DIAGNOSIS AND TREATMENT OF CONCUSSION

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- **38 million children and adolescents** participate in organized sports in the United States.
- **170 million adults** participate in physical activities, including sports.
- **1.6 to 3.8 million concussions** occur in sports and recreational activities annually. These numbers are vastly underestimated due to underreporting.

<table>
<thead>
<tr>
<th>Sport</th>
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<th>No. of Concussions</th>
<th>National Estimates†</th>
<th>Rates per 1000 Athlete-Exposures</th>
<th>Overall Rate Comparison</th>
<th>95% Confidence Interval</th>
<th>P Value</th>
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<td></td>
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<td>Practice</td>
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*Collegiate data for the 2005-2006 school year were provided by the National Collegiate Athletic Association Injury Surveillance System.
†National estimates for the National Collegiate Athletic Association data were not available.
‡Indicates not applicable.
The brain is a complex and complicated organ. **No two mTBIs are the same and, consequently, no two treatment programs can be identical.**

Athletes with concussion rapidly develop short-term impairment of neurologic function; among those, **80 to 90% resolve spontaneously within the first ten days**, although the recovery timeframe may be longer in children and adolescents than in their adult counterparts.

However, a **small percentage of patients experience prolonged, physical, behavioral, neuropsychological, and/or personality changes frequently termed post-concussive syndrome (PCS).**

- Isolated TBI has systemic consequences for several organs, leading to important clinical sequelae, including pneumonia, cardiovascular disorders, autonomic abnormalities, intestinal dysfunction, and multi-system organ failure.
- Several areas of intestinal dysfunction following TBI have been described, including stomach ulceration and gastritis (Cushing’s ulcer), prolonged ileus and other motility problems, and most importantly impairment of gut barrier function.
- TBI significantly decreased the expression of the intestinal tight junction proteins ZO-1 and occludin, which correlates to increased intestinal permeability and distinct changes in intestinal histology.
- We have observed an increase in intestinal permeability and marked changes in intestinal histology 6 hours following TBI. Levels of intestinal tight junction proteins may be an important factor in increased intestinal permeability following TBI.

- In patients with persistent vision and vestibular dysfunction, evaluation should include a **thorough neurologic examination** that emphasizes vision, vestibular, balance and coordination and hearing.
- If symptoms of benign positional vertigo are present, the **Dix-Hallpike Manouvre** should be used for assessment.
Diagnosis of Single or Multiple Canal Benign Paroxysmal Positional Vertigo According to the Type of Nystagmus. *International Journal of Otolaryngology*. 2011.

- Multiple-canal BPPV includes either involvement of the same canal on both sides or simultaneous involvement of different canals on the same or on both sides.
- It should be noticed that traumatic origin is quite common in multiple canal BPPV.
- We should particularly think of and search for multiple-canal BPPV versus single canal BPPV when the patient has suffered head trauma.

- It was recognized by the panelists that conventional structural neuroimaging is normal in concussive injury.
- Balance impairment, or postural instability, is a common source of residual physical disability after severe traumatic brain injury (TBI).
- There is an association between early balance deficits after TBI and late functional recovery.
- Similar to findings in mild TBI, vestibular dysfunction appears to underlie postural instability after severe TBI.
- It appears that postural stability testing provides a useful tool for objectively assessing the motor domain of neurologic functioning and should be considered a reliable and valid addition to the assessment of athletes suffering from concussion.
A common pathological feature of TBI includes distributed injuries to the subcortical white matter, or diffuse axonal injury (DAI), that may occur with or without focal injury.

Magnetic resonance imaging (MRI) technique of diffusion tensor imaging (DTI) can detect microscopic brain white matter tract lesions after concussion, or mild traumatic brain injury (mTBI).

In blunt closed head injury, these diffuse axonal damages have been attributed to shear strain and tissue deformation caused by the rotational accelerations of the brain as an external force is applied to the head.

- Imaging is not used to diagnose mTBI itself, but to test for hematomas as well as to rule out head injury complications from more severe trauma.
- Even though MRI is a premier modality for imaging the brain, when used in conventional clinical modes it adds little clinical diagnoses beyond what is provided by CT.
- Thus CT is faster and more cost-effective.
- Despite the large efforts to date, neuroimaging methods still lack the individual patient-level sensitivity and specificity to serve as a diagnostic tool for mTBI.

