hospital in Japan. Springerplus. 2016 Feb 25;5:176. DOI:10.1186/s40064-016-1781-9. PMID: 27026873; PMCID: PMC4766169.
49. Pearson K, Poltavskiy E, et al. Post-concussive orthostatic tachycardia is distinct from postural orthostatic tachycardia syndrome in children and adolescents. Child Neurol Open, 2022 Mar;2;9:2329048X221082753. DOI:10.1177/2329048X221082753
50. Thiagarajan P, Ciuffreda KJ. Effect of oculomotor rehabilitation on vergence responsivity in mild traumatic brain injury. J Rehabil Res Dev. 2013;50(9):1223-40. DOI:10.1682/JRRD.2012.12.0235. PMID: 24458963.
51. Haider MN, Johnson SL, et al. The buffalo concussion bike test for concussion assessment in adolescents. Sports Health Nov/Dec;11(8):492-497. DOI:10.1177/1941738119870189.
52. Lawrence DW, Richards D, et al. Earlier time to aerobic exercise is associated with faster recovery following acute sport concussion. PLOS ONE 2018 Apr;13(4):e0196062. DOI:10.1371/journal.pone.0196062.
53. Leddy JJ, Haider MN, Ellis M, Willer BS. Exercise is Medicine for Concussion. Curr Sports Med Rep. 2018 Aug;17(8):262-270. DOI:10.1249/JSR.0000000000000505. PMID: 30095546; PMCID: PMC6089233.
54. Leddy JJ, Haider MN, et al. A preliminary study of the effect of early aerobic exercise treatment for sport-related concussion in males. Clin J Sport Med 2019 Sep;29(5):1-8. DOI:10.1097/JSM.0000000000000663.

55. Leddy JJ, Haider MN, et al. Management of concussion and persistent post-concussive symptoms for neurologists. Current Neurology and Neuroscience Reports, 2021 Oct;21(72):1-7. DOI:10.1007/s11910-021-01160-9.
56. Balatsouras DG, Koukoutsis G, et al. Diagnosis of single- or multiple-canal benign paroxysmal positional vertigo according to the type of nystagmus. International Journal of Otolaryngology. 2011 Feb;Vol 2011, Article ID 483965:1-13. DOI: 10.1105/2011/483965.
57. Clendaniel RA. The effects of habituation and gaze-stability exercises in the treatment of unilateral vestibular hypofunction – preliminary results. NIH Public Access. J Neurol Phys Ther. 2010 June;34(2):111-116. DOI: 10.1097/NPT.0b013e3181deca01.
58. Leddy JJ, Haider MN, Noble JM, Rieger B, Flanagan S, McPherson JI, Shubin-Stein K, Saleem GT, Corsaro L, Willer B. Clinical assessment of concussion and persistent post-concussive symptoms for neurologists. Current Neurology and Neuroscience Reports. 2021 Nov;21(70):1-14. DOI: 10.1007/s11910-021-01159-2.
59. Leddy JJ, Haider MN, Noble JM, Rieger B, Flanagan S, McPherson JI, Shubin-Stein K, Saleem GT, Corsaro L, Willer B. Management of concussion and persistent post-concussive symptoms for neurologists. Current Neurology and Neuroscience Reports. 2021 Nov;21(72):1-7. DOI: 10.1007/s11910-021-01160-9.
60. Cheever K, Kawata K, et al. Cervical injury assessments for concussion evaluation: a review. J Athl Train. 2016 Dec;51(12):1037-1044. DOI: 10.4085/1062/6050-51.12.15
61. Kennedy E, Quinn, D, et al. Can the neck contribute to persistent post-concussion symptoms? A prospective descriptive case series. Journal of Orthpaedic & Sports Physical Therapy. 2019 Nov;49(11):845-854. DOI 10.2519/jospt.2019.8547.
62. Leddy JJ, Haider MN, Noble JM, Rieger B, Flanagan S, McPherson JI, Shubin-Stein K, Saleem GT, Corsaro L, Willer B. Management of concussion and persistent post-concussive symptoms for neurologists. Current Neurology and Neuroscience Reports. 2021 Nov;21(72):1-7. DOI: 10.1007/s11910-021-01160-9.
63. Leddy JJ, Haider MN, et al. Management of concussion and persistent post-concussive symptoms for neurologists. Current Neurology and Neuroscience Reports. 2021 Nov;21(72):1-14. DOI:10.1007/s11910-021-01160-9.
64. Silverberg ND, Mikolic A. Management of psychological complications following mild traumatic brain injury. Current Neurology and Neuroscience Reports. 2023;23:49-58. DOI: 10/1007/s11910-023-01251-9.
65. Katz DI, Bernick C, et al. National institute of neurological disorders and stroke consensus diagnostic criteria for traumatic encephalopathy. Neurology 2021;96:848-863. DOI: 10.1212/WNL.0000000000011850.
66. McKee AC, Mez J, et al. Neuropathologic and clinical findings in young contact sport athletes exposed to repetitive head impacts. JAMA Neurology. 2023 Aug. Open Access:E1-E13. DOI: 10.1001/jamaneruol.2023.2907.
67. Patricios JS, Schneider KJ, et al. Consensus statement on concussion in sport: the 6th international conference on concussion in sport – Amsterdam, October 2022. 2023 May;57:695-711. DOI: 10.1136/bjsports-2023-106898.
68. Leddy JJ, Haider MN, et al. Management of concussion and persistent post-concussive symptoms for neurologists. Current Neurology and Neuroscience Reports, 2021 Oct;21(72):1-7. DOI:10.1007/s11910-021-01160-9.

