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reSearch

A collection of research reviews on rehabilitation topics from NARIC and other information resources.

Sports-Related Concussion

In this edition of *reSearch* we explore the topic of sports-related concussion. In recent years, concussions due to head trauma have been in the news, specifically those associated with professional and youth sports. A concussion is a type of mild traumatic brain injury (TBI) that is caused by a direct bump, blow, or jolt to the head and that affects the brain from functioning normally. Symptoms of a concussion may include physical (e.g., headaches, nausea), cognitive (e.g., difficulty with concentration or memory), emotional (e.g., irritability, sadness), and metabolic (e.g., sleep disturbances, changes in appetite or energy levels) changes. Sports-related concussion may occur when an athlete's skull contacts another object (i.e., an opponent, the ball, or the ground) or comes to an abrupt halt (as in whiplash), causing the brain to rebound off of, or twist up against, the inside of the skull (<http://www.acsm.org/access-public-information/articles/2012/01/13/sport-related-concussions>). The shearing force can cause damage to blood vessels resulting in swelling and bleeding in the brain. Additionally, neurons can also be damaged impairing the brain's ability to convey information from one area of the brain to another. Although concussions are considered a "mild" and are often non-life threatening, they can have lasting effects. Repetitive brain trauma may have long-term neurological consequences such as [post-concussion syndrome \(PCS\)](#), [chronic traumatic encephalopathy \(CTE\)](#), and [chronic neurocognitive impairment \(CNI\)](#).

Naturally, avoiding concussion altogether would be ideal but sometimes that is not possible. The American College of Sports Medicine recommends several steps to reduce the chances of sustaining an injury:

1. Maintaining and properly using athletic equipment that meets recommended safety standards.
2. Educating athletes on proper tackling and heading techniques used in sports such as football and soccer.
3. Educating athletes, coaches, and parents on the signs and symptoms of concussions to avoid secondary injury.

This edition of *reSearch* provides a "snapshot" of over 20 years of research on sports-related concussion. This "snapshot" presents a general overview of this type of concussion: incidence; diagnosis, evaluation, and treatment; long-term effects, guidelines and recommendations; and professional and non-professional youth, young adult, and adult athletes. The combined search terms for this edition of *reSearch* included: sports-related concussion, concussion sports, head injury sports, brain injury sports, and traumatic encephalopathy. A listing of over 150 additional descriptor terms between the NARIC, CIRRIE, National Guideline Clearinghouse (NGC), ERIC, Cochrane, PEDro, and PubMed databases can be found at the end of this document.

A search of the REHABDATA database resulted in 47 documents published between 1993 and 2013. The CIRRIE and NGC database searches resulted in 3 documents between 2005 and 2012 and 1 document from 2007; respectively. The ERIC database search resulted in 26 documents from 1989 to 2013. The Cochrane and PEDro database searches resulted in 2 documents between 2001 and 2006 and 2 documents between 2012 and 2013; respectively. Finally, a search of the PubMed database resulted in 145 documents between 1991 and 2014. The complete citations are included in this research brief.

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NIDRR Funded Projects Related to Sports-Related Concussion

In addition to document searches, we searched our NIDRR Program Database to locate grantees/projects related to sports-related concussion. The search resulted in 20 currently funded projects including 15 TBI Model Systems, and 7 projects that are no longer active. Project information and their publications are offered as additional resources for our patrons.

TBI Model Systems (By State)

UAB Traumatic Brain Injury Model System – Alabama

Project Number: H133A120096
Phone: 205/934-3283
Email: tbi@uab.edu
www.uab.edu/tbi

The Rocky Mountain Regional Brain Injury Model System (RMRBIMS) – Colorado

Project Number: H133A120032
Phone: 303/789-8565
Email: charrison-felix@craighospital.org
www.craighospital.org/programs/traumatic-brain-injury

South Florida Traumatic Brain Injury Model System (SF-TBIMS) – Florida

Project Number: H133A120099
Phone: 305/243-8472, 305/243-4569
Email: djgreene@med.miami.edu

Brain Research in Aggression and Irritability Network (BRAIN): Building Evidence-Based Approaches to Managing Traumatic Brain Injury – Indiana

Project Number: H133A120035
Email: flora.hammond@rhin.com
Phone: 317/329-2106

Spaulding-Harvard Traumatic Brain Injury Model System – Massachusetts

Project Number: H133A120085
Email: SpauldingHarvardTBIMS@partners.org
www.sh-tbi.org

Mayo Clinic Traumatic Brain Injury Model System – Minnesota

Phone: 507/255-3116
Project Number: H133A120026
Email: bergquist.thomas@mayo.edu;
brown.allen@mayo.edu
www.mayo.edu/model-system

Northern New Jersey Traumatic Brain Injury System (NNJT BIS) – New Jersey

Project Number: H133A120030
Phone: 973/324-8440
Email: tbi@kesslerfoundation.org
kesslerfoundation.org/researchcenter/tbi/modelsystems.php

New York Traumatic Brain Injury Model System (NY-TBI-MS) – New York

Project Number: H133A120084
Phone: 212/824-8372
Email: wayne.gordon@mssm.edu
www.mssm.edu/tbcentral/nytbims

Rusk Rehabilitation Traumatic Brain Injury Model System of Care at NYU – New York

Project Number: H133A120100
Phone: 212/263-8022
Email: rusk.research@nyumc.org

Ohio Regional Traumatic Brain Injury Model System – Ohio

Project Number: H133A120086
Phone: 614/293-3802
Email: monica.lichi@osumc.edu
ohiovalley.org/modelsystems/ohioregionalms/index.cfm

The Moss Traumatic Brain Injury Model System – Pennsylvania

Project Number: H133A120037
Phone: 215/663-6153
Email: thart@einstein.edu
www.mrri.org/traumatic-brain-injury-model-system-of-care

North Texas Traumatic Brain Injury Model System – Texas

Project Number: H133A120098
Phone: 214/265-2607
Email: shahid.shafi@baylorhealth.edu

Texas TBI Model System of TIRR – Texas

Project Number: H133A120020

Phone: 713/799-7007

Email: mark.sherer@memorialhermann.org

www.memorialhermann.org/locations/tirr/forhealth-professionals/content.aspx?id=1162

Virginia Commonwealth Traumatic Brain Injury Model System – Virginia

Project Number: H133A120031

Phone: 804/828-3704

Email: jhmarwit@vcu.edu

model.tbinc.com

University of Washington Traumatic Brain Injury Model System (UWTBIMS) – Washington

Project Number: H133A120028

Phone: 206/221/6511

Email: jeanneh@uw.edu

depts.washington.edu/rehab/tbi

Other currently funded projects...

Amitriptyline to Prevent Headache After Traumatic Brain Injury

Project Number: H133G120055

Phone: 206/221-6511

Email: jeanneh@uw.edu

Health and Function: Advanced Rehabilitation Research Training (ARRT) at UTEP

Project Number: H133P130001

Phone: 915/747-7265

Email: asalvatore@utep.edu

Improving Trauma Outcomes: A Goal Management Approach

Project Number: H133G120052

Phone: 615/322-2732

Email: kristin.archer@vanderbilt.edu;

kristin.a.swygert@vanderbilt.edu

Prevention of Long-Term Consequences of Mild Traumatic Brain Injury

Project Number: H133G130021

Phone: 313/745-9763

Email: rhanks@med.wayne.edu

Treatment Development for Alcohol Craving and Rehabilitation Among Individuals with Co-Occur-

ring Mild Traumatic Brain Injury, Post-Traumatic Stress Disorder, and Alcohol Use Disorder

Project Number: H133F130011

Phone: 708/202-5867

Email: amy.herrold@gmail.com

These projects have completed their research activities...

Assessing Safety Risk after Traumatic Brain Injury

Project Number: H133G080153

Phone: 404/387-5625

Email: ron_seel@shepherd.org

Mild Traumatic Brain Injury in High School Football

Project Number: H133G70087

Phone: 504/588-5770

Email: gstewart@mailhost.tcs.tulane.edu

Natural History of Headache Following Mild Traumatic Brain Injury

Project Number: H133G090022

Phone: 206/221-6511

tbi.washington.edu

Positron Emission Tomography in Mild Traumatic Brain Injury

Project Number: H133G30092

Phone: 716/898-4759

Rehabilitation of Individuals with Traumatic Brain Injury through Utilization of an Attention Training Program

Project Number: H133F30004

Phone: 206/841-7414

Rehabilitation Research and Training Center on Rehabilitation and Childhood Trauma

Project Number: H133B50006

Phone: 617/636-5031 (V/TTY)

Rehabilitation Research and Training Center on Rehabilitation Interventions Following Traumatic Brain Injury

Project Number: H133B990014

Phone: 713/666-9550

Email: whigh@bcm.tmc.edu

www.braininjuryresearch.org



Documents from NARIC's REHABDATA search listed are listed below:

2013

Barr, W., Chabot, R.J., McCrea, M., Powell, M., & Prichep, L.S. (2013). **Time course of clinical and electrophysiological recovery after sport-related concussion.** *Journal of Head Trauma Rehabilitation*, 28(4), 266-273.

NARIC Accession Number: J66859

ABSTRACT: Study investigated the relationship among the Traumatic Brain Injury (TBI) Index, an index of brain dysfunction based on electrical activity; concussion severity; and outcome in individuals with a sport concussion. Electroencephalographic data was collected from forehead locations in 65 male athletes within 24 hours of concussion, with follow-up at 8 and 45 days after injury. Neurocognitive and symptom assessments were also performed and used to classify subjects in mild or moderate concussion categories. Time to return to play was recorded. The TBI Index was higher in the moderate than the mild concussion group at injury, day 8, and day 45. The moderate group had increased symptoms and decreased cognitive performance only at the time of injury. At the time of injury, only the TBI Index was significantly associated with the length of time to return to play. Findings suggest that recovery of brain function after sport-related concussion may extend well beyond the time course of clinical recovery and be related to clinical severity. An index of brain dysfunction may be an objective indicator of injury, recovery, and readiness to return to play. The relatively small sample indicates the need for further study on the time course of physiological recovery.

Gibson, S., Meehan III, W.P., Nigrovic, L.E., & O'Brien, M. (2013). **The effect of recommending cognitive rest on recovery from sport-related concussion.** *Brain Injury*, 27(7-8), 839-842.

NARIC Accession Number: J66909

ABSTRACT: Study examined whether recommending cognitive rest to athletes after a sport-related concussion affects time to symptom resolution. The International Conference on Concussion in Sport recommends cognitive rest, a limitation of activi-

ties that require attention, memory, concentration and reasoning, for the treatment of sport-related concussion. During the period of cognitive rest, it is recommended that athletes avoid such activities as schoolwork, video game playing, online activities, and text messaging. A retrospective cohort study was performed of patients who presented to a sports concussion clinic in an academic medical center between November 1, 2007 and July 31, 2009. The effect of recommending cognitive rest on symptom duration (days) was measured after adjusting for age, gender, initial Post-Concussion Symptom Scale (PCSS) score, history of amnesia, history of loss of consciousness and number of previous concussions. Using multivariate logistic regression, independent predictors of prolonged symptoms were identified, defined as 430 days. Of the 135 study patients with complete medical records, 85 (63 percent) had cognitive rest recommended. Of those, 79 (59 percent) had prolonged symptoms. In the multivariate analysis, only initial PCSS score was associated with the duration of concussion symptoms. The recommendation for cognitive rest was not significantly associated with time to concussion symptom resolution. Given the limited evidence regarding the effects of cognitive rest on recovery from concussion, recommendations of prolonged periods of cognitive rest, particularly absences from school, should be approached cautiously.

Iverson, G.L., & Silverberg, N.D. (2013). **Is rest after concussion "the best medicine?": Recommendations for activity resumption following concussion in athletes, civilians, and military service members.** *Journal of Head Trauma Rehabilitation*, 28(4), 250-259.

NARIC Accession Number: J66858

ABSTRACT: Article reviews the scientific basis for the recommendation to rest after mild traumatic brain injury (MTBI), the challenges and potential unintended negative consequences of implementing it, and how patient management could be improved by refining it. Practice guidelines universally recommend an initial period of rest for people who sustain a sports-related concussion or MTBI in daily life or military service. This practice is difficult to reconcile with the compelling evidence that other health conditions can be worsened by inactivity and improved by early mobilization and exercise. The best available

evidence suggests that complete rest exceeding 3 days is probably not helpful. Gradual resumption of pre-injury activities should begin as soon as tolerated (with the exception of activities that have a high MTBI exposure risk), and supervised exercise may benefit patients with persistent symptoms.

Victoroff, J. (2013). **Traumatic encephalopathy: Review and provisional research diagnostic criteria.** *Neurorehabilitation*, 32(2), 211-224.

NARIC Accession Number: J66143

ABSTRACT: In this study, every published case of traumatic encephalopathy (TE) was reviewed to determine the frequency of neurobehavioral signs and symptoms reported, with a view toward the development of clinical diagnostic criteria with predictive validity. TE is typically described as a persistent or progressive alteration in neurological or neurobehavioral status that follows exposure to head injury, traumatic brain injury, or concussion. Cases of TE have been reported since 1928. To date, however, no diagnostic criteria have been advanced or accepted for the clinical diagnosis. All published cases of TE in all languages were reviewed. All symptoms and signs reported in these cases were classified and enumerated. Ninety-seven cases met inclusion criteria based on sufficient documentation of the history and neurobehavioral examination. Provisional research diagnostic criteria for clinically probable and clinically possible TE were developed based on the most frequently reported clinical features. The most commonly reported features of the elementary neurological examination were nystagmus, masked face, speech disturbance, increased tone, hyperreflexia, tremor, limb ataxia, and gait disturbance. The most commonly reported neurobehavioral features were cognitive impairment, aggression, mood disorder, paranoid thought disorder, and sensitivity to alcohol. Provisional research diagnostic criteria are required not only for meaningful diagnosis but also to facilitate research to determine the epidemiology, etiology, course, prognosis, imaging and biomarkers, neuropathological features and potentially effective treatments of TE.

2012

Allain, P., Henry, M., Joyal, C.C., Nolin, P., & Stipanovic, A. (2012). **Virtual reality as a screening**

tool for sports concussion in adolescents. *Brain Injury*, 26(13-14), 1564-1573.

NARIC Accession Number: J65261

ABSTRACT: This study explored whether virtual reality could aid in the identification of attention and inhibition deficits in adolescents. It compared performance in attention and inhibition tests (both traditional and virtual) between two groups of adolescents enrolled in a sport and education program: 25 youth who had sustained a sports concussion and 25 youth who had not (controls). Participants were evaluated in immersive virtual reality using the ClinicaVR: Classroom-CPT and in real life using the traditional VIGIL-CPT (Vigil Continuous Performance Test). In order to verify the quality of the immersion during the virtual neuropsychological test, questionnaires assessing sense of presence and cybersickness were administered to each participant. Sense of presence refers to the propensity to respond to virtually generated sensory data as if they were real. Cybersickness denotes symptoms that may be felt during or after the participant's experience in virtual reality, such as nausea or eye strain. On average, individuals in the sports concussion group experienced roughly the same sense of presence as those in the control group. All participants felt "moderately" present during the virtual test. The neuropsychological assessment using virtual reality showed greater sensitivity to the subtle effects of sports concussion compared to the traditional test, which showed no difference between groups. The results also demonstrated that the sports concussion group reported more symptoms of cybersickness and more intense cybersickness than the control group. These results suggest that ClinicaVR: Classroom-CPT is sensitive enough to detect subtle effects in the sports concussion group when compared to the control group.

Baillargeon, A., Ellemberg, D., Lassonde, M., & Leclerc, S. (2012). **Neuropsychological and neurophysiological assessment of sport concussions in children, adolescents, and adults.** *Brain Injury*, 26(3), 211-220.

NARIC Accession Number: J63381

ABSTRACT: Study examined whether age differences exist with respect to neuropsychological and electrophysiological functioning following a sport concussion. Ninety-six athletes (32 who were 9 to

12 years old, 34 who were 13 to 16 years old, and 30 adults), half of whom had a sport concussion, participated in the study. Cognitive functioning was assessed using standardized neuropsychological tests and event-related potentials elicited by a visual 3-stimulus oddball paradigm. The Post-Concussion Symptom Scale was used to assess symptoms experienced at the time of injury. Neuropsychological assessment was conducted with an adaptation of the battery used by the National Hockey League. Latencies and amplitudes of the P3a and P3b components were analyzed in terms of group (concussed versus control) and age. All concussed athletes had significantly lower amplitude for the P3b component compared to their non-injured teammates. Adolescents also showed persistent deficits in working memory. These data suggest that persistent neurophysiological deficits that are present at least 6 months following a concussion and adolescents are more sensitive to the consequences of concussions than are children or adults.

Berger, K., Covassin, T., Elbin, R.J., Hakun, J., Kontos, A.P., Pfeiffer, K., & Ravizza, S. (2012). **Do brain activation changes persist in athletes with a history of multiple concussions who are asymptomatic?.** *Brain Injury*, 26(10), 1217-1225.

NARIC Accession Number: J64654

ABSTRACT: Study evaluated brain activation patterns of asymptomatic athletes with a history of two or more concussions. A paired case-control design was used to compare neurocognitive function, working memory performance, and brain activation patterns during cognitive performance in 14 asymptomatic athletes with a history of two or more concussions and 14 age- and sex-matched controls with no previous concussion. The N-back working memory task was assessed in all participants during functional magnetic resonance imaging. Performance on the Trail-Making Test Form A and B, Symbol-Digit Modalities Test, and the Immediate Post-concussion Assessment and Cognitive Test were also compared between groups. Results indicated that brain regions activated during the performance of the N-back were equivalent between groups. Despite similar performance between groups on the neurocognitive measures, the concussion history group was less accurate than controls on the 1-, 2- and 3-back conditions of the N-back. Findings suggest that, following the complete resolution

of symptoms, a history of two or more concussions is not associated with changes in regional brain activation during the performance of working memory task. Compensatory brain activation may only persist during the typically brief time athletes experience symptoms following concussion.

Broglio, S.P., Sosnoff, J.J., & Wessels, K.K. (2012). **Concussions in wheelchair basketball.** *Archives of Physical Medicine and Rehabilitation*, 93(2), 275-278.

NARIC Accession Number: J63278

ABSTRACT: Study examined the incidence rate and reporting of concussions in wheelchair basketball. A total of 263 wheelchair basketball players, including 188 men and 75 women ranging in age from 18 to 60 years, completed a survey on their concussion history. Questions addressed how many concussions they have sustained, how many days they refrained from physical activity because of injury, to whom they reported their injury, and reasons for not reporting an injury if they did not. Participants also provided demographic information about their disability, age, sex, and length of wheelchair use and sports participation. Within the sample of 263 wheelchair basketball players, 6.1 percent reported experiencing a concussion in the current season. Of those experiencing concussions during the current season, 44 percent did not report their concussion. Of those not reporting the incident, 67 percent did not because they did not want to be removed from physical activity. Analysis by sex indicated that 5.82 percent of the male athletes sustained a concussion during the current season, and 14.36 percent had sustained an injury during their athletic career. Female athletes, however, sustained concussions at a higher rate, with 6.67 percent having concussions during the current season and 30.6 percent during their athletic careers. Women were also 2.5 times more likely to sustain a concussion than men. Athletes were most likely to report their concussion to their coach.

Covassin, T., Elbin, R.J., Kontos, A.P., & Parker, T. (2012). **Depression and neurocognitive performance after concussion among male and female high school and collegiate athletes.** *Archives of Physical Medicine and Rehabilitation*, 93(10), 1751-1756.

