American Red Cross

Scientific Advisory Council

ARC SAC Scientific Review
Mild Traumatic Brain Injury (concussion)

Questions to be Addressed

How can a first aid provider identify a person with a *mild traumatic brain injury* (concussion) after sustaining trauma to the head and what are recommendations for managing this situation?

Introduction/Overview

According to the Centers for Disease Control and Prevention[1] a traumatic brain injury (TBI) is "caused by a bump, blow or jolt to the head or a penetrating head injury that disrupts the normal function of the brain." The trauma normally involves an acceleration-deceleration mechanism of injury (MOI) where the head sustains a coup, contra-coup or a combination of rotational acceleration and repetitive impact.[2] A forceful blow (eg., projectile [ball, fist, unrestricted objects in a vehicle]) to the resting, movable head produces a coup injury, producing maximal brain injury beneath the point of cranial impact or when the head strikes an unyielding object (contra-coup) (ie., falling to the ground and striking the head on surface) producing localized trauma opposite the site of cranial impact or a combination of rotational acceleration and repetitive impact[2] Depending on the type of trauma a variety of signs and symptoms may be recognized in adults and pediatric patients.[3-12]

In the military, a TBI can often the result of blast related injuries and occur from multiple mechanisms of injury, including[12-15]: 1) direct exposure to over the pressurization wave produced by the blast, 2) being stuck with flying debris (coup) being thrown across the environment, or 3) from jumping[16] from a plane (paratroopers). And while not all blows sustained by the head result in a TBI[17], the severity[1,8,9,18] of a TBI can range from "mild," diffuse injury (ie., a brief change in mental status or consciousness) to "moderate" or "severe," (ie., an extended period of unconsciousness or amnesia sustained after the trauma) depending on variety of factors at the time of injury. . Important factors in determining the severity of injury include: 1) the velocity of the head before impact, 2) time over which the force is applied, 3) magnitude of the force applied to the head[10,19] or body[10,19] 4) amount of linear and/or rotational accleration-deceleration[20], 5) criteria and tools used to determine the presence or absence of mTBI[21-24] and level of familiarity with the signs and symptoms of a concussion.[25]

The majority of TBIs that occur each year are concussions or other forms of mild TBI (mTBI).[26,27] A cerebral concussion is best classified as a mild diffuse injury with the term mTBI typically used interchangeably with the term concussion (as will be in the case of this document).[8,9,26,28] However, it should be noted that according to a review of literature by Mosenthal[29], concussions can and do occur even when a patient sustains moderate traumatic brain injuries. Currently, there is universally accepted agreement on a standard definition (Table 1) for both adults and children[3] and diagnosis or nature of concussion. This is likely due to the variations in the mechanism of injury and presentations of TBI, as well as the more severe, but less common head injuries that can cause damage to the brain stem and other vital centers of the brain.[9,30-32] Agreement does exist however on several features that incorporate clinical, pathologic, and biomechanical injury constructs associated with head injury.[9,10]

Table 1. Current Definitions/Diagnostic Criteria of mTBI.

Reference	Definition
Kelly JP, Nichols JS, Filley CM, Lillehei KO, Rubinstein D, Kleinschmidt-DeMasters BK. Concussion in sports. Guidelines for the prevention of catastrophic outcome. JAMA. 1991;266(20):2867-2869.[33]	Concussion (or mTBI) is a "biomechanically induced neurological injury, resulting in an alteration of mental status, such as a confusion or amnesia, which may or may not involve a loss of consciousness."
McCrory P, Meeuwisse W, Johnston K, et al. Consensus statement on concussion in sport: the 3rd International Conference on Concussion in Sport held in Zurich, November 2008. *J Athl Train*. 2009;44(4):434-448.[10]	A concussion is defined as a "complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces.
"Department of Veterans Affairs and Department of Defense. VA/ DOD clinical practice guideline for management of concussion/mild traumatic brain injury. 2009; http://www.healthquality.va.gov/mtbi/concussion_mtb full_1_0.pdf. Accessed December 18, 2011.[12]	A mTBI is a "traumatically induced structural injury and/or physiological disruption of brain function as a result of an external force that is indicated by new onset or worsening of at least one of the following clinical signs, immediately following the event."
Centers for Disease Control and Prevention. *Heads Up: Brain Injury in Your Practice*. Atlanta, GA: U.S. Department of Health and Human Services; 2007.[26]	Complex pathophysiologic process affecting the brain, induced by traumatic biomechanical forces secondary to direct or indirect forces to the head.
Holm L, Cassidy JD, Carroll LJ, Borg J; Neurotrauma Task Force on Mild Traumatic Brain Injury of the WHO Collaborating Centre. Summary of the WHO Collaborating Centre for Neurotrauma Task Force on Mild Traumatic Brain Injury. *J Rehabil Med.*2005;37(3):137-41.[34]	Closed acute brain injury resulting from mechanical energy to the head from external physical forces with the following: 1. 1 or more of a. confusion or disorientation, b. loss of consciousness for 30 minutes or less, c. posttraumatic amnesia for less than 24 hours, and -other transient neurological abnormalities, such as focal signs, seizures, and intracranial lesions not requiring surgery; 2. Glasgow Coma Scale score of 13 to 15 about 30 minutes after injury; and 3. Exclusion of other physical and mental causes
de Kruijk JR, Leffers P, Meerhoff S, Rutten J, Twijnstra A. Effectiveness of bed rest after mild traumatic brain injury: a randomised trial of no versus six days of bed rest. *J Neurol Neurosurg Psychiatry.* 2002;73(2):167-172.[35]	mTBI is a "blunt blow to the head resulting in post-traumatic amnesia of less than one hour; initial loss of consciousness of less than 15 minutes; a Glasgow coma score of 14 or 15 on presentation to the emergency department; and absence of focal neurological signs."
American Congress on Rehabilitation Medicine. Definition of mild traumatic brain injury. *J Head Trauma Rehabil.* 1993;1993(8):3.[36]	A mTBI is a "traumatically induced physiological disruption of brain function, as manifested by at least one of the following: 1. any period of loss of consciousness; 2. any loss of memory for events immediately before or after the accident;

	3. any alteration in mental state at the time of the accident (eg, feeling dazed, disoriented, or confused); and 4. focal neurological deficit(s) that may or may not be transient; but where the severity of the injury does not exceed the following: a. loss of consciousness of approximately 30 minutes or less b. after 30 minutes, an initial GCS of 13-15; and c. PTA not greater than 24."
Ptito A, Chen JK, Johnston KM. Contributions of functional magnetic resonance imaging (fMRI) to sport concussion evaluation. *Neuro Rehabilitation.* 2007;22(3):217-227.[28]	A concussion is a "temporary fluctuation in consciousness with no long-term effect on cognition."
Ropper AH, Gorson KC. Clinical practice. Concussion. *N Engl J Med.* 2007;356(2):166-172.[6]	A concussion is an "immediate and transient loss of consciousness accompanied by a brief period of amnesia after a blow to the head."
American Academy of Neurology. Practice parameter: the management of concussion in sports (summary statement). Report of the Quality Standards Subcommittee. *Neurology.* 1997;48(3):581-585.[37]	A cerebral concussion is an "altered mental state that may or may not include loss of consciousness."
Congress of Neurological Surgeons. Committee on head injury nomenclature: glossary of head injury. *Clin Neurosurg.* 1966;12:386-394.	A concussion is "a clinical syndrome characterised by the immediate and transient post traumatic impairment of neural function."
Canadian Paediatric Society. Identification and management of children with sport- related concussion. *Paediatr Child Health.* 2006;11(7):420-428.[38]	The Canadian Paediatric Society has also emphasized concussion as an impact-related mild traumatic brain injury (MTBI): "Concussion is defined as a complex pathophysiological process that affects the brain, induced by traumatic biomechanical forces resulting in the rapid onset of short-lived impairment of neurologic function that resolves spontaneously. Concussion may be sustained by a direct blow to the head, face, or neck or by a blow to somewhere else on the body that transmits an impulsive force to the head. Most concussions do not cause a LOC or cause only a transient (ie., lasting seconds) LOC.

Review Process and Literature Search Performed

The review of information was limited to PubMed using the following search parameters "mild traumatic brain injury" AND "assessment". Inclusion criteria were limited to: 1) humans, 2) practice guideline, randomized controlled trial and reviews, clinical trial, meta-analysis, 3) published in the English and published within the last 10 years (as of September 30). Based on the above inclusion criteria 48 articles were identified in the initial search, 40 were selected for review, 24 were included in this review. In situations where an article referred a possible source, the abstract and/or article was located and reviewed at www.pubmed.com.

A second review was conducted using another database, however, the file with search parameters was corrupted when attempting to open. A secondary file-found 32 articles addressing "mild traumatic brain injury" AND “assessment”. These articles were used in this review.

A third search using PubMed using the following search parameters " concussion assessment” was conducted. Inclusion criteria were limited to: 1) humans, 2) clinical trial, randomized controlled trial, case reports, controlled clinical trial, multicenter study, validation studies, 3) English, 4) published in the last 10 years (as of December), and 5) link to free full text. Based on above inclusion criteria 8 articles were identified in the initial search, 3 were selected for review.

A fourth search using PubMed using the following search parameters " concussion assessment tool” was conducted. Inclusion criteria were limited to: 1) humans, 2) clinical trial, randomized controlled trial, case reports, controlled clinical trial, multicenter study, validation studies, 3) English, 4) published in the last 10 years (as of December), and 5) links to full link. Based on above inclusion criteria 7 articles were identified in the initial search, 5 were selected for review.

A total of 63 articles/abstracts were used for this review.

Scientific Foundation

Providers of first aid must first recognize that no two mTBI (ie., concussions in this case) are identical in both the etiology and presentation. The extent of the resulting signs and symptoms from the physical trauma can be very different and difficult to visualize[12,14,36] depending upon the force of the blow to the head, the degree of metabolic, hemodynamic, structural, and electric changes that alter normal cerebral function and the duration of time needed to recover, the number of previous concussions, the time between injuries, and the extent of any other significant trauma present at the time of initial asseement[10,19,39,40] and the willingness of the person (eg., athlete) to be truthful about his/her symptoms.[41] Many concussions may goes unrecognized and are therefore incorrectly managed in a number of instances.[42]

In fact, mTBI can result in a rapid onset of short-lived neurological impairments that resolve spontaneously[22] and therefore may go undetected.[13] The diagnosis of a mTBI should involve the assessment of a range of domains including but not limited to a person’s: 1) clinical symptoms, 2) physical signs, 3) behavior, 4) balance, 5) sleep 6) cognition abilities and 7) physical exertion.[4,9,10,12,21,24-26,34,43,44] with each assessment measure adding additional information related to the status of the injured person by independently evaluating differing aspects of the person’s cerebral[23] and cerebellum functioning.

Neuropsychological/neurocognitive testing is commonly used by health care professionals and provides the greatest amount of objective measures of cognitive function and recovery after a concussive injury.[9,10,21,23,24,41,45,46] Neuropsychological/neurocognitive testing should be age approrpaite.[3,4,24] However, individual variations in scores based on numerous factors (eg., SAT score, gender, number of previous concussions) must be considered and requires careful interpretation of results after a concussion, requiring baseline testing (scores) for each person.[23,41,45]

Referrals for conventional structural neuroimaging such as CT scans[30] and MRIs are also options that can aid in the diagnosis and/or management of mTBI (concussion)[9,10] but are typically used only in cases involving LOC, severe memory deficits, abnormal physical or neurologic findings, increasing or intensified symptoms[9] and/or a person's age.[5] A normal CT scan result can be used to confirm the presence of a mTBI.[3] It is worth nothing as well that the clinical features of mTBI and it's associated sequela (post-concussive syndrome) are not unique to mTBI patients and can be seen in other conditions/pathologies[47] and can compromise any type of baseline testing.[48]

Review Articles

Bell et al[11] examined the effects of telephone counseling on reducing post-traumatic symptoms after sustaining a mTBI. Study inclusion criteria included: 1) admission to emergency department (ED) with 48 hours of injury, 2) likely circumstances for mTBI based on MOI, 3) ED GCS of 130-15, 4) documented, self-reported, or witnessed loss of consciousness of < 30 minutes, a period of impairment (eg., confusion) of < 24 hours or post-traumatic amnesia (PTA) of < 24 hour. 366 of 389 eligible subjects aged 16 years or older with mTBI were enrolled in the ED, with an 85% follow-up completion rate. Post-traumatic amnesia between 1-30 minutes was seen in 40% of all subjects, while PTA > 30 minutes was seen in 32% of subjects. Retrograde amnesia between 1-5 minutes was reported in 34% of subjects, while retrograde amnesia of > 5 minutes was reported in 14% of subjects. Five telephone calls were completed, individualized for patient concerns and scripted to address education, reassurance and reactivation. For the outcome assessment a battery of measures were used to assess Post-traumatic systems and general health status to determine treatment effect, including the use of *The Head Injury Symptoms Checklist*. *The Head Injury Symptoms Checklist* consists of 16 symptoms associated with mTBI, including: 1) headache, 2) fatigue, 3) dizziness, 4) blurred vision, 5) difficulty concentrating, 6) bothered by noise and light, 7) irritability, 8) lose temper easily, 9) memory difficulty, 10) anxiety, 11) sleep trouble, 12) balance, 13) sexual difficulties and 14) coordination. Two composite scores were analyzed, one relating to new or worse post-traumatic symptoms that developed and the number of functional areas impacted by the symptoms as reported on *The Head Injury Symptoms Checklist*. The telephone-counseling group had a significantly better outcome for symptoms (6.6 difference in adjusted mean symptom score, 95% confidence interval (CI) 1.2 to 12.0), but no difference in general health outcome (1.5 difference in adjusted mean functional score, 95% CI 2.2 to 5.2). The authors concluded that telephone counseling, focusing on symptom management, was successful in reducing chronic symptoms after suffering an mTBI.

Brenner, Vanderploeg and Terrio[49] discussed the challenges related to assessing and managing military personnel diagnosed with posttraumatic stress disorder (PTSD) and/or history of mTBI. Signals of mTBI can range from immediate confusion and disorientation to unconsciousness, however symptoms such as headache, dizziness, memory difficulty/problems, and irritability does not mean person has sustained a TBI. As these symptoms can be related to the TBI, but may also be associated with other factors and conditions.[12,49] They cite that according to the *Departments of Defense and Veterans Affairs Consensus*[12] (referenced in Brenner), the definition of a TBI[12] is a traumatically induced structural injury and/or physiological disruption of brain function as a result of an external force that is indicated by new onset or worsening of at least one of the following clinical signs, immediately following the event: 1) any period of loss of or a decreased level of consciousness, 2) any loss of memory for events immediately before or after the injury (posttraumatic amnesia), 3) any alteration in mental state at the time of the injury (confusion, disorientation, slowed thinking, etc) (alteration of consciousness/ mental state), 4) neurological deficits (weakness, balance disturbance, praxis, paresis/plegia, sensory loss, aphasia, etc) that may or may not be transient and 5) intracranial lesion. When trying to differentiate between acute and severe cases of mTBI, the results of neuroimaging may be useful. However, they report the "gold standard" for determining prior TBI is the patient's self-reported signals, facilitated by a structured or in-depth clinical interview.

Brenner, Vanderploeg and Terrio[49] further suggest that a TBI is a historical injurious event, while post-concussive symptoms (PCS) reflects a set of physical/somatic, cognitive, and emotional symptoms which began or worsened immediately after a TBI event. These signals include a spectrum of symptoms: headaches, dizziness, fatigue, disordered sleep, concentration problems, memory deficits, slowed thinking, depression, anxiety, and irritability. In fact, fatigue is believed to be an important symptoms that influences a patient's mental health and eventual participation in social, leisure and work activities.[50] The immediate onset and presence of these PCS symptoms in the minutes and days after the TBI event increases the likelihood that a TBI occurred.[49] However, their presence does not mean that a TBI occurred if the immediate event did not result in either a structural lesion to the brain or an immediate physiological disruption of brain functioning (eg., unconsciousness, memory deficits, or confused, and/or disorientation).

Broomhall et al[51] compared the concept of acute stress disorder (ASD) and posttraumatic stress disorder symptom presentation of injury survivors with and without mTBI in Australia. Of significance in this study was the criteria used to classify mTBI. mTBI status was determined from information obtained from the emergency medical responders (ambulance) hospital records and the patient's ongoing assessment. To be classified as having sustained a mTBI patients needed to meet at least one of the following criteria (as defined by the American Congress of Rehabilitation Guidliness-1993: 1) loss of consciousness of approximately 30 minutes or less, GCA of 13-15 after 30 minutes, or PTA not greater than 24 hours and had physical injury that required an admission of at least 24 hours to the trauma service. One thousand one hundred sixteen participants between the ages of 17 to 65 years (mean age: 38.97 years, SD: 14.23) were assessed in the acute hospital after a traumatic injury and 475 people met the criteria for mTBI. Results showed a trend toward higher levels of ASD in the MTBI group compared with the non-MTBI group. Those with a MTBI and ASD had longer hospital admissions and higher levels of distress associated with their symptoms.

Cohen et al[52] reviewed the most recent evidence and expert recommendations regarding initial diagnosis and management of sports-related concussions (mTBI) in children. This included a review of the symptoms, classification of concussion based on symptoms, pathophysiology, acute concussion evaluation, initial management, imagining, and return to play (RTP) criteria. Symptoms of concussion can include one or more of the following clinical domains: 1) physical, 2) cognitive, 3) emotional and/or 4) sleeping behaviors. Neuropsychological impairments are also often seen within the first 24 hours after sustaining trauma and include issues with memory acquisition and retrieval, cognitive processing and reaction time.

Gioia, Collins and Isquith[53] presents evidence of appropriate psychometric properties for the

Acute Concussion Evaluation (ACE) in primary care and emergency medicine settings based on the recent literature. The instrument is administered as part of the clinical interview of a patient directly or via a knowledgeable caretaker, spouse, or friend—in person as part of a clinical examination or over the telephone as an initial triage. Areas of inquiry include: "(1) specific characteristics of the injury including details of the direct or indirect blow to the head, retrograde and anterograde amnesia and loss of consciousness18,19,26; (2) a full array of 22 symptoms and 5 signs associated with mTBI,27 referred to as the ACE symptom checklist; and (3) risk factors that might predict a prolonged recovery such as a history of previous mTBI,28–30 headaches,31,32 learning disabilities,33 or attention-deficit/hyperactivity disorder, and anxiety or depression.34–36.".[p.232]

The ACE symptom checklist can be completed via telephone or live interview with the patient and/or parent/caretaker if the patient is a child.[53] It is 22-item dichotomous (presence/absence) inventory with the symptoms organized into 4 symptom areas: 1) physical, 2) cognitive, 3) emotional and 4) sleep. Because symptoms can be present prior to the injury (eg., inattention and headaches), patients are asked to indicate whether there is evidence of any changes from usual symptom presentation. A total symptom checklist score is calculated by summing the number of symptoms that are reported as present, and subtotals can be calculated for each of the 4 symptom areas. The total score can range from 0 (*no symptoms*) to 22 (*maximum number of symptoms*).