References

1. American Heart Association. Basic Life Support (BLS) Provider Manual. American Heart Association 2020.

2. Beckwith JG, Greenwald RM, et al. Timing of concussion diagnosis is related to head impact exposure prior to injury. Med Sci Sports Exerc. 2013 Apr;45(4):747-54. DOI: 10.1249/MSS.0b013e3182793067.

3. Bogglid M, Tator C. Concussion knowledge among medical students and neurology/neurosurgery residents. Can J Neurolg Sci. 2012;39:361-368. DOI:10.1017/S0317167100013524

4. Brennan JH, Mitra B, et al. Accelerometers for the assessment of concussion in male athletes: a systematic review and meta-analysis. Sports Med, 2017 Mar;47(3):469-478. DOI: 10.1007/s40279-016-0582-1.

5. Bull FC, Al-Ansari SS, et al. World Health Organization 2020 guidelines on physical activity and sedentary behavior. World Health Organization 2020;54:1451-1462. DOI: 10.1136/bjsports-2020-102955

6. Burke MJ, Chundamala J, Tator CH. Deficiencies in concussion education in Canadian medical schools. Canadian Journal of Neurological Sciences. 2012;39(6):763-766. DOI:10.1017/s0317167100015584

7. Carroll LJ et al. Methodological issues and research recommendations for mild traumatic brain injury: the WHO Collaborating Centre Task Force on Mild Traumatic Brain Injury. Journal of Rehabilitation Medicine. 2004;Suppl. 43:113-125. DOI:10.1080/16501960410023877

8. Carson JD, Lawrence DW, et al. Premature return to play and return to learn after a sport-related concussion: physician's chart review. 2014 Jun;60(6):e310, e312-5. Concussion in youth sport: A public health priority. CMAJ: Canadian Medical Association Journal, 186(8):585-586.

9. Centers for Disease Control and Prevention (CDC) - Traumatic Brain Injury & Concussion: https://www.cdc.gov/traumaticbraininjury/index.html

10. Centers for Disease Control and Prevention (CDC) - Traumatic Brain Injury & Concussion: https://www.cdc.gov/traumaticbraininjury/index.html

11. Clark JM, Hoshizaki TB, Gilchrist MD. Protective capacity of ice hockey goaltender helmets for three events associated with concussion. Computer Methods in Biomechanics and Biomedical Engineering, 2017;20(12):1299-1311. DOI:10.1080/10255842.2017.1341977.