NARIC Accession Number: J64793

ABSTRACT: Study examined the impact of sport-related concussion on depression and neurocognitive performance and symptoms among male and female high school and college athletes. A secondary objective was to explore age and gender differences. A total of 75 athletes (54 high school and 21 collegiate) with a diagnosed concussion were tested. The Beck Depression Inventory-II, computerized neurocognitive tests (verbal memory, visual memory, reaction time, and processing speed), and concussion symptoms were assessed at baseline and at 2, 7, and 14 days post-injury. All concussed athletes exhibited significantly higher levels of depression from baseline at 2 days, 7 days, and 14 days post-concussion. High school athletes followed an inverted-U pattern of depression with a return to near-baseline levels at 14 days post-concussion, while collegiate athletes reported increased depression levels at 14 days post-concussion. There were no gender differences in depression levels. Neurocognitive decrements at 14 days were supported for reaction time and visual memory. Somatic depression at 7 days post-concussion was related to slower reaction time at 7 days post-concussion. Somatic depression at 14 days post-injury was related to lower visual memory scores at 14 days post-injury. Overall, the results of this study showed that athletes experienced increased depression scores up to 14 days after concussion that coincided with neurocognitive decrements in reaction time and visual memory.

Diddams, M.J., Faraco, C.C., Miller, L.S., Puente, A.N., Smith, D., Terry, D.P. (2012). **Lack of long-term fMRI differences after multiple sports-related concussions.** *Brain Injury*, 26(13-14), 1684-1696. NARIC Accession Number: J65268

ABSTRACT: Study used functional magnetic resonance imaging (fMRI) to examine the effects of multiple concussions at least 6-months after mild traumatic brain injury. Twenty right-handed male athletes with a history of at least two concussions and 20 matched controls underwent neuropsychological assessment and fMRI scanning where they performed versions of a color-word Stroop interference task, an operation-span working memory task and a finger-tapping task. Results showed that the attention index score on the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS) was lower for the concussion group, but only at liberal statistical

threshold. Total RBANS score approached statistical significance. Reaction time during neurobehavioral tasks was similar across groups, but accuracy was reduced in the concussed group on the working memory task. Despite expected activation patterns within each group, there were no group differences in neural activation on any functional tasks using either whole-brain or region of interest analyses at liberal statistical thresholds. There were minimal differences between the two closely matched groups. Results point to the relative plasticity of younger adults' cognitive abilities following concussion.

2011

Allen, B.J., Gfeller, J.D. (2011). **The immediate post-concussion assessment and cognitive testing battery and traditional neuropsychological measures: A construct and concurrent validity study.** *Brain Injury*, 25(2), 179-191.

NARIC Accession Number: J60982

ABSTRACT: Study examined the construct and concurrent validity of Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT), a computerized neuropsychological test battery used for evaluating sports-related concussion. One hundred four neurologically intact undergraduates completed ImPACT and a battery of traditional neuropsychological tests utilized by the National Football League (NFL). Participants completed the two batteries in a counterbalanced order. Factor analyses examined the component structure of ImPACT and the NFL battery's factor structure. Correlational analyses assessed relationships among variables within and across the two batteries. Results revealed a four-factor solution explaining 70 percent of variance with the NFL battery, including general memory, mental processing speed, verbal memory and processing speed and auditory and verbal working memory. A five-factor solution explaining 69 percent of variance was found with the ImPACT battery, with components assessing forced choice efficiency, verbal and visual memory, inhibitory cognitive abilities, visual processing abilities with a memory component and a factor with a single loading from Colour Match Total Commissions. Correlations revealed a range of significant and non-significant correlations between the two batteries.

Bell, K.R., Blume, H.K., & Lucas, S. (2011). **Sub-acute concussion-related symptoms in youth.** *Physical Medicine and Rehabilitation Clinics of North America*, 22(4), 665-681.

NARIC Accession Number: J62282

Project Number: H133A070032

ABSTRACT: Article reviews the epidemiology of sub-acute symptoms after sports-related concussion and the current recommendations for the assessment and management of these symptoms in children and adolescents. Most children and adolescents recover to their pre-injury baseline relatively quickly after concussion, but a few children experience prolonged symptoms. School-aged children and adolescents seem to be at higher risk for prolonged sub-acute symptoms after concussion than either very young children or college-aged adults. This article discusses the evaluation and management of several of the most common sub-acute post-concussive symptoms, including headache, sleep disturbance, balance deficits, and emotional changes.

Bell, K.R., & Herring, S.A. (Eds.). (2011). **Youth sports concussions.** *Physical Medicine and Rehabilitation Clinics of North America*, 22(4), 565-737.

NARIC Accession Number: R09142

ABSTRACT: Articles in this journal issue address the management of sports-related concussion in adolescents. Topics include: epidemiology of youth sports concussion; the pathophysiology of concussions in youth; on-field and sideline assessment of sports-related concussion; return-to-play decisions; the role image in diagnosing concussion now and in the future; use of neuropsychological evaluations; sub-acute concussion-related symptoms in youth; long-term consequences: effects on normal development profile after concussion; recommendations for concussion education and management; and concussion prevention and management for youth athletes. Individual articles may be available for document delivery.

Broglio, S.P., & Guskiewicz, K.M. (2011). **Sport-related concussion: On-field and sideline assessment.** *Physical Medicine and Rehabilitation Clinics of North America*, 22(4), 603-617.

NARIC Accession Number: J62279

ABSTRACT: Article offers clinicians guidelines for conducting a careful and well-planned on-field/side-

line assessment of concussion in athletes. Contemporary methods of concussion assessment, involving the use of symptom checklists, neuropsychological testing, and postural stability testing, are indicated for any athlete suspected of having sustained a concussion, and research has shown the utility of these when incorporated into a systematic sideline assessment. Following a primary survey the clinician should obtain an injury history, and observe and palpate the athlete for indications of more severe trauma. Special tests for mental status and postural control, along with reports of concussion-related symptoms, can provide the objective information that supports the clinical examination. Throughout the evaluation process the clinician should inquire about the development, presence, intensity, or return of concussion-related symptoms. In no instance should an athlete be returned to play if he or she reports any symptoms consistent with concussion.

Brooks, B.L., Iverson, G.L., Krol, A.L., Mrazik, M., & Naidu, D. (2011). **Assessment of symptoms in a concussion management program: Method influences outcome.** *Brain Injury*, 25(13-14), 1300-1305
NARIC Accession Number: J62587

ABSTRACT: Study investigated how the administration method of a concussion assessment tool (self-report versus interview) affects the report of symptoms. A total of 117 athletes completed the Post-Concussion Scale (PCS) during pre-season evaluations. The PCS consists of 21 symptoms that are commonly experienced by athletes after concussion. Analysis revealed a significant difference in total symptom scores and number of endorsed symptoms across administration modes. Athletes had a greater total symptom score and reported a greater number of symptoms in the self-administration condition than in the interview condition. Furthermore, there was a significant difference in symptom reporting across interviewer gender. Athletes endorsed more symptoms when the interviewer was a woman. Because the method of collecting symptoms, as well as interviewer gender, can impact test results, self-report measures may be a better way of obtaining consistent results. Clinicians and researchers should be aware that both the nature and extent of symptom reporting is greater when using questionnaires than when athletes are interviewed.

Cantu, R.C., Daneshvar, D.H., McKee, A.C., Nowinski, C.J., Riley, D.O., & Stern, R.A. (2011). **Long-term consequences: Effects on normal development profile after concussion.** *Physical Medicine and Rehabilitation Clinics of North America*, 22(4), 683-700.

NARIC Accession Number: J62283

ABSTRACT: Article discusses the long-term consequences of concussions. While most concussions fully resolve within weeks of the injury, for some these concussions can have serious, long-term effects. Concussed individuals can sometimes experience prolonged post-concussion syndrome (PCS), lasting for months or even years, which can result in significant physical, emotional, and cognitive stress. In children and young adults, months of PCS can adversely affect one's developmental trajectory by keeping students out of class and straining personal relationships. In adults, suffering from PCS for an extended period of time may delay one's ability to return to work, resulting in an additional financial and social burden on the concussed individual. In addition, concussions and sub-concussive impacts have been shown to increase the risk of developing degenerative disease including Alzheimer's disease, Parkinson disease, and amyotrophic lateral sclerosis, and chronic traumatic encephalopathy, sometimes even decades after the injury.

Coppel, D.B. (2011). **Use of neuropsychological evaluations.** *Physical Medicine and Rehabilitation Clinics of North America*, 22(4), 653-664.

NARIC Accession Number: J62281

ABSTRACT: Article examines the role of neuropsychological testing in the evaluation and management of sports-related concussion. Neuropsychological or neurocognitive tests provide information about the cognitive and emotional status of the concussed athlete. The availability of pre-injury or baseline data regarding an athlete's level of cognitive functioning can provide an important marker for comparison with post-injury performance levels. The development and availability of computerized testing platforms has allowed the widespread application of the baseline and follow-up testing model at all levels of athletic involvement, and provide a more precise measurement of reaction time and processing speed. However, the ease and convenience of computer-

ized testing has sacrificed some important aspects of neurocognitive or neuropsychological testing, such as neurobehavioral observations, auditory processing performance, recall memory measurement, and assessment of psychosocial and emotional factors. A combination of computerized assessment and a more expanded battery of tests may be a better approach to understanding the often complex nature of the cognitive impact of sports concussion in youth athletes. This approach may be especially important for athletes with general risk factors for prolonged recovery and other potential modifiers or influencers on the cognitive performance data.

Gioia, G.A., Sady, M.D., & Vaughan, C.G. (2011). **School and the concussed youth: Recommendations for concussion education and management.** *Physical Medicine and Rehabilitation Clinics of North America*, 22(4), 701-719.

NARIC Accession Number: J62284

ABSTRACT: Article provides basic information for designing a concussion education and management program in the school setting. A concussive injury is a direct or indirect blow to the head that results in a neurometabolic cascade and ensuing cellular energy crisis in the brain, leaving the brain vulnerable to additional injury during the recovery phase. The ensuing symptoms and neurocognitive effects of concussion affect learning and performance, and many students engaging in cognitive activity shortly after a concussion experience symptom exacerbation and increased difficulty with work completion, concentrating, and remembering. Students who are highly symptomatic and try to maintain full academic schedules quickly realize that they will need temporary accommodations to prevent falling behind and effects on their grades. Successful gradual return to cognitive activities requires coordination among school personnel who are educated about the effects of concussions on students and are committed to providing accommodations for the resulting symptoms and neurocognitive deficits, continuously monitoring symptoms, and adjusting interventions accordingly until recovery. Key personnel would implement a well-developed accommodations plan that is specific to the recovering student's needs as soon as the concussion is suspected or identified. Team members include a range of school personnel, such as guidance counselor, nurse/health aide, school

psychologist, teachers, physical education and coaching staff, and athletic trainers, as well as the student, parents, and treating medical professionals.

Jarvik, J.G., & McCullough, B.J. (2011). **Diagnosis of concussion: The role of imaging now and in the future.** *Physical Medicine and Rehabilitation Clinics of North America*, 22(4), 635-652.

NARIC Accession Number: J62280

ABSTRACT: Article focuses on the role of imaging in the diagnosis of adolescent sports-related concussion. The primary role of neuroimaging in the context of concussion is the exclusion of a more serious, unsuspected diagnosis, such as an epidural hematoma. Computed tomography, and to a lesser extent magnetic resonance imaging (MRI), are the imaging modalities of choice for this purpose. New, more sensitive imaging techniques are currently being developed to detect the molecular and cellular pathophysiology underlying concussion to help guide rehabilitation and return-to-play decisions. These include magnetic resonance spectroscopy, diffusion tensor imaging, and functional MRI. Ultimately, the decision to image is a balance between the risks of an unsuspected, potentially life-threatening injury and the risks of radiation exposure.

2010

Barr, W.B., Chabot, R., McCrea, M., Powell, M.R., & Prichep, L. (2010). **Acute effects and recovery after sport-related concussion: A neurocognitive and quantitative brain electrical activity study.** *Journal of Head Trauma Rehabilitation*, 25(4), 283-292.

NARIC Accession Number: J59311

ABSTRACT: Study investigated the clinical utility and sensitivity of a portable, automatic, frontal quantitative electroencephalographic (QEEG) acquisition device in detecting abnormal brain electrical activity after sport-related concussion. Twenty-eight athletes with concussion and 28 matched controls were studied. All subjects underwent preseason baseline testing on measures of post-concussive symptoms, postural stability, and cognitive functioning, as well as QEEG. Clinical testing and QEEG were repeated on day of injury and days 8 and 45 post-injury for the concussion and control groups. The injured group reported more significant post-concussive symptoms during the first 3 days after injury, which resolved by days

5 and 8. Injured subjects also performed poorer than controls on neurocognitive testing on the day of injury, but no differences were evident on day 8 or day 45. QEEG studies revealed significant abnormalities in electrical brain activity in the injured group on day of injury and day 8 post-injury, but not on day 45. Results are consistent with early reports indicating a typical course of full recovery in symptoms and cognitive dysfunction within the first week of injury. QEEG results, however, suggest that the duration of physiological recovery after concussion may extend longer than observed clinical recovery.

Barth, J.T., Goodkin, H.P., Hertel, J.N., Ingersoll, C.D., Livingston, S.C., & Saliba, E.N. (2010). **A preliminary investigation of motor evoked potential abnormalities following sport-related concussion.** *Brain Injury*, 24(6), 904-913.

NARIC Accession Number: J59054

ABSTRACT: Study compared motor evoked potentials (MEPs) obtained through transcranial magnetic stimulation (TMS) in acutely concussed and non-concussed collegiate athletes. Participants were 18 collegiate athletes (12 males, six females, mean age 20.4 years) including 9 subjects with acute concussion (within 24 hours) matched to 9 control subjects. TMS was applied over the motor cortex and MEP responses were recorded from the contralateral upper extremity. MEP thresholds, latencies, and amplitudes were assessed. Central motor conduction time (CMCT) was calculated from MEP, M response and F wave latencies. Testing was performed on days 1, 3, 5 and 10 post-concussion. Results showed that ulnar MEP amplitudes were significantly different between post-concussion days 3 and 5 with smaller amplitudes recorded on day 3. Median MEP latencies were significantly longer 10 days post-concussion compared to day 1. No significant differences for motor thresholds or CMCTs were observed. MEP abnormalities among acutely concussed collegiate athletes provide direct electrophysiologic evidence for the immediate effects of concussion.

Comper, P., Hutchison, M., Magrys, S., Richards, D., & Wainwaring, L. (2010). **Evaluating the methodological quality of sports neuropsychology concussion research: A systematic review.** *Brain Injury*, 24(11), 1257-1271.

NARIC Accession Number: J59916

ABSTRACT: Study evaluated the methodological quality of neuropsychological sports-related concussion research using a comprehensive, systematic method. Of 349 studies initially selected by search criteria, a total of 43 studies were evaluated using a Cochrane-style review format. Studies were assigned a Level of Evidence using the Centre for Evidence-based Medicine framework. Relevant information related to the methods of each study were extracted and rated for methodological quality using a standardized form-based evaluation tool. The review revealed heterogeneity among the studies in terms of research design, as well as a number of methodological weaknesses and inconsistencies. Despite the proliferation of neuropsychological research on sports-related concussion over the past decade, the methodological quality of studies appears to be highly variable, with many lacking proper scientific rigor. Future research in this area needs to be carefully controlled, repeatable and generalizable, which will contribute to developing practical, evidence-based guidelines for concussion management.

Edwards, M.G., & Weber, M. (2010). **The effect of brain injury terminology on university athletes' expected outcome from injury, familiarity, and actual symptom report.** *Brain Injury, 24*(11), 1364-1371.

NARIC Accession Number: J59924

ABSTRACT: Study investigated the influence of the terms concussion, mild traumatic brain injury (TBI), and minor head injury on expected injury outcome; examined participants' familiarity with the terms used; and assessed actual symptom reporting. Two hundred and twenty-four university students were allocated one of three versions of questionnaire that varied only in the use of the terms concussion, mild TBI, and minor head injury. Participants rated injury outcome statements for their truthfulness, specified term familiarity, and completed measures on post-concussion symptoms, anxiety, depression, pain and affectivity. Chi-square tests compared response frequencies of statement ratings and familiarity between questionnaire versions and a rank-based multivariate method compared psychological measures between questionnaire versions. Results showed that terminology significantly influenced the athletes' expected injury outcome and familiarity. Outcome expectations

were reliably more negative for the term mild TBI than concussion or minor head injury. Mild TBI was the least familiar term. However, terminology groups did not differ in actual symptom reporting. The impact of the data and advice for the best terminology for future use are discussed. While it is not easy to make a clear recommendation, the data clearly indicate a strong need for education of brain injury at university level and possibly beyond.

Gultting, J., Higgins, M., Mansell, J.L., McDevitt, J., Tierney, R.T., & Toone, N. (2010). **Concussive signs and symptoms following head impacts in collegiate athletes.** *Brain Injury, 24*(9), 1070-1074.

NARIC Accession Number: J59269

ABSTRACT: Study evaluated the association between having a previously documented concussion and experiencing concussive signs and symptoms (S&S) following head impacts in collegiate athletes. One hundred sixty-eight male football and 33 female women's soccer athletes participated in the study. Participants completed a questionnaire and reported if they had been diagnosed with concussion and if they experienced concussive S&S following a head impact during a game or practice in the previous year. Almost 60 percent (89 of 152) of non-concussed athletes reported experiencing S&S following head impacts in the previous year compared to 80 percent (39 of 49) of concussed athletes. The Phi coefficient results indicated a significant association between previous history of concussion and the occurrence of S&S following a head impact. All of the reported instances were not related to documented concussions, indicating a lack of education or willingness to report their S&S. These findings highlight the need for more diligent surveillance from clinicians, as many concussions are being missed.

2009

Barr, W.B., Guskiewicz, K.M., Hammeke, T.A., Kelly, J.P., McCrea, M., Millis, S., & Randolph, C. (2009). **Concussion symptom inventory: An empirically derived scale for monitoring resolution of symptoms following sport-related concussion.** *Archives of Clinical Neuropsychology, 24*(3), 219-229.

NARIC Accession Number: J58970

Project Number: H133A020515

ABSTRACT: Article describes the development of scale for the detection and tracking of self-reported symptoms following a sport-related concussion. Researchers analyzed a large set of data from existing scales obtained from three separate case-control studies in order to derive a sensitive and efficient scale for this application by eliminating items that were found to be insensitive to concussion. Baseline data from symptom checklists including a total of 27 symptom variables were collected from a total of 16,350 high school and college athletes. Follow-up data were obtained from 641 athletes who subsequently incurred a concussion. Symptom checklists were administered at baseline (preseason), immediately post-concussion, post-game, and at 1, 3, and 5 days post-injury. Effect-size analyses resulted in the retention of only 12 of the 27 variables. Receiver-operating characteristic analyses were used to confirm that the reduction in items did not reduce sensitivity or specificity. The newly derived Concussion Symptom Inventory is presented and recommended as a research and clinical tool for monitoring recovery from sport-related concussion.

Bigler, E.D. (Ed.). (2009). **Forensic neuropsychology.** *Journal of Head Trauma Rehabilitation, 24*(2), 75-144.