- Dizziness has been reported in up to 80% of traumatic brain injury cases within the first few days after injury.
- Dizziness is a very non-specific term and can be placed into four broad categories.
  - (1) Vertigo: The illusion of movement. This is clearly related to the vestibular system.
  - (2) Pre-syncopal lightheadedness: A sensation of impending faint. This may be due to cerebral ischaemia, e.g. a drop in blood pressure related to postural change.
  - (3) Multisensory dizziness: Occurs with pathology involving multiple sensory systems. This diagnosis is said to be more common in older populations and in populations with systemic disorders (e.g. diabetes).
  - (4) Psycho-physiologic dizziness: Symptoms include visual vertigo and space phobia.

- Dizziness can be further explained in relation to a definition of vestibular function as the ‘neural sensory–motor interaction that leads to the maintenance of balance (motor function) and the perception of motion of objects relative to oneself (sensory function) as part of the larger and global function of orientation’.

- In recent years, **vestibular rehabilitation has emerged as an accepted and effective means of treating dizziness and vestibular disorders**. It involves exercises and activities designed to enhance central nervous system compensation to vestibular system dysfunction.
• In the assessment of traumatic brain injury, S100B is the most widely investigated biomarker.
• S100B is predominantly expressed in astrocytes, with a cerebrospinal fluid (CSF) to serum ratio of 18:1.
• When secreted by astrocytes, S100B has neurotrophic and neuroprotective effects at physiologic nanomolar concentrations.
• However, higher (micromolar) concentrations of S100B have been shown to be neurotoxic and expressed in astrocytic death.
• After a traumatic brain injury, S100B is released or leaked by the cells of the CNS and enters the peripheral bloodstream by passing through the presumably disrupted blood-brain barrier (BBB).
• Studies have reported that S-100b serum levels consistently correlate with both Glasgow Coma scores and neuroradiologic findings at hospital admission.
• S100B alone is not diagnostic for sport-related mTBI.
Blood-based diagnostics of traumatic brain injuries. 
*Expert Review of Molecular Diagnostics. 2011.*

- **Neuron-specific enolase** is located in the cytoplasm of neurons and is probably involved in increasing neuronal chloride levels during the onset of neural activity.

- This marker is thought to assess damage to the functional cells of the brain (i.e., the neurons), and a rapid appearance in serum after head injury has been reported.

- The slow elimination makes it difficult to assess the amount of primary damage and impossible to distinguish between primary and secondary injuries.

- **Neuron-specific enolase** is also released in the blood by hemolysis, which may be a serious source of error.

- **Myelin basic protein**, specific to the myelin sheet of CNS myelin, can be released into serum by brain damage or demyelinating diseases and appears to be a promising marker of TBI.
- Although CSF and serum levels in TBI patients have demonstrated excellent specificity, sensitivity has been limited.
Blood-based diagnostics of traumatic brain injuries. 

- **Ubiquitin C-terminal hydrolase-L1** is involved in either the addition or removal of ubiquitin from proteins that are destined for metabolism (via the ATP-dependent proteosome pathway), thus playing an important role in the removal of excessive, oxidized or misfolded proteins during both normal and neuropathological conditions in neurons.
- A recent study reported that levels of UCHL1 in CSF were significantly increased in severe TBI patients compared with control subjects, with significant associations observed between levels of UCH-L1 in CSF and injury severity measures.
- **UCH-L1 was demonstrated to be a sensitive and specific biomarker of TBI.**
Blood-based diagnostics of traumatic brain injuries.


- **Glial fibrillary acidic protein** represents the major part of the cytoskeleton of astrocytes, is found only in glial cells of the CNS and may, therefore, be considered to be a specific marker for CNS disease, and is also involved in various neuronal processes, including maintenance of the blood–brain barrier.

- Increased serum GFAP levels have been reported in patients suffering from severe head trauma. Recently, other reports have confirmed that serum GFAP is a specific marker of brain damage after head trauma.

- GFAP has also been demonstrated to be a potential useful biomarker to predict clinical outcome.