12. Crawford, M. Concussions and chiropractic. J Am Chiropr Assoc. 2011;7(9):33.

13. Curran-Sills G, Abedin T. Risk factors associated with injury and concussion in sanctioned amateur and professional mixed martial arts bouts in Calgary, Alberta. BMJ Open Sport Exerc Med 2018;4:e000348. DOI:10.1136/bmjsem-2018-000348

14. Dompier TP, Kerr ZY, et al. Incidence of concussion during practice and games in youth, high school, and collegiate American football players. JAMA Pediatrics 2015 May;169(7):659-665. DOI:10.1001/jamapediatrics.2015.0210

15. Donaworth MA, Grandhi RK, et al. Is current medical education adequately preparing future physicians to manage concussion: An initial evaluation. Physician and Sports Medicine. 2016;44(1):1-7. DOI:10.1080/00913847.2016.1135039

16. Faul M, Xu L, et al. Traumatic brain injury in the United States: national estimates of prevalence and incidents, 2002-2006. Injury and Prevention. 2010;16(Suppl 1):A1-A289. DOI:10.1136/ip.2010.029215.951

17. Giza CC, Hovda DA. The New Neurometabolic Cascade of Concussion. Neurosurgery; 2014 Oct;75(suppl_4):S24-S33. DOI:10.1227/NEU.0000000000000505

18. Guskiewicz KM, Mihalik JP. Biomechanics of sport concussion: quest for the elusive injury threshold. Neurosurgery, 2011 Jan;39(1):4-11. DOI: 10.1097/JES.0b013e318201f53e.

19. Harmon KG, Clugston JR, et al. American Medical Society for Sports Medicine Position Statement on Concussion in Sport. British Journal of Sports Medicine. 2019 Feb;53(4):213-225. DOI: 10.1136/bjsports-2018-100338

20. Hutchison MG, Lawrence DW, et al. Head trauma in mixed martial arts. The American Journal of Sports Medicine 2014;42(6):1352-1358. DOI:10.1177/0363546514526151

21. Iverson GI, Gardner AJ, et al. Predictors of clinical recovery from concussion: a systematic review. British Journal of Sports Medicine. 2017 May;51(12):941-948.

22. Johnson C, Green B, et al. Chiropractic and concussion in sport: a narrative review of the literature. J Chiropr Med. 2013 Dec;12(4):216-229. DOI:10.1016/j.jcm.2013.10.011

23. Kazemi M, Bogumil ME, et al. Concussion assessment and management knowledge among chiropractic fourth year interns and residents. The Journal of the Canadian Chiropractic Association. 2016;60(3):212-220.

24. Koutures CG, Gregory AJM. Injuries in youth soccer. Pediatrics 2016 Feb;137(2):410-4. DOI:10.1542/peds.2009-3009

25. Langlois JA, Rutland-Brown W, Wald M. The epidemiology and impact of traumatic brain injury: a brief overview. The Journal of head trauma rehabilitation. 2006 Sep-Oct;21(5):375-378. DOI: 10.1097/00001199-200609000-00001

26. Lingsma HF, Roozenbeek B, et al. Large between-center differences in outcome after moderate and severe traumatic brain injury in the International Mission on Prognosis and Analysis of Clinical Trials (IMPACT) study. Neurosurgery. 2011;76(2):153-162. DOI:10.1227/NEU.0b013e318209333b

27. Mann A, Tator CH, Carson JD. Concussion diagnosis and management: knowledge and attitudes of family medicine residents. Canadian Family Physician. 2017 Jun;63(6);e310-e315.

28. Manoogian SJ, McNeely D, et al. Head acceleration is less than 10 percent of helmet acceleration in football impacts. Biomechanics and modeling in mechanobiology, 2006 Jul;4(3):195-202.

29. Marar M, McIlvain NM, et al. Epidemiology of concussions among United States high school athletes in 20 sports. The American Journal of Sports Medicine 2012;40(4):747-755. DOI:10.1177/0363546511435626

30. Mathieu F, Ellis MJ. Concussion education in Canadian medical schools: a 5-year follow-up survey. Canadian Journal of Neurological Sciences. 2018;45(3):281-286. DOI:10.1186/s12909-018-1416-7.

31. McCrory P, Feddermann-Demont N. What is the definition of sports-related concussion: a systematic review. Br J Sports Med, 2017 Jun;51(11):877–87. DOI: 10.1136/bjsports-2016-097393.