NARIC Accession Number: R08991

ABSTRACT: Articles in this journal issue provide an overview of forensic neuropsychology as it applies to traumatic brain injury (TBI). Topics include: how advances in clinical and cognitive neuroscience affect neuropsychology in the courtroom; forensic neuropsychological evaluations in an academic medical center; evaluating constructs represented by symptom validity tests in forensic neuropsychological assessment of TBI; how the sports-related concussion literature can inform the expert witness; and best practice guidelines for forensic neuropsychological examinations of patients with TBI. Additional topics include ethical issues concerning brain dead patients and assessing fatigue after TBI. Individual articles may be available for document delivery.

Comstock, R.D., & Yard, E.E. (2009). **Compliance with return to play guidelines following concussion in US high school athletes, 2005-2008.** *Brain Injury, 23*(11), 888-898.

NARIC Accession Number: J57780

ABSTRACT: Study investigated whether US high school athletes who sustained a concussion complied with recommended return-to-play guidelines during the 2005 to 2008 school years. Certified athletic trainers from 100 US high schools submitted injury reports online for concussed athletes in five boys' sports (football, soccer, basketball, wrestling, baseball) and four girls' sports (soccer, basketball, volleyball, softball). Concussions were retrospectively graded and it was determined whether athletes followed American Academy of Neurology (AAN) or Prague return-to-play guidelines. There were 1,308 concussions reported during 5,627, 921 athlete-exposures (23.2 concussions per 100,000 athlete-exposures), reflecting an estimated 395 274 concussions sustained nationally. At least 40.5 percent and 15.0 percent of concussed athletes returned to play prematurely under AAN and Prague return-to-play guidelines, respectively. In football, 15.8 percent of athletes sustaining a concussion that resulted in loss-of-consciousness returned to play in less than one day. Males (12.6 percent) were more likely than females (5.9 percent) to return one to two days after sustaining an initial grade II concussion. The results suggest that too many adolescent athletes are failing to comply with recommended return-to-play guidelines. Sports medicine professionals, parents, coaches and sports administrators must work together to ensure athletes follow recommended guidelines.

De Beaumont, L., Filipinni, M., Gosselin, N., Lassonde, M., & Theriault, M. (2009). **Electrophysiological abnormalities in well functioning multiple concussed athletes.** *Brain Injury, 23*(11), 899-906
NARIC Accession Number: J57781

ABSTRACT: Study examined the short- and long-term effects of multiple concussions using an electrophysiological approach. Participants for this study were recruited from college football teams. They included athletes who never sustained concussions (controls) compared to two groups of asymptomatic multiple-concussed athletes: one that sustained their last concussion within the year and the other more than two years prior to testing. All participants were submitted to an auditory three-tone oddball task while event-related potentials (ERP) were recorded. Results from ERP recordings reveal significantly reduced P3a and P3b amplitudes in the recent concussed group

in the three-tone task compared to control athletes. In contrast, athletes who sustained their concussions more than two years prior to testing had equivalent P3a and P3b amplitude to that of controls. These findings suggest that, despite functioning normally in their daily lives, concussed athletes still show subtle neuronal changes in information processing. Thus, the persistence of sub-clinical abnormalities on ERP components despite normal overt functioning may indicate suboptimal compensation in multiple concussed athletes and leave them vulnerable to subsequent concussions.

Friedman, D., Gagnon, I., Galli, C., Grilli, L., & Iverson, G.L. (2009). **Active rehabilitation for children who are slow to recover following sport-related concussion.** *Brain Injury*, 23(12), 956-964.

NARIC Accession Number: J57915

ABSTRACT: This article presents an innovative approach to the management of children who are slow to recover after a sport-related concussion. It describes the underlying principles and the development of specific interventions for a new rehabilitation program, as well as preliminary data on pre- and post-rehabilitation changes in outcome measures. The intervention was developed using multiple perspectives including that of the literature, of experts in the field of traumatic brain injury, and of experienced clinicians involved with the pediatric and adolescent mild traumatic brain injury clientele. A logic model was developed providing sound theoretical background to the intervention. The intervention was implemented and evaluated with a sample of 16 children and adolescents. The cases presented suggest that involvement in controlled and closely-monitored rehabilitation in the post-acute period may promote recovery in children and adolescents who present with atypical recovery following a concussion. All 16 of the children and adolescents who participated in the program experienced a relatively rapid recovery and returned to their normal lifestyles and sport participation.

Toth, C. (Ed.). (2009). **Sports neurology.** *Physical Medicine and Rehabilitation Clinics of North America*, 20(1), i-xviii, 1-311.

NARIC Accession Number: R08963

ABSTRACT: This journal issue contains articles

examining aspects of sports-related injuries with emphasis on their impact to the nervous system. Topics include: epidemiology of injuries to the nervous system resulting from sport and recreation; biomechanical aspects and the neurophysiology and assessment of sports-related head injuries; recognition and management of spinal injuries; muscle physiology in healthy men and women and those with metabolic myopathies; enhancement drugs and the athlete; sleep, recovery, and performance; neuromuscular fatigue in racquet sports; peripheral nerve injuries in baseball players; concussion in the National Football League; neurologic injuries in hockey, boxing and other combat sports, cycling and bike riding, running injuries, and scuba diving; neurologic disorders associated with weight lifting and body building; and head injuries in winter sports (downhill skiing, snowboarding, sledding, snowmobiling, ice skating, and ice hockey).

2007

Bellon, M.L., & Rees, R.J. (2007). **Post-concussion syndrome ebb and flow: Longitudinal effects and management.** *NeuroRehabilitation*, 22(3), 229-242
NARIC Accession Number: J53746

ABSTRACT: Study examined the effects of post-concussion syndrome (PCS) symptoms in a group of 20 adults immediately following their trauma (ebb phase) and two years later (flow phase). Typical symptoms included physical and cognitive fatigue, depressive behaviors, sensitivity to noise, social withdrawal, irritability, concentration and problem solving difficulties, loss of libido, and much difficulty making decisions at even the simplest strategic level. Counseling and psychotherapy intervention took place between ebb and flow evaluations. Items on the PCS schedules and the Beck Depression Inventory demonstrated significant decline in the presence of overall symptoms, most noticeably in reduction of agitation, irritability, and suicidal wishes. However, subjects throughout generally experienced the feeling that they were being punished which equated with behaviors comparable with learned helplessness. The adults with PCS considered themselves to be different people after trauma. They had different goals, changing lifestyle, relationships and employment and were more often in a dependent state.

Bergen, A., Kozlowski, K.F., Leddy, J.J., Tomita, M., & Willer, B.S. (2007). **Use of the ICECI and ICD-10 E-coding structures to evaluate causes of head injury and concussion from sport and recreation participation in a school population.** *NeuroRehabilitation*, 22(3), 191-198.

NARIC Accession Number: J53742

ABSTRACT: Study describes the mechanisms of head injury and concussion associated with various types of school-related sports and recreation activities. A total of 7,765 head injury reports were coded using the International Classification of External Causes of Injury (ICECI) and the International Classification of Diseases External Causes (ICD-10 E-codes). Descriptive statistics were used to describe the total number of head injuries, the total number of those with injuries with concussive symptoms, and the rate of concussion for each code. Of the 7,765 head injury reports examined, 1,338 cases reported symptoms of concussion. The rates of concussion identified by the ICD-10E-codes and ICECI coding systems were 17.2 percent and 16.9 percent, respectively. The majority of head injuries occurred during school free-play or recess (59.8 percent). Combative sports and wheeled non-motored sports were the activities most often associated with concussion symptoms. The most common causes of head injury were struck by an object and falling on the same level. Falling from a transport was the only etiological code significantly associated with concussion symptoms after head injury.

Bloom, G.A., Delaney, J.S., Johnston, K.M., Loughhead, T.M., & Shapcott, E.J.B. (2007). **The effects of explanatory style on concussion outcomes in sport.** *NeuroRehabilitation*, 22(3), 161-167.

NARIC Accession Number: J53741

ABSTRACT: Study examined the effects of explanatory style on recovery time and number of sports-related concussions. Explanatory style refers to the ways that individuals explain their positive and negative experiences. One hundred seventy university varsity athletes suffering from at least one concussion over the last 12 months from contact or collision team sports completed both the Attributional Style Questionnaire and the Sport History Questionnaire. The results indicated that athletes with an optimistic explanatory style took longer to recover than athletes with a pessimistic or average explanatory style.

More specifically, optimistic athletes who suffered a complex concussion (requiring more than seven days to recover) took significantly longer to return to play. However, the results showed that explanatory style did not influence whether an athlete suffered subsequent concussions. Overall, the current results can be used to better understand the psychology of concussions, as well as concussion prevention efforts and management strategies.

Chen, J-K., Johnston, K.M., & Ptito, A. (2007). **Contributions of functional magnetic resonance imaging (fMRI) to sport concussion evaluation.** *NeuroRehabilitation*, 22(3), 217-227.

NARIC Accession Number: J53745

ABSTRACT: Article reviews the use of functional magnetic resonance imaging (fMRI) in studies of concussion. Existing and ongoing fMRI studies are described to highlight the potential and contribution of this non-invasive functional neuroimaging technique in the assessment of sports-related concussion and its management. 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 structural imaging methods.

Collins, M.W., Fazio, V.C., Lovell, M.R., & Pardini, J.E. (2007). **The relation between post-concussion symptoms and neurocognitive performance in concussed athletes.** *NeuroRehabilitation*, 22(3), 207-216.

NARIC Accession Number: J53744

ABSTRACT: Study examined differences in neurocognitive performance between symptomatic concussed athletes, a group of concussed athletes with no subjective symptoms, and a non-concussed control group of athletes. All concussed athletes were evaluated within 1 week of injury using the ImPACT computerized test battery. Results indicate that concussed athletes who denied subjective symptoms demonstrated poorer performance than control subjects on all 4 composite scores of the ImPACT test (verbal memory, visual memory, reaction time, and processing speed). However, the concussed but asymptomatic group demonstrated significantly better

performance than did the concussed and symptomatic group. Thus, concussed athletes who did not report subjective symptoms were not fully recovered based on neurocognitive testing.

Dywan, J., MacGregor, L., Mahaney, P., Santesso, D.L., Segalowitz, S.J., & Willer, B. (2007). **Retest reliability in adolescents of a computerized neuropsychological battery used to assess recovery from concussion.** *NeuroRehabilitation*, 22(3), 243-251. NARIC Accession Number: J53747

ABSTRACT: Study examined the test-retest reliability of the Automated Neuropsychological Metrics (ANAM) when used with a group of adolescents. ANAM is a computer-based battery of neuropsychological tests designed to assess concussion effects. Since the principle behind these computerized batteries is to assess athletes before injury and after injury to determine the level of deficit and whether the individual is safe to return to play, it is critical that such batteries have excellent retest reliability. Participants were assessed twice, using the same computers, at the same time of day, with seven days between administrations. Retest reliability of the ANAM was good, especially for the aggregate of throughput scores, reaching 0.87, but lower for individual subtests, especially for those measuring only speed of processing. Thus, the ANAM aggregated score appears to have robust reliability for cognitive measures involving memory and attention in adolescents.

Fung, M., Kozlowski, K., Leddy, J.J., Pendergast, D.R., & Willer, B. (2007). **Regulatory and auto-regulatory physiological dysfunction as a primary characteristic of post-concussion syndrome: Implications for treatment.** *NeuroRehabilitation*, 22(3), 199-205.

NARIC Accession Number: J53743

ABSTRACT: Article examines the metabolic and physiological changes in the brain and other organs following a concussion and explains why post-concussion syndrome (PCS) occurs. Concussion is most commonly defined as a trauma induced alteration of mental status that may or may not involve loss of consciousness. Concussion produces a temporary alteration of the central regulatory systems that control, for example, the autonomic nervous system and circadian rhythms, as well as the auto-regulatory protection of the brain, which under normal conditions maintains a constant state of cerebral blood flow. The authors propose that PCS represents a condition whereby the

regulatory and auto-regulatory mechanisms of the brain do not naturally return to normal. They further propose that this physiologic dysfunction may be reduced or alleviated by individualized controlled sub-symptom threshold aerobic exercise rehabilitation. The implications of this theory of concussion and PCS for treatment and further research are discussed.

Gilchrist, J., Langlois, J., Thomas, K.E., & Wald, M. (2007). **Nonfatal traumatic brain injuries from sports and recreation activities - United States, 2001-2005.** *Morbidity and Mortality Weekly Report (MMWR)*, 56(29), 733-737.

NARIC Accession Number: J53202

ABSTRACT: Article characterizes nonfatal sports- and recreation-related (SR-related) traumatic brain injuries (TBIs) among patients treated in hospital emergency departments (EDs), based on an analysis of data from the National Electronic Injury Surveillance System-All Injury Program (NEISS-AIP). The NEISS-AIP contains information on initial visits for all types and causes of injuries treated in EDs in the United States each year. The findings indicate that an estimated 207,830 patients with nonfatal SR-related TBIs were treated in EDs each year for the period 2001 to 2005. Overall, males accounted for about 70.5 percent of the visits. The highest rates of SR-related TBI ED visits for both males and females occurred among those aged 10 to 14 years, followed by those aged 15 to 19 years. Activities associated with the greatest number of TBI-related ED visits included bicycling, football, playground activities, basketball, and riding all-terrain vehicles.

Leddy, J.J., & Willer, B. (Eds.). (2007). **Special issue: Sports and concussion.** *NeuroRehabilitation*, 22(3), 159-251.

NARIC Accession Number: R08877

ABSTRACT: Articles in this issue review research on concussions resulting from sports- and recreation-related activities. Topics include: the effects of explanatory style on concussion outcomes in sports, use of computer-based testing of youth hockey players with concussions, concussion sideline management intervention for rugby union leads to reduced concussion claims, use of ICECI and ICD-10 E-coding structures to evaluate causes of head injury and concussion from sport and recreation participation in a school population, regulatory and auto-regulatory physiological dysfunction as a primary characteristic of post-concussion syndrome, the relation between

post-concussion symptoms and neurocognitive performance in concussed athletes, contributions of functional magnetic resonance imaging to sport concussion evaluation, post-concussion syndrome ebb and flow, and retest reliability of a computerized neuropsychological battery to assess recovery from concussion in adolescents. Individual articles may be available for document delivery; see accession number J53741 through J53747.

2006

(2006). *TBI Updates, 4(3)*.

NARIC Accession Number: O16830

Project Number: H133A020508

ABSTRACT: Newsletter of the University of Washington Traumatic Brain Injury Model System (UWT-BIMS) presents information of interest to people with traumatic brain injury (TBI) and their families. In this issue: (1) exercise after TBI, (2) research corner, (3) conference on vocational outcomes, and (4) sports concussion.

2004

(2004). *TBI Updates, 2(1)*.

NARIC Accession Number: O15913

Project Number: H133A020508

ABSTRACT: Newsletter of the University of Washington Traumatic Brain Injury Model System (UWT-BIMS) presents information of interest to people with traumatic brain injury (TBI) and their families. In this issue: (1) sports and concussions; (2) constraint induced therapy for upper extremity motor function at the University of Alabama, Birmingham; (3) housing resources; (4) recent staff presentations; (5) recent staff publications; and (6) updates on current TBI studies.

2002

Browndyke, J., & Schatz, P. (2002). **Applications of computer-based neuropsychological assessment.** *Journal of Head Trauma Rehabilitation, 17(5)*, 395-410.

NARIC Accession Number: J44505

ABSTRACT: Article discusses current trends in computer-based neuropsychological assessment, including the assessment of sports-related concussion, symptom validity testing, and the remote administration of tests through the Internet. Outlines benefits and limitations of computer-based service delivery.

2001

Bennett, T.L. (2001). **The management and evaluation of sports-related mild traumatic brain injuries in student athletes.** *Journal of Cognitive Rehabilitation, 19(2)*, 14-16.

NARIC Accession Number: J42996

ABSTRACT: Article discussing the prevalence of mild traumatic brain injury (TBI) in high school and college students participating in sports. The guidelines for grading concussions and general guidelines for return to competition following sports related and non-sports related mild TBI are listed. Evaluation of persisting cognitive difficulties in sports related TBI is described. A neuropsychological testing battery for sports-related TBI in the student athlete is suggested.

1999

Aldred, H.E., (ed.). (1999). *Sports injuries sourcebook. Health Reference Series, First Edition.*

NARIC Accession Number: R07896

ABSTRACT: Book provides basic information about common sports injuries including head and face injuries, neck injuries, shoulder injuries, knee injuries, stress fractures, sprains, and strains. Details are provided about causes, treatment and rehabilitation of these injuries. Injury prevention covers tips for specific sports, describes safety precautions in a variety of sporting activities, particularly those with a high risk of injury. These include football, basketball, baseball, softball, bicycling, skateboarding, in-line skating, scuba diving, soccer, and skiing. Treatment and rehabilitation provides information on aspects of recovering from an injury, especially those related to non-prescription pain relief, over-the-counter injury treatments, overcoming depression in recovery, and a guide to research and advances in sports medicine. Information is provided about special concerns for children, young girls in athletic training programs, senior athletes, and women athletes. A directory of resources for further information is included.

Barber-Foss, K.D., & Powell, J.W. (1999). **Traumatic brain injury in high school athletes.** *Journal of the American Medical Association (JAMA), 282(10)*, 958-963.

NARIC Accession Number: J37350

ABSTRACT: Study of the type, frequency, and severity of mild traumatic brain injury (MTBI) in selected high school sports activities. In this observational

cohort study, sponsored by the National Athletic Trainers Association (NATA), 246 certified athletic trainers recorded injury and exposure data for high school varsity athletes participating in boys' football, wrestling, baseball, and field hockey, girls' volleyball and softball, and boys' and girls' basketball and soccer at 235 U.S. high schools during 1 or more of the 1995-1997 academic years. MTBI rates were found to vary among sports, but none of the 10 popular high school sports studied were without occurrences of MTBI. National estimates were made based on the MTBI frequencies found in the study.

1998

Branche, C.M., Sniezek, J.E., & Thurman, D.J. (1998). **The epidemiology of sports-related traumatic brain injuries in the United States: Recent developments.** *Journal of Head Trauma Rehabilitation*, 13(2), 1-8.

NARIC Accession Number: J34784

ABSTRACT: Article examining recent population-based data from the National Health Interview Survey (NHIS), Consumer Product Safety Commission (CPSC), and state-based traumatic brain injury (TBI) surveillance programs that provide estimates of the overall incidence of sports-related TBI in the United States. Data indicate that approximately 300,000 people a year experience sports-related TBI in the United States. The authors discuss changes that could be made in surveillance to improve data collection. They also discuss sports injury mortality, risk factors, and possible interventions.

1993

Rocky Mountain Regional Brain Injury Center. (1993). ***When the Cheering Stops: A Manual for the Assessment and Management of Concussion/Brain Injury in Sports.***

NARIC Accession Number: R06767

Training Manual available through National Clearinghouse of Rehabilitation Materials: <http://library.ncrtm.org/pdf/S110.0008.01.pdf>

Video: <http://library.ncrtm.org/players/jwplayer.html?basename=S110.0008.02>

ABSTRACT: Manual accompanying video in a training program When the Cheering Stops. This program was developed to assist in the assessment of injuries of an athlete on the playing field. The goal is the identification of concussion/brain injury

and prevention of TBI and permanent disability. The manual is organized into 11 chapters: introduction, head and neck injury management for coaches, side line mental testing, equipment list, the football helmet, references, what athletes and families should know, TBI, emergency room forms, resources, and supplementary articles.

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(CIRRIE-3) search at [*\[buffalo.edu\]\(http://buffalo.edu\) are listed below:*](http://cirrie.</i></p></div><div data-bbox=)*

2012

Alla, S., McCrory, P., & Sullivan, S.J. (2012). **Defining asymptomatic status following sports concussion: Fact or fallacy?** *British Journal of Sports Medicine*, 46(8), 562-9.