The time needed to complete the ACE symptom checklist in 232 participants was a mean time of 5.5 minutes (SD = 2.1).[53] According to Gioia, Collins and Isquith[53] the frequency of symptoms is consistent with the literature, indicating the highest frequency symptoms to be **headache** (74%), **fatigue** (60%), and **feeling slowed down** (48%) (see Table 2). Furthermore, the ACE symptom checklist's predictive validity, the instrument's ability to detect symptoms or diagnoses, such as those based on clinic-based symptom assessment. The checklist is correlated significantly with the parent- and child- *Post-Concussion Symptom Inventory* (PCSI), a 7-point graded symptom rating scores at the first clinic appointment (6-day median interval) as follows: parent post-concussion ratings (n = 314; ρ = 0.679, P < .001); patient (age = 8–12 years) post-concussion ratings (n = 63; ρ = 0.421, P = .001); and patient (age = 13–18 years) post-concussion ratings (n = 236; ρ = 0.587, P < .001). Overall, the ACE symptom checklist appears to exhibits reasonably strong psychometric properties as an initial assessment tool for mTBI.

While the ACE symptom checklist demonstrated reasonably strong psychometric properties including construct, predictive, and convergent validity and strong internal item consistency in children and young adults being seen in a post-concussion clinic following head trauma, a survey of ED nurses found that the physical (ie., headache, nausea, vomiting, problems with balance, vision or dizziness, fatigue, sensitivity to light or noise, numbness or tingling) and cognitive symptoms of mTBI were assessed and documented more than emotional or sleep symptoms and that some cognitive and physical symptoms were rarely assessed or even documented.[54] The majority (80%) of respondents also indicated that they frequently or always assessed and documented on the physical indicators, with the exception of fatigue, balance, and sensitivity to light and noise and that they frequently or always assessed and documented cognitive symptoms with the exception of anterograde amnesia, "mentally foggy," "feeling slowed down, ""difficulty concentrating," and "remembering."[54]

de Kruijk et al[35] examined the effectiveness of no bed rest versus six days of bed after sustaining mTBI in 107 patient presenting to the ED. Eligibility for the study included: 1) 15 years of age or older and 2) presentation to the emergency department within six hours after the trauma where the duration of PTA and presence of transient loss of consciousness were estimated from patient or witness interviews. A mTBI was defined as a blunt blow to the head resulting in: 1) PTA < one hour, 2) initial loss of consciousness < 15 minutes, 3) GCS of 14 or 15 on presentation to the ED and 4) absence of focal neurological signs. One group was advised not to take bed rest (NO)

Table 2. Acute Concussion Evaluation Symptom Report Frequencies.[53]

Symptom	Reporting Symptom %
Head	74
Fatigue	60
Feeling slowed down	48
Difficulty concentrating	43
Difficulty remembering	42
Dizziness	41
Feeling drowsy	41
Feeling mentally foggy	40
Sleeping more than usual	40
Irritability	35
More emotional	34
Sensitivity to light	28
Sadness	27
Sensitivity to noise	27
Nausea	25
Balance	22
Trouble falling asleep	21
Visual problems	20
Nervousness	18
Sleeping less than usual	11
Numbness and tingling	9
Vomiting	4.5

and the other to take full bed rest (FULL) for six days after the trauma. The primary outcome measures were severity of post-traumatic complaints on a visual analogue scale (VAS) and physical and mental health on the medical outcomes study 36 item *Short Form Health Survey* (SF-36) at two weeks and three and six months after the trauma. No clear effect of bed rest on outcome after mTBI was noted. Patients advised to take full bed rest reported significantly less dizziness than patients who were advised not to take bed rest. However, patient compliance to take bed rest is often difficult and requires the use of more oral analgesics. Bed rest is not recommended to improve a patient's outcome after sustaining a mTBI.

Kennedy et al[8] suggests that a set of post concussive symptoms occurs immediately after sustaining trauma to the brain and may include the following: 1) cognitive deficits in memory, attention, and concentration, 2) physical or somatic complaints of fatigue, disordered sleep, dizziness, and headache and 3) affective complaints of irritability, anxiety, and depression.

Levin et al[30] conducted a prospective longitudinal study of TBI associated with mild impairment of consciousness in 80 children (5–15 years of age), including neuropsychological examinations over the course of 12 months. Inclusion criteria in this study included: 1) GCS score of 13–15 on examination in the ED, 2) history of an altered or a loss of consciousness not > 30 minutes, 4) closed head trauma as a mechanism of injury and 5) CT scanning data obtained within 24 hours after injury. No loss of consciousness occurred in 54 and 62% in those diagnosed with mTBI and CT findings that were normal or limited to a linear skull fracture or mTBI complicated by neuropathology visible on CT, respectively. A GCS of 13 was identified in 6.25% of the cases for both groups. Significant interactions confirmed that the pattern of recovery over 12 months after injury differed depending on the intracranial pathology, presence and severity of injuries to body regions other than the head, pre-injury attention-deficit hyperactivity disorder (ADHD), and socioeconomic status. Children in the mTBI complicated by neuropathology on a CT scan had significantly poorer episodic memory, slower cognitive processing, diminished recovery in managing cognitive interference, and poorer performance in calculating and reading than patients in the mTBI group. Among the patients with mild or no extracranial injury, visual motor speed was slower in those in the mTBI complicated by neuropathology on a CT scan group; and among patients without pre-injury ADHD, working memory was worse in those in the mTBI complicated by neuropathology on a CT scan group.

According to Maruta et al[18] acute TBI can lead to axonal degeneration and neuronal cell death (secondary injury) after the initial biomechanical event has occurred resulting from 1) blunt closed- head injury, 2) rotational acceleration (linear or angular acceleration) and 3) blast-related injuries (ie., primary = direct effects of the over- and under-pressure wave, secondary = effects from projectiles, tertiary = effects of wind, fragmentation of buildings and vehicles, and 4) quaternary = burns, asphyxia, and exposure to toxic). This neuro-metabolic cascade and neuro-chemical responses contribute to neurologic, psychiatric, and functional disability and the post-injury neurologic symptoms viewed in mTBI patients.[22]

Traumatic brain injury is graded from mild to severe, based on the acute effects of the injury on an individual's level of arousal and duration of amnesia with functional deficits occurring due to micro-structural changes in the frontal white matter of the brain.[18] The authors[18] report that the cognitive symptoms occurring as a result of diffusional axonal injury and focal frontal lobe damage include deficits associated with a person's concentration, memory, and high-level executive functions (ie., decision-making skills). Diagnosis of mTBI is dependent upon information obtained from patient interviews and self-reports about the acute characteristics of injury making the information more ambiguous during the acute phase particularly because diagnostic testing such as CT scanning and MRI[10] lacks sensitivity to detect concussions. It is suggested that these diagnostic tools are used to furnish knowledge of intracranial anatomical abnormalities rather than neuronal activation.[28] As a result, current definitions of mTBI (concussion) do not include parameters of physical or functional imaging/testing.[17,28]

Moderate or severe TBI normally more easily diagnosed due to lower GCS scores and/ or abnormality in CT images.[18] A more conclusive diagnoses of mTBI may not occur until a patient begins complaining of PCS or experiences difficulties in their social interactions or in work (ie., job) or school performance. PCS in this article was identified via the presentation of changes in a

Table 3. Cognitive, Somatic, Affective Response in Patients with PCS[47]

Cognitive	Somatic	Affective
Memory difficulties	Headache	Irritability
Decreased concentration	Dizziness	Depression
Decreased processing speed	Fatigue	Anxiety
	Nausea	
	Sleep disturbances	
	Blurred vision	
	Tinnitus	
	Hypersensitivity to light or noise	

patient's cognitive, somatic, affective response (Table 3). Currently various methods exist to evaluate mTBI, with neuropsychological testing considered to be one of the most important assessment tools during both the acute and chronic phases of PCS.

A review of literature by Petchprapai and Winkelman[22] found the Glasgow Coma Scale (GCS) to be a commonly used tool to clinically categorize brain injury. However, the authors note that the GCS fails to provide assessment of the person's symptoms (ie., headache, fogginess) or cognitive deficits.[4] According to Petchprapai and Winkelman[22] a GCS score of 13–15 is the earliest determinants of mTBI. They further cite that the GCS is internationally accepted as a valid and reliable approach to identifying the severity of brain trauma. However, of the 44 investigation examined, 31 used a GCS score of 13–15 to define mTBI. These studies though were inconsistent in their use of the GCS score with large variability in the use of GCS[3] throughout the care process when determining treatment groups.

In addition the duration of loss of consciousness (LOC) and PTA have also been used to determine the presence of mTBI. They define loss of consciousness as an "unawareness or inability to respond to the environment."[22] In this case, LOC does not include any transient confusion or altered mental status (eg, dazed, disoriented, or confused). They define PTA as "any loss of memory for events immediately before or after the accident until the person returns to continuous memory (Swann & Teasdale, 1999)."[22] Petchprapai and Winkelman[22] noted that of the 44 investigations reviewed, 24 included LOC as a determinant for mTBI. The challenge they note is that 18 of these investigations adopted the American Congress of Rehabilitation Medicine's criteria of 30 minutes for mTBI, whereas the remaining investigations used the 1) *Diagnostic and Statistical Manual of Mental Disorders* (*DSM-IV)* cut-score of 5 minutes, 2)

LOC duration for up to 60 minutes, and 3) in some cases any period of LOC. Post-traumatic amnesia faced the same challenges with 27/44 investigations using PTA as a determinant of mTBI. Of these 27, 17 studies used American Congress of Rehabilitation Medicine's cut-score of 24 hours or less, 2 used the *DSM*'s criterion of 12 hours or less, 6 set the duration of PTA at less than 60 minutes and 2 investigations had multiple values for the duration of PTA.[22]

Sheedy et al[7] examined the utility of a brief ED bedside screen for the prediction of PCS at 3 months following a mTBI. To meet the inclusion criteria subjects had to meet the criteria for a mTBI as defined by the American Congress of Rehabilitation Medicine.[36] Subjects were exclude if the ED GCS was < 13 or acute injuries were noted on CT scan, or balance testing could not be completed. One hundred patients with MTBI (78% men; mean age = 33.6 years); 2 control groups (each n = 100), a "minor non-head injury" group (77% men; mean age = 32.2 years) and an "uninjured ED visitor" group (78% men; mean age = 33.6 years) were utilized in this study. Outcomes measures included: 1) neuropsychological functioning (immediate and delayed verbal recall, speed of sentence comprehension, and DSST subtest of the *Wechlser Adult Intelligence Scale-Revised*), 2) acute pain (VAS) and 3) postural stability (*Balance Error Scoring System* [BESS]) were collected in the ED. The *Rivermead Post-Concussion Symptoms Questionnaire* was used to assess the number and severity of the symptoms at 3 month post-injury through a telephone interview. On initial measurement, mTBI subjects recalled fewer delayed memory items, judged fewer speed and capacity of language processing test sentences and completed fewer DSST items compared to the control groups. BESS testing revealed a significant difference in balance testing with 11.27 errors versus 5.4 errors for the mTBI and control groups respectively. Reported acute symptoms included: 1) **headache**, 2) jaw pain, 3) **dizziness** and 4) **visual disturbances**. A regression formula using 3 easily obtainable measures obtained during acute stage of injury-immediate and delayed memory for 5 words and a visual analog scale score of acute headache-provided 80% sensitivity and 76% specificity for the prediction of clinically significant symptoms at 3 months post-injury.

Covassin, Stearne and Elbin[55] examined the relationship between concussion history and post-concussion neurocognitive performance and symptoms in collegiate athletes. Fifty-seven athletes were assessed for using the Immediate Post-Concussion Assessment Cognitive Testing (ImPACT) (version 2.0; NeuroHealth System, LLC, Pittsburgh, PA) computer software program for neurocognitive function and concussion symptoms. For those athletes with no history of concussion trauma the mean baseline concussion symptom score was 10.38±9.49 compared to 22.08±17.8 at day 1 and 6.40±6.8 at day 5-post injury. For those with a history of ≥ 2 concussions, the baseline concussion symptom score was 5.9±7.67 compared to 25.91±21.05 at day 1 and 5.30±7.0 at day 5-post injury. Fatigue was the most commonly report concussion symptoms (22 were identified) followed by trouble following asleep and drowsiness. No vomiting or balance issues were identified at baseline. One day post-injury, feeling slowed down, downiness and headache topped the list of post-concussive symptoms.

Andersson, Bedics and Falkmer[50] examined the long-term consequences of mTBI based on a 10-year follow-up of patients from a previously-published randomized controlled study of mTBI to describe the changes over time in patients relative to the extent of persisting PCS, life satisfaction, perceived health, activities of daily living (ADL), changes in life roles and sick leave using s self-report questionnaire. The control group 56 persons, while the intervention group comprised 142 persons who in the original study[56] meet the definition of mTBI as defined by the American Congress of Rehabilitation Medicine (Mild Traumatic Brain Injury Committee 1993).[36] Randomization in the original study included two groups, balanced according to the 10 variables (ie., age, sex, loss of consciousness, amnesia, acute alcohol intoxication, focal neurology, dizziness, headache, vomiting, and nausea). No statistical differences were found between the intervention (ie., received rehabilitation care) and control groups. Patients who experienced few PCS two to eight weeks after the injury and declined rehabilitation recovered and returned to their pre-injury status. Patients who suffered several PCS and accepted rehabilitation did not recover after one year. A ten-year follow-up again demonstrated that individual intervention by a qualified rehabilitation team did not appear to impact on the long-term outcome for persons with symptoms related to mTBI. The authors suggest that the person's status after approximately 3 weeks is indicative of the status after 10 years.

Onate, Beck and Van Lunen[57] examined whether the testing environment affects *Balance Error Scoring System* (BESS) scores in healthy collegiate baseball players. The BESS was developed as a standardized, objective assessment tool for the clinical sideline assessment of postural control during sports participation.[58] Twenty-one players performed the BESS test in 2-environments, 1) controlled locker room and 2) uncontrolled sideline, in 2-testing sessions 1 week apart during the baseball pre-season. The BESS scores were evaluated for each of the 6 conditions (double-leg, single-leg, and tandem stances on an AstroTurf (Dalton, GA) carpeted, rubberized floor mat (firm) and again on a 46 × 43 × 13-cm^3 block of medium-density Airex pad) and total score across the testing sessions. Significant group mean differences were found between testing environments for single-leg foam stance (P = .001), with higher scores reported for the uncontrolled sideline environment (7.33 +/- 2.11 errors) compared with the controlled clinical environment (5.19 +/- 2.16 errors). Medium to large effect sizes (0.53 to 1.03) were also found for single-leg foam, tandem foam, and total BESS scores, with relative increases (worse scores) of 30% to 44% in the sideline environment compared with the clinical environment. The subjects' BESS performance was impaired when subjects were tested in a sideline environment compared with a clinical environment. The authors suggest that baseline testing for postural control using the BESS should be conducted in the setting or environment in which testing after injury will most likely be conducted.

Hettich et al[32] reported on the use of ImPACT testing to assist with return to duty determination of special operations soldiers who sustained a mTBI. Two U.S. soldiers were ejected from a vehicle after swerving violently. Both casualties were confused, but responded appropriately to questions with only minor complaints, and no life-threatening injuries. They were immediately evacuated for further evaluation that included a detailed neurological exam, a trauma panel of labs, x-rays, and a head CT. All exams and tests were unremarkable and both soldiers were discharged later that day back to their unit.

Within hours, both soldiers began experiencing symptoms of PCS including: 1) headache, 2) fatigue, 3) "feeling foggy" and 4) balance difficulties. Baseline ImPACT data was on file and on observation of the solider symptoms, post-injury ImPACT testing was administered. This testing revealed deficits in several areas and both solider were clinically managed based on the tests findings. Subsequent ImPACT testing at 48 hours after the initial post-injury test confirmed both solider were demonstrating improvement in their deficient areas. One soldier had a complete resolution of symptoms and his ImPACT results returned to baseline within a couple of days, while the other took almost a week to see a return to baseline across all cognitive domains before being allowed to return to duty.[32]

Self-reported symptoms (SRS) scales comprise one aspect of assessment of sport-related concussions, however, athletes may present with concussion-related symptoms at baseline making it difficult to interpret the data correctly. Piland et al[48] evaluated the influence of a history of concussion, sex, acute fatigue, physical illness, and orthopedic injury on baseline responses to 2 summative symptom scales to determine the psychometric properties of all responses. 1,065 subjects (mean age = 19.81 ± 1.53 years) participated in the cross-sectional analysis. Subjects completed the 9-item *Head Injury Scale* (HIS), a summative 7-point Likert-type scale instrument designed to measure the overall duration (length of symptom experienced over a 24-hour period) of concussion-related symptoms The 9-item HIS in a previous validation study exhibited strong evidence of factorial validity.[59] "Headache, nausea, and difficulty in balancing tapped into the somatic symptoms group. Fatigue, trouble falling asleep, and drowsiness tapped into the neuropsychological group. Feeling "slowed down," feeling "in a fog," and difficulty concentrating tapped into the cognitive group of symptoms."[p.110] In this study, Piland et al[59] suggest that the 9 symptoms in the final model represent excellent descriptors of a concussion. In the current study, Piland et al[48] administered the 9-item HIS in conjunction with the *Severity Scale and Brief Health Questionnaire*. The authors found that non-concussed athletes reported a constellation of self-reported symptoms related to concussion, including **fatigue** and **drowsiness** which topped the list and which "are consistent with previously reported results in non-concussed athletes and studies involving healthy non-athlete groups.[9,11,22, 23]"[48 p. 276]. The authors further suggest that "baseline composite scores from measures designed to characterize SRS were (1) inflated by a history of concussion, fatigue, physical illness, and orthopedic injury; (2) consistent internally and across time; and (3) factorially valid when confounding clinical variables were removed."[48 p. 276]

Sullivan et al[60] examined the effect of different levels of exercise intensity on a timed *Finger-to-Nose (FTN) Task*. The timed (finger-to-nose (FTN) task is a measure of upper limb coordination included in the *Sport Concussion Assessment Tool* (SCAT2) which "has been shown to be robust in different testing situations[3] and has well- established reliability[3–5] and normative data.[6 7]".[60 p. 46] Ninety asymptomatic participants completed the FTN under three different levels of exercise intensity; 1) no exercise/rest (NE), 2) moderate intensity exercise (ME) and 3) high-intensity exercise (HE). Results of the study suggested that performance on the FTN task is enhanced by a short period of high intensity exercise, and this effect persists for at least 15 min suggesting that any baseline test scores must cautiously interpreted when assessing the FTN in person who has just completed high intensity exercise within 15 minutes of injury as the post-injury results may not be an accurate representation of the neurological status of the person.

Makdissi et al[46] examined whether or not concussed players who returned to play using an individual clinical management strategy were at risk of impaired performance or increased risk of injury or concussion. Subjects were recruited into the study after sustaining a concussive injury with a subset of players undergoing brief screening cognitive tests at baseline and after their concussion. Of the 138 concussive injuries assessed, 127 players returned to play without missing a game (92%). The remainder of concussed subjects returned to play after missing only a single game (8%). Overall, there was no significant decline in disposal rates in concussed players on return to competition. In the subset of subjects completing the cognitive screening tests, all had returned to their individual baseline performance before being returned to play. The authors concluded that RTP decisions based should be based on individual clinical assessment of recovery by trained health care professionals can allows safe and appropriate return to sport following a concussive injury.