- **Brain-derived neurotrophic factor (BDNF)** is important for neuronal survival and regeneration.
- While healthy people averaged 60 nanograms per milliliter of BDNF in their bloodstreams, patients with brain injuries had less than one-third of that amount, averaging less than 20 nanograms per milliliter, and those with the most severe TBIs had even lower levels, around 4 nanograms per milliliter.
- Patients with high levels of BDNF had mostly recovered from their injuries six months later. But in patients with the lowest levels of BDNF, symptoms still lingered at follow-up.
- Day-of-injury serum BDNF is associated with TBI diagnosis and also provides 6-month prognostic information regarding recovery from TBI.

- Patients’ complaints of instability after TBI may have objective correlates and may be rectifiable. Balance and gait testing in these patients is warranted.
- Subtle complaints of persistent imbalance by patients after a TBI should be investigated.
- Gait analysis and balance and vestibular testing can document subtle changes in gait and balance among those with TBI.
- Imbalance may not be due merely to diffuse brain injury.
- Comprehensive vestibular testing seems appropriate in all patients with persistent complaints of imbalance and instability after TBI.
While an accurate biomechanical diagnostic pathway continues to evade researchers, the clinical examination remains the gold standard for concussion diagnosis.

Medical organizations recommend that the clinician employ a battery of tests that evaluate a number of cognitive domains known to be affected by concussion.

An assessment battery that employs measures of concussion related symptoms, neurocognitive functioning, and postural control remains the most sensitive to injury in excess of 90% from which to base the diagnosis.

- The VOMS, a brief (5–10 minute) screen for vestibular and ocular motor impairments and symptoms, possesses internal consistency and demonstrates basic validity.
- **The VOMS was able to distinguish concussed from non-concussed athletes.**
- The VOMS appears to assess distinct vestibular and ocular motor symptoms, which are unrelated to current clinical balance measures.
- The VOMS may help clinicians to identify patients for vestibular and ocular referrals and more targeted treatment, thereby enhancing recovery from this injury.
Medical records of 220 individuals with either TBI (n 160) or CVA (n 60) were reviewed retrospectively investigating the frequency of occurrence of oculomotor dysfunctions including accommodation, version, vergence, strabismus, and cranial nerve (CN) palsy.

The majority of individuals with either TBI (90%) or CVA (86.7%) manifested an oculomotor dysfunction. Accommodative and vergence deficits were most common in the TBI subgroup, whereas strabismus and CN palsy were most common in the CVA subgroup.

These new findings should alert the clinician to the higher frequency of occurrence of oculomotor dysfunctions in these populations and the associated therapeutic, rehabilitative, and quality-of-life implications.

Predictive visual tracking shows promise as an attention metric to assess severity of mTBI.

Deficits seen during predictive visual tracking correlate with DTI findings and with observed damage to neural pathways known to carry out cognitive and affective functions that are vulnerable to mTBI.

- Our results indicate that eye movement function is impaired in post concussion syndrome (PCS), the deficits being unrelated to the influence of depression or estimated intellectual ability.
- The majority of eye movement deficits in the PCS group were found on measures relating to motor functions executed under both conscious and semi-conscious control (directional errors; poorer visuospatial accuracy; more saccades and marginally poorer timing and rhythm keeping in memory-guided sequences; smaller number of self-paced saccades; deficits in OSP).
- Importantly, the PCS group also had poorer performance on several eye movement functions that are beyond conscious control and indicative of subcortical brain function (slowed velocity of self-paced saccades and indications of longer saccade durations of self-paced saccades, anti-saccades and larger amplitude memory-guided saccades).

- Saccades are rapid eye movements that move the line of sight between successive points of fixation. Their dynamic properties are well understood and easily measured, including reaction time, amplitude, peak velocity, duration, and frequency of errors.
- In our study, there was some correlation between saccadic reaction times and self-reporting symptoms.
- Persistent prolonged saccadic reaction times in mTBI patients may separate patients with persistent mTBI from those with recovering mTBI.

- The time taken to look at a suddenly presented visual target, saccadic latency, reflects cortical decision time, and has proved a useful measure of the general level of cerebral function, being affected by conditions ranging from sedative levels of anaesthesia to metabolic disorders. Furthermore, because saccades to the left and right are independently controlled by each hemisphere, it can provide information about lateral functional asymmetry.