ABSTRACT: The current management of sports concussion involves a return to the baseline 'asymptomatic' status prior to returning to play and training. Unfortunately, although the term 'asymptomatic' is widely used it has not been operationally defined. This review identifies the need to formally define the term 'asymptomatic' as used in sports concussion, discusses some of the challenges associated with its definition and offers some possible solutions for further debate. The operational definition of the term 'asymptomatic' may provide the stimulus for further informed discussion at a future meeting of the international Concussion in Sport group, and by other peak sports medicine bodies involved in management guideline development.

2011

McCrory, P. (2011). **Sports concussion and the risk of chronic neurological impairment.** *Clinical Journal of Sport Medicine*, 21(1), 6-12.

ABSTRACT: Intense recent media focus on long-term outcomes from sports concussion has highlighted concerns on both cognitive deterioration and mental health issues, such as depression and suicide. At this time, the scientific evidence to support these views is limited, with only a handful of cases thus far reported. Based on the literature on this topic that extends back over 50 years, it is clear that only a small percentage of athletes suffer such sequelae presumably due to recurrent concussive or sub-concussive head impacts. At this stage, determining which athletes are at future risk is not possible; however, following existing concussion guidelines (e.g., Zurich guidelines) is likely to be the safest option based on current evidence.

2008

Boutin, D., Lassonde, M., Robert, M., & Vanassing, P., et al. (2008). **Neurophysiological assessment prior to and following sports-related concussion during childhood: A case study.** *Neurocase*, 14(3), 239-248.

ABSTRACT: The goal of this study was to measure the neurophysiological and cognitive functions of a sport-concussed child and to longitudinally assess the recovery pattern. An 8-year-old girl suffered a concussion while playing soccer. Visual evoked potentials (VEPs) were recorded at 7 weeks pre-injury and 24 hours, 7, 22, 32 and 55 weeks post-injury. A neuropsychological assessment performed at 24 hours post-injury reveals cognitive impairments, mainly attentional, that resolved within 22 weeks. VEPs and spectral analyses confirm the presence of cortical impairments up to one year post-injury, especially affecting vigilance and attention, which were reflected in school performance.

Kim, P., & Ogino, M. (2008). **[Sports related head injury].** *Neurological Surgery*, 36(11), 949-959. [Article is in Japanese].
No abstract is available.



*Document from the
National Clearinghouse
of Rehabilitation Training
Materials (NCRTM) search*

at ncrtm.org are listed below:

Bleiberg, J., Chew, K.T.L., Lew, H.L., & Thomander, D. (2007). **Review of sports-related concussion: Potential for application in military settings.** *Journal of Rehabilitation Research & Development*, 44(7), 11.

Full-text is available at <http://library.ncrtm.org/pdf/321.079.pdf>

ABSTRACT: A review of current issues and practices in the assessment and clinical management of sports-related concussion and how it can be applied to the diagnosis and management of concussion in military settings. Discusses the incidence, definition, and diagnosis of concussion; concussion grading scales; sideline evaluation tools; neuropsychological assessment; return-to-action criteria; and complications of concussion.



*Documents from the Education
Resource Information Center
(ERIC) search at www.eric.ed.gov
are listed below:*

2013

Chinn, N.R., & Porter, P. (2013). **Concussion management in community college athletics: Revealing and understanding the gap between knowledge and practice.** *Community College Journal of Research and Practice*, 37(6), 409-423.

ERIC Number: EJ1009999

ABSTRACT: The seriousness of concussions in athletics is only recently becoming fully understood and appreciated. There are significant implications for the concussed student-athlete both in returning to the playing field and the classroom. Although practices are now in place to improve identification and management of concussions in professional sports, little is known about how it is managed in community colleges. This mixed method study identified the extent to which California Community College athletic

trainers are implementing best practices set forth by the National Athletic Trainers' Association in their management of concussion. It also sought to understand the training, cultural pressures, and resources that may impact the degree to which community college athletic trainers implement these guidelines.

2012

Covassin, T., Elbin, R.J., & Sarmiento, K. (2012). **Educating coaches about concussion in sports: evaluation of the CDC's "Heads Up: Concussion in youth sports" initiative.** *Journal of School Health*, 82(5), 233-238.

ERIC Number: EJ1013460

ABSTRACT: Background: Concussions remain a serious public health concern. It is important that persons involved in youth sports, particularly coaches, be made aware and educated on the signs and symptoms of concussion. This study assessed the perceptions of youth sport coaches who have received the Centers for Disease Control and Prevention's (CDC's) "Heads Up: Concussion in Youth Sports" materials in preventing, recognizing, and responding to concussions. Methods: A 22-item survey was developed with questions pertaining to demographics, awareness of sports-related concussion, and the usefulness of the CDC's "Heads Up: Concussion in Youth Sports" initiative and materials. A total of 340 youth sport coaches completed the survey, for a response rate of 34.0 percent. Results: All youth sport coaches reported having the "Heads Up" materials for approximately 6 months before completing the survey. Seventy-seven percent of youth sports coaches reported being better able to identify athletes who may have a concussion, with 50 percent reported having learned something new about concussion after reviewing the materials. Sixty-three percent of youth sport coaches viewed concussions as being more serious, while 72 percent of coaches reporting that they are now educating others on concussion. Conclusion: The "Heads Up" materials demonstrated that youth sports coaches' were able to appropriately prevent, recognize, and respond to sports-related concussions after reviewing the materials. Future studies should concentrate on evaluating the impact of concussion policies, laws and media coverage on coaches' awareness and prevention, recognition, and response to concussions using a rigorous design including a control group.

Johnson, L.S. (2012). **Return to play guidelines cannot solve the football-related concussion problem.** *Journal of School Health*, 82(4), 180-185.

ERIC Number: EJ1013450

ABSTRACT: Background: High school football players are the single largest cohort of athletes playing tackle football, and account for the majority of sport-related concussions. Return to play guidelines (RTPs) have emerged as the preferred approach for addressing the problem of sport-related concussion in youth athletes. Methods: This article reviews evidence of the risks and effects of football-related concussion and sub-concussive brain trauma, as well as the effectiveness of RTPs as a preventative measure. Literature review utilized PubMed and Google Scholar, using combinations of the search terms "football," "sports," "concussion," "Chronic Traumatic Encephalopathy," "athlete," "youth," and "pediatric." Literature review emphasized medical journals and primary neuroscientific research on sport-related concussion and concussion recovery, particularly in youth athletes. Results: Sport-related concussion is a significant problem among student athletes. Student athletes are more vulnerable to concussion, and at risk of neurocognitive deficits lasting a year or more, with serious effects on academic and athletic performance. RTPs do little to address the problem of sport-related concussion or the chronic damage caused by sub-concussive brain trauma. Conclusions: Emphasizing RTPs as the solution to the concussion problem in tackle football risks neglecting genuine reforms that would prevent concussions. More effective concussion prevention is needed. Eliminating tackling from school football for youth under the age of 16 is recommended to reduce concussions. Additional modifications to football are recommended to enhance safety and reduce brain trauma at all levels of play.

2011

Boyer, C. (2011). **Stay aHEAD of the game: Get the facts about concussion in sports.** *Exceptional Parent*, 41(3), 22-23.

ERIC Number: EJ921995

Full-text is available at http://www.thefreelibrary.com/_/print/PrintArticle.aspx?id=252006480

ABSTRACT: Sports offer so many benefits to kids, from fun and fitness to responsibility and teamwork

skills. With sports also come bumps and bruises--and one type of injury requires much more than an ice pack or a band-aid. Head trauma is one of the most common injuries sustained by young athletes, with more than 60,000 concussions occurring each year in U.S. high school sports, reports the American Council on Exercise. The consequences can include impaired intellectual abilities, severe neurological disorders and other long-term disabilities. That's why it's vital for parents, coaches and others who care for kids to better understand concussions, how to prevent them, and what to do when kids sustain them. This article provides some facts about concussion in sports.

Brady, D., & Brady, F. (2011). **Sport-related concussions.** *Communique*, 39(8), 38-39.

ERIC Number: EJ934070

Full-text is available at <http://www.nasponline.org/publications/cq/39/8/sport-related-concussions.aspx>

ABSTRACT: Sport-related concussions (SRC) are not limited to specific age ranges, professional athletes, or gender. The primary focus of much of SRC research pertains to the assessment, management, and return to play of the concussed athlete. This article highlights some major issues of SRC along with some controversies that presently exist within the field. Readers are encouraged to discuss specific SRC concerns with qualified and knowledgeable healthcare providers who are familiar with the person suffering from a concussion.

Reed, N. (2011). **Sport-related concussion and occupational therapy: Expanding the scope of practice.** *Physical & Occupational Therapy in Pediatrics*, 31(3), 222-224.

ERIC Number: EJ962166

ABSTRACT: Sport participation is a common occupation for many children and youth and can lead to improved physical and psychosocial health. Despite these benefits, it exposes children and youth to the increased risk of injury. Concussion, also referred to as mild traumatic brain injury (mTBI), is one of the most common sports injuries reported in the pediatric population, where a child is six times more likely to suffer a concussion during organized sport participation than during other physical leisure activities (Browne & Lam, 2006). The profession of occupational therapy has yet to be widely recognized

or utilized within the world of sport when rehabilitating athletes following a concussion. However, the importance of an interdisciplinary approach to sport-related concussion management has been promoted internationally (McCroory et al., 2005; McCroory et al., 2009). The combinations of symptoms associated with sport-related concussion can have a significant impact on occupational performance, both on and off the playing field. Occupational therapists can assume a variety of roles specific to the safe return of athletes to their meaningful daily occupations. This commentary aims to act as a starting point for exploration of sport-related concussion from an occupational perspective and to expand the scope of occupational therapy practice into the world of sport.

2010

Chinn, N.R. (2010). *Concussion Assessment in California Community College Football: Athletic Trainers' Strides Toward a safer Return to Play*. ProQuest LLC, Ed.D. Dissertation, University of California, Davis.

ERIC Number: ED519879

ABSTRACT: The purpose of this mixed method study was to compare current practices of athletic trainers in the management of concussion in football at California Community Colleges (CCC) with the concussion management guidelines set forth by the National Athletic Trainers Association (NATA). The study also set out to gain understanding of why some athletic trainers comply with best practices in concussion management, such as performing baseline testing, while others do not. The first phase of the research was a population study, and consisted of one athletic trainer from each of the California Community Colleges that had a football program at the time of the study, which totaled seventy-two. Telephone surveys were conducted with 64 of the 72 CCC athletic trainers. The second part of the research consisted of follow-up in-depth interviews with eight of the athletic trainers at their corresponding work sites. Quantitative data was analyzed utilizing descriptive statistics, correlations, and multiple regression utilizing SPSS. Qualitative data reflecting responses to research questions was systematically analyzed and synthesized into corresponding themes. The results of this research indicated that a large number

of California Community College athletic trainers (71 percent of those surveyed) are not currently conducting baseline testing. Further, number of years practicing as an athletic trainer negatively correlated with frequency of obtaining cognitive baselines. At the sideline, the most commonly utilized method of assessment by surveyed subjects was a symptoms checklist. Informal cognitive assessment was performed by half of the study's subjects, while approximately one third incorporated a standardized assessment. Methods of assessment for return to play also varied. Standardized methods of assessment were employed in making return to play decisions by 42 percent of subjects, and 10 percent utilized ImPact computerized software. Those subjects in the study who conducted baseline testing considered it part of providing the best care for athletes, linking it to meeting "the gold standard" in concussion management. Other reasons for conducting baseline testing included identifying baseline testing as a valuable tool for reducing further injury, viewing baseline testing as a method for reducing risk and liability, and experiencing a sense of responsibility in adhering to the NATA position statement on management of concussion. Themes identified for not conducting baseline testing included time constraints, and viewing baseline testing as an unnecessary component of a concussion management program. Respondents reported on pressure to return an athlete to play, frequency of receiving concussion education and amount of workload. Results of these variables are discussed as they relate to concussion assessment and return to play practices. Finally, recommendations are offered that include the creation of a system-wide approach to concussion management that reflects best practices utilized in systems such as the NFL, as well as baseline testing of athletes in all contact sports at California Community Colleges.

Faure, C. (2010). **Creating concussion management policy: How school leaders, coaches, and parents can work together to ensure kids stay safer in sport.** *American Secondary Education*, 39(1), 5-14.

ERIC Number: EJ906434

Full-text is available at <http://springfieldlibrary.wikispaces.com/file/view/concussion.pdf>

ABSTRACT: School leaders, parents and coaches are challenged to ensure the safety of athletes participating in interscholastic programs, including

concussion management. With an estimated 300,000 sport-related concussions occurring annually in the United States and a public perception that bell ringers are not concussions, many head-injured children are being allowed to continue to play through their symptoms. That decision puts those athletes at additional catastrophic risk. While several states have passed legislation to set minimum concussion management guidelines, an alarming need still exists to better educate those on America's sport sidelines. This article provides school leaders, parents and coaches with a snapshot of appropriate concussion management practices by presenting policy recommendations for establishing uniform guidelines consistent with the current published literature. It also provides recommendations to teachers for making classroom accommodations for athletes with concussions.

Faure, C., & Pemberton, C.L.A. (2010). **Concussion and the young athlete: Critical management strategies.** *Journal of Physical Education, Recreation, & Dance (JOPERD)*, 81(1), 19-26.

ERIC Number: EJ886354

ABSTRACT: One in six high school football players in the United States will sustain a concussion at some point during their playing career. The consequences of concussion can be catastrophic, especially since the symptoms are rarely visible and often overlooked. To ensure the safety of athletes in youth and interscholastic sports programs, having Certified Athletic Trainers (ATCs) on staff or having a physician available at practices and games to oversee concussion and other injury management, is the best-case scenario. However, when an ATC or physician is not available, it is critical for coaches to be trained to identify and manage concussion. The purpose of this article is to review the need for and use of both subjective and objective concussion assessment. Since the responsibility for athletic health care often falls on the shoulders of sport administrators and coaches, injury identification training and immediate-care-management education are essential.

Klein, C., Mitchko, J., Sarmiento, K., & Wong, S. (2010). **Evaluation of the centers for disease control and prevention's concussion initiative for high school coaches: "Heads Up: Concussion in high school sports."** *Journal of School Health*,

80(3), 112-118.

ERIC Number: EJ882509

Full-text is available at <http://onlinelibrary.wiley.com/doi/10.1111/j.1746-1561.2010.00491.x/pdf>

ABSTRACT: Background: To reduce the number of sports-related concussions, the Centers for Disease Control and Prevention (CDC), with the support of partners and experts in the field, has developed a tool kit for high school coaches with practical, easy-to-use concussion-related information. This study explores the success of the tool kit in changing knowledge, attitudes, and practices related to the prevention and management of concussions. Methods: A mail questionnaire was administered to all eligible high school coaches who received the tool kit. Follow-up focus groups were conducted for additional information. Both quantitative data from the surveys and qualitative data from the focus groups were analyzed to support the objectives of the study. Results: Respondents self-reported favorable changes in knowledge, attitudes, and practices toward the prevention and management of concussions. Qualitative responses augmented the quantitative data. Conclusion: Barriers to concussion prevention and management are complex; however, these results highlight the role that coaches can play in school settings in establishing a safe environment for their athletes.

Kohn, L.T. (2010). **Concussion in High School Sports: Overall Estimate of Occurrence is not Available, but Key State Laws and Nationwide Guidelines Address Injury Management. Testimony Before the Committee on Education and Labor, House of Representatives. GAO-10-569T. U.S. Government Accountability Office.**

ERIC Number: ED509869

Full-text is available at <http://files.eric.ed.gov/fulltext/ED509869.pdf>

ABSTRACT: Participation in school sports can benefit children but also carries a risk of injury, including concussion. Concussion is a brain injury that can affect memory, speech, and muscle coordination and can cause permanent disability or death. Concussion can be especially serious for children, who are more likely than adults both to sustain a concussion and to take longer to recover. These factors may affect return-to-play decisions, which determine when it is safe for an athlete to participate in sports again. Gov-

ernment Accountability Office (GAO) was asked to testify on concussion incurred in high school sports. This statement focuses on (1) what is known about the nationwide occurrence of concussion; (2) federal concussion prevention programs; (3) the components of key state laws related to the management of concussion; and (4) the recommendations of voluntary nationwide concussion management guidelines. To do this work, GAO conducted literature searches; reviewed injury databases, state laws, and documents from federal agencies and organizations that conduct work in high school athletics or sports medicine; and interviewed federal officials and experts who identified key state laws and nationwide guidelines and provided other information. GAO shared the information in this statement with the relevant federal agencies.

Samuels, C.A. (2010). **Efforts to prevent concussions target schools.** *Education Week*, 30(5), 1, 11. ERIC Number: EJ900621

Full-text is available at <http://www.edweek.org/ew/articles/2010/09/29/05concussion-2.h30.html>

ABSTRACT: The number of sports-related concussions reported by young athletes is on the rise, prompting awareness campaigns from athletic and medical groups, as well as proposed federal legislation to set minimum standards for concussion management in public schools. Concussions are caused by a jolt to the body or a blow to the head that causes the head to move rapidly back and forth. Concussion symptoms include dizziness, nausea, confusion, slurred speech, and memory problems. With the increasing concussion cases in schools, the National Athletics Trainers' Association and the National Academy of Neuropsychology Foundation launched a campaign to educate athletes, coaches, teachers, and parents about concussions. Their efforts coincided with legislation from the U.S. House Education and Labor Committee that would require schools to develop a plan for concussion safety and management, implement an "if in doubt, sit it out" policy, and provide supports for student athletes recovering from concussion as they return to school and play.

2009

De Souza, M.J., Ducher, G., Gentner, N., Miller, K.E., Shakib, S., Staurowsky, E.J., Theberge, N., &

Williams, N.I. (2009). *Her Life Depends on it II: Sport, Physical Activity, and the Health and Well-Being of American Girls and Women.* *Women's Sports Foundation.*

ERIC Number: ED515841

Full-text is available at <http://files.eric.ed.gov/fulltext/ED515841.pdf>

ABSTRACT: In 2004, the Women's Sports Foundation published the first edition of "Her Life Depends On It" (Don Sabo, Kathleen E. Miller, Merrill J. Melnick, and Leslie Heywood). At that time, it was clear that evidence-based research confirmed that regular physical activity and sport provides the critical foundation, in no small part, that allows girls and women to lead healthy, strong, and fulfilled lives. Now, five years later, "Her Life Depends On It II", provides an updated, and even more comprehensive, review of the existing research on the links between sports and physical activity and the health and well-being of American girls and women. This expanded review of existing research and health information is co-authored by a team of experts from several related disciplines, including epidemiology, exercise physiology, kinesiology, psychology, and sociology. Some key contributions of this new report include the following: (1) Research affirms, even more definitively than five years ago, that engagement in moderate and consistent levels of physical activity and sport for girls and women is essential to good health and well-being; (2) Although more research needs to be done, early studies examining the connections between physical activity and academic achievement show there is a positive relationship between the two in girls and women; (3) Females from lower economic backgrounds and females of color engage less in physical activity, have less access to sport and physical fitness programs, and suffer negative health consequences as a result; and (4) Emerging research in prevention and training practices show that gender-conscious approaches to physical training and conditioning for female athletes help to reduce the likelihood of anterior cruciate ligament (ACL) injuries and concussions. [Funding for this paper was provided by Gatorade. For the executive summary, see ED515840.]