Kennedy, Lumpkin and Grissom[61]surveyed health care providers about how they would evaluate and treat mild traumatic brain injury (mTBI) in adults using two vignettes describing mTBI cases to staff in the ED and in a primary care clinic. Emergency department personnel reported the need to solicit complaints relative to **visual** changes, **nauseas/vomiting** and **headache** 64, 64, and 68% of the time respectively. Primary care clinical focused on **visual** changes, **neck pain**, and **nausea/vomiting** and **mental status** changes 69, 63, and 50% of the time respectively. Recommended evaluation strategies included a neurological exam (69%), eye (59%) and head palpation (32%) by the ED personnel and neurological exam (69%), eye (69%) and motor strength in the primary clinical care practices. Overall, 95% of the treating personnel (n=38) would recommend order some form of diagnostic imagining and 76% ad 21% would require a follow-up or would recommend a follow-up visit. More ED personnel than primary care clinic providers would make referrals to different specialties, whereas more primary care clinic providers would schedule a follow-up appointment. Neither group of providers mentioned assessing common PCS of fatigue, emotional changes, and problems sleeping. Comparing findings to current literature suggest that added focus on emotional, cognitive and psychosocial factors, and education of the patient and family could improve early identification of mild TBI patients at risk for poor recovery

Naunheim, Materom, and Fucetola[62] assessed the validity of the *Standardized Assessment of Concussion* (SAC) instrument in characterizing the early evolution of concussion-related symptoms and mental status changes in patients in the ED setting and to compare it to the *Conner's Continuous Performance Test 2nd Edition* (CPT-II). Sixty-two persons with concussion as defined by a GCS of 15 and a negative head CT scan result was examined on arrival in the ED and 3 and 6 hours later. The SAC and CPT-II scores improved significantly over the time course in the ED. Patient symptoms did not correlate with improvements instrument scores, with many subjects complaining of headache or nausea after their scores improved. The average initial score on the SAC was 21 +/- 5.4/30. The authors concluded that the SAC instrument appears sensitive to the acute changes following concussion and may be used as a tool to assess mental status changes after a concussion, when Glasgow Coma Scale and radiologic findings are normal.

Brown, Guskiewicz, and Bleiberg[45] investigated factors effecting baseline neuropsychological test scores and established preliminary reference data for non-symptomatic collegiate athletes. 327 National Collegiate Athletic Association Division I athletes from 12 men's and women's sports were baseline tested before their first competitive season using the used the *Automated Neuropsychological Assessment Metrics* (Army Medical Research and Materiel Command, Ft Detrick, MD) and measured throughput scores (the number of correct responses per minute).. Subsets measurements included 2 simple reaction time (SRT) tests, math processing (MTH), Sternberg memory search (ST6), matching to sample pairs (MSP), procedural reaction time

(PRO), code digit substitution (CDS), and the *Stanford Sleep Scale* Likert-type score. The authors concluded that performance on computerized neuropsychological tests may be affected by a number of factors, including but not limited to: 1) sex, 2) SAT scores, 3) alertness at the time of testing and the 4) athlete's sport. To avoid making clinical misinterpretations, clinicians should acknowledge that individual baselines vary over time and should account for this variation. Therefore, a first aid provider without baseline testing or baseline testing not performed during optimal times and setting should not make decisions about the management of the mTBI (concussion) with out all of the necessary or accurate information.

Makdissi et al[41] measured cognitive impairment after concussion in a case series of concussed Australian Rules footballers, using both computerized and paper and pencil neuropsychological tests. Testing included baseline measures on the *Digit Symbol Substitution Test* (DSST), *Trail Making Test-Part B* (TMT), and a *Simple Reaction Time* (SRT) test from a computerized Cognitive Test Battery (CogState) in 240 footballers. Tests were repeated in players who had sustained a concussive injury. A group of seven matched non-injured players were recruited as control. Only 6 players were concussed during the first nine weeks of the football season. Data for these players and seven matched non- injured controls are reported here. A concussion was defined as "…a clinical syndrome characterized by the immediate and transient post traumatic impairment of neural function" with the clinical diagnosis made by the medical practitioner of each club. Of the six players concussed in the first nine weeks of the season, headache was the most commonly reported symptom (5/6 players). Four players reported that the **headache** began up to six hours after the sustaining the trauma. For 3 players, **headaches** were the most persistent symptom, lasting up to four days. Other reported symptoms included: 1) **fatigue/ lethargy** (longest lasting symptom), 2) **dizziness** (4/6), 3) **confusion** (4/6), 4) **nausea** (2/6) and 5) **blurred vision** (1/6). In all players, subjective symptoms had resolved within four days of injury (range one hour to four days). Only 1 player suffered a **loss of consciousness**, lasting less than one minute. At follow up, DSST and TMT scores did not significantly differ from baseline scores in both control and concussed groups. However, the *Simple Reaction Time* data showed an increase in response variability and latency after concussion in the injured athletes. This was in contrast with a decrease in response variability and no change in latency on follow up of the control players ($p<0.02$). However, 2 players were symptomatic at the time of follow up testing and recorded the largest and second largest increase in response variability from baseline to follow up. The authors concluded that computerized neuropsychological tests may be particularly sensitive to the cognitive consequences of sports related concussion, and also that conventional testing does not share this sensitivity in mildly concussed athletes. They also point out that an increased variability in response time may be an important cognitive deficit after concussion and requires careful interoperation by a qualified medical professional.

Grubenhoff et al[4] evaluated the performance of the SAC among pediatric patients with and without head injury in a pediatric ED. Children 6 to 18 years of age who presented to an ED with blunt head injury (case-patients) or minor extremity injury (controls) participated in the study. Three hundred forty-eight children were enrolled in the study. Inclusion in the case group required a patient to have suffered blunt head trauma in the previous 24 hours and present with an initial GCS of 13. Case-patients were categorized as those with and without unambiguous evidence of AMS, which was defined as 1) any history of LOC, 2) any history of posttraumatic amnesia or 3) a GCS of 14. Control-patients suffered minor extremity trauma (contusions, sprains, strains, minor non-displaced fractures) without concomitant head injury. SAC and graded-symptom-checklist scores were administer and compared. The graded symptom checklist in this study consisted of 15 symptoms (see Table 4) on a 3-point scale (none, mild, moderate, and severe). The American Academy of Neurology concussion grades (1-3), presence of loss of consciousness and posttraumatic amnesia were also compared with SAC and graded-symptom-checklist scores among case-patients. SAC scores trended lower (greater cognitive deficits) for

Table 4. Modified Graded-Symptom-Checklist Based on Age.

Symptoms
Headache
Nausea
Vomiting
Dizziness
Poor balance
Blurred/Double Vision
Sensitivity to light
Sensitivity to noise
Tinnitus
Poor concentration
Memory deficits
Not feeling “sharp”
Fatigue/sluggish
Sadness/depression
Irritability

case-patients compared with controls but did not reach significance. Graded-symptom-checklist scores were significantly higher among case-patients. Presence of altered mental status magnified this effect. There was no correlation between SAC scores and other indicators of mTBI. The authors concluded that the graded symptom checklist reliably identified mTBl symptoms for all children aged 6 years and that patients with AMS at the time of injury manifest an increased number and severity of symptoms.

Rathlev et al[5] examined the presentations and prevalence of head injury among elder victims of blunt trauma and estimated the prevalence of occult injuries associated with a normal level of consciousness, absence of neurologic deficit, and no evidence of significant skull fracture. A total of 1,934 elder patients were identified among the 13,326 subjects in National Emergency X-Radiography Utilization Study (NEXUS) II head injury cohort (14.5%). In this study significant intracranial injury was defined as an injury that typically requires procedural intervention or is associated with persistent neurologic impairment or long-term disability. Significant intracranial injury was identified in 178 elder patients (9.2%; 95% confidence interval = 8.0% to 10.6%) as compared with 697 individuals among 11,392 younger patients (6.1%; 95% confidence interval = 5.7% to 6.6%). **Focal neurologic deficits**, **loss of consciousness**, **abnormal GCS** and **altered**

mental status were present in 55.8%, 54.1%, 51.7% and 51.7% of elder patients with injury respectively. These finding were consist among the younger populations examined in this study that also found that neurologic deficits, loss of consciousness, abnormal GCS and altered mental status were the most common clinical finding among patients with Intracranial Injury The prevalence of certain injuries among elder and younger patients, respectively, included the following: 1) subdural hematoma, 4.4% and 2.4%; 2) contusion, 4.0% and 3.2%; 3) hematoma, 0.5% and 1.0%; and 4) depressed skull fracture, 0.2% and 0.5%. Forty-two elder patients (2.2%) had an occult injury, compared with only 92 younger patients (0.8%). The authors concluded that elder patients with head trauma are at higher risk of developing a significant intracranial injury, including subdural and epidural hematoma and is a factor that must be considered in developing policies and procedures for selective cranial imaging.

Dematteo et al[3] examined the clinical correlates of a concussion diagnosis to identify the factors that lead to the use of this term in a regional pediatric center. Medical data was prospectively collected from 434 children with traumatic brain injury who were admitted to a Canadian children's hospital. Three hundred forty-one children and adolescents, aged 0 (birth trauma) to 18 years, were diagnosed with a TBI. Among them, 300 had a recorded GCS score and 73% were categorized as having mild injuries on the basis of their GCS scores on admission to the ED. The authors reported that the concussion label was significantly more likely to be applied to children with mild Glasgow Coma Scale scores of 13 to 15 (P = .03), but the label may also be applied to more- severe injuries as well. The concussion label was strongly predictive of earlier hospital discharge and earlier return to school. A diagnosis of a concussion was significantly more likely when CT results were normal and the child had a loss consciousness, the next important predictor of whether the child would receive the label if the CT results were normal. This study would suggest that in order to correctly label a child as having mTBI a CT scan should be ordered.

Lau et al[21] attempted to identify specific symptoms and neuropsychological test patterns that may serve as prognostic indicators of recovery in concussed high school football players. Utilizing the ImPACT neurocognitive testing and self-reported symptom data concussed and control participants were evaluated at baseline and within an average of 2.23 days of injury evaluated participants. Both neurocognitive test results and self-reported symptom data had prognostic value in determining time to clinical recovery. There was a self-reported cognitive decline, Immediate Postconcussion Assessment and Cognitive Testing reaction time, and migraine headache symptoms were associated with longer time to clinical recovery. The authors concluded that specific symptom clusters and neurocognitive test results might have predictive value when classifying and managing concussions.

Valovich et al[24] used a quasi-experimental; repeated-measures design to evaluate the test-retest reliability of the concussion assessments tools in young athletes (M=24, F=26).
They also examined the reliable change indices (used to asses changes in cognitive function after concussion) of concussion assessments in athletes and the relationship between the *Standardized Assessment of Concussion* (SAC) and neuropsychological assessments in young athletes. All subjects underwent baseline testing which included: 1) SAC, 2) BESS and 3) a neuropsychological test battery (ie*., Buschke Selective Reminding Test*, *Trail Making Test B*, and *Coding and Symbol Search subsets of the Wechsler Intelligence Scale for Children*) designed for

children between the ages of 9 and 14 years. The test-retest indices for each of the 6 scores were poor to good, ranging from r = .46 to .83. Good reliability was found for the Coding and Symbol Search test (> .80). BESS testing demonstrated moderate results at .70. The reliable change indices found that at a 70% CI, a conservative index, a decrease in 2 SAC points, 5 Buschke SRT words, 16 CLTR words, 2 Coding points, 2 Symbol points, and 2 SRT delayed recalls, as well as an increase of 3 BESS errors and 14 seconds in the Trails B time, would indicate a change in performance consistent with impairment on these measures. A weak relationship (r < .36) between the SAC and each of the neuropsychological assessments was noted; however, stronger relationships (r > .70) were found between certain neuropsychological measures. While the results of this study provide evidence for using the SAC along with a more complex neuropsychological assessment battery in the evaluation of concussion in young athletes, this should be performed in conjunction with the a complete clinical examination of the athlete's symptoms and that neuropsychological assessments as utilized in this study are designed by and for the trained neuropsychologist and should only be interpreted by qualified medical or health care personnel.

Sveen et al[63] examined the extent injury severity and post-concussion symptoms after 3 months predict ability in activities 12 months after TBI and assessed the frequency of problems in daily activities. A cohort of 63 persons with mild to severe TBI was assessed on admission to ED, after three and 12 months. Injury severity was assessed using the Glasgow Coma Scale, *Abbreviated Injury Scale* for the head and *Injury Severity Score*. Post-concussion symptoms were reported using the *Rivermead Post Concussion Symptoms Questionnaire* after three months. Activity problems at 12 months were related to perceived cognitive and interpersonal/emotional competency. The author found that the PCS reported at three-month follow-up were main predictors of cognitive and interpersonal/emotional competency at 12 months. They further suggest that the symptoms evolving after the trauma are a strong predictor of perceived ability in activities requiring the need for follow-up after TBI to identify persons at risk of developing long-term activity limitations.

Leddy et al[43] evaluated the effects of a graded treadmill test for retest reliability and interrater reliability in the evaluation of the physiologic effects of symptom exacerbation from a concussion. Twenty-one refractory concussed patients (11 athletes and 10 non-athletes) and 10 healthy subjects were used to measure retest reliability and interrater reliability respectively. Thirty-two, raters representing a variety of health care disciplines were used to measure interrater reliability. Raters achieved a sensitivity of 99% for identifying actors with symptom exacerbation and a specificity of 89% for ruling out concussion symptoms and agreed on 304 of 320 observations (accuracy of 95%). The ICC for the symptom exacerbation for maximal heart rate was large at 0.90 (95% CI, 0.78-0.98). The treadmill test had good retest reliability for maximal heart rate (ICC, 0.79) but not for systolic blood pressure, diastolic blood pressure, or rating of perceived exertion. The authors concluded that the Balke exercise treadmill protocol had very good interrater reliability and sufficient retest reliability for identifying patients with symptom exacerbation from concussion.

Broglio et al[44] attempted to establish the sensitivity and specificity of the *NeuroCom Sensory Organization Test* (SOT) and develop a cut-scores for clinical decision making using estimates of reliable change in patient with a concussion. Subjects included 66 healthy and 33 concussed young adults who completed postural control assessments on the NeuroCom SOT at baseline and follow-up. The reliable change technique was used to calculated cut-scores for each SOT variable (composite balance; somatosensory, visual, and vestibular ratios) at the at 5% intervals from 95% to 70% confidence interval levels. The researchers found that an evaluation for change on one or more SOT variables resulted in the highest combined sensitivity (57%) and specificity (80%) at the 75% confidence interval. They concluded that some concussed athletes may not show large changes in post-concussion postural control and this postural control evaluation should not be used in exclusion of other assessment techniques when evaluating a concussed athlete.

Coghlin, Myles and Howitt[25] examined the ability recognize concussion symptoms in their Bantam-aged (13-14 year old) minor hockey league children. A questionnaire was developed in order to gather information from parents of Bantam aged athletes participating in the 7th Annual Penguins International Winter Classic hockey tournament. The majorities of the questions used in questionnaire were taken from the Sport Concussion Assessment Tool and specifically targeted the parent's knowledge of concussions, signs, and symptoms. Eight false detractors, which were considered "red herrings" were added to the questionnaire and included: 1) difficulty with urination, 2) lowered pulse rate, 3) difficulty with defecation, 4) hearing voices, 5) sinus congestion, 6) feelings of euphoria, 7) inability to swallow and 8) chest pain. One hundred and fourteen questionnaires were analyzed. The mean number of correct responses to signs and symptoms (see Table 5) of concussion was 21.25/25 for mothers and 20.41/25 for fathers. The mean number of detractors identified as not associated with concussion was 5.93/8 for the mothers and 4.85/8 for the fathers, indicating that mothers were more capable of recognizing the signs and symptoms than fathers. Researchers suggest that there is still a disconnect regarding the key components of recognizing a concussion, such as difficulty with sleep, disorientation symptoms, and emotional irritability. Mothers displayed an ability to better differentiate between true and false signs and symptoms of concussion as compared to fathers.

Table 5. Signs and Symptoms of a Concussion.

Physical Symptoms	Cognitive Symptoms	Emotional Symptoms	Physical Signs
Headache	Confusion	Depression	Loss of consciousness
Dizziness	Amnesia	Irritability	Poor coordination
Nausea	Disorientation	Moodiness	Easily distracted
Feeling 'Unsteady'	Poor concentration		Poor concentration
Feeling 'Dinged'	Memory disturbance		Slow responses
Feeling 'Stunned'			Vomiting
Feeling 'Dazed"			'Glassy eyed'
Describe 'Bell rung'			Photophobia
'Seeing stars'			Aphasia
Visual Disturbances			Personality change

Tinnitus			Inappropriate behavior
Diplopia			Decreased physical ability

Broglio and Puetz[23] conducted a meta-analysis examine the effects of sport concussions on neurocognitive function, self-report symptoms and postural control. PubMed and PsychINFO databases were searched from January 1970 to June 2006 in which 39 were included for review. Inclusion criteria include: concussed athletes who were evaluated using one of the three assessment measures with 1 post-morbid assessment completed within 14 days of injury and compared with a baseline measure or control group. Sport-related concussion had a large negative effect (mean Delta; 95% confidence interval) on neurocognitive functioning (-0.81; -1.01, -0.60), self-report symptoms (-3.31; -6.35, -0.27) and postural control (-2.56; -6.44, 1.32) in the initial assessment following injury. Further results suggest administration of the SAC tool may provide clinician with the greatest amount of information pertaining to neurocognitive status immediately following injury.

However, following a concussion, the sensitivity of the SAC declines and an alternate assessment battery should be considered.[23] Sport concussion showed the largest effect on self-report symptoms at the immediate post-concussion assessment and while it would appear self-report symptoms would clearly indicate the presence of concussion, the authors caution against it sole use as they found that "over one-third of unreported concussions may result from the athlete not being aware of the injury's signs and symptoms.[25] In addition, it has been proposed that some athletes may deliberately under-report concussion-related symptoms in an effort to return to play sooner.[24]"[23 p.38] Use of postural control assessment technique (*Balance Error Scoring System* or *NeuroCom Sensory Organization Test*) is warranted as demonstrated by large post-concussion effects and the additional clinical information may provide a better understanding of the injury.

Overall Recommendations

Providers of first aid must first recognize that no two mTBI (ie., concussions) are identical in both the cause and presentation. The degree of the resulting signs and symptoms from the physical trauma can be very different and difficult to visualize[12,14,36] by a first aid provider depending upon a variety of factors. The diagnosis of a mTBI should involve the assessment of a range of domains including, but not limited to the person's: 1) symptoms, 2) signs, 3) behavior, 4) balance and coordination, 5) sleeping patterns 6) cognition and analytical abilities and 7) response to physical exertion. [4,9,10,12,21,24-26,34,43,44] with each assessment tool adding additional information regarding the status of the injured person by independently evaluating differing aspects of cerebral functioning.[23] However, while assessment tools such as neuropsychological and neurocognitive and balance and coordination testing are commonly used and provide the greatest amount of objective measures regarding a person's of cognitive function and recovery after a concussive injury[9,10,21,23,24,41,45,46]; individual variations in test scores and the necessity of baseline assessment makes it difficult for providers of first aid to administer these tools and interpret the results.