- **Useful comparisons can be made between an individual’s baseline and post-injury saccadic latency distributions**, and that large changes are a relatively common outcome of boxing, even in the absence of a period of unconsciousness; **those experiencing more head trauma generally showed the largest latency increases**.

- This implies that mild traumatic brain injury impairs cortical decision processes, causing a shift in latency distribution.

- **Even very mild traumatic brain injury there are obvious alterations in saccadic latency distributions, with increased mean latency**, but that they return to pre-fight levels within a small number of days.

- The **higher number** of **directional errors** of the PCS group in the **anti-saccade task** suggests **suboptimal function in prefrontal cortical areas**, in particular the **dorsolateral prefrontal cortex**.
- The **smaller number** of self-paced saccades and **prolonged inter-saccadic latency of self-paced saccades** in the PCS group supports the interpretation of **poorer prefrontal function**.

- The oculomotor performance for horizontal saccades was in the expected range for the control group and showed a significant deficit in peak velocity and some aspects of the onset latencies and amplitudes in the concussion group.
- Vergence eye movements also showed a significant slowing of the peak velocities for the concussion group relative to the control group.
- **In the concussion group, fMRI signals from the oculomotor nuclei and abducens nuclei showed about a 50% reduction relative to controls.**
- For vergence, the supra-ocular motor area showed almost a complete reduction in activity relative to controls on fMRI.

- In conclusion, **our findings indicate that eye movement function in PCS does not follow the normal recovery path of eye movements after mCHI, marking ongoing cerebral impairment independently of patient self-report and neuropsychological assessment.**

- Whilst oculomotor and neuropsychological tests partially overlapped in identifying suboptimal brain function, eye movements provided additional evidence of dysfunction in areas such as decision making under time pressure, response inhibition, short-term spatial memory, motor-sequence programming and execution, visuospatial processing and integration, visual attention and subcortical brain function.

- **Indications of poorer subcortical/subconscious oculomotor function in the PCS group support the notion that PCS is not merely a psychological entity but also has a biological substrate.**

- Despite the cost-intensive nature of eye movement assessment in terms of required equipment, eye movement testing should be feasible in centers, which have easy access to eye tracking technology.

- Performance variability during predictive visual tracking is a powerful indicator for decreased integrity in frontal white matter tracts vulnerable to mTBI as well as for altered cognitive functioning.
- Visual tracking performance can be monitored precisely and continuously, allowing detection and objective quantification of subtle momentary lapses in attention over a matter of seconds, a significantly shorter time than required for administration of traditional neurocognitive testing.
- **Measurement of visual tracking performance is promising as a fast and practical screening tool for mTBI.**

- Although subjective patient self-report is the leading method of diagnosing mTBI, current scientific evidence suggests that quantitative measures of predictive timing, such as visual tracking, could be a useful adjunct to guide the assessment of attention and to screen for advanced brain imaging.
- Magnetic resonance diffusion tensor imaging (DTI) has demonstrated that mTBI is associated with widespread microstructural changes that include those in the frontal white matter tracts.
- **Deficits observed during predictive visual tracking correlate with DTI findings that show lesions localized in neural pathways subserving the cognitive functions often disrupted in mTBI.**
- Predictive visual tracking shows promise as an attention metric to assess severity of mTBI. Deficits seen during predictive visual tracking correlate with DTI findings and with observed damage to neural pathways known to carry out cognitive and affective functions that are vulnerable to mTBI.

- The application of neuropsychological (NP) testing in concussion has been shown to be of clinical value and continues to contribute significant information in concussion evaluation.
- It must be emphasized, however, that **NP assessment should not be the sole basis of management decisions**; rather, it should be seen as an aid to the clinical decision-making process in conjunction with a range of clinical domains and investigational results.

- Neuropsychological assessment has been described as an important ‘cornerstone’ of concussion management.
- **Neuropsychological instruments should not be used in a stand-alone manner to make return-to-play decisions.**
- Although popular, **there is insufficient published evidence to recommend the widespread universal use of baseline neuropsychological testing within a sport concussion management program.**

- Rest is the primary treatment for the acute symptoms of concussion.
- Ongoing symptoms reflect either a prolonged version of the concussion or a manifestation of other processes, such as cervical injury, migraine headaches, depression, chronic pain, vestibular dysfunction, visual dysfunction, or a combination of conditions.
- The pathophysiology of ongoing symptoms from the original concussion injury may reflect multiple causes: anatomic, neurometabolic, and physiologic.
- Treatment approaches depend on the clinician’s ability to differentiate among the various conditions associated with PCS.