32. McCrory P, Meeuwisse W, et al. Consensus statement on concussion in sport—the 5th international conference on concussion in sport held in Berlin, October 2016. British Journal of Sports Medicine. 2017 Apr;51(11):838-847. DOI:10.1136/bjsports-2017-097699

33. National Institute of Neurological Disorders and Stroke (NINDS). Traumatic Brain Injury: Hope Through Research. Retrieved from https://www.ninds.nih.gov/Disorders/Patient-Caregiver-Education/Hope-Through-Research/Traumatic-Brain-Injury-Hope-Through.

34. Nordin M, Frankel VH. 2012. Basic Biomechanics of the Musculoskeletal System. Lippincott Williams & Wilkins.

35. Patrick, P. Sean. Emergency Physician Training on Mild Traumatic Brain Injury: A Systematic Review. National Library of Medicine. 2017 Oct;1(4):346–356. DOI:10.1002/aet2.10053.

36. Prien A, Grafe A, et al. Epidemiology of head injuries focusing on concussions in team contact sports: a systematic review. Sports Medicine 2018 Jan;48(4):953-969. DOI:10.1007/s40279-017-0854-4

37. Reith FC, Van den Brande R, et al. The reliability of the Glasgow Coma Scale: a systematic review. Intensive Care Medicine 2016 Jan;42(1):3-15. DOI:10.1007/s00134-015-4124-3

38. Romeu-Mejia R, Giza CC. Concussion Pathophysiology and Injury Biomechanics. Current Reviews in Musculoskeletal Medicine, 2019;12(2):105-116. DOI:10.1007/s12178-019-09536-8.

39. Rowson S, Duma SM. Brain injury prediction: Assessing the combined probability of concussion using linear and rotational head acceleration. Annals of Biomedical Engineering, 2013 May;41(5):873-882. DOI:10.1007/s10439-012-0731-0.

40. Taylor CA, Bell JM, et al. Traumatic brain injury-related emergency department visits, hospitalizations, and deaths - United States, 2007 and 2013. MMWR Surveillance Summaries. 2017 Mar;66(9):1-16. DOI:10.15585/mmwr.ss6609a1

41. Teasdale G, Jennett B. Assessment of coma and impaired consciousness. A practical scale. Lancet 1974 Jul 13;2(7872):81-84. DOI:10.1016/S0140-6736(74)91639-0

42. Teasdale G, Maas A, et al. The Glasgow coma scale at 40 years: standing the test of time. Lancet Neurol. 2014 Aug;13(8):844-54. DOI:10.1016/S1474-4422(14)70120-6.

43. Zemek R, Barrowman N, et al. Clinical risk score for persistent post-concussion symptoms among children with acute concussion in the ED. JAMA 2016;315(10):1014-1025. DOI:10.1001/jama.2016.1203

44. Berg JM, Tymoczko JL, Stryer L. Biochemistry. 5th edition. New York: W.H. Freeman; 2002. Section 16.1, ATP Is Generated by the Oxidative Phosphorylation of Mitochondria.

45. Duchen MR. Mitochondria and calcium: from cell signaling to cell death. J Physiol. 2000;529(Pt 1):57-68. DOI: 10.1111/j.1469-7793.2000.00057.x.

46. Giza CC, Hovda DA. The New Neurometabolic Cascade of Concussion. Neurosurgery; 2014 Oct;75(suppl_4):S24-S33. DOI:10.1227/NEU.0000000000000505.

47. Kandel ER, Schwartz JH, Jessell TM. (2021). Principles of neural science (6th ed.). McGraw-Hill.

48. Langlois JA, Rutland-Brown W, Wald M. The epidemiology and impact of traumatic brain injury: a brief overview. The Journal of head trauma rehabilitation. 2006 Sep-Oct;21(5):375-378. DOI: 10.1097/00001199-200609000-00001

49. Payne W, De Jesus O, Payne A. Contrecoup brain injury. StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing, 2023 Jan:1-5.

50. Pivovarova NB, Andrews SB. Calcium-dependent mitochondrial function and dysfunction in neurons. FEBS J. 2010;277(18):3622-3636. DOI: 10.1111/j.1742-4658.2010.07754.x.