DeSouza, M.J., Ducher, G., Gentner, N., Miller, K.E., Shakib, S., Staurowsky, E.J., Theberge, N., & Williams, N.I. (2009). *Her Life Depends on it II: Sport,*

Physical Activity, and the Health and Well-Being of American Girls and Women. Executive summary. Women's Sports Foundation.

ERIC Number: ED515840

Full-text is available at: <http://files.eric.ed.gov/full-text/ED515840.pdf>

ABSTRACT: In 2004, the Women's Sports Foundation published the first edition of "Her Life Depends On It" (Sabo et al.). At that time, it was clear that evidence-based research confirmed that regular physical activity and sport provides the critical foundation, in no small part, that allows girls and women to lead healthy, strong, and fulfilled lives. Now, five years later, "Her Life Depends On It II", provides an updated, and even more comprehensive, review of the existing research on the links between sports and physical activity and the health and well-being of American girls and women. This expanded review of existing research and health information is co-authored by a team of experts from several related disciplines, including epidemiology, exercise physiology, kinesiology, psychology, and sociology. Some key contributions of this new report include the following: (1) Research affirms, even more definitively than five years ago, that engagement in moderate and consistent levels of physical activity and sport for girls and women is essential to good health and well-being; (2) Although more research needs to be done, early studies examining the connections between physical activity and academic achievement show there is a positive relationship between the two in girls and women; (3) Females from lower economic backgrounds and females of color engage less in physical activity, have less access to sport and physical fitness programs, and suffer negative health consequences as a result; and (4) Emerging research in prevention and training practices show that gender-conscious approaches to physical training and conditioning for female athletes help to reduce the likelihood of anterior cruciate ligament (ACL) injuries and concussions. [Funding for this paper was provided by Gatorade. For the main report, see ED515841.]

2007

Hayes, G., Huitric, M., Mitchko, J., Pruzan, M., Sarmiento, K., & Sawyer, R. (2007). **CDC's approach to educating coaches about sports-related concussion.** *American Journal of Health Education,*

38(2), 99-103.

ERIC Number: EJ795813

Full-text is available at <http://files.eric.ed.gov/full-text/EJ795813.pdf>

ABSTRACT: Sports-related concussions can happen to any athlete in any sport. Each year in the United States, an estimated 1.6-3.8 million sports and recreation-related traumatic brain injuries (TBIs) occur, most of which can be classified as concussions. To help coaches prevent, recognize, and better manage sports-related concussions, the Centers for Disease Control and Prevention's (CDC) National Center for Injury Prevention and Control (CDC's Injury Center) applied a comprehensive health-education approach to developing a multimedia tool kit for high school athletic coaches. From developing an expert panel and pretesting message concepts to pilot testing, promoting, and evaluating the final product, CDC has shown that this undertaking is highly effective. Results of the pilot study and promotion efforts show that the tool kit is well received by coaches and school officials and that it meets a critical health education need.

Vance, E. (2007). **The science of hard knocks.** *Chronicle of Higher Education, 53*(41), A36.

ERIC Number: EJ771750

ABSTRACT: Head injuries in sports are nothing new, but in recent years, college athletes have reported a steady rise in concussions. Football players still get the most knocks to the head. Women have managed to keep up with, and often surpass, men in sports-related concussions in the last few years. In basketball, women reported 24 percent more concussions than men did during games in the 2004-5 season. In soccer, women had concussions at almost twice the rate of men. A flurry of recent research about head injuries has called attention to the issue, but concussions remain a medical mystery. Some medical experts fear that athletics trainers are overlooking many concussions and that coaches sometimes push to get players back into games before their head injuries have healed. Recent studies have shown that concussions are cumulative: once you have one concussion, you are more likely to have a second that is more severe. As it stands, the only accepted treatment for a concussion is to rest the brain. That means no contact sports, no exercise, and no strenuous thinking, all of which creates a challenge for college athletes. Experts

say that taking an important exam or memorizing the periodic table will not cause additional damage, but it will likely slow the recovery. Dr. Robert Cantu says treating an injury that cannot be directly observed is tricky, especially in a young brain, which is not fully developed until about age 22 and so takes longer to mend. He and other medical experts stress the importance of rest. However, National Collegiate Athletic Association (NCAA) guidelines leave it up to the individual trainer, suggesting that the player have no symptoms and return gradually. The Centers for Disease Control and Prevention, which recently released a primer on concussions, recommends at least one week's rest after symptoms disappear. Perhaps the biggest unknown with concussions is whether they affect long-term health. Recent news reports have detailed how several former professional players who suffered multiple concussions during their playing days have developed premature Alzheimer's disease, dementia or have been treated for clinical depression. Although some medical experts say it is too early to link concussions with long-term health problems, most people who study brain injuries do not doubt that concussions can have some lasting effect on athletes. What effects they have and who is at risk remain unclear.

2006

Bizzochi, J., Bradley, N.L., Goodman, D., Paras, B., & Williamson, I.J. (2006). **Video gaming promotes concussion knowledge acquisition in youth hockey players.** *Journal of Adolescence*, 29(3), 351-360.

ERIC Number: EJ737778

ABSTRACT: While the positive uses for video games in an educational setting have also been established, the educational aim is usually made explicit. The goal of this research was to develop a video game wherein the educational aspect was implicitly embedded in the video game, such that the gaming activity remained interesting and relevant. Following a pilot study to confirm the usability of an in-house developed game, two studies were conducted with 11-17 year old hockey players ("N"[1]=130, "N"[2]=39). Results demonstrated that participants playing the experimental version of the video game scored significantly higher on a concussion symptoms questionnaire, in a significantly faster time, than participants playing

the control version of the game. Most participants indicated that they enjoyed the game and would play it again. These results suggest that educational material can be conveyed successfully and in an appealing manner via video game play.

2005

Centers for Disease Control and Prevention (2005). ***Heads Up: Concussion in High School Sports. Guide for Coaches.***

Full-text is available at <http://files.eric.ed.gov/fulltext/ED486066.pdf>

ERIC Number: ED486066

ABSTRACT: This guide provides general information to high school sports coaches about concussions. It focuses on the fact that coaches can play a key role in preventing concussions and managing them properly when they occur. The following sections are included: (1) The Facts; (2) Signs and Symptoms; (3) Prevention and Preparation; (4) When a Concussion Occurs; and (5) Communicating Effectively about Concussions.

2004

Battin, B., & Cobb, S. (2004). **Second-impact syndrome.** *Journal of School Nursing*, 20(5), 262-267.

ERIC Number: EJ885174

ABSTRACT: Sports-related injuries are among the more common causes of injury in adolescents that can result in concussion and its sequelae, post-concussion syndrome and second-impact syndrome (SIS). Students who experience multiple brain injuries within a short period of time (hours, days, or weeks) may suffer catastrophic or fatal reactions related to SIS. Adolescents are particularly susceptible to the dangers of SIS, and current return-to-play guidelines may be too lenient to protect a student from SIS. Any student with signs of a concussion should receive medical evaluation and not be allowed to return to play in the current game or practice. The role of the school nurse includes being knowledgeable about management of head injuries and return-to-play guidelines, providing follow-up for athletes who have concussions, and providing education on prevention and management of head injuries.

2002

Aubry, M., Cantu, R., Dvorak, J., Graf-Baumann, T., Johnston, K., Kelly, J., Lovell, M., McCrory, P., Meeuwisse, W., & Schamasch, P. (2002). **Summary and Agreement Statement of the First International Conference on Concussion in Sport, Vienna 2001.** *Physician and Sportsmedicine*, 30(2), 57-63.

ERIC Number: ED519879

Full-text is available at <http://bjsm.bmj.com/content/36/1/6.full.pdf+html>

ABSTRACT: An international group of concussion experts met in 2001 to discuss the most recent research and findings and to establish guidelines for clinical practice. They addressed such issues as epidemiology, basic and clinical science, grading systems, cognitive assessment, new research methods, protective equipment, management, prevention, and long-term outcome. The results of their work is summarized in this agreement statement.

2001

Anderson, S., Hooker, D., & Oliaro, S. (2001). **Management of cerebral concussion in sports: The athletic trainer's perspective.** *Journal of Athletic Training*, 36(3), 257-62.

ERIC Number: EJ636263

Full-text is available at <http://europemc.org/articles/PMC155416?pdf=render>

ABSTRACT: Presents a new approach in the evaluation and management of concussions from the athletic trainer's perspective. This quantifiable assessment technique provides more information on which return-to-play decisions can be made based on the athlete's symptoms and performance on objective tests. It can be used during initial sideline examinations as well as during subsequent follow-up examinations.

Garrett, W.E., Jr., & Kirkendall, D.T. (2001). **Heading in soccer: Integral skill or grounds for cognitive dysfunction?** *Journal of Athletic Training*, 36(3), 328-33.

ERIC Number: EJ636265

ABSTRACT: Discusses how purposeful heading of soccer balls and head injuries affect soccer players' cognitive dysfunction. Cognitive deficits may occur

for many reasons. Heading cannot be blamed when details of the actual event and impact are unknown. Concussions are the most common head injury in soccer and a factor in cognitive deficits and are probably the mechanism of the reported dysfunction.

Mueller, F.O. (2001). **Catastrophic head injuries in high school and collegiate sports.** *Journal of Athletic Training*, 36(3), 312-15.

ERIC Number: EJ636264

ABSTRACT: Describes the incidence of catastrophic head injuries within high school and college sports. Data from a national surveillance system indicated that a football-related fatality occurred every year except one from 1945-99, mainly related to head injuries. From 1984-99, 69 football head-related injuries resulted in permanent disability. Deaths and permanent disability injuries also occurred in other sports.

1999

(1999). *NCAA Sports Medicine Handbook, 1999-2000. Twelfth Edition. National Collegiate Athletic Association, Indianapolis, IN.*

ERIC Number: ED435361

ABSTRACT: This handbook, first published in 1975, is the primary educational tool used by the National Collegiate Athletic Association Committee on Competitive Safeguards and Medical Aspects of Sports, and is designed to assist schools in the development of safe intercollegiate athletics programs. The handbook's first section on administrative issues covers sports medicine administration; medical evaluations, immunizations, and records; dispensing prescription medication; and lightning safety. The second section dealing with medical issues covers medical disqualification of the student-athlete; skin infections in wrestling; prevention of heat illness; weight loss/hypohydration; assessment of body composition; eating disorders/anorexia and bulimia; menstrual cycle dysfunction; blood borne pathogens; nontherapeutic drugs; nutritional ergogenic aids; use of local anesthetics; use of injectable corticosteroids for sports injuries; cold stress; "burners," or brachial plexus injuries; and concussion and second-impact syndrome. The third section on special populations covers participation by impaired and pregnant

student-athletes and student-athletes with sickle cell trait. The final section on equipment covers protective equipment; eye safety; use of the trampoline and minitramp; mouth guards; use of the head as a weapon in football and other contact sports; and guidelines for fitting and removing helmets. Appended is a NCAA injury surveillance system summary.

1997

Hutchinson, M.R. (1997). **Cheerleading injuries. Patterns, prevention, case reports.** *Physician and Sportsmedicine*, 25(9), 83-86, 89-91, 96.

ERIC Number: EJ553078

ABSTRACT: Although cheerleading carries a relatively low injury risk, injuries that do occur can be severe, commonly affecting the ankle, head, and neck. Two case reports are presented that illustrate acute injuries typical of cheerleading. Prevention recommendations are offered related to supervising, screening, limiting stunts, optimizing the environment and equipment, and preparing for emergencies.

1989

Fields, K.B. (1989). **Head injuries in soccer.** *Physician and Sportsmedicine*, 17(1), 69, 72-73.

ERIC Number: EJ404505

ABSTRACT: This article reviews the medical literature on head injuries in soccer and concludes that protective headgear to reduce these injuries may not be as effective as rule changes and other measures, such as padding goal posts.



Documents from the Cochrane Database of Systematic Reviews search at www.thecochranelibrary.org are listed below:

2006

Collins, M.W., Fu, F.H., Kampen, D.A., Lovell, M.R., & Pardini, J.E. (2006). **The “value added” of neurocognitive testing after sports-related concussion.** *The American Journal of Sports Medicine*, 34(10), 1630-5.

ID: CN-00571004

ABSTRACT: BACKGROUND: Neurocognitive testing has been endorsed as a “cornerstone” of concussion management by recent Vienna and Prague meetings of the Concussion in Sport Group. Neurocognitive testing is important given the potential unreliability of athlete self-report after injury. Relying only on athletes’ reports of symptoms may result in premature return of athletes to contact sport, potentially exposing them to additional injury. HYPOTHESIS: Use of computer-based neurocognitive testing results in an increased capacity to detect post-concussive abnormalities after injury. STUDY DESIGN: Case control study; Level of evidence, 3. METHODS: High school and college athletes with a diagnosed concussion were tested 2 days after injury. Post-injury neurocognitive performance (Immediate Post-concussion Assessment and Cognitive Testing) and symptom (post-concussion symptom) scores were compared with pre-injury (baseline) scores and with those of an age- and education-matched non-injured athlete control group. “Abnormal” test performance was determined statistically with Reliable Change Index scores. RESULTS: Sixty-four percent of concussed athletes reported a significant increase in symptoms, as judged by post-concussion symptom scores, compared with pre-injury baseline at two days after injury. Eighty-three percent of the concussed sample demonstrated significantly poorer neurocognitive test results relative to their own baseline performance. The addition of neurocognitive testing resulted in a net increase in sensitivity of 19 percent. Ninety-three percent of the sample had either abnormal neurocognitive test results or a significant increase in symptoms, relative to their own baseline; 30 percent of a control group demonstrated either

abnormalities in neurocognitive testing or elevated symptoms, as judged by post-concussion symptom scores. For the concussed group, use of symptom and neurocognitive test results resulted in an increased yield of 29 percent overreliance on symptoms alone. In contrast, 0 percent of the control group had both symptoms and abnormal neurocognitive testing. **CONCLUSION:** Reliance on patients' self-reported symptoms after concussion is likely to result in underdiagnosis of concussion and may result in premature return to play. Neurocognitive testing increases diagnostic accuracy when used in conjunction with self-reported symptoms.

2001

Bennell, K., Bush, A., Collie, A., Darby, D.G., Makdissi, M., Maruff, P., & McCrory, P. (2001). **Computerized cognitive assessment of concussed Australian Rules footballers.** *British Journal of Sports Medicine*, 35(5), 354-60.

ID: CN-00374130

Full-text is available at <http://bjsm.bmj.com/content/35/5/354.full.pdf+html>

ABSTRACT: 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 computerized 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 computerized and paper and pencil neuropsychological tests. To investigate the role of computerized 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 computerized 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.

Documents from the Physiotherapy Evidence Database search at www.pedro.org.au are listed below:

2013

Athens, J., Balasundaram, A.P., Schneiders, A.G., & Sullivan, J.S. (2013). **Symptom response following acute bouts of exercise in concussed and non-concussed individuals – A systematic narrative review.** *Physical Therapy in Sport*, 14(4), 253-258. **ABSTRACT: BACKGROUND:** Athletes suspected of being concussed are frequently evaluated on the side-line for self-reported symptoms which guide subsequent management and return-to-play decisions. Concussion-like symptoms have been shown to be influenced by prior participation in physical activity; however, the potential contribution of acute exercise on symptoms is not well understood. **OBJECTIVE:** The purpose of this study was to systematically review the literature in order to further understand the acute effects of exercise on documented self-reported symptoms in both concussed and non-concussed individuals. **DESIGN:** Systematic narrative review. **METHODS:** Nine electronic databases were systematically searched using keywords and MeSH terms that included; self-reported symptoms, sports-related concussion, brain concussion, exercise and athletic injuries. In addition, an extensive search of the grey

literature was conducted. RESULTS: Of the 785 articles retrieved, only five met the inclusion criteria comprising a total of 295 concussed and non-concussed participants. In general, the mean symptom scores increased from pre-exercise to post-exercise levels immediately following acute bouts of exercise in both concussed and non-concussed individuals. CONCLUSION: Although the symptom scores increased following exercise in both concussed and non-concussed participants, this increase was only maintained for a relatively short duration. Thus, the application to real world situation is still to be established.

2012

Garza, D., Klugl, M., Matheson, G.O., McBain, K., Meeuwisse, W.H., Shrier, I., & Shultz, R. (2012). **Prevention of sport injury II: A systematic review of clinical science research [with consumer summary]**. *British Journal of Sports Medicine*, 46(3), 174-179.

Full-text is available at <http://bjsm.bmj.com/content/46/3/174.full.pdf+html>

ABSTRACT: OBJECTIVE: To characterize the nature of the sport injury prevention literature by reviewing published articles that evaluate specific clinical interventions designed to reduce sport injury risks. DATA SOURCES: PubMed, Cinahl, Web of Science and Embase. MAIN RESULTS: Only 139 of 2,525 articles retrieved met the inclusion criteria. Almost 40 percent were randomized controlled trials and 30.2 percent were cohort studies. The focus of the study was protective equipment in 41 percent, training in 32.4 percent, education in 7.9 percent, rules and regulations in 4.3 percent, and 13.3 percent involved a combination of the above. Equipment research studied stability devices (42.1 percent), head and face protectors (33.3 percent), attenuating devices (17.5 percent) as well as other devices (7 percent). Training studies often used a combination of interventions (e.g., balance and stretching); most included balance and coordination (63.3 percent), with strength and power (36.7 percent) and stretching (22.5 percent) being less common. Almost 70 percent of the studies examined lower extremity injuries, and a majority of these were joint (non-bone)-ligament injuries. Contact sports were most frequently studied (41.5 percent), followed by collision (39.8 percent) and non-contact

(20.3 percent). CONCLUSION: The authors found only 139 publications in the existing literature that examined interventions designed to prevent sports injury. Of these, the majority investigated equipment or training interventions whereas only 4 percent focused on changes to the rules and regulations that govern sport. The focus of intervention research is on acute injuries in collision and contact sports whereas only 20 percent of the studies focused on non-contact sports.



Documents from the National Library of Medicine PubMed search at www.pubmed.com are listed below:

2014

Balcer, L.J., Galetta, S.L., Leong, D.F., Liu, Z., & Master, C.L. (2014). **The King-Devick test as a concussion screening tool administered by sports parents**. *The Journal of Sports Medicine & Physical Fitness*, 54(1), 70-7.

PMID: 24445547

ABSTRACT: Background: Sports-related concussion has received increasing awareness due to short- and long-term neurologic sequelae seen among athletes. The King-Devick (K-D) test captures impairment of eye movements and other correlates of suboptimal brain function. We investigated the K-D test as a screening for concussion when administered by layperson sports parents in a cohort of amateur boxers. Methods: The K-D test was administered pre-fight and post-fight by laypersons masked to the head trauma status of each athlete. Matches were watched over by a ringside physician and boxing trainer. Athletes with suspected head trauma received testing with the Military Acute Concussion Evaluation (MACE) by the ringside physician to determine concussion status. Athletes sustaining concussion were compared to the athletes screened using the K-D test. Results: Post-fight K-D scores were lower (better) than the best baseline score (41 vs. 39.3 s, P=0.34, Wilcoxon signed-rank test), in the absence of concussion. One

boxer sustained a concussion as determined by the ringside physician. This boxer was accurately identified by the layperson K-D testers due to a worsening in K-D test compared to baseline (3.2 seconds) and an increased number of errors. High levels of test-retest reliability were observed (intra-class correlation coefficient 0.90 [95 percent CI 0.84-0.97]). Additionally, 6 boxers who participated in multiple bouts showed no worsening of their K-D times further supporting that scores are not affected by the fatigue associated with sparring. Conclusion: The K-D test is a rapid sideline screening tool for concussion that can be effectively administered by non-medically trained laypersons.