- **There are several possible problems with rest as an approach to MTBI management.**
  - The benefits of rest are largely assumed rather than evidence based. In light of the considerable evidence that other health conditions can be worsened by inactivity and improved by exercise, it may be imprudent to advise rest beyond the acute stage.
  - Defining asymptomatic status can be very challenging.
  - A minority of patients who sustain this injury remain symptomatic for months to years. Ongoing inactivity is almost certainly more detrimental than therapeutic in the chronic stage.

- Being sedentary after an injury or illness is one of the most consistent risk factors for chronic disability.
- Inactivity can precipitate, exacerbate, and/or prolong recovery from many health conditions, including those most often comorbid with MTBI—vestibular disorders, depression, posttraumatic stress disorder, chronic fatigue, and pain disorders.
- After 3 to 6 days of bed rest, complaints of headache, restlessness, and difficulty sleeping, and after a week, mood changes, and vestibular sensitivity are common.
- It appears that complete bed rest beyond a few days is sufficient to cause postconcussion-like symptoms and may exacerbate symptoms after MTBI.
• There is no evidence that complete rest (recumbence in bed and avoidance of cognitive stimulation) for any duration improves or adversely impacts outcome after MTBI.

• The only randomized controlled trial had null results. Multiple systematic reviews for many health conditions other than MTBI have concluded that full bed rest beyond 1 to 2 days is unhelpful and potentially harmful.

• Negative physiological consequences of prescribed rest are evident after as little as 3 days.

- Returning to competitive sports within the first week following injury is associated with an elevated risk of repeat concussion, regardless of whether the athlete is symptomatic or asymptomatic.
- Vigorous exercise within the first 2 weeks following injury might delay recovery in some people, particularly those who are more seriously injured.

- Current guidelines recommend a **period of cognitive and physical rest in the early post-injury period** because symptoms can increase with cognitive and physical exertion.
- **Prolonged rest**, especially in athletes, can lead to physical deconditioning, metabolic disturbances, and secondary symptoms such as fatigue and reactive depression.
- There is **no scientific evidence** that prolonged rest for more than several weeks in concussed patients is beneficial.

- Low-level exercise for those who are slow to recover may be of benefit, although the optimal timing following injury for initiation of this treatment is currently unknown. However, 1 month post-injury has been proposed.

- Experimental animal data show that premature voluntary exercise within the first week after concussion impairs recovery, while aerobic exercise performed 14 to 21 days after concussion improves cognitive performance.
- Neurotrophins (brain-derived neurotrophic factor) promote neuronal recovery.
- Premature voluntary exercise within the first week after concussion interferes with the postconcussion rise of brain-derived neurotrophic factor and is associated with impaired cognitive memory task performance.
- Conversely, aerobic exercise performed 14 to 21 days after TBI upregulated brain-derived neurotrophic factor in association with improved cognitive performance.

- Patients who have **persistent signs and symptoms 4 weeks after injury benefit from “active rehabilitation.”**
- Common problems include impaired **balance, vestibulo-ocular dysfunction, and aerobic intolerance and memory deficits.**
- Rehabilitation prescriptions should be customized to therapies specific to the patient’s deficits.

- Persons who complain about somatic, cognitive or behavioural difficulties after mTBI should be assessed and treated symptomatically, even if it has been a prolonged time after injury.
- The patient should be advised that a full recovery of symptoms is seen in the majority of cases.
- A patient experiencing reduced cognitive functioning in the first few days following injury, with education and support, should be expected, in the majority of cases, to have these symptoms resolve and pre-injury cognitive functioning return within days or up to 3 months.
- **For patients whose symptoms do not improve by 3 months post injury, it is recommended that these patients be referred for more comprehensive evaluation to a specialized brain injury environment.**
The sooner patients begin neurorehabilitation, the better their functional outcome. *Brain Injury*. 2013.