51. Povlishock JT. Traumatically induced axonal injury: pathogenesis and pathobiological implications. Brain pathology, 1992 Jan;2(1):1-12. DOI:10.1111/j.1750-3639.1991.tb00050.x.

52. Raghupathi R. Cell death mechanisms following traumatic brain injury. Brain pathology, 2004 Apr;14(2): 215-222. DOI: 10.1111/j.1750-3639.2004.tb00056.x.

53. Taylor CA, Bell JM, et al. Traumatic brain injury–related emergency department visits, hospitalizations, and deaths—United States, 2007 and 2013. MMWR Surveillance Summaries, 2017 Mar;66(9):1-16. DOI: 10.15585/mmwr.ss6609a1.

54.Fleming KD and Jones LK Jr. May Clinic Neurology Board Review: Clinical Neurology for Initial Certification and MOC. Mayo Clinic Scientific Press. 2015.

55. Katz DI, Bernick C, et al. National institute of neurological disorders and stroke consensus diagnostic criteria for traumatic encephalopathy. Neurology 2021;96:848-863. DOI: 10.1212/WNL.0000000000011850.

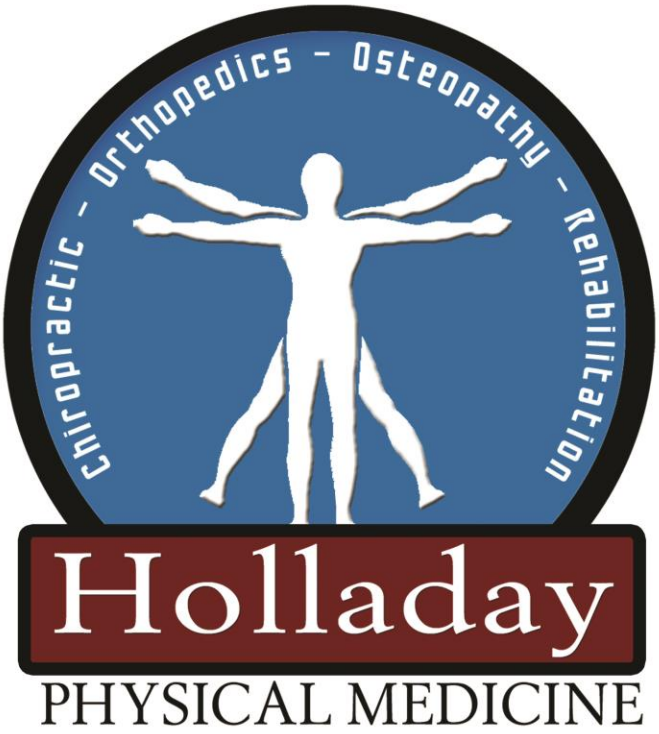
56. Leddy JJ, Haider MN, Ellis M, Willer BS. Exercise is Medicine for Concussion. Curr Sports Med Rep. 2018 Aug;17(8):262-270. DOI:10.1249/JSR.0000000000000505. PMID: 30095546; PMCID: PMC6089233.

57. Leddy JJ, Haider MN, et al. Management of concussion and persistent post-concussive symptoms for neurologists. Current Neurology and Neuroscience Reports, 2021 Oct;21(72):1-7. DOI:10.1007/s11910-021-01160-9.

58. Leddy JJ, Halder MN, Willer BS. Buffalo Concussion Treadmill Test (BCTT) – Instruction Manual. https://cdn-links.lww.com/permalink/jsm/a/jsm_2020_01_28_haider_19-313_sdc1.pdf.

59. McKee AC, Mez J, et al. Neuropathologic and clinical findings in young contact sport athletes exposed to repetitive head impacts. JAMA Neurology. 2023 Aug. Open Access:E1-E13. DOI: 10.1001/jamaneruol.2023.2907.

60. Patricios JS, Schneider KJ, et al. Consensus statement on concussion in sport: the 6th international conference on concussion in sport – Amsterdam, October 2022. 2023 May;57:695-711. DOI: 10.1136/bjsports-2023-106898.



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