Bazarian, J., Bigler, E., Cantu, R., Hallett, M., Harbaugh, R., Hovda, D., Kou, Z., Lazzarino, G., Mayer, A.R., Nuwer, M.R., Papa, L., Slobounov, S., & Vagnozzi, R. (2014). **Sports-related concussion: Ongoing debate.** *British Journal of Sports Medicine*, 48(2), 75-6.

PMID: 23501836

No abstract is available.

Brown, S.T., Crowther, M., Ferguson, D., Gran, K., Johnston, J.M., Jr., Shannon, C.N., Vance, E.H., Wellons, J.C., 3rd, & Wilkins, S.A. (2014). **Establishment of a multidisciplinary concussion program: Impact of standardization on patient care and resource utilization.** *Journal of Neurosurgery: Pediatrics*, 13(1), 82-9.

PMID: 24236447

ABSTRACT: Objective: Recent legislation and media coverage have heightened awareness of concussion in youth sports. Previous work by the authors' group defined significant variation of care in management of children with concussion. To address this variation, a multidisciplinary concussion program was established based on a uniform management protocol, with emphasis on community outreach via traditional media sources and the Internet. This retrospective study evaluates the impact of standardization of concussion care and resource utilization before and after standardization in a large regional pediatric hospital center. Methods: This retrospective study included all patients younger than 18 years of age evaluated for sports-related concussion between January 1, 2007, and December 31, 2011. Emergency depart-

ment, sports medicine, and neurosurgery records were reviewed. Data collected included demographics, injury details, clinical course, Sports Concussion Assessment Tool-2 (SCAT2) scores, imaging, discharge instructions, and referral for specialty care. The cohort was analyzed comparing patients evaluated before and after standardization of care. Results Five hundred eighty-nine patients were identified, including 270 before standardization (2007-2011) and 319 after standardization (2011-2012). Statistically significant differences ($p < 0.0001$) were observed between the two groups for multiple variables: there were more girls, more first-time concussions, fewer initial presentations to the emergency department, more consistent administration of the SCAT2, and more consistent supervision of return to play and return to think after adoption of the protocol. Conclusions: A combination of increased public awareness and legislation has led to a 5-fold increase in the number of youth athletes presenting for concussion evaluation at the authors' center. Establishment of a multidisciplinary clinic with a standardized protocol resulted in significantly decreased institutional resource utilization and more consistent concussion care for this growing patient population.

Davis, G., Donaldson, A., Ewing, M.T., Finch, C.F., Makdissi, M., McCrory, P., Newton, J.D., Sullivan, S.J., & White, P.E. (2014). **Knowledge about sports-related concussion: Is the message getting through to coaches and trainers?** *British Journal of Sports Medicine*, 48(2), 119-24.

PMID: 24043666

ABSTRACT: AIM: The need for accurate diagnosis and appropriate return-to-play decisions following a concussion in sports has prompted the dissemination of guidelines to assist managing this condition. This study aimed to assess whether key messages within these guidelines are reflected in the knowledge of coaches and sports trainers involved in community sport. METHODS: An online knowledge survey was widely promoted across Australia in May-August 2012 targeting community Australian Football (AF) and Rugby League (RL) coaches and sports trainers. 260 AF coaches, 161 AF sports trainers, 267 RL coaches and 228 RL sports trainers completed the survey. Knowledge scores were constructed from

Likert scales and compared across football codes and respondent groups. **RESULTS:** General concussion knowledge did not differ across codes but sports trainers had higher levels than did coaches. There were no significant differences in either concussion symptoms or concussion management knowledge across codes or team roles. Over 90 percent of respondents correctly identified five of the eight key signs or symptoms of concussion. Fewer than 50 percent recognized the increased risk of another concussion following an initial concussion. Most incorrectly believed or were uncertain that scans typically show damage to the brain after a concussion occurs. Fewer than 25 percent recognized, and >40 percent were uncertain that younger players typically take longer to recover from concussion than adults. **CONCLUSIONS:** The key messages from published concussion management guidelines have not reached community sports coaches and sports trainers. This needs to be redressed to maximize the safety of all of those involved in community sport.

Dimou, S., & Lagopoulos, J. (2014). **Toward objective markers of concussion in sport: A review of white matter and neurometabolic changes in the brain after sports-related concussion.** *Journal of Neurotrauma*, Jan. 2013. [Epub ahead of print].

PMID: 24266534

ABSTRACT: Sports-related concussion is an issue that has piqued the public's attention of late as concerns surrounding potential long-term sequelae as well as new methods of characterizing the effects of this form of injury continue to develop. For the most part, diagnosis of concussion is based on subjective clinical measures and thus is prone to under-reporting. In the current environment, where conventional imaging modalities, such as computed tomography and magnetic resonance imaging, are unable to elucidate the degree of white matter damage and neuro-metabolic change, a discussion of two advanced imaging techniques-diffusion tensor imaging (DTI) and magnetic resonance spectroscopy (MRS)-is undertaken with a view to highlighting their potential utility. Our aim is to outline a variety of the approaches to concussion research that have been employed, with special attention given to the clinical considerations and acute complications attributed to concussive

injury. DTI and MRS have been at the forefront of research as a result of their noninvasiveness and ease of acquisition, and hence it is thought that the use of these neuroimaging modalities has the potential to aid clinical decision making and management, including guiding return-to-play protocols.

Dougan, B.K., Geffen, G.M., & Horswill, M.S. (2014). **Athletes' age, sex, and years of education moderate the acute neuropsychological impact of sports-related concussion: A meta-analysis.** *Journal of the International Neuropsychological Society: JINS*, 20(1), 64-80.

PMID: 23375058

ABSTRACT: The objective of this study is to determine which pre-existing athlete characteristics, if any, are associated with greater deficits in functioning following sports-related concussion, after controlling for factors previously shown to moderate this effect (e.g., time since injury). Ninety-one independent samples of concussion were included in a fixed+systematic effects meta-analysis (n = 3,801 concussed athletes; 5,631 controls). Moderating variables were assessed using analogue-to-ANOVA and meta-regression analyses. Post-injury assessments first conducted 1-10 days following sports-related concussion revealed significant neuropsychological dysfunction, postural instability and post-concussion symptom reporting (d = -0.54, -1.10, and -1.14, respectively). During this interval, females (d = -0.87), adolescent athletes competing in high school competitions (d = -0.60), and those with 10 years of education (d = -1.32) demonstrated larger post-concussion neuropsychological deficits than males (d = -0.42), adults (d = -0.25), athletes competing at other levels of competition (d = -0.43 to -0.41), or those with 16 years of education (d = -0.15), respectively. However, these sub-groups' differential impairment/recovery beyond 10 days could not be reliably quantified from available literature. Pre-existing athlete characteristics, particularly age, sex and education, were demonstrated to be significant modifiers of neuropsychological outcomes within 10 days of a sports-related concussion. Implications for return-to-play decision-making and future research directions are discussed.

Echlin, P.S., Forwell, L.A., Fredman, E., Helmer, K.G., Holmes, J.D., Johnson, A.M., Koerte, I.K., Mayinger, M., Pasternak, O., Preciado, R.I., Sasaki, T., Shenton, M.E., & Skopelja, E.N. (2014). **Hockey Concussion Education Project, Part 1. Susceptibility-weighted imaging study in male and female ice hockey players over a single season.** *Journal of Neurosurgery*, Feb. 2014. [Epub ahead of print]. PMID: 24490839

ABSTRACT: Object Concussion, or mild traumatic brain injury (mTBI), is a commonly occurring sports-related injury, especially in contact sports such as hockey. Cerebral micro-bleeds (CMBs), which appear as small, hypo-intense lesions on T2*-weighted images, can result from TBI. The authors use susceptibility-weighted imaging (SWI) to automatically detect small hypo-intensities that may be subtle signs of chronic and acute damage due to both sub-concussive and concussive injury. The goal was to investigate how the burden of these hypo-intensities changes over time, over a playing season, and post-concussion, in comparison with subjects who did not suffer a medically observed and diagnosed concussion. **Methods** Images were obtained in 45 university-level adult male and female ice hockey players before and after a single Canadian Interuniversity Sports season. In addition, 11 subjects (5 men and 6 women) underwent imaging at 72 hours, 2 weeks, and 2 months after concussion. To identify subtle changes in brain tissue and potential CMBs, non-vessel clusters of hypo-intensities on SWI were automatically identified, and a hypo-intensity burden index was calculated for all subjects at the beginning of the season (BOS), the end of the season (EOS), and at post-concussion time points (where applicable). **Results** A statistically significant increase in the hypo-intensity burden, relative to the BOS, was observed for male subjects with concussions at the 2-week post-concussion time point. A smaller, non-significant rise in the burden for female subjects with concussions was also observed within the same time period. There were no significant changes in burden for non-concussed subjects of either sex between the BOS and EOS time points. However, there was a statistically significant difference in the burden between male and female subjects in the non-concussed group at both the BOS and EOS time points, with males having a higher burden. **Conclusions** This method extends the

utility of SWI from the enhancement and detection of larger (> 5 mm) CMBs, which are often observed in more severe cases of TBI, to cases involving smaller lesions in which visual detection of injury is difficult. The hypointensity burden metric proposed here shows statistically significant changes over time in the male subjects. A smaller, non-significant increase in the burden metric was observed in the female subjects.

Kay, M.C., Valovich McLeod, T.C., & Welch, C.E. (2014). **Positive and negative factors that influence concussion reporting among secondary school athletes.** *Journal of Sport Rehabilitation*, Jan. 2014. [Epub ahead of print]. PMID: 24458373

ABSTRACT: Concussions are one of the most common sport-related injuries affecting athletes participating at all levels across a variety of sports. It has been reported that up to 3.8 million concussive events occur per year that are sports-related. One significant issue with identifying concussions is that a clinical diagnosis is based on the presence of signs and symptoms, which are self-reported by the patient. In the adolescent population, injury to the brain is possible with even the slightest insult, which can affect recovery and predispose them to subsequent concussions. Recent legislative efforts have included athlete education as a means to improve concussion reporting. More specifically, 49 of the 50 states have implemented concussion legislation³ that includes some type of concussion education protocol, but there is still little evidence to suggest that enhanced knowledge levels result in behavior changes, including improved concussion reporting practices. It is unclear as to what factors make an adolescent athlete more or less likely to report the symptoms of a concussion. **CLINICAL QUESTION:** What factors positively or negatively influence secondary school athletes' likelihood to report symptoms of sport-related concussions?

Marion, D.W., & West, T.A. (2014). **Current recommendations for the diagnosis and treatment of concussion in sport: A comparison of three new guidelines.** *Journal of Neurotrauma*, 31(2), 159-68. PMID: 23879529

ABSTRACT: Currently, there is considerable debate within the sports medicine community about the role

of concussion and the risk of chronic neurological sequelae. This concern has led to significant confusion among primary care providers and athletic trainers about how to best identify those athletes at risk and how to treat those with concussion. During the first quarter of 2013, several new or updated clinical practice guidelines and position statements were published on the diagnosis, treatment, and management of mild traumatic brain injury/concussion in sports. Three of these guidelines were produced by the American Medical Society for Sports Medicine, The American Academy of Neurology, and the Zurich Consensus working group. The goal of each group was to clearly define current best practices for the definition, diagnosis, and acute and post-acute management of sports-related concussion, including specific recommendations for return to play. In this article, we compare the recommendations of each of the three groups, and highlight those topics for which there is consensus regarding the definition of concussion, diagnosis, and acute care of athletes suspected of having a concussion, as well as return-to-play recommendations.

2013

Balcer, L.J., Dorman, E.S., Dziemianowicz, E.M., Galetta, K.M., Galetta, S.L., Laudano, E., Phillips, H.W., Torres, D.M., & Wilson, J.A. (2013). **Sports-related concussion: Anonymous survey of a collegiate cohort.** *Neurology: Clinical Practice*, 3(4), 279-287.

PMID: 24195017

ABSTRACT: Studies suggest that a lack of standardized knowledge may lead to underreporting and undertreatment of sports-related concussion. However, there has been little work done to establish how this knowledge may affect athletes' behaviors toward reporting their concussions and removing themselves from play. We conducted an anonymous online survey to assess athletes' knowledge of signs and symptoms of concussion, and also sought to estimate the potential frequency of underreporting in a collegiate athlete cohort. Among 262 athletes who responded to the survey, 43 percent of those with a history of concussion reported that they had knowingly hidden symptoms of a concussion to stay in a game, and 22 percent of athletes overall indicated that they would be

unlikely or very unlikely to report concussion symptoms to a coach or athletic trainer in the future. These data suggest that there may be a substantial degree of underreporting of concussion among collegiate athletes, despite most acknowledging that they have been formally educated about the risks of concussion.

Berz, K., Divine, J., Ford, K.R., Foss, K.B., Heyl, R., & Myer, G.D. (2013). **Sex-specific differences in the severity of symptoms and recovery rate following sports-related concussion in young athletes.** *The Physician & Sportsmedicine*, 41(2), 58-63.

PMID: 23703518

ABSTRACT: INTRODUCTION: While research on adult recovery from concussion indicates sex-specific symptoms and recovery rates, there is little existing data on younger patient populations. **OBJECTIVE:** To determine sex-specific differences in the severity of presenting symptoms and recovery rate between groups of young athletes who presented ≤ 7 or > 7 days after sports-related concussion. **METHODS:** This study was a retrospective review of athletes aged 9 to 17 years who were referred for evaluation of a sports-related concussion over a 24-month period. The study groups were divided by sex and post-injury presentation to the clinic at ≤ 7 days and > 7 days from the date of injury. Athletes with learning disabilities were excluded from the study and data analysis. Age, height, and weight were recorded for each subject. Each subject also reported their initial degree of confusion, amnesia, or loss of consciousness, and whether a helmet was worn when the injury was sustained. A 22-item post-concussion symptom score (SS) scale was completed by both groups on initial assessment (SS1) and follow-up visit (SS2). The recovery rate (SSR) was calculated as $(SS2-SS1)/\text{days}$ between SS2 and SS1. Sex and group comparisons for SS1 and SSR were performed using 2×2 analysis of variance. A similar analysis was also performed for effects of sex on SS1 and SSR in patients who were not wearing a helmet. **RESULTS:** Thirty-seven athletes aged 15.0 ± 1.9 years were evaluated. Males, regardless of day of presentation, had a lower SS1 evaluation than females (15.8 vs 30.9; $P < 0.05$). Males without helmets did not differ from females without helmets, but this was not significantly different (14.1 vs 29.6; $P = 0.1$). There was not a significant difference in SS1 evaluation between the groups who presented at ≤ 7

or > 7 days. The overall mean SSR was -1.2/day, with no significant difference seen between groups or sex. There were no significant differences in degree of loss of consciousness, amnesia, confusion, or age between the sexes or groups. **CONCLUSION:** Whether presenting at ≤ 7 or > 7 days following a sports-related concussion, female athletes reported a higher SS1 evaluation. With SSR being similar between sexes, the current data suggest that young, female athletes may take longer to become symptom free following sports-related concussion. This information may be an important factor in returning a young athlete to sport after sports-related concussion.

Brody, D., Cernak, I., McKee, A., Peskind, E.R., & Ruff, R.L. (2013). **Military- and sports-related mild traumatic brain injury: Clinical presentation, management, and long-term consequences.** *The Journal of Clinical Psychiatry, 74*(2), 180-8, quiz 188.

PMID: 23473351

ABSTRACT: Awareness that concussions are more serious than previously believed has been increasing. Also known as mild traumatic brain injury (mTBI), concussions often occur, and often multiple times, in both military and sports settings. Brain injuries can seriously and negatively impact patients, leading to changes in personality, sleep problems, and cognitive impairments and can increase the risk for suicide, posttraumatic stress disorder, depression, and anxiety. In some people, repetitive mTBI can lead to chronic traumatic encephalopathy (CTE), a neurodegenerative disorder. Evidence-based treatments are needed for both mTBI and CTE. Currently, symptom management and education are the best strategies to help those who have received multiple concussions. Prevention education about concussions and the use of return-to-play guidelines are especially important for young athletes.

Burkhart, S., Collins, M.W., Elbin, R.J., Fazio-Sumrock, V.C., Kontos, A.P., Maroon, J., & Swindell, H. (2013). **Incidence of sports-related concussion among youth football players aged 8-12 years.** *The Journal of Pediatrics, 163*(3), 717-20.

PMID: 23751761

ABSTRACT: OBJECTIVE: To determine the risk of concussion among youth football players (ages 8-12 years). **STUDY DESIGN:** Participants included 468 male youth football players in western Pennsylvania

during the 2011 youth football season. Incidence rates (IRs) and incidence density ratios (IDRs) of concussion were calculated for games and practices and for age groups. **RESULTS:** There was a total of 11,338 (8415 practice and 2923 game) athletic exposures (AEs) in the study period, during which 20 medically diagnosed concussions occurred. A majority of concussions were the result of head-to-head (45 percent) contact. The combined concussion IR for practices and games was 1.76 per 1000 AEs (95 percent CI 0.99-2.54). The concussion IR was 0.24 per 1000 AEs (95 percent CI 0.04-0.79) in practices and 6.16 per 1000 AEs (95 percent CI 3.76-9.54) in games. The IDR for concussions in games to practices was 25.91 (95 percent CI 6.01-111.70). The IDR of concussions for youth aged 11-12 years compared with youth aged 8-10 years was 2.72 (95 percent CI 0.66-4.78). **CONCLUSIONS:** The overall IR for concussion in youth football players aged 8-12 years was comparable with that reported previously for high school and collegiate samples. However, participation in games was associated with an increase in risk of concussion compared with practices, which was higher than rates previously reported for high school and collegiate athletes. Younger players were slightly less likely to incur a concussion than were older players.

Burkhart, S., Covassin, T., Crutcher, B., & Elbin, R.J. (2013). **The management of sport-related concussion: Considerations for male and female athletes.** *Translational Stroke Research, 4*(4), 420-4.

PMID: 24323339

ABSTRACT: Sport-related concussion continues to be a centerpiece of attention in the field of sports medicine. The benefit to using neurocognitive testing when managing concussion will be documented in this review. In addition to providing critical objective information on the neurocognitive status of the concussed athlete, research data will be provided on the pre- and post-concussion neurocognitive profiles of concussed male and female athletes. Specifically, an overview of research will be presented on the epidemiology of male and female concussion rates, as well as concussion outcomes including symptoms and cognitive function post-injury. Finally, a clinician's perspective on managing sports-related concussion will be presented focusing on three factors regarding sex differences: risk factors, clinical presentation, and management.

Cantu, R.C., Chin, L.S., Montenegro, P., Padalino, D.J., & Yi, J. (2013). **Chronic traumatic encephalopathy.** *Current Sports Medicine Reports*, 12(1), 28-32.

PMID: 23314081

ABSTRACT: Sports-related concussion has gained increased prominence, in part due to media coverage of several well-known athletes who have died from consequences of chronic traumatic encephalopathy (CTE). CTE was first described by Martland in 1928 as a syndrome seen in boxers who had experienced significant head trauma from repeated blows. The classic symptoms of impaired cognition, mood, behavior, and motor skills also have been reported in professional football players, and in 2005, the histopathological findings of CTE were first reported in a former National Football League (NFL) player. These findings were similar to Alzheimer's disease in some ways but differed in critical areas such as a predominance of tau protein deposition over amyloid. The pathophysiology is still unknown but involves a history of repeated concussive and sub-concussive blows and then a lag period before CTE symptoms become evident. The involvement of excitotoxic amino acids and abnormal microglial activation remain speculative. Early identification and prevention of this disease by reducing repeated blows to the head has become a critical focus of current research.