- The results indicate that intensive integral multidisciplinary rehabilitation programs have a positive effect on the neuropsychological outcome of patients with severe TBI.
- After rehabilitation, all 58 subjects showed improvement in deteriorated cognitive, motor, communication and psychosocial functioning.
- Patients that entered the rehabilitation program earlier, before 9 months post-injury, showed better global functionality than patients who began later treatment.

- Late exercise initiation beginning at 5 weeks after trauma, but not early initiation of exercise at 1 week, significantly reduced working and retention memory impairment at 3 months, and decreased lesion volume compared to nonexercise injury controls.
- Cognitive recovery was associated with attenuation of classical inflammatory pathways, activation of alternative inflammatory responses and enhancement of neurogenesis.
- In contrast, early initiation of exercise failed to alter behavioral recovery or lesion size, while increasing the neurotoxic pro-inflammatory responses.
- These data underscore the critical importance of timing of exercise initiation after trauma and its relation to neuroinflammation, and challenge the widely held view that effective neuroprotection requires early intervention.
The sooner patients begin neurorehabilitation, the better their functional outcome. *Brain Injury*. 2013.

- Early rehabilitation led to a 92.31% gain in locomotion functionality.
- Communication also showed significant gain in this group, reaching 91.67% in most cases. These improvements included enhanced expression, comprehension, reading, writing and speech intelligibility.
- **It was found that intensive integral multidisciplinary rehabilitation has a positive effect on functional recovery after TBI.**
- Significant improvement was observed in motor, cognitive and communication skills.
- It is concluded that the sooner patients begin neurorehabilitation, the better their functional outcome.

- With headaches, consideration should be given to non-pharmacological therapies targeted to the presumed source of the headache, including relaxation therapy, biofeedback, massage therapy, manual therapy of the spine, acupuncture, vision therapy and cognitive therapy.
- Cognitive-Behavioral Therapy (CBT) for insomnia is established as the treatment of choice for either primary insomnia or insomnia co-morbid to a medical or psychiatric condition.
- A canalith repositioning maneuver should be used to treat benign postional vertigo if the Dix-Hallpike test is positive.
- Vestibular therapy is recommended for unilateral peripheral vestibular dysfunction.

- After concussion, **two of the most commonly reported symptoms are headache and dizziness**, followed closely by nausea and neck pain.
- **Cervical spine trauma may cause prolonged postconcussion headache.**
- The upper cervical spine can cause cervicogenic headaches.
- Dizziness and balance dysfunction are also commonly reported symptoms following sport-related concussion and may be due to dysfunction of the vestibular, proprioceptive or central systems.

- Manual physical therapy for the cervical spine is used to address physical impairments in range of motion (ROM) and muscle tightness that are thought to contribute to symptoms of headache, dizziness, and neck pain.
- Manual physical therapy has been shown to be effective in patients with cervicogenic headache and cervicogenic dizziness.

- In this study, we demonstrated that a significantly higher proportion of individuals who were treated with cervical spine physiotherapy and vestibular rehabilitation were medically cleared to return to sport within 8 weeks of initiating treatment.
- Manual therapy is believed to decrease pain and improve function through a variety of biomechanical and neurophysiological effects.
- A combination of manual therapy and exercise has been shown to be more effective than passive treatment modalities in individuals with neck pain.

- Post-traumatic dizziness is believed to occur secondary to benign paroxysmal positional vertigo, central vestibular, peripheral vestibular, visual or proprioceptive dysfunction.
- Many of these conditions have been shown to respond well to vestibular rehabilitation, which is the current standard of care.
- Multimodal treatment of the cervical spine is effective in individuals with neck pain and with mechanical neck disorders with or without headaches.
- Additionally, treatment of the cervical spine has demonstrated improvements in individuals with suspected cervicogenic dizziness.

- Smaller mean neck circumference, smaller mean neck to head circumference ratio, and weaker mean overall neck strength were significantly associated with concussion.
- **Overall neck strength was found to be a significant predictor of concussion.**
- For every one pound increase in neck strength, odds of concussion decreased by 5%.
- We conclude that identifying differences in **overall neck strength may be useful in developing a screening tool** to determine which athletes are at higher risk of concussion.
- Once identified, these athletes could be targeted for **concussion prevention programs**.
A recent study by Schneider and colleagues conducted an RCT with a sample of 12- to 30-year-olds with dizziness, neck pain, and/or headache following sports related concussion.