To help recognize a concussion, providers of first aid should observe for two items. First, the person sustaining a mTBI should experience a forceful bump, blow, or jolt to the head or body that results in rapid movement of the head and brain. Second, providers of first aid should observe for any change in the person's physical, cognitive, emotional or sleeping patterns. These signs and symptoms can be located in Table 6. Note that these signals may or may not appear immediately and that some people do not recognize or admit (athletes) that they are having problems.

Any person who a provider of first aid believes is experiencing any of the signs and symptoms listed in table 6 and who has sustained trauma to the head should be removed from activity [ie,. sport] and referred to a qualified health care professional, experienced in evaluating and managing concussion.

Table 6. Signs and Symptoms of a Concussion.

Physical	Cognitive	Affective	Sleep
Headache	Difficulty thinking clearly	Irritability	Drowsiness
Nausea or vomiting	Feeling mentally "foggy"	Sadness/depression	Sleeping more or less than usual
Balance or coordination problems	Difficulty concentrating	Anxiety	Difficulty falling asleep
Dizziness	Decreased processing speed	Heighted emotions	
Double or blurry vision	Difficulty remembering new information	Nervousness	
Sensitivity to light	Difficulty remembering events *prior* to the trauma		
Sensitivity to noise	Difficulty recalling events *after* to the trauma		
Tinnitus	Feeling "sluggish" or slowed down		
Fatigue			
Does not "feel right" or is "feeling down"			

Feeling "sluggish", having no energy			
Numbness/tingling			
Loss of consciousness			

Recommendations and Strength (using table below)

Standards:
Any person who a provider of first aid believes has sustained trauma [forceful bump, blow, or jolt to the head or body that results in rapid movement of the head and brain], along with any of the signals listed in table 6 [may be delayed] must be assumed to have sustained a mild traumatic brain injury or concussion.

Any person having sustained a mild traumatic brain injury or concussion must be removed from activity (ie., sport or other recreational activities) and must be referred to a qualified health care professional, experienced in evaluating and managing concussion.

Guidelines:
None

Options:
None

Scientific Advisory Council

ARC SAC Scientific Review
Mild Traumatic Brain Injury (concussion)

Summary of Key Articles/Literature Found and Level of Evidence/Bibliography

Author	Full Citation	Summary of Article	LOE
Centers for Disease Control and Prevention.	Centers for Disease Control and Prevention. Traumatic brain injury. 2011; http://www.cdc.gov/traumaticbraininjury/. Accessed December 17, 2011.	Website reviewing Traumatic Brain Injury	
Guskiewicz KM	Guskiewicz KM, Bruce SL, Cantu RC, et al. National Athletic Trainers' Association Position Statement: Management of Sport-Related Concussion. *J Athl Train.* 2004;39(3):280-297.	Position statement provides the recommendations for certified athletic trainers (ATCs), physicians, and other medical professionals caring for athletes at the youth, high school, collegiate, and elite levels. The recommendations are derived from the most recent scientific and clinic-based literature on sport-related concussion. The justification for these recommendations is presented in the summary statement following the recommendations. The summary statement is organized into the following sections: ''Defining and Recognizing Concussion,'' ''Evaluating and Making the Return-to-Play Decision,'' ''Concussion Assessment Tools,'' ''When to Refer an Athlete to a Physician After Concussion,'' ''When to Disqualify an Athlete,'' ''Special Considerations for the Young Athlete,'' ''Home Care,'' and ''Equipment Issues.''	5
McCrory P	McCrory P, Meeuwisse W, Johnston K, et al. Consensus statement on concussion in sport: the 3rd International Conference on Concussion in Sport held in Zurich, November 2008. *J Athl Train* 2009;44(4):434-448.	The Zurich Consensus statement is designed to build on the principles outlined in the original Vienna and Prague documents and to develop further conceptual understanding of this problem using a formal consensus-based approach. A detailed description of the consensus process is outlined at the end of this document under the "background" section (See Section 11). This document was developed for use by physicians, therapists, certified athletic trainers, health professionals, coaches and other people involved in the care of injured athletes, whether at the recreational, elite, or professional level.	5
Gennarelli T	Gennarelli T.	Head injuries vary widely in their etiology, pathophysiology, clinical presentation, and optimal	5

	Mechanisms of brain injury. *J Emerg Med.* 1993;11(suppl 1):5-11.	treatment strategies. Broadly speaking, there are two categories of brain injury: focal injuries and diffuse injuries. Focal brain injuries, which are usually caused by direct blows to the head, comprise contusions, brain lacerations, and hemorrhage leading to the formation of hematoma in the extradural, subarachnoid, subdural, or intracerebral compartments within the head. Diffuse brain injuries, which are usually caused by a sudden movement of the head, comprise classical brief cerebral concussion and more prolonged posttraumatic coma, also known as diffuse axonal injury. Primary traumatic effects involve neural or vascular elements of the brain, which can be affected by delayed effects such as deafferentation or secondary events such as ischemia, swelling, cerebral edema, and increased intracranial pressure. Axonal damage at the node of Ranvier results in a traumatic defect in the axonal membrane that causes the excessive accumulation of calcium ions within the intracellular compartment of the axon. Brain ischemia can result in a similar effect, further increasing the accumulation of calcium ions, which can lead to axonal degeneration. Injury-specific treatments are now being designed to alter the various pathophysiological mechanisms of brain injury.
Coronado VG	Coronado VG , Xu L, Basavaraju SV, et al. Surveillance for traumatic brain injury-related deaths--United States, 1997-2007. *MMWR.* 2011;60(5):1-32.	Problem/Condition: Traumatic brain injury (TBI) is a leading cause of death and disability in the United States. Approximately 53,000 persons die from TBI-related injuries annually. During 1989--1998, TBI-related death rates decreased 11.4%, from 21.9 to 19.4 per 100,000 population. This report describes the epidemiology and annual rates of TBI-related deaths during 1997--2007. Reporting Period: January 1, 1997--December 31, 2007. Description of System: Data were analyzed from the CDC multiple-cause-of-death public-use data files, which contain death certificate data from all 50 states and the District of Columbia. Results: During 1997--2007, an annual average of 53,014 deaths (18.4 per 100,000 population; range: 17.8--19.3) among U.S. residents were associated with TBIs. During this period, death rates decreased 8.2%, from 19.3 to 17.8 per 100,000 population ($p = 0.001$). TBI-related death rates decreased significantly among persons aged 0--44 years and increased significantly among those aged ≥75 years. The rate of TBI deaths was three times higher among males (28.8 per 100,000 population) than among females (9.1). Among males, rates were highest among non-Hispanic American Indian/Alaska Natives (41.3 per 100,000 population) and lowest among Hispanics (22.7). Firearm- (34.8%), motor-vehicle-- (31.4%), and fall-related TBIs (16.7%) were the leading causes of TBI-related death. Firearm-related death rates were highest among persons aged 15--34 years (8.5 per 100,000 population) and ≥75 years (10.5). Motor vehicle--related death rates were highest among those aged 15--24 years (11.9 per 100,000 population). Fall-related death rates were highest among adults aged ≥75 years (29.8 per 100,000 population). Overall, the rates for all causes except falls decreased. Interpretation: Although the overall rate of TBI-related deaths decreased during 1997--2007, TBI remains a public health problem; approximately 580,000 persons died with TBI-related diagnoses during this reporting period in the United States. Rates of TBI-related deaths were higher among young and older adults and certain minority populations. The leading external causes of this

		condition were incidents related to firearms, motor vehicle traffic, and falls. Public Health Actions: Accurate, timely, and comprehensive surveillance data are necessary to better understand and prevent TBI-related deaths in the United States. CDC multiple-cause-of-death public-use data files can be used to monitor the incidence of TBI-related deaths and assist public health practitioners and partners in the development, implementation, and evaluation of programs and policies to reduce and prevent TBI-related deaths in the United States. Rates of TBI-related deaths are higher in certain population groups and are primarily related to specific external causes. Better enforcement of existing seat belt laws, implementation and increased coverage of more stringent helmet laws, and the implementation of existing evidence-based fall-related prevention interventions are examples of interventions that can reduce the incidence of TBI in the United States.	
Kelly JP	Kelly JP, Nichols JS, Filley CM, Lillehei KO, Rubinstein D, Kleinschmidt-DeMasters BK. Concussion in sports. Guidelines for the prevention of catastrophic outcome. *JAMA.* 1991;266(20):2867-2869.	Concussion (defined as a traumatically induced alteration in mental status, not necessarily with loss of consciousness) is a common form of sports-related injury too often dismissed as trivial by physicians, athletic trainers, coaches, sports reporters, and athletes themselves. While head injuries can occur in virtually any form of athletic activity, they occur most frequently in contact sports, such as football, boxing, and martial arts competition, or from high-velocity collisions or falls in basketball, soccer, and ice hockey. The pathophysiology of concussion is less well understood than that of severe head injury, and it has received less attention as a result. We describe a high school football player who died of diffuse brain swelling after repeated concussions without loss of consciousness. Guidelines have been developed to reduce the risk of such serious catastrophic outcomes after concussion in sports.	3b
Bell KR	Bell KR, Hoffman JM, Temkin NR, et al. The effect of telephone counselling on reducing post-traumatic symptoms after mild traumatic brain injury: a randomised trial. *J Neurol Neurosurg Psychiatry.* 2008;79(11):1275-1281.	Objective: To evaluate the effect of a Scheduled Telephone Intervention (STI) compared with usual care (UC) on function, health/emotional status, community/work activities, and well-being at 1 and 2 years after **traumatic brain injury** (TBI). Design: Two group, **randomized controlled trial**. Setting: Telephone contacts with subjects recruited in inpatient rehabilitation. Participants: Eligible subjects (N=433) with TBI (age>16y) were randomly assigned to STI plus UC (n=210) or UC (n=223) at discharge. STI subjects (n=169) completed the outcome at year 1 (118 at year 2) and 174 UC subjects at year 1 (123 at year 2). Interventions: STI subjects received calls at 2 and 4 weeks and 2, 3, 5, 7, 9, 12, 15, 18, and 21 months consisting of brief training in problem solving, education, or referral. Main Outcome Measures: A composite outcome at 1 year was the primary endpoint. Analysis on intent-to-treat basis used linear regression adjusted for site, Glasgow Coma Scale, race/ethnicity, age, FIM, sex, and Disability Rating Scale (DRS). Secondary analyses were conducted on individual and composite measures (FIM, DRS, community participation indicators, Glasgow Outcome Scale [Extended], Short Form-12 Health Survey, Brief Symptom Inventory-18, EuroQOL, and modified Perceived Quality of Life). Results: No significant differences were noted between the groups at years 1 or 2 for primary (P=.987 regression for year 1, P=.983 for year 2) or secondary analyses. Conclusions: This study failed to replicate the findings of a previous single center study of telephone-based counseling. While telephone mediated treatment has shown promise in other studies, this model of flexible counseling in problem solving and education for varied problems was not	1a

		effective over and above usual care.	
Barkhoudarian G	Barkhoudarian G, Hovda DA, Giza CC. The molecular pathophysiology of concussive brain injury. *Clin Sports Med.* 2011;30(1):33-48, vii-iii.	Concussion or mild traumatic brain injury (mTBI) is a condition that affects hundreds of thousands of patients worldwide. Understanding the pathophysiology of this disorder can help manage its acute and chronic repercussions. Immediately following mTBI, there are several metabolic, hemodynamic, structural, and electric changes that alter normal cerebral function. These alterations can increase the brain's vulnerability to repeat injury and long-term disability. This review evaluates current studies from the bench to the bedside of mTBI. Acute and chronic effects of concussion are measured in both animal and clinical studies. Also, the effect of repeat concussions is analyzed. Concussion-induced pathophysiology with regards to glucose metabolism changes, mitochondrial dysfunction, axonal injury, and structural damage are evaluated. Translational studies such as functional magnetic resonance imaging, magnetic resonance spectroscopy and diffusion tensor imaging prove to be effective clinical tools for both prognostic and treatment parameters. Understanding the neurobiology of concussion will lead to development and validation of physiological biomarkers of this common injury. These biomarkers (eg, laboratory tests, imaging, electrophysiology) will then allow for improved detection, better functional assessment and evidence-based return to play recommendations.	5
Belanger HG	Belanger HG, Uomoto JM, Vanderploeg RD. The Veterans Health Administration's (VHA's) Polytrauma System of Care for mild traumatic brain injury: costs, benefits, and controversies. *J Head Trauma Rehabil.* 2009;24(1):4	The Veterans Health Administration's (VHA's) Polytrauma System of Care, developed in response to a new cohort of patients back from Iraq and Afghanistan, is described with particular focus on the assessment and treatment of mild traumatic brain injury (mild TBI). The development of systemwide TBI screening within the VHA has been an ambitious and historic undertaking. As with any population-wide screening tool, there are benefits and costs associated with it. The purpose of this article is to identify and discuss the strengths and weaknesses of the VHA's TBI clinical reminder and subsequent evaluation and treatment processes. Complicating factors such as increased media attention and other contextual factors are discussed.	5
Brenner LA	Brenner LA, Vanderploeg RD, Terrio I Assessment and diagnosis of mild traui brain injury, posttraumatic stress disorc and other polytrauma conditions: burde adversity hypothesis. *Rehabil Psychol.* 2009;54(3):239-246.	OBJECTIVE/METHOD: Military personnel returning from Iraq and Afghanistan have been exposed to physical and emotional trauma. Challenges related to assessment and intervention for those with posttraumatic stress disorder (PTSD) and/or history of mild traumatic brain injury (TBI) with sequelae are discussed, with an emphasis on complicating factors if conditions are co-occurring. Existing literature regarding cumulative disadvantage is offered as a means of increasing understanding regarding the complex symptom patterns reported by those with a history of mild TBI with enduring symptoms and PTSD. IMPLICATIONS: The importance of early screening for both conditions is highlighted. In addition, the authors suggest that current best practices include treating symptoms regardless of etiology to decrease military personnel and veteran burden of adversity.	5
Department of Defense	Department of Veterans Affairs and Department of Defense. VA/ DOD clin practice guideline for management of	The Clinical Practice Guideline for the Management of Concussion/Mild Traumatic Brain Injury (mTBI) was developed under the auspices of the Veterans Health Administration (VHA) and the Department of Defense (DoD) pursuant to directives from the Department of Veterans Affairs (VA).	5

	concussion/mild traumatic brain injury. 2009; http://www.healthquality.va.gov/mtbi/c ion_mtbi_full_1_0.pdf. Accessed Dece 18, 2011.	The intent of the document is to reduce current practice variation and provide facilities with a structured framework to help improve patient outcomes, provide evidence-based recommendations to assist providers and their patients in the decision-making process related to the patient health care problems, identify outcome measures to support the development of practice-based evidence that can ultimately be used to improve clinical guidelines.	
Broomhall LG	Broomhall LG, Clark CR, McFarlane A et al. Early stage assessment and course acute stress disorder after mild traumat brain injury. *J Nerv Ment Dis.* 2009;197(3):178-181.	Although it has been established that acute stress disorder (ASD) and posttraumatic stress disorder occur after mild traumatic brain injury (MTBI) the qualitative differences in symptom presentation between injury survivors with and without a MTBI have not been explored in depth. This study aimed to compare the ASD and posttraumatic stress disorder symptom presentation of injury survivors with and without MTBI. One thousand one hundred sixteen participants between the ages of 17 to 65 years (mean age: 38.97 years, SD: 14.23) were assessed in the acute hospital after a traumatic injury. Four hundred seventy-five individuals met the criteria for MTBI. Results showed a trend toward higher levels of ASD in the MTBI group compared with the non-MTBI group. Those with a MTBI and ASD had longer hospital admissions and higher levels of distress associated with their symptoms. Although many of the ASD symptoms that the MTBI group scored significantly higher were also part of a postconcussive syndrome, higher levels of avoidance symptoms may suggest that this group is at risk for longer term poor psychological adjustment. Mild TBI patients may represent a injury group at risk for poor psychological adjustment after traumatic injury.	1b
Cohen JS	Cohen JS, Gioia G, Atabaki S, Teach SJ. Sports-related concussions in pediatrics. *Curr Opin Pediatr.* 2009;21(3):288-293.	PURPOSE OF REVIEW: Mild traumatic brain injury (mTBI) accompanied by concussion is a common presenting complaint among children presenting to emergency departments (EDs). There is wide practice variation regarding diagnosis and management of sports-related concussions in children. Our aim is to review the most recent evidence and expert recommendations regarding initial diagnosis and management of sports-related concussions in children. RECENT FINDINGS: Previous classifications and return-to-play guidelines for sports-related concussions in children were inadequate and have been abandoned. The most recent recommendations, from the Third International Conference on Concussion in Sport (CIS), reinforce an individualized evaluation of the athlete's neurocognitive functioning, symptoms and balance. They further reinforce a step-wise approach in the return-to-play process once neurocognitive function has returned to baseline and all	5

		symptoms have resolved. The need for a standardized and objective tool to aid in the initial evaluation and diagnosis of mTBI in the clinical setting led to the development of the Acute Concussion Evaluation (ACE) protocol, which is currently being modified for specific use in the ED. Computed tomography (CT) in the acute setting is not likely to be useful for children with mTBI. Newer functional imaging techniques may prove relevant in the future. SUMMARY: Further research on both the incidence of sports-related concussions in children and management paradigms is needed. The role of novel imaging modalities in clinical assessment also needs to be elucidated. An individualized approach to evaluation and management of sports-related concussions is recommended. It should incorporate standard symptom assessment, neuropsychological testing and postural stability testing.	
Centers for Disease Control and Prevention.	Centers for Disease Control and Prever *Heads Up: Brain Injury in Your Practi* Atlanta, GA: U.S. Department of Healt and Human Services,; 2007.		5
Gioia	Gioia GA, Collins M, Isquith PK. Improving identification and diagnosis of mild traumatic brain injury with evidence: psychometric support for the acute concussion evaluation. *J Head Trauma Rehab.* 2008;23(4):230-242.	OBJECTIVES: A dearth of standardized assessment tools exists to properly assess and triage mild traumatic brain injury (mTBI) in primary care and acute care settings. This article presents evidence of appropriate psychometric properties for the Acute Concussion Evaluation (ACE), a new structured clinical interview. PARTICIPANTS: Parent informants of 354 patients, aged 3 to 18 years, with suspected mTBI completed the ACE via telephone interview. MEASURE: Acute Concussion Evaluation. RESULTS: Evidence is presented for appropriate item-scale membership, internal consistency reliability as well as content, predictive, convergent/divergent, and construct validity of the ACE symptom checklist. CONCLUSIONS: Overall, the ACE symptom checklist exhibits reasonably strong psychometric properties as an initial assessment tool for mTBI.	2a
Holm L	Holm L, Cassidy JD, Carroll LJ, Borg . Summary of the WHO Collaborating Centre for Neurotrauma Task Force on Mild Traumatic Brain Injury. *J Rehab Medicine.* 2005;37(3):137-141.	This report aims to summarize the key findings of a recent, systematic review of the literature performed by the WHO Collaborating Centre for Neurotrauma Task Force on Mild Traumatic Brain Injury published in a supplement of the Journal of Rehabilitation Medicine. The Task Force performed a comprehensive search and critical review of the literature published between 1980 and 2002 to assemble the best evidence on the epidemiology, diagnosis, prognosis and treatment of MTBI. The Task Force identified 38,806 citations and 743 relevant studies, of which 313 (42%) were accepted on scientific merit and formed the basis of the best evidence synthesis.	5
Thompson JM	Thompson JM, Scott KC, Dubinsky L. Battlefield brain: unexplained sympton and blast-related mild traumatic brain injury. *Can Fam Physician.* 2008;54(11):1549-1551.	A 40-year-old male military Veteran* presents to a family physician with chronic symptoms that include recurrent headaches, dizziness, depression, memory problems, difficulty sleeping, and relationship troubles. He has not had a family physician since leaving the military 2 years ago. His Military Occupation Classification had been infantry. He explains that he had been deployed to war zones and that during a firefight several years earlier an enemy weapon exploded nearby, killing a fellow soldier and wounding others. He does not recall being injured, but remembers feeling a thump	3b