Collins, M.W., Kegel, N.E., Kontos, A.P., Lovell, M.R., & Sandel, N.K. (2013). **The relationship of symptoms and neurocognitive performance to perceived recovery from sports-related concussion among adolescent athletes.** *Applied Neuropsychology: Child*, 2(1), 64-9.

PMID: 23427778

ABSTRACT: Sports medicine practitioners often consider athletes' self-reports of recovery for the management of concussion, and it is not clear which factors (i.e., neurocognitive performance and symptoms) athletes consider when forming perceptions of recovery from concussion. The current study assessed the relationship of perceptions of recovery to neurocognitive performance on the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) battery and to symptoms using the Post-Concussion Symptom Scale (PCSS). A total of 101 concussed athletes (62 males, 39 females) aged 12

to 18 years old were included in the study ($M(\text{age}) = 14.75$, $SD = 1.76$). Athletes were asked to rate their "percent back to normal" (i.e., perception of recovery) at the time of evaluation. A multiple regression for neurocognitive performance and symptoms revealed a significant model that accounted for 58 percent of the variance in perceptions of recovery. Adolescent athletes base their perceptions primarily on somatic symptoms (e.g., headache, nausea, vomiting, etc.), and these perceptions may be incongruent with objective neurocognitive measures. Athletes' tendency to overlook several factors when forming their perceptions of recovery should caution the sports medicine practitioner from relying on self-reported symptoms as their primary criterion for return-to-play decisions. These data further support the need for valid and reliable measures for concussion management.

Collins, M., Kontos, A.P., Lovell, M., & Reddy, C.C. (2013). **Efficacy of amantadine treatment on symptoms and neurocognitive performance among adolescents following sports-related concussion.** *The Journal of Head Trauma Rehabilitation*, 28(4), 260-5. PMID: 22613947

ABSTRACT: OBJECTIVE: To evaluate the efficacy of amantadine in the treatment of symptoms and neurocognitive performance in adolescents following sports-related concussion. **PARTICIPANTS:** A clinical sample of 25 male ($n=11$) and female ($n=14$) adolescent subjects with an age-, sex-, and concussion history-matched group of 25 male ($n=11$) and female ($n=14$) control subjects. **SETTING:** Outpatient concussion clinic. **INTERVENTION:** Retrospective, case-control design. Treatment group consisted of patients treated with 100 mg of amantadine twice daily (200 mg total per day) following a period of rest. Matched controls were evaluated and treated conservatively without medication at the same concussion program prior to the start of the current amantadine protocol. **MAIN OUTCOME MEASURES:** Immediate Post-concussion Assessment and Cognitive Test computerized neurocognitive test battery and symptom report. **RESULTS:** Results support significantly greater improvements from pre- to post-test in reported symptoms, verbal memory, and reaction time performance for the amantadine group than the matched controls. There were no significant differences for visual memory or visual motor processing

speed. **CONCLUSION:** This study provides empirical support for amantadine as an effective pharmacologic treatment of certain concussion-related cognitive deficits and symptoms in athletes with protracted recovery of more than three weeks.

Comper, P., Echemendia, R.J., Gioia, G.A., Iverson, G.L., Macciocchi, S.N., McCrea, M., & Putukian, M. (2013). **Advances in neuropsychological assessment of sport-related concussion.** *British Journal of Sports Medicine*, 47(5), 294-8.

PMID: 23479487

ABSTRACT: OBJECTIVE: To critically review the literature from the past 12 years regarding the following key issues in sports-related neuropsychological assessment: (1) the advantages and disadvantages of different neuropsychological assessment modalities; (2) the evidence for and against the current paradigm of baseline/post-injury testing; (3) the role of psychological factors in the evaluation and management of concussion; (4) advances in the neuropsychological assessment of children; (5) multi-modal assessment paradigms; (6) the role of the neuropsychologist as part of the sports healthcare team; and (6) the appropriate administration and interpretation of neuropsychological tests. **DESIGN:** Targeted computerized literature review (MEDLINE, PubMed, CINAHL and PsychInfo) from 2000 to the present using key words: neuropsychological, neurocognitive, assessment, testing, concussion and sports. **RESULTS:** More than 2600 articles were identified using key word searches of the databases, including many duplicates. Several books were also reviewed. The articles were pared down for review if they specifically addressed the key areas noted above. **CONCLUSIONS:** Traditional and computerized neuropsychological tests are useful in the evaluation and management of concussion. Brief cognitive evaluation tools are not substitutes for formal neuropsychological assessment. At present, there is insufficient evidence to recommend the widespread routine use of baseline neuropsychological testing. Although scant, research suggests that psychological factors may complicate and prolong recovery from concussion in some athletes. Age-appropriate symptom scales for children have been developed but research into age-appropriate tests of cognitive functions lags behind. Neuropsychologists are uniquely qualified to interpret neuropsychological tests and can play an important role within the context of a

multifaceted-multimodal approach to manage sports-related concussions.

Davenport, E.M., Golman, A.J., Maldjian, J.A., Powers, A.K., Stitzel, J.D., Urban, J.E., & Whitlow, C.T. (2013). **Head impact exposure in youth football: High school ages 14 to 18 years and cumulative impact analysis.** *Annals of Biomedical Engineering*, 41(12), 2474-87.

PMID: 23864337

ABSTRACT: Sports-related concussion is the most common athletic head injury with football having the highest rate among high school athletes. Traditionally, research on the biomechanics of football-related head impact has been focused at the collegiate level. Less research has been performed at the high school level, despite the incidence of concussion among high school football players. The objective of this study is to twofold: to quantify the head impact exposure in high school football, and to develop a cumulative impact analysis method. Head impact exposure was measured by instrumenting the helmets of 40 high school football players with helmet mounted accelerometer arrays to measure linear and rotational acceleration. A total of 16,502 head impacts were collected over the course of the season. Biomechanical data were analyzed by team and by player. The median impact for each player ranged from 15.2 to 27.0 g with an average value of 21.7 (± 2.4) g. The 95th percentile impact for each player ranged from 38.8 to 72.9 g with an average value of 56.4 (± 10.5) g. Next, an impact exposure metric utilizing concussion injury risk curves was created to quantify cumulative exposure for each participating player over the course of the season. Impacts were weighted according to the associated risk due to linear acceleration and rotational acceleration alone, as well as the combined probability of injury associated with both. These risks were summed over the course of a season to generate risk weighted cumulative exposure. The impact frequency was found to be greater during games compared to practices with an average number of impacts per session of 15.5 and 9.4, respectively. However, the median cumulative risk weighted exposure based on combined probability was found to be greater for practices vs. games. These data will provide a metric that may be used to better understand the cumulative effects of repetitive head impacts, injury mechanisms, and head impact exposure of athletes in football.

Gardner, A., Jordan, B.D., Kutcher, J.S., McCrory, P., & Meeuwisse, W.H. (2013). **What is the evidence for chronic concussion-related changes in retired athletes: Behavioral, pathological, and clinical outcomes?** *British Journal of Sports Medicine*, 47(5), 327-30.

PMID: 23479493

ABSTRACT: **OBJECTIVE:** The purpose of this paper was to review the current state of evidence for chronic traumatic encephalopathy (CTE) in retired athletes and to consider the potential differential diagnoses that require consideration when retired athletes present with cognitive and psychiatric problems. **DATA SOURCES:** MEDLINE, CINAHL, EMBASE, Mosby's Index, PsycEXTRA, PsycINFO and Scopus. Key words included CTE, dementia pugilistica, punch drunk syndrome, traumatic encephalopathy, CTE, repetitive head injury, sports concussion, multiple concussions, chronic concussions, sub-concussive blow and sports-related traumatic brain injury. **RESULTS:** At present, there are no published epidemiological, cross-sectional or prospective studies relating to modern CTE. Owing to the nature of the published studies, being case reports or pathological case series, it is not possible to determine the causality or risk factors with any certainty. As such, the speculation that repeated concussion or sub-concussive impacts cause CTE remains unproven. The extent to which age-related changes, psychiatric or mental health illness, alcohol/drug use or coexisting dementing illnesses contribute to this process is largely unaccounted for in the published literature. **CONCLUSIONS:** At present, the interpretation of causation in the modern CTE case studies should proceed cautiously. The causal assumptions require further prospective or longitudinal studies on the topic.

Geling, O., Shirakawa, N., & Tsushima, W.T. (2013). **Neurocognitive functioning and symptom reporting of high school athletes following a single concussion.** *Applied Neuropsychology: Child*, 2(1):13-6. PMID: 23427772

ABSTRACT: The aim of this research was to evaluate the neurocognitive functioning and symptom reporting of high school athletes with the Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT) battery after sustaining a single sports-related concussion. The ImPACT battery was administered to 26 athletes at an average of 6.8 days after their head injury. ImPACT composite scores, including

neurocognitive measures of Verbal Memory, Visual Memory, Processing Speed, and Reaction Time, as well as a Total Symptom Score, were also obtained from an equivalent group of 25 non-concussed football players. The composite scores of the concussed athletes were lower but not statistically different than the non-concussed athletes. The findings were consistent with previous ImPACT research that reported no differences between concussed and non-concussed athletes seven days after a concussion. The symptom scores of the concussed athletes, on the other hand, were significantly higher than those who had no concussion. The similarities and differences in ImPACT test performances of the present sample of concussed high school athletes as compared with previous studies of concussed high school athletes are discussed. This study raises awareness that with high school athletes, symptom complaints may persist, even after cognitive functioning has returned to pre-injury levels.

Gómez, J.E., Hergenroeder, A.C. (2013). **New guidelines for management of concussion in sport: Special concern for youth.** *The Journal of Adolescent Health: Official Publication of the Society for Adolescent Medicine*, 53(3), 311-3.

PMID: 23972583

The incidence of sports related concussion appears to be increasing, raising alarm over long-term consequences of these head injuries on cognitive function in youth. The American Academy of Neurology (AAN) has recently revised its position statement on concussion in sports, reflecting the burgeoning scientific evidence on its epidemiology, neurophysiology and prognosis. The AAN, along with other scientific organizations addressing concussion policy, has abandoned the use of algorithms for assigning a grade to concussions and instead stresses an individualized approach to concussion management. Recent evidence suggests that children and adolescents may be more susceptible to concussions from head blows, and may take longer to recover, than adults. Young women in certain sports also appear to be more susceptible to concussion than young men. The AAN recommends a more conservative approach to management of sports concussion in children and adolescents. Under no circumstances should a young athlete be allowed to participate in sport while still symptomatic. The use of standardized assessment tools is recommended to aid the healthcare provider in assessing the young athlete's recovery.

Härtl, R., McCrea, H.J., Niogi, S., Perrine, K. (2013). **Concussion in sports.** *Sports Health*, 5(2), 160-4. PMID: 24427385

ABSTRACT: CONTEXT: Recently, concussion has become a topic of much discussion within sports. The goal of this review is to provide an overview of the literature concerning the definition of concussion, management of initial injury, return to play, and future health risks. EVIDENCE ACQUISITION: This article reviews the most recent findings on recognizing and managing sports-related concussion, which has become a significant health risk. We reviewed articles from the literature discussing concussion and its effects. RESULTS: Though concussion patients typically have negative head imaging, imaging is warranted in those with severe mechanism, significant loss of consciousness, focal neurologic deficit, or worsening symptoms. The existence of “second-impact syndrome,” whereby a first minor head injury predisposes an athlete to later catastrophic injury, remains controversial; however, it is clear that concussion has significant effects on a patient and should be considered carefully in return-to-play decisions. CONCLUSIONS: A comprehensive understanding of concussion and its related risks is important in making return-to-play decisions as well as health care and league policy.

Institute of Medicine (US) & National Research Council (US). (2013). *Sports-Related Concussions in Youth: Improving the Science, Changing the Culture.* Washington, DC: National Academies Press (US); 2013.

PMID: 24199265

Full-text is available at <http://www.iom.edu/~media/Files/Report%20Files/2013/Concussions/concussions-RB.pdf>

EXCERPT: In the past decade, few issues at the intersection of medicine and sports have had as high a profile or have generated as much public interest as sports-related concussions. In recent years there has been a growing awareness and understanding that all concussions involve some level of injury to the brain and that athletes suspected of having a concussion should be removed from play for further evaluation (CDC, 2013; Halstead et al., 2010). Despite the increased attention, however, confusion and controversy persist in many areas, from how to define

a concussion and how multiple concussions affect the vulnerability of athletes to future injury, to when it is safe for a player to return to sports and the effectiveness of protective devices and other interventions in reducing the incidence and severity of concussive injuries (Wilde et al., 2012). Parents worry about choosing sports that are safe for their children to play, about finding the equipment that can best protect their children, and about when, if a child does receive a concussion, it will be safe for him or her to return to play or if it might be time to quit a much-loved sport entirely. It is within this context that the Institute of Medicine (IOM) and National Research Council (NRC), in October 2012, convened the Committee on Sports-Related Concussions in Youth to review the science of sports-related concussions in youth from elementary school through young adulthood, including military personnel and their dependents, and to prepare a report on that topic based on that review. The committee was charged with reviewing the available literature on concussions within the context of developmental neurobiology, specifically relating to the causes of concussions, their relationship to impacts to the head or body during sports, the effectiveness of protective devices and equipment, screening for and diagnosis of concussions, their treatment and management, and their long-term consequences.

Jordan, B.D. (2013). **The clinical spectrum of sport-related traumatic brain injury.** *Nature Reviews: Neurology*, 9(4), 222-30.

PMID: 23478462

Full-text is available at <http://www.nature.com/nrneuro/journal/v9/n4/pdf/nrneuro.2013.33.pdf>

ABSTRACT: Acute and chronic sports-related traumatic brain injuries (TBIs) are a substantial public health concern. Various types of acute TBI can occur in sport, but detection and management of cerebral concussion is of greatest importance as mismanagement of this syndrome can lead to persistent or chronic post-concussion syndrome (CPCS) or diffuse cerebral swelling. Chronic TBI encompasses a spectrum of disorders that are associated with long-term consequences of brain injury, including chronic traumatic encephalopathy (CTE), dementia pugilistica, post-traumatic parkinsonism, post-traumatic dementia and CPCS. CTE is the prototype of chronic TBI,

but can only be definitively diagnosed at autopsy as no reliable biomarkers of this disorder are available. Whether CTE shares neuro-pathological features with CPCS is unknown. Evidence suggests that participation in contact-collision sports may increase the risk of neurodegenerative disorders such as Alzheimer disease, but the data are conflicting. In this Review, the spectrum of acute and chronic sport-related TBI is discussed, highlighting how examination of athletes involved in high-impact sports has advanced our understanding of pathology of brain injury and enabled improvements in detection and diagnosis of sport-related TBI.

Lee, H., Schneiders, A.G., & Sullivan, S.J. (2013). **The use of the dual-task paradigm in detecting gait performance deficits following a sports-related concussion: A systematic review and meta-analysis.** *Journal of Science & Medicine in Sport/Sports Medicine Australia*, 16(1), 2-7.

PMID: 22609052

ABSTRACT: **OBJECTIVES:** The purpose of this systematic review was to determine the viability of the dual-task paradigm in the evaluation of a sports-related concussion. **DESIGN:** Systematic review and meta-analysis. **METHODS:** Eight electronic databases were searched from their inception until the 11(th) of April 2011. Studies were grouped according to their reported gait performance variables and their time(s) of assessment(s). Raw mean differences (MD) and 95 percent confidence intervals (CI) were calculated based on raw means and standard deviations for gait performance measures in both single- and dual-task conditions. Dual-task deficits were pooled using a random effects model and heterogeneity (I²) between studies was assessed. **RESULTS:** Ten studies representing a total sample of 168 concussed and 167 matched (age and gender) non-concussed participants met the inclusion criteria. Meta-analysis demonstrated that dual-task performance deficits were detected ($p < 0.05$) in the concussed group for gait velocity (GV) (MD=-0.133; 95 percent CI -0.197, -0.069) and range of motion of the center of mass in the coronal plane (ML-ROM) (MD=0.007; 95 percent CI 0.002, 0.011), but not in the non-concussed group; GV (MD=-0.048; 95 percent CI -0.101, 0.006), ML-ROM (MD=0.002; 95 percent CI -0.001, 0.005). **CONCLUSIONS:** The

results of this study indicate that GV and ML-ROM are sensitive measures of dual-task related changes in concussed patients and should be considered as part of a comprehensive assessment for a sports-related concussion.

Lovell, M.R., & Solomon, G.S. (2013). **Neurocognitive test performance and symptom reporting in cheerleaders with concussions.** *The Journal of Pediatrics*, 163(4), 1192-5.

PMID: 23941669

ABSTRACT: **OBJECTIVE:** To evaluate neurocognitive test results and symptom reporting after sports-related concussion in a group of female cheerleaders. **STUDY DESIGN:** Junior and senior high school female cheerleaders (n=138) underwent pre-participation baseline testing and repeated the ImPACT (Immediate Post-concussion Assessment and Cognitive Testing) evaluation within 7 days of concussive injury (range, 0-7 days; mean, 3.9 days). Post-injury neurocognitive and symptom scores were compared with pre-injury (baseline) scores. "Abnormal" test performance was determined statistically using Reliable Change Index scores and self-reported symptoms. Main outcome variables included the composite scores indices from the ImPACT test, as well as symptoms reported by participants. Pre-injury baseline and post-injury test results were compared using MANOVA. **RESULTS:** As a group, cheerleaders with concussion evaluated within 7 days of injury performed poorly on the ImPACT test battery relative to their own baseline ($F=6.5$; $P=.00$). In addition, 61 percent of the cheerleaders with concussions reported an increase in symptoms compared with baseline. The groups did not differ significantly by position on the squad ($F=0.37$; $P=.96$). Of the group of cheerleaders who did not report increased symptoms at the time of post-injury evaluation, 37 percent had at least 1 abnormal ImPACT composite score result, suggesting some residual cognitive decline compared with baseline. **CONCLUSION:** The diagnosis and management of concussion in cheerleaders should not consist solely of self-reported symptoms. Neurocognitive test results represent an important component of the evaluation process and may identify athletes with residual neurocognitive deficits who report being clinically asymptomatic.

Porcher, N.J., & Solecki, T.J. (2013). **A narrative review of sports-related concussion and return-to-play testing with asymptomatic athletes.** *Journal of Chiropractic Medicine*, 12(4), 260-8.

PMID: 24396328

ABSTRACT: **OBJECTIVE:** The purpose of this literature review was to demonstrate, through examples in the current literature, the cumulative and long-term effects of multiple concussions, post-injury protocols, and the efficacy of current and past return-to-play guidelines. **METHODS:** A PUBMED search was performed using the keywords and key phrases: concussions and long-term effects, concussions and return to play, and multiple concussions. We limited the search to articles that had been published from August 2007 to August 2012 and were specific to human participants. Of the 450 total articles that the search returned, we selected studies specifically demonstrating athletes who were symptom-free, passed neuropsychological testing, returned to play, and were tested in measures of postural control, trans-cranial magnetic stimulation, electroencephalographic studies, and magnetic resonance imaging spectroscopy. **RESULTS:** Selected studies show evidence that, although a previously concussed athlete may be symptom-free and returned to a neuropsychological baseline, the athlete may continue to have prolonged neurological abnormalities that could disqualify them from being ready to return to play. **CONCLUSION:** It appears that some neurological deficits persist beyond the current return-to-play standards and that discrepancy exists between common practices of returning athletes to competition and new standards of published research.