After 8 weekly physical therapy sessions consisting of vestibular and cervical spine rehabilitation, subjects in the treatment group were nearly 4 times more likely to be medically cleared when compared with a control group.
Current and Emerging Rehabilitation for Concussion. 
*Clinical Sports Medicine.* 2015.

- In a retrospective chart review, Alsalaheen and colleagues examined the response of a population of concussed patients to vestibular physical therapy.
- Data from 114 patients referred for vestibular rehabilitation following concussion demonstrated a significant treatment effect for 15 different measures of dizziness severity, balance confidence, gait, and static/dynamic balance.
- Gottshall and Hoffer assessed computerized VOR and gaze stability measures in 82 military individuals who experienced blast-related mTBI.
- Impairment was significant at the time of initial evaluation, but returned to normative levels after 4 to 12 weeks of vestibular physical therapy.
• Hoffer and colleagues examined the effect of vestibular rehabilitation in a population of 58 active duty military individuals with postconcussive dizziness.

• They found that after a 6- to 8-week vestibular rehabilitation program, patients had improved with respect to symptoms of dizziness, perception of balance function, and measures of VOR function.

• However, the effectiveness of vestibular rehabilitation differed based on type of posttraumatic dizziness. Specifically, patients with post-traumatic migraine-associated dizziness were most responsive to treatment (84%) in contrast with the spatial disorientation group (27%).
• Dizziness due to migraine as well as patients with central vestibular dysfunction has been shown in studies to **improve with vestibular physical therapy intervention.**

• Therapies for visual motion sensitivity, such as optokinetic stimulus exposure, have been shown to be effective with **peripheral vestibular disorders.**

• Several studies have investigated the efficacy of physical therapy treatment of the cervical spine for cervicogenic dizziness demonstrating **significant reduction in intensity and frequency of cervicogenic dizziness with 2 different manual therapy techniques over placebo.**

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- Vestibular dysfunction is commonly associated with TBI.
- **Vestibular suppressants**, may delay recovery and have been replaced by vestibular rehabilitation for posttraumatic vertigo.
- Vestibular rehabilitation may reduce dizziness and improve gait and balance in children and adults.
A retrospective study by Ciuffreda and colleagues examined patients with mTBI who were enrolled in a vision therapy program consisting of combined vergence, version, and accommodative exercises. They reported that 90% of patients improved markedly or completely in symptoms and subjective reports of enhanced reading at a 2 to 3 month follow-up.

In a recent study involving 12 subjects following mTBI, Thiagarajan and Ciuffreda demonstrated that an oculomotor training program targeting the version, vergence, and accommodation components of the ocular motor system significantly improved the amplitudes of vergence and accommodation, accuracy of saccadic eye movements, and overall reading.

- Our results showed that **performing saccades improves postural stability with respect to a simple task (fixation) regardless of age.**
- This study shows an **interaction between the oculomotor and the postural system**, according to the fact that the **same structures of the central nervous system play an important role in postural control as well as in programming and executing saccadic eye movements.**

- The current findings showed a wide range of vergence, versional, and accommodative problems that could be remediated successfully, at a level **of 90% or better**, incorporating conventional optometric vision therapy in the affected oculomotor areas.
- Both symptoms and signs, with most being related to near vision activities, were either markedly reduced or totally eliminated.
- These findings suggest the presence of considerable **visual system plasticity in response to the targeted vision rehabilitation** in this brain-injured sample.
- Thus, despite the **presence of brain damage** in this predominantly adult population, **considerable improvement in oculomotor skills was evident**.
Following training, there was a significant **25% improvement in reading rate and improved subjectively based visual comfort and visual attention scores**.

The number of fixations/100 words **reduced by 18%**, thus demonstrating a **reduced number of excessive and unnecessary saccades** after the training.

Since comprehension did not change after the training, it suggests that the increased reading rate was primarily oculomotor-based, and an effect of OMT training.

Based on the present results, it is clear that the **oculomotor-based training had a significant positive effect on reading rate and related aspects**.
Proper orientation in space requires accurate and consistent input from the proprioceptive, visual and vestibular systems.