		and that his "computer had to reboot." This was followed by headaches and a few days of ringing in his ears. He also suffered a concussion during a military hockey game. He was assessed and treated for persistent headaches in the service and recalls that results of a head computed tomography scan were negative. Veterans Affairs Canada (VAC) granted him a disability award for posttraumatic headache and provided certain treatment benefits. He took medication for the headaches. Following transition to civilian life he had difficulty holding jobs, but had been reluctant to seek help. He saw stories on television about blast-induced minor traumatic brain injury in Iraq and Afghanistan, and wonders if he "has MTBI." Findings from his physical examination, bloodwork, and Mini Mental State Examination are normal, but his Montreal Cognitive Assessment score is 24, suggesting possible cognitive impairment. The physician organizes follow-up appointments and a neurology consultation. After reading about Canada's military-aware operational stress injury (OSI) clinics in a medical journal, he refers the Veteran to a VAC district office for access to mental health assessment.	
de Kruijk JR	de Kruijk JR, Leffers P, Meerhoff S, Rutten J, Twijnstra A. Effectiveness of bed rest after mild traumatic brain inju a randomised trial of no versus six day of bed rest. *J Neurol Neurosurg Psychi* 2002;73(2):167-172.	BACKGROUND: Outcome after mild traumatic brain injury (MTBI) is determined largely by the appearance of post-traumatic complaints (PTC). The prevalence of PTC after six months is estimated to be between 20 and 80%. Bed rest has been advocated to prevent PTC but its effectiveness has never been established. OBJECTIVE: To evaluate the effect of bed rest on the severity of PTC after MTBI. METHODS: Patients presenting with MTBI to the emergency room were randomly assigned to two intervention strategies. One group was advised not to take bed rest (NO) and the other to take full bed rest (FULL) for six days after the trauma. The primary outcome measures were severity of PTC on a visual analogue scale and physical and mental health on the medical outcomes study 36 item short form health survey (SF-36) at two weeks and three and six months after the trauma. RESULTS: Between October 1996 and July 1999, 107 (54 NO, 53 FULL) patients were enrolled. Outcome variables in both groups clearly improved between two weeks and six months. After adjustment for differences in baseline variables, most PTC tended to be somewhat more severe in the FULL group six months after the trauma, but no significant differences were found. Neither were there any significant differences in the outcome parameters between the two groups after three months. Two weeks after the trauma, most PTC in the FULL group were slightly less severe than those in the NO group, and physical subscores of the SF-36 in the FULL group were slightly better. These differences were not significant. Patients in the FULL group reported significantly less dizziness during the intervention period. CONCLUSIONS: As a means of speeding up recovery of patients with PTC after MTBI, bed rest is no more effective than no bed rest at all. Bed rest probably has some palliative effect within the first two weeks after the trauma.	1b
Ruff RM	Ruff RM, Jurica P. In search of a unifie definition for mild traumatic brain inju *Brain Inj.* Dec 1999;13(12):943-952.	Discrepant criteria are utilized by various disciplines for the diagnosis of mild traumatic brain injury (TBI). This study evaluates 76 patients, all of whom were diagnosed as having sustained a mild TBI according to the diagnostic criteria set forth by the American Congress of Rehabilitation Medicine	

		(ACRM); yet only 34% of these patients were classified as having a concussion according to DSM-IV. A unified definition is proposed which is comprised of grades: Type I for ACRM, Type III for DSM-IV, and Type II to bridge the two discrepant definitions. An examination of the patients, subdivided into the three types, revealed no significant differences for (1) number of subjective complaints, (2) neurocognitive performances, and (3) pre-existing emotional risk factors. Thus, the proposed gradation unifies the definitions across the heterogeneity of mild TBI. However, further research is indicated for their clinical validation.	
American Congress on Rehabilitation Medicine	American Congress on Rehabilitation Medicine. Definition of mild traumatic brain injury. *J Head Trauma Rehabil.* 1993;1993(8):3.		5
	Kennedy JE, Jaffee MS, Leskin GA, Stokes JW, Leal FO, Fitzpatrick PJ. Posttraumatic stress disorder and posttraumatic stress disorder-like symptoms and mild traumatic brain injury. *J Rehabilitation Research & Development.* 2007;44(7):895-919.	This article reviews the literature on posttraumatic stress disorder (PTSD) and PTSD-like symptoms that can occur along with mild traumatic brain injury (TBI) and concussion, with specific reference to concussive injuries in the military. We address four major areas: (1) clinical aspects of TBI and PTSD, including diagnostic criteria, incidence, predictive factors, and course; (2) biological overlap between PTSD and TBI; (3) comorbidity between PTSD and other mental disorders that can occur after mild TBI; and (4) current treatments for PTSD, with specific considerations related to treatment for patients with mild TBI or concussive injuries.	
Levin HS	Levin HS, Hanten G, Roberson G, et al Prediction of cognitive sequelae based abnormal computed tomography findin in children following mild traumatic br injury. *J Neurosurg Pediatr.* 2008;1(6):461-470.	OBJECT: The aim of this study was to determine whether the presence of intracranial pathophysiology on computed tomography (CT) scans obtained within 24 hours of mild traumatic brain injury (MTBI) in children adversely affects neuropsychological outcome during the 1st year postinjury. METHODS: A prospective longitudinal design was used to examine the neuropsychological outcomes in children (ages 5-15 years) who had been treated for MTBI, which was defined as a loss of consciousness for up to 30 minutes and a lowest Glasgow Coma Scale (GCS) score of 13-15. Exclusion criteria included any preinjury neurological disorder. Outcome assessments were performed within 2 weeks and at 3, 6, and 12 months postinjury. Outcomes were compared between patients with MTBI whose postinjury CT scans revealed complications of brain pathophysiology (32 patients, CMTBI group) and those with MTBI but without complications (48 patients, MTBI group). RESULTS: Significant interactions confirmed that the pattern of recovery over 12 months after injury differed depending on the intracranial pathology, presence and severity of injuries to body regions other than the head, preinjury attention-deficit hyperactivity disorder (ADHD), and socioeconomic status. Children in the CMTBI group had significantly poorer episodic memory, slower cognitive processing, diminished recovery in managing cognitive interference, and poorer performance in calculating and reading than patients in the MTBI group. Among the patients with mild or no extracranial injury, visuomotor speed was slower in those in the CMTBI group; and among patients without preinjury ADHD, working memory was worse in those in the CMTBI group. CONCLUSIONS: Neuropsychological recovery during the 1st year following MTBI is related to the presence of radiographically detectable intracranial pathology. Children with intracranial pathology on acute CT performed more poorly in several cognitive domains when compared with patients	***Prospective longitudinal design***

		whose CT findings were normal or limited to a linear skull fracture. Depending on the presence of preinjury ADHD and concomitant extracranial injury, working memory and visuomotor speed were also diminished in patients whose CT findings revealed complications following MTBI. Computed tomography within 24 hours postinjury appears to be useful for identifying children with an elevated risk for residual neuropsychological changes.	
Smith-Seemiller L	Smith-Seemiller L, Fow NR, Kant R, Franzen MD. Presence of post-concuss syndrome symptoms in patients with chronic pain vs mild traumatic brain injury. *Brain Inj.* 2003;17(3):199-206.	PRIMARY OBJECTIVE: Post-concussion syndrome (PCS) is a controversial diagnosis, in part because many symptoms may be present in other conditions, such as chronic pain (CP). However, direct comparisons between people with CP and mild traumatic brain injury (MTBI) are limited. The purpose of this study was to compare people with CP and MTBI on a measure of PCS symptoms. DESIGN: Group comparison between patients with CP and MTBI on the Rivermead Post-Concussion Questionnaire (RPCQ). METHODS: Sixty-three patients with CP and 32 with MTBI were evaluated at the authors' institutions. Patients completed the RPCQ as part of their initial evaluation. RESULTS: No group differences were found for total RPCQ scores. There were some differences in the proportion of patients endorsing specific symptoms. However, most people with CP endorsed symptoms consistent with PCS. CONCLUSIONS: PCS symptoms are not unique to MTBI, and may be seen in conditions such as CP.	***Group comparison between patients***
Maruta J	Maruta J, Lee SW, Jacobs EF, Ghajar J. A unified science of concussion. *Ann N Y Acad Sci.* 2010;1208:58-66.	The etiology, imaging, and behavioral assessment of mild traumatic brain injury (mTBI) are daunting fields, given the lack of a cohesive neurobiological explanation for the observed cognitive deficits seen following 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. Unifying the anatomical and behavioral approaches, the emerging evidence supports an explanation for mTBI that the observed cognitive impairments are a result of predictive timing deficits caused by shearing injuries in the frontal white matter tracts.	5
Petchprapai N	Petchprapai N, Winkelman C. Mild traumatic brain injury: determinants an subsequent quality of life. A review of the literature. *J Neurosci Nurs*. Oct 2007;39(5):260-272.	In this review, we analyzed literature related to the clinical, theoretical, and empirical determinants of mild traumatic brain injury (MTBI) in adults, with a focus on outcomes. Consequences after MTBI were summarized, patient outcomes were organized following Ferrans and Powers' conceptual model of quality of life, and gaps in knowledge were identified. The following databases were searched for publications related to MTBI: PubMed, PsycINFO, CINAHL, and Digital Dissertation. A total of 44 publications related to MTBI in adults were identified. Neither clinical nor theoretical definitions nor empirical descriptions agreed on the determinants of MTBI in adults. Nine reports included a holistic evaluation of outcomes after MTBI; an additional 35 studies examined health and functioning, psychological, or socioeconomic consequences. Results were mixed regarding how MTBI affects	*5 – Review*

		individuals in overall quality of life and which domains of quality of life are affected. With more than one million adults experiencing MTBI annually in the United States, it benefits the healthcare professional to understand the challenges of identifying adults who experience MTBI. Furthermore, the consequences of MTBI may be clinically important. Further research about MTBI using clear definitions and a holistic approach to recovery is warranted.	
Pelso PM	Peloso PM, Carroll LJ, Cassidy JD, et al. Critical evaluation of the existing guidelines on mild traumatic brain injury. *J Rehabil Med.* 2004(43 Suppl):106-112.	The purpose of guidelines is to reduce practice variability, but they need to be evidence-based. We examine current mild traumatic brain injury guidelines, critique their basis in evidence and examine their variability in recommendations. A systematic search of the literature found 38,806 abstracts, with 41 guidelines. There were 18 sports-related guidelines, 13 related to admission policies, 12 related to imaging and 5 related to neuropsychological assessment. Some guidelines addressed several areas. Only 5 guidelines reported a methodology for the assembly of evidence used to develop the guideline. After appraising the guidelines against a validated index, we found that 3 of the 41 guidelines could be categorized as evidence-based. Two of these focused on paediatric patients and 1 on adult patients. Limited methodological quality in the current guidelines results in conflicting recommendations amongst them.	
Polito MZ	Polito MZ, Thompson JW, DeFina PA. review of the International Brain Research Foundation novel approach to mild traumatic brain injury presented at the International Conference on Behavioral Health and Traumatic Brain Injury. *J Am Acad Nurse Pract.* 2010;22(9):504-509.	"The International Conference on Behavioral Health and Traumatic Brain Injury" held at St. Joseph's Regional Medical Center in Paterson, NJ., from October 12 to 15, 2008, included a presentation on the novel assessment and treatment approach to mild traumatic brain injury (mTBI) by Philip A. DeFina, PhD, of the International Brain Research Foundation (IBRF). Because of the urgent need to treat a large number of our troops who are diagnosed with mTBI and post-traumatic stress disorder (PTSD), the conference was held to create a report for Congress titled "Recommendations to Improve the Care of Wounded Warriors NOW. March 12, 2009." This article summarizes and adds greater detail to Dr. DeFina's presentation on the current standard and novel ways to approach assessment and treatment of mTBI and PTSD. Pilot data derived from collaborative studies through the IBRF have led to the development of clinical and research protocols utilizing currently accepted, valid, and reliable neuroimaging technologies combined in novel ways to develop "neuromarkers." These neuromarkers are being evaluated in the context of an "Integrity-Deficit Matrix" model to demonstrate their ability to improve diagnostic accuracy, guide treatment programs, and possibly predict outcomes for patients suffering from traumatic brain injury.	5
Ptito A	Ptito A, Chen JK, Johnston KM. Contributions of functional magnetic resonance imaging (fMRI) to sport c oncussion evaluation. *Neuro Rehabilitation.* 2007;22(3):217-227.	Mild traumatic brain injury (mTBI) in contact sport is a problem of such magnitude that improved approaches to diagnosis, investigation and management are urgent. Concussion has traditionally been described as a transient, fully reversible, cerebral dysfunction. However, this seemingly 'mild' injury sometimes results in long-lasting and disabling post-concussion symptoms (PCS) and abnormal neuropsychological profiles characteristic of frontal and/or temporal lobe dysfunction. At present, the pathological changes following concussion remain unclear, but it is now widely accepted that concussion results mainly in functional disturbance rather than structural damage. Therefore, functional imaging techniques can help in demonstrating brain abnormalities undetectable by	5

		structural imaging methods. This paper will review the use of functional magnetic resonance imaging (fMRI) in studies of concussion. Our existing and ongoing fMRI studies will be described as examples to highlight the potential and contribution of this non-invasive functional neuroimaging technique in the assessment of sports-related concussion and its management.	
Sheedy J	Sheedy J, Harvey E, Faux S, Geffen G, Shores EA. Emergency department assessment of mild traumat brain injury and the prediction of postconcussive symptoms: a 3-month prospective study. *J of Head Trauma Rehab.* 2009;24(5):333-343.	BACKGROUND: There is considerable uncertainty about the indications for cranial computed tomography (CT) scanning in patient with minor traumatic brain injury (TBI). This analysis involves an evidence-based comparison of several strategies for selecting patients for CT with regard to effectiveness and cost. METHODS: We performed a structured literature review of mild traumatic brain injury and constructed a cost-effectiveness model. The model estimated the impact of missed intracranial lesions on longevity, quality of life and costs. Using a 20-year-old patient for primary analysis, we compared the following strategies to screen for the need to perform a CT scan: observation in the emergency department or hospital floor, skull radiography, Selective CT based on the presence of additional risk factors and scanning all. RESULTS: Outcome measures for each strategy included average years of life, quality of life and costs. Selective CT and the CT All policy performed significantly better than the alternatives with respect to outcome. They were also less expensive in terms of total direct health care costs, although the differences did not reach statistical significance. The model yielded similar, but smaller, differences between the selective imaging and other strategies when run for older patients. CONCLUSIONS: Although the incidence of intracranial lesions, especially those that require surgery, is low in mild TBI, the consequences of delayed diagnosis are forbidding. Adverse outcome of an intracranial hematoma is so costly that it more than balances the expense of CT scans. In our cost-effectiveness model, the liberal use of CT scanning in mild TBI appears justified.	*Small prospec tive*
Weightmman	Weightman MM, Bolgla R, McCulloch KL, Peterson MD. Physical therapy recommendations for service members with mild traumatic brain injury. *J Head Trauma Rehabil.* 2010;25(3):206-218.	Mild traumatic brain injuries (MTBIs) are of increasing concern in both the military and civilian populations as the potential long-term effects and costs of such injuries are being further recognized. Injuries from conflicts in Afghanistan and Iraq have increased public awareness and concern for TBI. The Proponency Office for Rehabilitation and Reintegration, Office of the Surgeon General, US Army tasked a team of physical and occupational therapists to assemble evidence-informed guidelines for assessment and intervention specific to MTBI. Given the paucity of specific guidelines for physical therapy related to MTBI, we focused on literature that dealt with the specific problem area or complaint of the Service member following MTBI. Recommendations, characterized as practice standards or practice options based on strength of evidence, are provided relative to patient/client education, activity intolerance, vestibular dysfunction, high-level balance dysfunction, posttraumatic headache, temporomandibular disorder, attention and dual-task performance deficits, and participation in exercise. While highlighting the need for additional research, this work can be considered a starting point and impetus for the development of evidence-based practice in physical therapy for our deserving Service members.	5
Bay	Bay E. Mild traumatic brain injury: a midwest survey about the assessment	Research reported that mild traumatic brain injury (MTBI), the most common neurological condition in the world, is often undetected in the emergency department. Failure to properly detect and offer	*Descrip*

	and documentation practices of emergency department nurses. *Adv Emerg Nurs J.* 2011;33(1):71-83.	treatment therapies has been linked to chronic complications such as, mood disorders and postconcussion syndrome. This descriptive study used a tailored survey (25.0% response rate) to determine emergency department nurses' practices for the assessment and documentation of persons with MTBI. The primary purpose was to determine the extent to which these practices were aligned with the Centers for Disease Control and Prevention guidelines contained within the Acute Concussion Evaluation care plan. Results indicated that physical and cognitive symptoms were assessed and documented more than emotional or sleep symptoms. Still, some cognitive and physical symptoms were rarely assessed or documented. Focus seemed to be on ruling out more severe brain injury versus detection of a mild brain injury. Aligning the systematic assessment and documentation of persons with suspected concussion MTBI with recommendations from the Centers for Disease Control and Prevention is suggested.	*tive*
Ropper AH	Ropper AH, Gorson KC. Clinical pract Concussion. *N Engl J Med.* 2007;356(2):166-172.		*Review*
American Academy of Neurology	American Academy of Neurology. Practice parameter: the management of concussion in sports (summary stateme Report of the Quality Standards Subcommittee. *Neurology.* 1997;48(3): 585.		5
Andersson EE	Andersson EE, Bedics BK, Falkmer T. traumatic brain injuries: a 10-year Follow-up. *J Rehabil Med.* 2011;43(4):323-329.	OBJECTIVE AND DESIGN: Long-term consequences of mild traumatic brain injuries were investigated based on a 10-year follow-up of patients from a previously-published randomized controlled study of mild traumatic brain injuries. One aim was to describe changes over time after mild traumatic brain injuries in terms of the extent of persisting post-concussion symptoms, life satisfaction, perceived health, activities of daily living, changes in life roles and sick leave. Another aim was to identify differences between the intervention and control groups. PATIENTS: The intervention group comprised 142 persons and the control group 56 persons. METHODS: Postal questionnaires with a response rate of 56%. RESULTS: No differences over time were found for the intervention and control groups in terms of post-concussion symptoms. In the intervention group some variables in life satisfaction, perceived health and daily life were decreased. Some roles had changed over the years for both groups. No other differences between the intervention and control groups were found. However, in both groups sick leave decreased. CONCLUSION: Early individual intervention by a qualified rehabilitation team does not appear to impact on the long-term outcome for persons with symptoms related to mild traumatic brain injuries. The status after approximately 3 weeks is indicative of the status after 10 years.	
	Elgmark Andersson E, Emanuelson I, Bjorklund R, Stalhammar DA.	BACKGROUND: Positive results from early clinical intervention of mild traumatic brain injury (MTBI) patients by rehabilitation specialists have been reported. Various treatments have been used,	*RCT*