If one or more of these systems provide inaccurate information about spatial location, alteration in balance and dizziness may result due to mismatching of sensory information.

Additionally, dysfunction of these systems may persist and may alter risk of future concussion.

- **There is no scientific evidence that medication speeds recovery from concussion in humans.**
- The most common medications prescribed for PCS are antidepressants.
- Selective serotonin reuptake inhibitors have become the primary treatment for head injury–associated depression and can improve depression and the cognitive deficits associated with concussion.
- Tricyclic antidepressants such as low dose amitriptyline are often used clinically to aid sleep and headaches in patients with PCS, but there are no controlled trials of their efficacy in restoring normal function.

- Given the absence of FDA approved pharmacotherapies for neuropsychiatric problems after TBI, clinicians should be mindful that all treatments for the neuropsychiatric sequelae of TBI must be regarded as “off-label”.

- Catecholaminergic and cholinergic dysfunction may be involved in the genesis of attention, memory, and executive function impairments after TBI. Consequently, most of the treatments for these problems are used for the purpose of augmenting the function of these neurotransmitter systems.

- Concurrently, inflammation due to microglial activation occurs soon after the concussive injury, causing damage to cellular structures.
- The v-3 FA DHA has been shown to address several of the hallmark pathologic features of this injury, such as excitotoxicity, oxidative stress, and inflammation. NMDA, N-methyl-D-aspartate; ROS, reactive oxygen species.
- The mechanisms involved include decreased neuroinflammation and oxidative stress, neurotrophic support, and activation of cell survival pathways.
- The level of total omega-3 PUFA in plasma is inversely correlated with the level of pro-inflammatory markers (IL-6, TNFa, IL-1ra, and Creactive protein) and the omega-6/omega-3 PUFA ratio is negatively correlated with the anti-inflammatory marker IL-10.

- We found that the **combination of dietary DHA and voluntary exercise** was particularly effective to counteract the effects of TBI on cognitive function and several parameters of synaptic plasticity, and plasma membrane homeostasis.

- From a mechanistic point of view, we found that exercise influences DHA function by normalizing DHA content in the brain, whose process seems mediated through enzymes that control the metabolism of DHA in the membrane.

- These findings indicate that the combined actions of **exercise and DHA supplementation** have strong therapeutic potential for reducing the deleterious effects of TBI on membrane homeostasis, synaptic plasticity and cognition.

- The excitatory amino acid, glutamate, induces secondary injuries and leads to the excitotoxicity in neuronal and glial cells.
- Glutamate-induced neuronal apoptosis may be dependent on calcium overload, ER stress induction, and ROS generation.
- Antioxidants such as edaravone and schizandrin can protect neurons against glutamate-induced necrosis and apoptosis, respectively.
- Resveratrol and vitamin C suppressed the production of these ROS and thereby reduced cell death.

- Resveratrol induces a neuroprotective state via several disparate pathways.
- The exact mechanism of resveratrol-mediated neuroprotection is **not yet understood**, but the downstream anti-oxidative, anti-inflammatory and anti-apoptotic effectors have been well documented.

- The results of new studies indicate that impaired cognition after TBI appears to be associated with dysfunction in molecular systems that support synaptic plasticity such as brain-derived neurotrophic factor (BDNF).
- The results show that TBI increases oxidative damage and impairs cognitive function and that these events may be related to a disruption in molecular systems associated with the action of BDNF.
- We provide evidence that the dietary application of the antioxidant curcumin can reduce the deleterious effects of TBI on synaptic plasticity and cognition.
Interventions to improve cognition have improved performance on selected neuropsychological test scores and cognitive function following neurocognitive rehabilitation in patients with mild or mild-to-moderate TBI.

Neurocognitive rehabilitation uses cognitive tasks to improve cognitive processes, or it may involve developing compensatory strategies to address difficulties with aspects of cognition, such as attention, memory, and executive functioning.

Neurocognitive rehabilitation of attention processes has received the most empirical support after TBI.

- Cognitive-behavioral therapy (CBT) is an education-based treatment approach that can be tailored to a patient’s particular cognitive or behavioral symptoms.
- Data have suggested a **potential benefit of CBT in patients with post concussion syndrome**, particularly when initiated soon after injury in patients believed to be high risk for cognitive or behavioral deficits.
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