	Mild traumatic brain injuries: the impact of early intervention on late sequelae. A randomized controlled trial. *Acta Neurochir (Wien).*2007; 149(2):151-159; discussion 160.	but few controlled studies are published. We hypothesised that early rehabilitation of selected MTBI patients would reduce long term sequelae. METHOD: A randomised controlled trial with one year follow-up. Among 1719 consecutive patients with MTBI, 395 individuals, 16-60 years of age, met the MTBI definition. Exclusion criteria were: previous clinically significant brain disorders and/or a history of substance abuse. The control group (n = 131) received regular care. The intervention group (n = 264) was examined by a rehabilitation specialist. 78 patients were mainly referred to an occupational therapist. The problems were identified in daily activities and in terms of post-concussion symptoms (PCS), an individualised, tailored treatment was given. Primary endpoint was change in rate of PCS and in life satisfaction at one-year follow-up between the groups. FINDINGS: No statistical differences were found between the intervention and control groups. Patients who experienced few PCS two to eight weeks after the injury and declined rehabilitation recovered and returned to their pre-injury status. Patients who suffered several PCS and accepted rehabilitation did not recover after one year. INTERPRETATION: In this particular MTBI sample, early active rehabilitation did not change the outcome to a statistically-significant degree. Further studies should focus on patients with several complaints during the first 1-3 months and test various types of interventions.	
Onate JA	Onate JA, Beck BC, Van Lunen BL. On-field testing environment and balance error scoring system performance during preseason screening of healthy collegiate baseball players. *J Athl Train.* 2007;42(4):446-451.	CONTEXT: To determine if testing environment affects Balance Error Scoring System (BESS) scores in healthy collegiate baseball players. DESIGN: Experimental, randomized, repeated-measures design with a sample of convenience. SETTING: Uncontrolled sideline and controlled locker room baseball environments. PATIENTS OR OTHER PARTICIPANTS: A total of 21 healthy collegiate baseball players (age = 20.1 +/- 1.4 years, height = 185.1 +/- 6.8 cm, mass = 86.3 +/- 9.5 kg) with no history of head injury within the last 12 months, no lower extremity injuries reported within the past 2 months that caused them to miss 1 or more days of practice or game time, and no history of otitis media, Parkinson disease, or Meniere disease. MAIN OUTCOME MEASURE(S): Participants performed the BESS test in 2 environments, controlled locker room and uncontrolled sideline, in 2 testing sessions 1 week apart during the baseball preseason. The BESS scores were evaluated for each of the 6 conditions and total score across the testing sessions. Separate, paired-samples t tests with Bonferroni adjustment (P < .008) were used to examine differences between testing environments for each BESS subcategory and total score. Cohen d tests were calculated to evaluate effect sizes and relative change. RESULTS: Significant group mean differences were found between testing environments for single-leg foam stance (P = .001), with higher scores reported for the uncontrolled sideline environment (7.33 +/- 2.11 errors) compared with the controlled clinical environment (5.19 +/- 2.16 errors). Medium to large effect sizes (0.53 to 1.03) were also found for single-leg foam, tandem foam, and total BESS scores, with relative increases (worse scores) of 30% to 44% in the sideline environment compared with the clinical environment. CONCLUSIONS: The BESS performance was impaired when participants were tested in a sideline environment compared with a clinical environment. Baseline testing for postural control using the BESS should be conducted in the setting or environment in which testing after injury will most likely be conducted.	Experimental, randomized

Riemann BL	Riemann BL, Guskiewicz KM, Shields Relationship between clinical and force measures of postural stability. J Sport F 1999;8:71–82.	Although sophisticated forceplate systems are available for postural stability analyses, their use is limited in many sports medicine settings because of budgetary constraints. The purpose of this investigation was to compare a clinical method of evaluating postural stability with a force-platform sway measure. Participants completed a battery of three stance variations (double, single, and tandem) on two different surfaces (firm and foam) while standing on a force platform. This arrangement allowed for simultaneous comparisons between forceplate sway measures and clinical assessments using the Balance Error Scoring System (BESS). Significant correlations were revealed for the single-leg and tandem stances on the firm surface and for double, single, and tandem stances on the foam surface. These results suggest that the BESS is a reliable method of assessing postural stability in the absence of computerized balance systems.	Experi mental,
Hettich T	Hettich T, Whitfield E, Kratz K, Frament C. Case report: use of the Immediate Post Concussion Assessment and Cognitive Testing (ImPACT) to assist with return to duty determination of special operations soldiers who sustained mild traumatic brain injury. *J Spec Oper Med.* Fall 2010;10(4):48-55.		Case report
Piland SG	Piland SG, Ferrara MS, Macciocchi SN, Broglio SP, Gould TE. Investigation of baseline self-report concussion symptom scores. *J Athl Train.* May-Jun 2010;45(3):273-278.	CONTEXT: Self-reported symptoms (SRS) scales comprise one aspect of a multifaceted assessment of sport-related concussion. Obtaining SRS assessments before a concussion occurs assists in determining when the injury is resolved. However, athletes may present with concussion-related symptoms at baseline. Thus, it is important to evaluate such reports to determine if the variables that are common to many athletic environments are influencing them. OBJECTIVE: To evaluate the influence of a history of concussion, sex, acute fatigue, physical illness, and orthopaedic injury on baseline responses to 2 summative symptom scales; to investigate the psychometric properties of all responses; and to assess the factorial validity of responses to both scales in the absence of influential variables. DESIGN: Cross-sectional study. SETTING: Athletic training facilities of 6 National Collegiate Athletic Association institutions. PATIENTS OR OTHER PARTICIPANTS: The sample of 1065 was predominately male (n = 805) collegiate athletes with a mean age of 19.81 +/- 1.53 years. MAIN OUTCOME MEASURE(S): Participants completed baseline measures for duration and severity of concussion-related SRS and a brief health questionnaire. RESULTS: At baseline, respondents reporting a previous concussion had higher composite scores on both scales (P <or= .01), but no sex differences were found for concussion-related symptoms. Acute fatigue, physical illness, and orthopaedic injury increased composite SRS scores on both duration and severity measures (P <or= .01). Responses to both scales were stable and internally consistent. Confirmatory factor analysis provided strong evidence for the factorial validity of the responses of participants reporting no fatigue, physical illness, or orthopaedic injury on each instrument. CONCLUSIONS: A history of concussion, acute fatigue, physical illness, and orthopaedic injury increased baseline SRS scores.	Crossse ction

		These conditions need to be thoroughly investigated and controlled by clinicians before baseline SRS measures are collected.	
Piland SG	Piland SG, Motl RW, Ferrara MS, Peterson CL. Evidence for the factorial and construct validity of a s elf-report concussion symptoms scale. *J Athl Train.* 2003;38(2):104-112.	OBJECTIVE: To evaluate the factorial and construct validity of the Head Injury Scale (HIS) among a sample of male and female collegiate athletes. DESIGN AND SETTING: Using a cross-sectional design, we established the factorial validity of the HIS scale with confirmatory factor analysis and the construct validity of the HIS with Pearson product moment correlation analyses. Using an experimental design, we compared scores on the HIS between concussed and nonconcussed groups with a 2 (groups) x 5 (time) mixed-model analysis of variance. SUBJECTS: Participants (N = 279) in the cross-sectional analyses were predominately male (n = 223) collegiate athletes with a mean age of 19.49 +/- 1.63 years. Participants (N = 33) in the experimental analyses were concussed (n = 17) and nonconcussed control (n = 16) collegiate athletes with a mean age of 19.76 +/- 1.49 years. MEASUREMENTS: All participants completed baseline measures for the 16-item HIS, neuropsychological testing battery, and posturography. Concussed individuals and paired controls were evaluated on days 1, 2, 3, and 10 postinjury on the same testing battery. RESULTS: Confirmatory factor analysis indicated that a theoretically derived, 3-factor model provided a good but not excellent fit to the 16-item HIS. Hence, the 16-item HIS was modified on the basis of substantive arguments about item-content validity. The subsequent analysis indicated that the 3-factor model provided an excellent fit to the modified 9-item HIS. The 3 factors were best described by a single second-order factor: concussion symptoms. Scores from the 16-item HIS and 9-item HIS were strongly correlated, but there were few significant correlations between HIS scores and scores from the neuropsychological and balance measures. A significant group-by-day interaction was noted on both the 9-item HIS and 16-item HIS, with significant differences seen between groups on days 1 and 2 postconcussion. CONCLUSIONS: We provide evidence for the factorial and construct validity of the HIS among collegiate athletes. This scale might aid in return-to-play decisions by physicians and athletic trainers.	Cross section
Sullivan SJ	Sullivan SJ, Schneiders AG, Handcock P, Gray A, McCrory PR. Changes in the timed finger-to-nose task performance following exercise of different intensities. *Br J Sports Med.* 2011;45(1):46-48.	OBJECTIVE: The purpose of this study was to determine the effect of different levels of exercise intensity on the timed finger-to-nose (FTN) task, a measure of upper limb coordination included in the Sport Concussion Assessment Tool (SCAT2). METHODS: A three-group crossover randomised design was used to investigate changes in FTN times at three levels of exercise intensity; no exercise/rest (NE), moderate intensity exercise (ME) and high-intensity exercise (HE). Heart rates and a rating of perceived exertion (Borg Scale) were recorded to verify the level of exercise intensity. Participants performed three trials of the timed FTN task: pre-exercise, post-exercise and 15 min after the cessation of exercise. Linear mixed models were used to compare FTN change scores associated with exercise. RESULTS: Ninety asymptomatic participants (45male symbol:45female symbol) aged 18-32 years completed the study. Changes in FTN scores from pre-exercise showed that the HE condition was facilitated relative to NE at post-exercise (8% faster, 95% CI 5% to 10%, p<0.001) and at post-15 (3% faster, 95% CI 1% to 6%, p=0.005). ME did not show such a facilitation following exercise (2% faster, 95% CI 0% to 4%, p=0.081 and 1% faster, 95% CI 1% to 4%, p=0.225	crossov er randomi sed design

		respectively). CONCLUSIONS: Performance on the FTN task is enhanced by a short period of HE, and this effect persists for at least 15 min. There was no evidence of such an effect with ME.	
Snell FI	Snell FI, Halter MJ. A signature wound of war: mild traumatic brain injury. *J Psychosoc Nurs Ment Health* 2010;48(2):22-28.	Improvised explosive devices are the weapons of choice for the insurgent enemy in Iraq and Afghanistan. More soldiers are surviving these blast injuries due to improved torso protection yet are sustaining head and neck wounds in numbers that exceed those from previous wars. Although moderate and severe traumatic head injuries are easily identified and aggressively treated, mild traumatic brain injuries (m-TBIs), or concussions, had previously been deemed inconsequential and often overlooked. Recently, however, the U.S. Department of Defense and Veterans Health Administration have placed emphasis on identifying service members at risk for m-TBI because a select number continue to have disabling symptoms that can negatively affect quality of life. Research regarding the effects and treatment of blasts injury are gaining momentum, but further work needs to be accomplished. This article provides a three-question screening tool that can be used to identify these at-risk veterans.	5
Makdissi M	Makdissi M, McCrory P, Ugoni A, Dar Brukner P. A prospective study of postconcussive outcomes after return tc in Australian football. *Am J Sports Med* 2009;37(5):877-883.	BACKGROUND: Decisions regarding safe return to play after concussion in sport remain difficult. OBJECTIVE: To determine whether a concussed player returned to play using an individual clinical management strategy is at risk of impaired performance or increased risk of injury or concussion. STUDY DESIGN: Cohort study; Level of evidence, 3. METHODS: All elite Australian football players were followed for 4 seasons. Players were recruited into the study after sustaining a concussive injury. Outcome measures included performance statistics (disposals per hour match-time), injury rates, and recurrence of concussion on return to play. A subset of players had brief screening cognitive tests performed at baseline and after their concussion. Noninjured players matched for team, position, age, and size were chosen as controls. RESULTS: A total of 199 concussive injuries were observed in 158 players. Sixty-one concussive injuries were excluded from analysis because of incomplete data (45 players) or presence of concurrent injury (16 players). Of the 138 concussive injuries assessed, 127 players returned to play without missing a game (92%). The remainder of concussed players returned to play after missing a single game (8%). Overall, there was no significant decline in disposal rates in concussed players on return to competition. Furthermore, there were no significant differences in injury rates between concussed and team, position, and game-matched controls. In the subset of players who had completed screening cognitive tests, all had returned to their individual baseline performance before being returned to play. CONCLUSION: Return to play decisions based on individual clinical assessment of recovery allows safe and appropriate return to sport following a concussive injury.	Prospec tive- cohort
Kennedy JE	Kennedy JE, Lumpkin RJ, Grissom JR. A survey of mild traumatic brain injury treatment in the emergency room and primary care medical clinics. *Military Medicine.*	This study surveyed health care providers about their evaluation and treatment of mild traumatic brain injury (TBI) in adults. We presented two vignettes describing mild TBI cases to staff in the emergency department (N = 22) and primary care clinics (N = 16) at Wilford Hall Air Force Medical Center and asked how they would evaluate and treat these patients. Most providers said they would assess visual changes, nausea/vomiting, headache, and neck pain. More emergency department	Descript ive surbey

	2006;171(6):516-521.	personnel than primary care clinic providers would make referrals to different specialties, whereas more primary care clinic providers would schedule a follow-up appointment. Neither group of providers mentioned assessing common postconcussive symptoms of fatigue, emotional changes, and problems sleeping. Comparing findings to current literature suggest that added focus on emotional, cognitive and psychosocial factors, and education of the patient and family could improve early identification of mild TBI patients at risk for poor recovery.	Survey
Naunheim RS	Naunheim RS, Matero D, Fucetola R. Assessment of patients with mild concussion in the emergency department. *J Head Trauma Rehabil.* 2008;23(2):116-122.	OBJECTIVES: (1) To test the validity of the Standardized Assessment of Concussion (SAC) in characterizing the early evolution of concussion-related symptoms and mental status changes in the emergency department (ED) setting and (2) to compare it to the Conner's Continuous Performance Test 2nd Edition (CPT-II). DESIGN: Prospective within-subject (repeated measures) design. PARTICIPANTS: Sixty-two persons with concussion (Glasgow Coma Scale = 15) and negative head computed tomographic scan results were examined on arrival in the ED and 3 and 6 hours later. SETTING: A large urban, tertiary medical center ED. MAIN OUTCOME MEASURES: SAC; CPT-II; Post-Concussion Symptom Scale-Revised (PCS-R). RESULTS: SAC and CPT-II scores improved significantly over the time course in the ED. Symptoms did not correlate with improvement, with many subjects complaining of headache or nausea after their scores improved. The average initial score on the SAC was 21 +/- 5.4/30. Conclusion: The SAC appears sensitive to the acute changes following concussion. It may be a useful tool for clinicians in detecting mental status changes after a concussion, when Glasgow Coma Scale and radiologic findings are normal.	Prospec tive study
Brown CN	Brown CN, Guskiewicz KM, Bleiberg J. Athlete characteristics and outcome scores for computerized neuropsychological assessment: a preliminary analysis. *J Athl Train.* 2007;42(4):515-523.	CONTEXT: Computerized neuropsychological testing is used in athletics; however, normative data on an athletic population are lacking. OBJECTIVE: To investigate factors, such as sex, SAT score, alertness, and sport, and their effects on baseline neuropsychological test scores. A secondary purpose was to begin establishing preliminary reference data for nonsymptomatic collegiate athletes. DESIGN: Observational study. SETTING: Research laboratory. PATIENTS OR OTHER PARTICIPANTS: The study population comprised 327 National Collegiate Athletic Association Division I athletes from 12 men's and women's sports. MAIN OUTCOME MEASURE(S): Athletes were baseline tested before their first competitive season. Athletes completed demographics forms and self-reported history of concussion (1 or no concussion and 2 or more concussions) and SAT scores (<1000, 1000 to 1200, and >1200). The 108 women had a mean age of 18.39 +/- 0.09 years, height of 167.94 +/- 0.86 cm, and mass of 62.36 +/- 1.07 kg. The 219 men had a mean age of 18.49 +/- 0.07 years, height of 183.24 +/- 1.68 cm, and mass of 88.05 +/- 1.82 kg. Sports participation included women's soccer, lacrosse, basketball, and field hockey; men's football, soccer, lacrosse, and wrestling; and women's and men's track and cheerleading. We used the Automated Neuropsychological Assessment Metrics (Army Medical Research and Materiel Command, Ft Detrick, MD) and measured throughput scores (the number of correct responses per minute) as the dependent variable for each subtest, with higher scores reflecting increased speed and accuracy of responses. Subsets included 2 simple reaction time (SRT) tests, math processing (MTH), Sternberg memory search (ST6), matching to sample pairs (MSP), procedural reaction time (PRO), code digit	Observa tional

		substitution (CDS), and the Stanford sleep scale Likert-type score. RESULTS: Women scored better than men on the ST6 (P < .05), while men scored significantly better than women on the SRT and MSP tests. The highest-scoring SAT group performed better than other SAT groups on selected subtests (SRT, MTH, ST6, MSP, and CDS) (P < .05), and athletes tested during their season were more likely to score lower on the alertness scale (chi(2) (2)[n = 322] = 11.32, P = .003). The lowest alertness group performed worse on the MSP and CDS subtests (P < .05). No differences were found between the group with a history of 1 or no concussion and the group with a history of 2 or more concussions (P > .05). CONCLUSIONS: Performance on computerized neuropsychological tests may be affected by a number of factors, including sex, SAT scores, alertness at the time of testing, and the athlete's sport. To avoid making clinical misinterpretations, clinicians should acknowledge that individual baselines vary over time and should account for this variation.	
Makdissi M	Makdissi M, Collie A, Maruff P, et al. Computerised cognitive assessment of concussed Australian Rules footballers. *Br J Sports Med.* 2001;35(5):354-360.	BACKGROUND: "Paper and pencil" neuropsychological tests play an important role in the management of sports related concussions. They provide objective information on the athlete's cognitive function and thus facilitate decisions on safe return to sport. It has been proposed that computerised cognitive tests have many advantages over such conventional tests, but their role in this domain is yet to be established. OBJECTIVES: To measure cognitive impairment after concussion in a case series of concussed Australian Rules footballers, using both computerised and paper and pencil neuropsychological tests. To investigate the role of computerised cognitive tests in the assessment and follow up of sports related concussions. METHODS: Baseline measures on the Digit Symbol Substitution Test (DSST), Trail Making Test-Part B (TMT), and a simple reaction time (SRT) test from a computerised cognitive test battery (CogState) were obtained in 240 players. Tests were repeated in players who had sustained a concussive injury. A group of non-injured players were used as matched controls. RESULTS: Six concussions were observed over a period of nine weeks. At the follow up, DSST and TMT scores did not significantly differ from baseline scores in both control and concussed groups. However, analysis of the SRT data showed an increase in response variability and latency after concussion in the injured athletes. This was in contrast with a decrease in response variability and no change in latency on follow up of the control players (p<0.02). CONCLUSION: Increased variability in response time may be an important cognitive deficit after concussion. This has implications for consistency of an athlete's performance after injury, as well as for tests used in clinical assessment and follow up of head injuries.	Case-Control
Vorst MV	Vorst MV, Ono K, Chan P, Stuhmiller Correlates to traumatic brain injury in nonhuman primates. *J Trauma.* 2007;62(1):199-206.	BACKGROUND: Traumatic brain injury (TBI) is a major health problem, both in terms of the economic cost to society and the survivor's quality of life. The development of devices to protect against TBI requires criteria that relate observed injury to measurements of head kinematics. The objective of this study is to find the best statistical correlates to impact-induced TBI in nonhuman primates using a qualified, self-consistent set of historical kinematic and TBI data from impact tests on nonhuman primates. METHODS: A database was constructed and qualified from historical head impact tests on nonhuman primates. Multivariate logistic regression analysis with backwards stepwise elimination was performed. Variables considered are the peak rotational acceleration	4

		(Omegamax), the peak linear acceleration (Amax), and the number of impacts (N). RESULTS: Bivariate combinations of angular acceleration and the number of impacts are the best correlates to all modes of TBI considered, i.e., concussion, subarachnoid hemorrhage, brain contusion, and subdural hematoma. For a nonhuman primate with 100-g brain mass, the criteria that the probability of TBI is less than 10% by injury mode are:Concussion: OmegamaxN(0.84) < 70 krad/s/s SAH: OmegamaxN(0.70) < 160 krad/s/s Contusion: Omegamax N(0.35) < 160 krad/s/s SDH: Omegamax N(0.60) < 280 krad/s/s CONCLUSIONS: Based on this dataset, the best statistically based risk factor for all modes of TBI in nonhuman primates is the bivariate combination of rotational acceleration and number of impacts.	
Grubenhoff JA	Grubenhoff JA, Kirkwood M, Dexiang G, Deakyne S, Wathen J. Evaluation of the Standardized Assessment of Concussion in a Pediatric Emergency Department. *Pediatrics.* 2010;126(4):688-695.	OBJECTIVE: The Standardized Assessment of Concussion (SAC) is a validated tool for identifying the effects of mild traumatic brain injury (mTBI). Previous research focused on sport-related sideline evaluation of adolescents and adults. Our goal was to evaluate performance of the SAC among subjects with and without head injury in a pediatric emergency department (ED). METHODS: This was an observational study of children 6 to 18 years of age who presented to an ED with blunt head injury (case-patients) or minor extremity injury (controls). SAC and graded-symptom-checklist scores were compared. American Academy of Neurology concussion grades, presence of loss of consciousness and posttraumatic amnesia were also compared with SAC and graded-symptom-checklist scores among case-patients. RESULTS: Three hundred forty-eight children were enrolled. SAC scores trended lower (greater cognitive deficits) for case-patients compared with controls but did not reach significance. Graded-symptom-checklist scores were significantly higher among case-patients. Presence of altered mental status magnified this effect. There was no correlation between SAC scores and other indicators of mTBI. There was a positive correlation between graded-symptom-checklist scores and posttraumatic amnesia and American Academy of Neurology concussion grade. CONCLUSIONS: The graded symptom checklist reliably identified mTBl symptoms for all children aged 6 years and older. SAC scores tended to be lower for case-patients compared with controls but did not reach significance. Patients with altered mental status at the time of injury manifest an increased number and severity of symptoms. Additional research into strategies to identify cognitive deficits related to mTBI and classify mTBl severity in children is needed.	Observational study – Case-control
Rathlev NK	Rathlev NK, Medzon R, Lowery D, et al. Intracranial pathology in elders with blunt head trauma. *Acad Emerg Med.* 2006;13(3):302-307.	OBJECTIVES: To examine presentations and prevalence of head injury among elder victims of blunt trauma and to estimate the prevalence of occult injuries associated with a normal level of consciousness, absence of neurologic deficit, and no evidence of significant skull fracture. METHODS: The study population consisted of all patients aged 65 years or older enrolled in the National Emergency X-Radiography Utilization Study (NEXUS) II head injury cohort. The authors assessed the prevalence and patterns of intracranial injuries among this cohort and compared the prevalence of specific presenting signs and symptoms among injured and uninjured patients. An occult injury subcohort was also constructed, and injury prevalence was examined among this group. RESULTS: A total of 1,934 elder patients were identified among the 13,326 subjects in NEXUS II (14.5%). Significant intracranial injury, defined as an injury that typically requires procedural	National Emergency X-Radiography

		intervention or is associated with persistent neurologic impairment or long-term disability, was found in 178 elder patients (9.2%; 95% confidence interval = 8.0% to 10.6%) as compared with 697 individuals among 11,392 younger patients (6.1%; 95% confidence interval = 5.7% to 6.6%). Focal neurologic deficits were present in 55.8% of elder patients with injury. Prevalence of specific injuries among elder and younger patients, respectively, included the following: subdural hematoma, 4.4% and 2.4%; contusion, 4.0% and 3.2%; epidural hematoma, 0.5% and 1.0%; and depressed skull fracture, 0.2% and 0.5%. Forty-two elder patients (2.2%) had an occult injury, compared with only 92 younger patients (0.8%). CONCLUSIONS: Elder patients with head trauma are at higher risk of developing a significant intracranial injury, including subdural and epidural hematoma. An occult presentation is also more common in elders.	Utilization Study (NEXUS) II head injury cohort
DeMatteo CA	DeMatteo CA, Hanna SE, Mahoney WJ, et al. "My child doesn't have a brain injury, he only has a concussion" *Pediatrics.* 2010;125(2):327-334.	OBJECTIVE: The term "concussion" is frequently used in clinical records to describe a traumatic head injury; however, there are no standard definitions of this term, particularly in how it is used with children. The goals of this study were to examine the clinical correlates of the concussion diagnosis and to identify the factors that lead to the use of this term in a regional pediatric center. METHODS: Medical data were prospectively collected from 434 children with traumatic brain injury who were admitted to a Canadian children's hospital. A proportional hazards regression was used to examine the association of the concussion diagnosis and the times until discharge and school return. A classification-tree analysis modeled the clinical correlates of patients who received a concussion diagnosis. RESULTS: The concussion label was significantly more likely to be applied to children with mild Glasgow Coma Scale scores of 13 to 15 (P = .03). The concussion label was strongly predictive of earlier hospital discharge (odds ratio [OR]: 1.5; 95% confidence interval [CI]: 1.2-1.9; P = .003) and earlier return to school (OR: 2.4 [95% CI: 1.6-3.7]; P < .001). A diagnosis of a concussion was significantly more likely when the computed-tomography results were normal and the child had lost consciousness. CONCLUSIONS: Children with mild traumatic brain injuries have an increased frequency of receiving the concussion label, although the label may also be applied to children with more-severe injuries. The concussion diagnosis is associated with important clinical outcomes. Its typical use in hospital settings likely refers to an impact-related mild brain injury, in the absence of indicators other than a loss of consciousness. Clinicians may use the concussion label because it is less alarming to parents than the term mild brain injury, with the intent of implying that the injury is transient with no significant long-term health consequences.	Prospectively collected medical data
Lau B	Lau B, Lovell MR, Collins MW. Pardini J. Neurocognitive and symptom predictors of recovery in high school athletes. *Clin J Sport Med.* 2009;19(3):216-221.	OBJECTIVES: The purpose of this study was to identify specific symptom and neuropsychological test patterns that might serve as prognostic indicators of recovery in concussed high school football players. The recently proposed simple versus complex concussion classification was examined and specific symptom clusters were identified. DESIGN: Case-control study. SETTING: High school football. PARTICIPANTS: Subjects were 108 recently concussed male high school football athletes between the ages of 13 and 19 (mean, 16.01) years. ASSESSMENT OF RISK FACTORS:	Case-control study

		Participants were evaluated by utilizing the Immediate Postconcussion Assessment and Cognitive Testing computer-based neurocognitive test battery at before injury and within an average of 2.23 days of injury. All athletes were followed until they met criteria for clinical recovery. MAIN OUTCOME MEASURES: Symptom ratings and neurocognitive test performance. RESULTS: Both neurocognitive test results and self-reported symptom data had prognostic value in determining time to clinical recovery. Self-reported cognitive decline, Immediate Postconcussion Assessment and Cognitive Testing reaction time, and migraine headache symptoms were associated with longer time to clinical recovery. Overall, these difficulties were predictive of concussions that were retrospectively classified as complex. CONCLUSIONS: Specific symptom clusters and neurocognitive test results may have predictive value to classifying and managing concussions.	
Valovich McLeod TC	Valovich McLeod TC, Barr WB, McCrea M, Guskiewicz KM. Psychometric and measurement properties of concussion assessment tools in youth sports. *J Athl Train.* 2006;41(4):399-408.	Context: Establishing psychometric and measurement properties of concussion assessments is important before these assessments are used by clinicians. To date, data have been limited regarding these issues with respect to neurocognitive and postural stability testing, especially in a younger athletic population. Objective: To determine the test-retest reliability and reliable change indices of concussion assessments in athletes participating in youth sports. A secondary objective was to determine the relationship between the Standardized Assessment of Concussion (SAC) and neuropsychological assessments in young athletes. Design: We used a repeated-measures design to evaluate the test-retest reliability of the concussion assessments in young athletes. Correlations were calculated to determine the relationship between the measures. All subjects underwent 2 test sessions 60 days apart. Setting: Sports medicine laboratory and school or home environment. Patients or Other Participants: Fifty healthy young athletes between the ages of 9 and 14 years. Main Outcome Measure(s): Scores from the SAC, Balance Error Scoring System, Buschke Selective Reminding Test, Trail Making Test B, and Coding and Symbol Search subsets of the Wechsler Intelligence Scale for Children were used in the analysis. Results: Our test-retest indices for each of the 6 scores were poor to good, ranging from r = .46 to .83. Good reliability was found for the Coding and Symbol Search tests. The reliable change scores provided a way of determining a meaningful change in score for each assessment. We found a weak relationship (r < .36) between the SAC and each of the neuropsychological assessments; however, stronger relationships (r > .70) were found between certain neuropsychological measures. Conclusions: We found moderate test-retest reliability on the cognitive tests that assessed attention, concentration, and visual processing and the Balance Error Scoring System. Our results demonstrated only a weak relationship between performance on the SAC and the selected neuropsychological tests, so it is likely that these tests assess somewhat different areas of cognitive function. Our correlational findings provide more evidence for using the SAC along with a more complex neuropsychological assessment battery in the evaluation of concussion in young athletes.	Reliability of the concussion assessments in young athletes
Sveen U	Sveen U, Bautz-Holter E, Sandvik L, Alvs√•ker K, R√∏e C. Relationship between competency in activities,	Objective: To determine to what extent injury severity and post-concussion symptoms after 3 months predict ability in activities 12 months after traumatic brain injury (TBI) and assess the frequency of problems in daily activities. Methods: A one-year cohort of 63 persons with mild to severe TBI was	Cohort

	injury severity, and post-concussion symptoms after traumatic brain injury. *J Occup Ther*. 2010;17(3):225-232.	assessed on admission, after three and 12 months. Injury severity was assessed using the Glasgow Coma Scale, Abbreviated Injury Scale for the head and Injury Severity Score. Post-concussion symptoms were reported using the Rivermead Post Concussion Symptoms Questionnaire after three months. The Patient Competency Rating Scale (PCRS), a self-rating scale of ability in activities, was applied 12 months post-injury. The PCRS consists of the domains interpersonal/emotional and cognitive competency, and instrumental ADL. Multiple backward regression models were performed with the three subscales of PCRS as dependent variables. Results: Activity problems at 12 months were related to perceived cognitive and interpersonal/emotional competency. Post-concussion symptoms reported at three-month follow-up were main predictors of cognitive and interpersonal/emotional competency at 12 months. Injury severity predicted only cognitive competency. Conclusion: Symptoms evolving after the trauma seem to be the strongest predictor of perceived ability in activities in this population. This underlines the need for follow-up after TBI to identify persons at risk of developing long-term activity limitations.	
Leddy JJ	Leddy JJ, Baker JG, Kozlowski K, Bisson L, Willer B. Reliability of a Graded Exercise Test for Assessing Recovery From Concussion. *Clin J Sport Med.* 2011;21(2):89-94.	Objective: To evaluate a graded treadmill test for retest reliability (RTR) and interrater reliability (IRR) in the evaluation of the physiologic effects of symptom exacerbation from concussion. Design: Prospective case series (RTR) and blinded rater assessment of 10 actors portraying patients with and without symptom exacerbation (IRR). Setting: University Sports Medicine Concussion Clinic. Participants: For RTR, 21 refractory concussed patients (11 athletes and 10 nonathletes) and 10 healthy subjects; for IRR, 32 raters representing a variety of health care disciplines. Intervention: For RTR, a Balke protocol treadmill test to symptom exacerbation before and after 2 to 3 weeks. For IRR, video recordings of actors during the treadmill test viewed by raters blinded to condition. Main Outcome Measures: For RTR, agreement of the tests for maximal heart rate (HR), systolic blood pressure, diastolic blood pressure, and rating of perceived exertion. For IRR, presence or absence of symptom exacerbation and the symptom exacerbation HR. Results: Raters achieved a sensitivity of 99% for identifying actors with symptom exacerbation and a specificity of 89% for ruling out concussion symptoms and agreed on 304 of 320 observations (accuracy of 95%). The intraclass correlation coefficient for the symptom exacerbation HR was large at 0.90 (95% confidence interval, 0.78-0.98). The treadmill test had good RTR for maximum HR (intraclass correlation coefficient, 0.79) but not for systolic blood pressure, diastolic blood pressure, or rating of perceived exertion. Conclusions: The Balke exercise treadmill protocol has very good IRR and sufficient RTR for identifying patients with symptom exacerbation from concussion.	Prospec tive case series
Broglio SP	Broglio SP, Ferrara MS, Sopiarz K, Kelly MS. Reliable change of the Sensory Organization Test. *Clin J Sport Med.* 2008;18(2):148-154.	OBJECTIVE: To establish the sensitivity and specificity of the NeuroCom Sensory Organization Test (SOT) and provide practitioners with cut-scores for clinical decision making using estimates of reliable change. DESIGN: Retrospective cohort study. SETTING: Research laboratory. PATIENTS: Healthy (n = 66) and concussed (n = 63) young adult participants. INTERVENTIONS: Postural control assessments on the NeuroCom SOT were completed twice (baseline and follow-up) for both groups. Postconcussion assessments were administered within 24 hours of injury diagnosis. MAIN OUTCOME MEASUREMENTS: The reliable change technique was used to calculated cut-scores	Retrosp ective cohort study

		for each SOT variable (composite balance; somatosensory, visual, and vestibular ratios) at the 95%, 90%, 85%, 80%, 75%, and 70% confidence interval levels. RESULTS: When cut-scores were applied to the post-concussion evaluations, sensitivity and specificity varied with SOT variable and confidence interval. An evaluation for change on one or more SOT variable resulted in the highest combined sensitivity (57%) and specificity (80%) at the 75% confidence interval. CONCLUSIONS: Use of reliable change scores to detect significant changes in performance on the SOT resulted in decreased sensitivity and improved specificity compared to a previous report. These findings indicate that some concussed athletes may not show large changes in postconcussion postural control and this postural control evaluation should not be used in exclusion of other assessment techniques. The postural control assessment should be combined with other evaluative measures to gain the highest sensitivity to concussive injuries.	
Coghlin CJ	Coghlin CJ, Myles BD, Howitt SD. The ability of parents to accurately report concussion occurrence in their Bantam-aged minor hockey league children. *J Can Chiropr Assoc.* 2009;53(4):233-250.	Objective: The objective of this study was to assess the ability of hockey parents/guardians to recognize concussion symptoms in their 13-14 year old (Bantamaged) children. Outcome Measures: The outcome measures were the ability to recognize different signs and symptoms listed on the Sport Concussion Assessment Tool (SCAT) as well as 8 detractors consisting of signs and symptoms not associated with post concussive syndrome. Additional questions assessing the parents' knowledge of concussion management and recognition abilities were also posed. Participants: Parents of Bantam-aged minor hockey league athletes volunteered for the study. Methods: The study investigators distributed questionnaires during the warm up period or following their children's games to the study participants. Following questionnaire completion, participants were provided with an information package outlining the correct signs and symptoms of concussion. Results: The mean number of correct responses to signs and symptoms of concussion was 21.25/25 for the mothers and 20.41/25 for the fathers. The mean number of detractors identified as not associated with concussion was 5.93/8 for the mothers and 4.85/8 for the fathers, indicating that mothers were more capable of recognizing the signs and symptoms than fathers. An analysis of variance including sporting experience in the model did not strengthen the relationship between parent gender and test outcome. Conclusion: This investigation revealed that there is still a disconnect in regards to key components of recognizing a concussion, such as difficulty with sleep, disorientation symptoms, and emotional irritability. Mothers have displayed an ability to better differentiate between true and false signs and symptoms of concussion as compared to fathers. Continued education and awareness of mild traumatic brain injury in athletes should address the misconceptions amongst parents in regards to the true signs and symptoms of a concussion.	Descriptive Survey
Shuttleworth-Edwards AB	Shuttleworth-Edwards AB, Noakes TD, Radloff SE, et al. The comparative incidence of reported concussions presenting for follow-up management in South African Rugby Union. *Clin J Sport Med.* 2008;	OBJECTIVE: The objective of this study was to compare the seasonal concussion incidence for school, university, club and provincial level Rugby Union players in South Africa. DESIGN: The study presents a retrospective statistical analysis of the number of reported concussions documented annually for groups of Rugby Union players as a proportion of those who received preseason neurocognitive assessment. SETTING: Between 2002 and 2006, concussion management programs using computerized neuropsychological assessment were implemented for clinical and research	Retrospective statistical

	18(5):403-409.	purposes by psychologists in selected South African institutions involved in Rugby Union from school through to the professional level. PARTICIPANTS: The incidence figures were based on 175 concussive episodes reported for 165 athletes who were referred for neurocognitive assessment from a population of 1366 athletes who received preseason baseline testing. INTERVENTIONS: Concussion management routines varied according to the protocols adopted by the different psychologists and rugby organizations. MAIN OUTCOME MEASUREMENTS: It was expected that the incidence of concussion would vary significantly due to level of play and different management protocols. RESULT: There was wide disparity in the manner in which concussion follow-up was managed by the various organizations. Within broadly comparable cohorts, tighter control was associated with a relatively higher concussion incidence for athletes per rugby playing season, with average institutional figures ranging from 4% to 14% at school level and 3% to 23% at adult level. CONCLUSIONS: This analysis suggests that concussion goes unrecognized and therefore incorrectly managed in a number of instances. Recommendations for optimal identification of concussed athletes for follow-up management are presented.	analysis
Broglio SP	Broglio SP, Puetz TW. The effect of sport concussion on neurocognitive function, self-report symptoms and postural control: a meta-analysis. *Sports Medicine.* 2008;38(1):53-67.	Sport concussion is commonly assessed using a battery of tests that evaluate neurocognitive functioning, postural control and self-report symptoms. The degree to which concussion affects each of these measures is unclear. Thus, the purpose of this meta-analysis is to systematically review and quantify the effect of sport concussion on each assessment measure when administered immediately post-injury and in the 2 weeks following injury. PubMed and PsychINFO databases were searched from January 1970 to June 2006, from which 39 were included for review. Studies were selected for review if they included concussed athletes who were evaluated using one of the three assessment measures. One post-morbid assessment must have been completed within 14 days of injury and compared with a baseline measure or control group. Study design, type of neurocognitive assessment, timing of assessment following injury and number of post-concussion assessments were extracted as potential moderators. Sport-related concussion had a large negative effect (mean Delta; 95% confidence interval) on neurocognitive functioning (-0.81; -1.01, -0.60), self-report symptoms (-3.31; -6.35, -0.27) and postural control (-2.56; -6.44, 1.32) in the initial assessment following injury. A reduced, but large effect, was also seen in the 14 days following the initial assessment for neurocognitive functioning (-0.26; -0.46, -0.06), self-report symptoms (-1.09; -2.07, -0.11) and postural control (-1.16; -2.59, 0.27). Our findings demonstrated large effects for each aspect of the assessment battery. These findings support the use of the multifaceted concussion evaluation.	Meta- Any
	Beckwith JG, Chu JJ, Greenwald RM. Validation of a noninvasive system for measuring head acceleration for use du boxing competition. *J Appl Biomech.* 2007;23(3):238-244.	Although the epidemiology and mechanics of concussion in sports have been investigated for many years, the biomechanical factors that contribute to mild traumatic brain injury remain unclear because of the difficulties in measuring impact events in the field. The purpose of this study was to validate an instrumented boxing headgear (IBH) that can be used to measure impact severity and location during play. The instrumented boxing headgear data were processed to determine linear and rotational acceleration at the head center of gravity, impact location, and impact severity metrics, such as the Head Injury Criterion (HIC) and Gadd Severity Index (GSI). The instrumented boxing	4

		headgear was fitted to a Hybrid III (HIII) head form and impacted with a weighted pendulum to characterize accuracy and repeatability. Fifty-six impacts over 3 speeds and 5 locations were used to simulate blows most commonly observed in boxing. A high correlation between the HIII and instrumented boxing headgear was established for peak linear and rotational acceleration (r2 = 0.91), HIC (r2 = 0.88), and GSI (r2 = 0.89). Mean location error was 9.7 - 5.2DG. Based on this study, the IBH is a valid system for measuring head acceleration and impact location that can be integrated into training and competition.	
Ivins BJ	Ivins BJ, Crowley JS, Johnson J, Ward Schwab KA. Traumatic brain injury ris parachuting: comparison of the personr armor system for ground troops helmet the advanced combat helmet. *Military Medicine.* 2008;173(12):1168-1172.	Military paratroopers are inherently at risk for a variety of injuries when they jump, including traumatic brain injuries (TBIs). U.S. Army paratroopers rely on their ballistic helmets for protection against TBIs when jumping. Currently, two different helmets are available to Army paratroopers, that is, the personnel tumor system for ground troops helmet and the advanced combat helmet. This study compared the incidence of self reported, jump-related TBIs in a small sample of paratroopers (N = 585) using each type of helmet. Data were obtained from surveys of soldiers at Fort Bragg, North Carolina. The overall relative risk of sustaining a TBI while jumping was 2.3 times (95% confidence interval, 1.3-4.3) higher for personnel armor system for ground troops helmet users. Most of the increase in risk was accounted for by the most-minor TBIs American Academy of Neurology grade I or 2 concussion).	Prospec tive- small

Level of Evidence	Definitions (See manuscript for full details)
Level 1a	**Experimental and Population based studies -** population based, randomized prospective studies or meta-analyses of multiple higher evidence studies with substantial effects
Level 1b	**Smaller Experimental and Epidemiological studies -** Large non-population based epidemiological studies or randomized prospective studies with smaller or less significant effects
Level 2a	**Prospective Observational Analytical** - Controlled, non-randomized, cohort studies
Level 2b	**Retrospective/Historical Observational Analytical** - non-randomized, cohort or case-control studies
Level 3a	**Large Descriptive studies** – Cross-section, Ecological, Case series, Case reports
Level 3b	**Small Descriptive studies** – Cross-section, Ecological, Case series, Case reports
Level 4	**Animal studies or mechanical model studies**
Level 5	**Peer-reviewed Articles** - state of the art articles, review articles, organizational statements or guidelines, editorials, or consensus statements
Level 6	**Non-peer reviewed published opinions -** such as textbook statements, official organizational publications, guidelines and policy statements which are not peer reviewed and consensus statements
Level 7	**Rational conjecture** (common sense); common practices accepted before evidence-based guidelines
Level 1-6E	**Extrapolations** from existing data collected for other purposes, theoretical analyses which is on-point with question being asked. Modifier E applied because extrapolated but ranked based on type of study.

American Red Cross

Scientific Advisory Council

ARC SAC Scientific Review
Mild Traumatic Brain Injury (concussion)

References

1. Centers for Disease Control and Prevention. Traumatic brain injury. 2011; http://www.cdc.gov/traumaticbraininjury/. Accessed December 17, 2011.
2. Vorst MV, Ono K, Chan P, Stuhmiller J. Correlates to traumatic brain injury in nonhuman primates. *J Trauma.* 2007;62(1):199-206.
3. DeMatteo CA, Hanna SE, Mahoney WJ, et al. "My child doesn't have a brain injury, he only has a concussion". *Pediatrics.* 2010;125(2):327-334.
4. Grubenhoff JA, Kirkwood M, Dexiang G, Deakyne S, Wathen J. Evaluation of the Standardized Assessment of Concussion in a Pediatric Emergency Department. *Pediatrics.* 2010;126(4):688-695.
5. Rathlev NK, Medzon R, Lowery D, et al. Intracranial pathology in elders with blunt head trauma. *Acad Emerg Med.* 2006;13(3):302-307.
6. Ropper AH, Gorson KC. Clinical practice. Concussion. *N Engl J Med.* 2007;356(2):166-172.
7. Sheedy J, Harvey E, Faux S, Geffen G, Shores EA. Emergency department assessment of mild traumatic brain injury and the prediction of postconcussive symptoms: a 3-month prospective study. *Journal of Head Trauma Rehabilitation.* 2009;24(5):333-343.
8. Kennedy JE, Jaffee MS, Leskin GA, Stokes JW, Leal FO, Fitzpatrick PJ. Posttraumatic stress disorder and posttraumatic stress disorder-like symptoms and mild traumatic brain injury. *Journal of Rehabilitation Research & Development.* 2007;44(7):895-919.
9. Guskiewicz KM, Bruce SL, Cantu RC, et al. National Athletic Trainers' Association position statement: management of sport-related concussion. *J Athl Train.* 2004;39(3):280-297. http://www.nata.org/sites/default/files/MgmtOfSportRelatedConcussion.pdf.
10. McCrory P, Meeuwisse W, Johnston K, et al. Consensus statement on concussion in sport: the 3rd International Conference on Concussion in Sport held in Zurich, November 2008. *J Athl Train.* 2009;44(4):434-448.
11. Bell KR, Hoffman JM, Temkin NR, et al. The effect of telephone counselling on reducing post-traumatic symptoms after mild traumatic brain injury: a randomised trial. *J Neurol Neurosurg Psychiatry.* 2008;79(11):1275-1281.
12. Department of Veterans Affairs and Department of Defense. VA/ DOD clinical practice guideline for management of concussion/mild traumatic brain injury. 2009; http://www.healthquality.va.gov/mtbi/concussion_mtbi_full_1_0.pdf. Accessed December 18, 2011.
13. Snell FI, Halter MJ. A signature wound of war: mild traumatic brain injury. *J Psychosoc Nurs Ment Health Serv.* 2010;48(2):22-28.
14. Belanger HG, Uomoto JM, Vanderploeg RD. The Veterans Health Administration's (VHA's) Polytrauma System of Care for mild traumatic brain injury: costs, benefits, and controversies. *J Head Trauma Rehabil.* 2009;24(1):4-13.
15. Thompson JM, Scott KC, Dubinsky L. Battlefield brain: unexplained symptoms and blast-related mild traumatic brain injury. *Can Fam Physician.* 2008;54(11):1549-1551.

16. Ivins BJ, Crowley JS, Johnson J, Warden DL, Schwab KA. Traumatic brain injury risk while parachuting: comparison of the personnel armor system for ground troops helmet and the advanced combat helmet. *Military Medicine.* 2008;173(12):1168-1172.

17. Polito MZ, Thompson JW, DeFina PA. A review of the International Brain Research Foundation novel approach to mild traumatic brain injury presented at the International Conference on Behavioral Health and Traumatic Brain Injury. *J Am Acad Nurse Pract.* 2010;22(9):504-509.

18. Maruta J, Lee SW, Jacobs EF, Ghajar J. A unified science of concussion. *Ann N Y Acad Sci.* 2010;1208:58-66.

19. Gennarelli T. Mechanisms of brain injury. *J Emerg Med.* 1993;11(suppl 1):5-11.

20. Beckwith JG, Chu JJ, Greenwald RM. Validation of a noninvasive system for measuring head acceleration for use during boxing competition. *J Appl Biomech.* 2007;23(3):238-244.

21. Lau B, Lovell MR, Collins MW, Pardini J. Neurocognitive and symptom predictors of recovery in high school athletes. *Clin J Sport Med.* 2009;19(3):216-221.

22. Petchprapai N, Winkelman C. Mild traumatic brain injury: determinants and subsequent quality of life. A review of the literature. *J Neurosci Nurs.* Oct 2007;39(5):260-272.

23. Broglio SP, Puetz TW. The effect of sport concussion on neurocognitive function, self-report symptoms and postural control: a meta-analysis. *Sports Medicine.* 2008;38(1):53-67.

24. Valovich McLeod TC, Barr WB, McCrea M, Guskiewicz KM. Psychometric and measurement properties of concussion assessment tools in youth sports. *J Athl Train.* 2006;41(4):399-408.

25. Coghlin CJ, Myles BD, Howitt SD. The ability of parents to accurately report concussion occurrence in their Bantam-aged minor hockey league children. *J Can Chiropr Assoc.* 2009;53(4):233-250.

26. Centers for Disease Control and Prevention. *Heads Up: Brain Injury in Your Practice*. Atlanta, GA: U.S. Department of Health and Human Services; 2007.

27. Coronado VG, Xu L, Basavaraju SV, et al. Surveillance for traumatic brain injury-related deaths--United States, 1997-2007. *MMWR.* 2011;60(5):1-32.

28. Ptito A, Chen JK, Johnston KM. Contributions of functional magnetic resonance imaging (fMRI) to sport concussion evaluation. *Neuro Rehab.* 2007;22(3):217-227.

29. Mosenthal AC, Livingston DH, Lavery RF, et al. The effect of age on functional outcome in mild traumatic brain injury: 6-month report of a prospective multicenter trial. *J Trauma.* May 2004;56(5):1042-1048.

30. Levin HS, Hanten G, Roberson G, et al. Prediction of cognitive sequelae based on abnormal computed tomography findings in children following mild traumatic brain injury. *J Neurosurg Pediatr.* 2008;1(6):461-470.

31. Ruff RM, Jurica P. In search of a unified definition for mild traumatic brain injury. *Brain Inj.* Dec 1999;13(12):943-952.

32. Hettich T, Whitfield E, Kratz K, Frament C. Case report: use of the Immediate Post Concussion Assessment and Cognitive Testing (ImPACT) to assist with return to duty determination of special operations soldiers who sustained mild traumatic brain injury. *J Spec Oper Med.* Fall 2010;10(4):48-55.

33. Kelly JP, Nichols JS, Filley CM, Lillehei KO, Rubinstein D, Kleinschmidt-DeMasters BK. Concussion in sports. Guidelines for the prevention of catastrophic outcome. *JAMA.* 1991;266(20):2867-2869.
34. Holm L, Cassidy JD, Carroll LJ, Borg J. Summary of the WHO Collaborating Centre for Neurotrauma Task Force on Mild Traumatic Brain Injury. *J Rehabil Med.* 2005;37(3):137-141.
35. de Kruijk JR, Leffers P, Meerhoff S, Rutten J, Twijnstra A. Effectiveness of bed rest after mild traumatic brain injury: a randomised trial of no versus six days of bed rest. *J Neurol Neurosurg Psychiatry.* Aug 2002;73(2):167-172.
36. American Congress on Rehabilitation Medicine. Definition of mild traumatic brain injury. *J Head Trauma Rehabil.* 1993;1993(8):3.
37. American Academy of Neurology. Practice parameter: the management of concussion in sports (summary statement). Report of the Quality Standards Subcommittee. *Neurology.* 1997;48(3):581-585.
38. Canadian Paediatric Society. Identification and management of children with sport-related concussion. *Paediatr Child Health.* 2006;11(7):420-428.
39. Weightman MM, Bolgla R, McCulloch KL, Peterson MD. Physical therapy recommendations for service members with mild traumatic brain injury. *J Head Trauma Rehabil.* May-Jun 2010;25(3):206-218.
40. Barkhoudarian G, Hovda DA, Giza CC. The molecular pathophysiology of concussive brain injury. *Clin Sports Med.* 2011;30(1):33-48.
41. Makdissi M, Collie A, Maruff P, et al. Computerised cognitive assessment of concussed Australian Rules footballers. *Br J Sports Med.* 2001;35(5):354-360.
42. Shuttleworth-Edwards AB, Noakes TD, Radloff SE, et al. The comparative incidence of reported concussions presenting for follow-up management in South African Rugby Union. *Clin J Sport Med.* 2008;18(5):403-409.
43. Leddy JJ, Baker JG, Kozlowski K, Bisson L, Willer B. Reliability of a Graded Exercise Test for Assessing Recovery From Concussion. *Clin J Sport Med.* 2011;21(2):89-94.
44. Broglio SP, Ferrara MS, Sopiarz K, Kelly MS. Reliable change of the Sensory Organization Test. *Clin J Sport Med.* 2008;18(2):148-154.
45. Brown CN, Guskiewicz KM, Bleiberg J. Athlete characteristics and outcome scores for computerized neuropsychological assessment: a preliminary analysis. *J Athl Train.* 2007;42(4):515-523.
46. Makdissi M, McCrory P, Ugoni A, Darby D, Brukner P. A prospective study of postconcussive outcomes after return to play in Australian football. *Am J Sports Med.* 2009;37(5):877-883.
47. Smith-Seemiller L, Fow NR, Kant R, Franzen MD. Presence of post-concussion syndrome symptoms in patients with chronic pain vs mild traumatic brain injury. *Brain Inj.* 2003;17(3):199-206.
48. Piland SG, Ferrara MS, Macciocchi SN, Broglio SP, Gould TE. Investigation of baseline self-report concussion symptom scores. *J Athl Train.* 2010;45(3):273-278.
49. Brenner LA, Vanderploeg RD, Terrio H. Assessment and diagnosis of mild traumatic brain injury, posttraumatic stress disorder, and other polytrauma conditions: burden of adversity hypothesis. *Rehabil Psychol.* 2009;54(3):239-246.
50. Andersson EE, Bedics BK, Falkmer T. Mild traumatic brain injuries: a 10-year follow-up. *J Rehabil Med.* 2011;43(4):323-329.

51. Broomhall LG, Clark CR, McFarlane AC, et al. Early stage assessment and course of acute stress disorder after mild traumatic brain injury. *J Nerv Ment Dis.* 2009;197(3):178-181.
52. Cohen JS, Gioia G, Atabaki S, Teach SJ. Sports-related concussions in pediatrics. *Curr Opin Pediatr.* 2009;21(3):288-293.
53. Gioia GA, Collins M, Isquith PK. Improving identification and diagnosis of mild traumatic brain injury with evidence: psychometric support for the acute concussion evaluation. *The Journal of head trauma rehabilitation.* 2008;23(4):230-242.
54. Bay E. Mild traumatic brain injury: a midwest survey about the assessment and documentation practices of emergency department nurses. *Adv Emerg Nurs J.* 2011;33(1):71-83.
55. Covassin T, Stearne D, Elbin R. Concussion history and postconcussion neurocognitive performance and symptoms in collegiate athletes. *J Athl Train.* 2008;43(2):119-124.
56. Elgmark Andersson E, Emanuelson I, Bjorklund R, Stalhammar DA. Mild traumatic brain injuries: the impact of early intervention on late sequelae. A randomized controlled trial. *Acta Neurochir (Wien).* 2007;149(2):151-159; discussion 160.
57. Onate JA, Beck BC, Van Lunen BL. On-field testing environment and balance error scoring system performance during preseason screening of healthy collegiate baseball players. *J Athl Train.* 2007;42(4):446-451.
58. Riemann BL, Guskiewicz KM, Shields EW. Relationship between clinical and forceplate measures of postural stability. *J Sport Rehabil.* 1999;8:71-82.
59. Piland SG, Motl RW, Ferrara MS, Peterson CL. Evidence for the factorial and construct validity of a self-report concussion symptoms scale. *Journal of Athletic Training.* 2003;38(2):104-112.
60. Sullivan SJ, Schneiders AG, Handcock P, Gray A, McCrory PR. Changes in the timed finger-to-nose task performance following exercise of different intensities. *Br J Sports Med.* 2011;45(1):46-48.
61. Kennedy JE, Lumpkin RJ, Grissom JR. A survey of mild traumatic brain injury treatment in the emergency room and primary care medical clinics. *Military Medicine.* 2006;171(6):516-521.
62. Naunheim RS, Matero D, Fucetola R. Assessment of patients with mild concussion in the emergency department. *J Head Trauma Rehabil.* 2008;23(2):116-122.
63. Sveen U, Bautz-Holter E, Sandvik L, Alvs√•ker K, R√∏e C. Relationship between competency in activities, injury severity, and post-concussion symptoms after traumatic brain injury. *Scand J Occup Ther.* 2010;17(3):225-232.