Schneiders, A.G. (2013). **A heads-up on what's new in sports-related concussion assessment and management.** *Physical Therapy in Sport: Official Journal of the Association of Chartered Physiotherapists in Sports Medicine*, 14(2):75-6.

PMID: 23517811

No abstract is available.

Seifert, T.D. (2013). **Sports concussion and associated post-traumatic headache.** *Headache*, 53(5), 726-36.

PMID: 23593938

ABSTRACT: Despite an incidence of approximately

3.8 million sports-related concussions per year, the pathophysiological basis of this injury remains poorly understood. Associated post-traumatic headache, both acute and chronic, can also provide a unique treatment challenge for medical personnel. The presence of new onset or persistent headache following injury often complicates return to play decisions. It is also now evident that recurrent head trauma may be associated with the development of some chronic neurodegenerative disorders. Although anecdotal reports and consensus guidelines are utilized in the management of sports concussion and associated post-traumatic headache, further evidence-based data are needed. Improved prevention and management of this injury will occur with ongoing educational and research efforts. As such advances are made, it is imperative the headache specialist have continued understanding of this evolving field.

Tepper, D. (2013). **Headache after sports-related concussion.** *Headache*, 53(7), 1197-8.

PMID: 23865919

Full-text is available at <http://onlinelibrary.wiley.com/doi/10.1111/head.12146/pdf>

No abstract is available.

2012

Altaye, M., Cecil, K.M., Farley, C., Leach, J., & Maugans, T.A. (2012). **Pediatric sports-related concussion produces cerebral blood flow alterations.** *Pediatrics*, 129(1), 28-37.

PMID: 22129537

Full-text is available at <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3255471/pdf/peds.2011-2083.pdf>

ABSTRACT: **OBJECTIVES:** The pathophysiology of sports-related concussion (SRC) is incompletely understood. Human adult and experimental animal investigations have revealed structural axonal injuries, decreases in the neuronal metabolite N-acetyl aspartate, and reduced cerebral blood flow (CBF) after SRC and minor traumatic brain injury. The authors of this investigation explore these possibilities after pediatric SRC. **PATIENTS AND METHODS:** Twelve children, ages 11 to 15 years, who experienced SRC were evaluated by ImpACT neurocognitive testing, T1 and susceptibility weighted MRI, diffusion tensor imaging, proton magnetic resonance spectroscopy,

and phase contrast angiography at <72 hours, 14 days, and 30 days or greater after concussion. A similar number of age- and gender-matched controls were evaluated at a single time point. RESULTS: ImPACT results confirmed statistically significant differences in initial total symptom score and reaction time between the SRC and control groups, resolving by 14 days for total symptom score and 30 days for reaction time. No evidence of structural injury was found on qualitative review of MRI. No decreases in neuronal metabolite N-acetyl aspartate or elevation of lactic acid were detected by proton magnetic resonance spectroscopy. Statistically significant alterations in CBF were documented in the SRC group, with reduction in CBF predominating (38 vs 48 mL/100 g per minute; $P = .027$). Improvement toward control values occurred in only 27 percent of the participants at 14 days and 64 percent at >30 days after SRC. CONCLUSIONS: Pediatric SRC is primarily a physiologic injury, affecting CBF significantly without evidence of measurable structural, metabolic neuronal or axonal injury. Further study of CBF mechanisms is needed to explain patterns of recovery.

Amene, C., Baird, L.C., Kasasbeh, A.S., Levy, M.L., Marshall, L., & Skeen, J. (2012). **Concussions in soccer: A current understanding.** *World Neurosurgery*, 78(5), 535-44.

PMID: 22120567

ABSTRACT: OBJECTIVE: Traumatic brain injury (TBI) is a significant public health problem in the United States, with approximately 1.5-2 million TBIs occurring each year. However, it is believed that these figures underestimate the true toll of TBI. Soccer is the most popular sport in the world and has a following of millions in the United States. Soccer is a sport not traditionally identified as high-risk for concussions, yet several studies have shown that concussion rates in soccer are comparable to, and often exceed those of, other contact sports. As many as 22 percent of all soccer injuries are concussions. METHODS: Soccer is a sport not traditionally identified as high risk for concussions, yet several studies have shown that concussion rates in soccer are comparable to, and often exceed those of, other contact sports. As many as 22 percent of all soccer injuries are concussions. Head injury during soccer is usually the result of either "direct contact" or contact with the ball

while "heading" the ball. Relationships between the number of headers sustained in a single season and the degree of cognitive impairment (attention and visual/verbal memory) have been demonstrated. It is also likely that multiple concussions may cause cumulative neuro-psychologic impairment in soccer players. RESULTS: Although our understanding of risk factors for sports-related concussions is far from complete, there is great potential for prevention in sports-related concussions. Several measures must be taken to avert the development of concussions in soccer and, when they take place, reduce their effects. These include the development and testing of effective equipment during play, the maintenance of regulatory standards for all such equipment, educating young athletes on the safe and appropriate techniques used during play, and strict adherence to the rules of competition. CONCLUSIONS: In spite of such preventive measures, concussions in soccer will continue to occur. Considering the frequency of concussions in soccer, the serious sequelae of these concussions, and because almost half of concussed soccer players were noncompliant with recommended American Academy of Neurology return-to-play guidelines, further measures must be taken to protect players, in addition to understanding those criteria that result in removing an injured player from competition and the steps by which to safely return an athlete to competition after injury.

Arnett, P., Bailey, C.M., Bruce, J.M., Echemendia, R.J., Sanders, J.F., & Vargas, G. (2012). **The utility of post-concussion neuropsychological data in identifying cognitive change following sports-related MTBI in the absence of baseline data.** *The Clinical Neuropsychologist*, 26(7), 1077-91.

PMID: 23003560

ABSTRACT: Neuropsychological tests have become commonplace in the assessment of sports-related concussion. Typically, post-injury test data are compared to pre-injury "baselines." Baseline testing can be expensive and logistically challenging, yet the usefulness of neuropsychological baseline testing has not been tested empirically. This paper examines the extent to which baseline testing is useful for detecting neurocognitive deficits following sports concussion in a college-age population. A total of 223 collegiate athletes from multiple sports who sustained concus-

sions and had both baseline and post-injury testing using Immediate Post-concussion Assessment and Cognitive Testing (ImPACT) were included in the study. Reliable change (RC) in scores was determined by two approaches, the Jacobson and Truax (JT) and the Gulliksen-Lord-Novick (GLN) methods. The 90 percent confidence interval was used for both. Classification using these methods was compared to standard normative methods that compared post-concussion performance to baseline population means. Agreement between reliable change and normative methods was examined using Cohen's Kappa scores to determine whether post-injury scores alone could identify reliable cognitive decline. Mean time from concussion to post-injury testing was 3.40 days. The percentage of athletes who declined when using the JT method was similar to the percentage that would be expected to decline due to chance alone. Although the GLN and JT methods demonstrated moderate to substantial agreement, the GLN method consistently identified more cognitively compromised athletes than the JT method. Post-injury scores alone identified a significant majority of athletes with a reliable decline on ImPACT. Although preliminary and in need of replication across age groups and instruments, these findings suggest that the majority of collegiate athletes who experience clinically meaningful post-concussion cognitive decline can be identified without baseline data.

Balcer, L.J., Dziemianowicz, M.S., Galetta, S.L., Kirschen, M.P., Laudano, E., & Pukenas, B.A. (2012). **Sports-related concussion testing.** *Current Neurology & Neuroscience reports*, 12(5), 547-59. PMID: 22791281

ABSTRACT: Due to the recent focus on concussion in sports, a number of tests have been developed to diagnose and manage concussion. While each test measures different brain functions, no single test has been shown to quickly and reliably assess concussion in all cases. In addition, most of the current concussion tests have not been validated by scientific investigation. This review identifies the pros and cons of the most commonly used noninvasive tests for concussion in order to provide a more complete picture of the resources that are available for concussion testing. The potential utility of research tools such as the head impact telemetry system, advanced magnetic resonance imaging protocols, and biomarkers are discussed in the context of the currently employed tools.

Bay, R.C., Chhabra, A., Lam, K.C., & Valovich McLeod, T.C. (2012). **Representative baseline values on the Sport Concussion Assessment Tool 2 (SCAT2) in adolescent athletes vary by gender, grade, and concussion history.** *The American Journal of Sports Medicine*, 40(4), 927-33. PMID: 22238056

ABSTRACT: BACKGROUND: To improve and standardize the sideline evaluation of sports-related concussion, the Sport Concussion Assessment Tool 2 (SCAT2) was developed. This tool assesses concussion-related signs and symptoms, cognition, balance, and coordination. This newly published assessment tool has not established representative baseline data on adolescent athletes. HYPOTHESIS: Representative baseline SCAT2 scores in adolescent athletes will differ by gender, grade in school, and self-reported concussion history. STUDY DESIGN: Descriptive epidemiology study. METHODS: Interscholastic athletes were administered the SCAT2 during a preseason concussion baseline testing session. The SCAT2 total score ranges from 0 to 100 points, with lower scores indicating poorer performance. Overall, representative values were calculated using descriptive statistics. Separate independent-samples t tests, with gender and concussion history as the independent variables, and a 1-way analysis of variance, with grade as the independent variable, were conducted to assess differences in SCAT2 total score ($P < .05$). RESULTS: There were 1134 high school athletes (872 male and 262 female) who participated. The SCAT2 total score across all participants was 88.3 ± 6.8 (range, 58-100); skewness was -0.86 ± 0.07 , and kurtosis was 0.73 ± 0.14 . Male athletes scored significantly lower on the SCAT2 total score ($P = .03$; 87.7 ± 6.8 vs 88.7 ± 6.8), and 9th graders (86.9 ± 6.8) scored significantly lower than 11th (88.7 ± 7.0) and 12th (89.0 ± 6.6) graders ($P < .001$). Athletes with a self-reported concussion history scored significantly lower on the SCAT2 total score than those with no concussion history ($P < .001$; 87.0 ± 6.8 vs 88.7 ± 6.5). CONCLUSION: These data provide representative scores on the SCAT2 in adolescent athletes and show that male athletes, 9th graders, and those with a self-reported concussion history scored significantly lower than their female, upperclassmen, or non-concussed peers. CLINICAL RELEVANCE: These results suggest that healthy adolescent athletes display variability on the SCAT2 at baseline. Therefore, clinicians should administer baseline assessments of the

SCAT2 because assuming a perfect baseline score of 100 points is not appropriate in an adolescent athlete population.

Bazarian, J.J., Blyth, B., Borrino, A., Zhong, J., & Zhu, T. (2012). **Subject-specific changes in brain white matter on diffusion tensor imaging after sports-related concussion.** *Magnetic Resonance Imaging*, 30(2), 171-80.

PMID: 22079073

Full-text is available at <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3254806/pdf/nihms339625.pdf>

ABSTRACT: BACKGROUND AND PURPOSE: Current approaches to diffusion tensor imaging (DTI) analysis do not permit identification of individual-level changes in DTI indices. We investigated the ability of wild bootstrapping analysis to detect subject-specific changes in brain white matter (WM) before and after sports-related concussion. **MATERIALS AND METHODS:** A prospective cohort study was performed in nine high school athletes engaged in hockey or football and six controls. Subjects underwent DTI pre- and postseason within a 3-month interval. One athlete was diagnosed with concussion (scanned within 72 h), and eight suffered between 26 and 399 sub-concussive head blows. Fractional anisotropy (FA) and mean diffusivity (MD) were measured in each WM voxel. Bootstrap samples were generated, and a permuted t test was used to compare voxel-wise FA/MD changes in each subject pre- vs. postseason. **RESULTS:** The percentage of WM voxels with significant ($p < .05$) pre-post FA changes was highest for the concussion subject (3.2 percent), intermediary for those with sub-concussive head blows (mean 1.05 percent \pm .15 percent) and lowest for controls (mean 0.28 percent \pm .01 percent). Similarly, the percentage of WM voxels with significant MD changes was highest for the concussion subject (3.44 percent), intermediary for those with sub-concussive head blows (mean 1.48 percent \pm .17 percent) and lowest for controls (mean 0.48 percent \pm .05 percent). Significantly changed FA and MD voxels colocalized in the concussion subject to the right corona radiata and right inferior longitudinal fasciculus. **CONCLUSIONS:** Wild bootstrap analysis detected significantly changed WM in a single concussed athlete. Athletes with multiple sub-concussive head blows had significant changes in a percentage of their

WM that was over three times higher than controls. Efforts to understand the significance of these WM changes and their relationship to head impact forces appear warranted.

Beckwith, J.G., Brolinson, P.G., Chu, J.J., Crisco, J.J., Duhaime, A.C., Duma, S.M., Greenwald, R.M., Maerlender, A.C., McAllister, T.W., & Rowson, S. (2012). **Rotational head kinematics in football impacts: An injury risk function for concussion.** *Annals of Biomedical Engineering*, 40(1), 1-13.

PMID: 22012081

ABSTRACT: Recent research has suggested a possible link between sports-related concussions and neurodegenerative processes, highlighting the importance of developing methods to accurately quantify head impact tolerance. The use of kinematic parameters of the head to predict brain injury has been suggested because they are indicative of the inertial response of the brain. The objective of this study is to characterize the rotational kinematics of the head associated with concussive impacts using a large head acceleration dataset collected from human subjects. The helmets of 335 football players were instrumented with accelerometer arrays that measured head acceleration following head impacts sustained during play, resulting in data for 300,977 sub-concussive and 57 concussive head impacts. The average sub-concussive impact had a rotational acceleration of 1230 rad/s² and a rotational velocity of 5.5 rad/s, while the average concussive impact had a rotational acceleration of 5022 rad/s² and a rotational velocity of 22.3 rad/s. An injury risk curve was developed and a nominal injury value of 6383 rad/s² associated with 28.3 rad/s represents 50 percent risk of concussion. These data provide an increased understanding of the biomechanics associated with concussion and they provide critical insight into injury mechanisms, human tolerance to mechanical stimuli, and injury prevention techniques.

Beyer, J.A., Duma, S.M., & Rowson, S. (2012). **Concussions experienced by Major League Baseball catchers and umpires: Field data and experimental baseball impacts.** *Annals of Biomedical Engineering*, 40(1), 150-9.

PMID: 22012084

ABSTRACT: Some reports have shown that head

injuries in baseball may comprise up to 18.5% of all competitive sports-related head injuries. The objective of this study was to evaluate the response of catcher and umpire masks to impacts at these different regions to discover the impact conditions that represent the greatest risk of injury. A series of 10 events in which a catcher or umpire in Major League Baseball, who experienced a foul ball to the mask that resulted in a concussion, were analyzed through video and data on pitch characteristics. It was found that the impacts were distributed across the face, and the median plate speed was approximately 38 m/s (84 mph). To determine the relative severity of each identified impact location, an instrumented Hybrid III head outfitted with a catcher or umpire mask was impacted with baseballs. Testing at 27 and 38 m/s (60 and 84 mph) suggested that impacts to the center-eyebrow and chin locations were the most severe. Peak linear and rotational accelerations were found to be lower than the suggested injury thresholds. While impacts to a mask result in head accelerations which are near or below levels commonly associated with the lower limits for head injury, the exact injury mechanism is unclear, as concussions are still experienced by the mask wearers.

Bodle, J., Edwards, J., Madey, J., Sas, A., Scovel, L., & Williams, N. (2012). **High school coaches perceptions of physicians' role in the assessment and management of sports-related concussive injury.** *Frontiers in Neurology*, 3, 130.
PMID: 23060851

Full-text is available at <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3464423/pdf/fneur-03-00130.pdf>

ABSTRACT: Sports concussions are an increasingly recognized common type of mild traumatic brain injury (TBI) that affects athletes of all ages. The need for an increased involvement of trained physicians in the diagnosis and treatment of concussion has become more obvious as the pathophysiology and long-term sequelae of sports concussion are better understood. To date, there has been great variability in the athletic community about the recognition of symptoms, diagnosis, management, and physician role in concussion care. An awareness assessment survey administered to 96 high school coaches in a large metropolitan city demonstrated that 37.5 percent of responders refer their concussed players to an emergency department after the incident, only 39.5 percent of responders have a physician available to

evaluate their players after a concussion, 71.6 percent of those who had a physician available sent their players to a sports medicine physician, and none of the responders had their player's concussion evaluated by a neurologist. Interestingly, 71.8 percent of responders stated that their players returned to the team with "return to play" guidelines from their physician. This survey has highlighted two important areas where the medical community can better serve the athletic community. Because a concussion is a sport-inflicted injury to the nervous system, it is optimally evaluated and managed by a clinician with relevant training in both clinical neuroscience and sports medicine. Furthermore, all physicians who see patients suffering concussion should be educated in the current recommendations from the Consensus Statement on Concussion and provide return to play instructions that outline a graduated return to play, allowing the athlete to return to the field safely.

Canadian Paediatric Society, Healthy Active Living and Sports Medicine Committee, & Purcell, L.K. (2012). **Evaluation and management of children and adolescents with sports-related concussion.** *Paediatrics & Child Health*, 17(1), 31-4. [Article in English, French].

PMID: 23277754

Full-text is available at <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3276525/pdf/pch17031.pdf>

ABSTRACT: Concussions are common sport injuries, and are particularly common among children and adolescents involved in organized sports and recreational activities. Symptoms of concussion can be subtle, and may be overlooked by athletes, coaches/trainers and parents. If a child or youth sustains a concussion, they should immediately be removed from play and assessed by a physician as soon as possible. The athlete should rest from physical and cognitive activities to allow for recovery from concussion. Once symptoms have completely resolved at rest, the athlete can progress through a medically supervised stepwise exertion protocol before being medically cleared to return to play. It is imperative that everyone involved in child and youth sports be aware of the signs and symptoms of concussion so that an accurate and timely diagnosis can be made, and proper evaluation and management instituted. The present position statement replaces the previous document published in 2006.

Carson, E.W., Diduch, B.K., Hogan, M.V., Ma, R., Miller, C.D., & Miller, M.D. (2012). **Sports-related concussion: Assessment and management.** *The Journal of Bone & Joint Surgery: American Volume*, 94(17), 1618-27.

PMID: 22992853 [PubMed - indexed for MEDLINE]

ABSTRACT: Most major U.S. professional sports and the National Collegiate Athletic Association (NCAA) have adopted concussion policies. Current National Football League and NCAA guidelines do not permit an athlete with a concussion to return to play on the same day as the injury. No adolescent or high-school athletes with a concussion should be allowed to return to play on the same day regardless of severity. Loss of consciousness is uncommon with concussion. Acute concussion symptoms are generally self-limited, and most symptoms typically resolve within two weeks. Concussion risk and severity may be affected by age, sex, and genetic predisposition. Athletes with a concussion should rest physically and cognitively until symptoms have resolved at rest and with exertion. Rehabilitation following concussion progresses through a stepwise graded fashion. Neuropsychological testing can provide objective data on an athlete after a concussion. However, it alone cannot be used to diagnose a concussion or determine when an athlete is allowed to return to play. Retirement from contact or collision sports may be necessary for an athlete who has sustained multiple concussions or has a history of prolonged symptoms after concussions. Long-term effects of concussions are still relatively unknown, and further research is required to offer guidance for athletes of all levels.

Castile, L., Collins, C.L., Comstock, R.D., & McIlvain, N.M. (2012). **The epidemiology of new versus recurrent sports concussions among high school athletes, 2005-2010.** *British Journal of Sports Medicine*, 46(8), 603-10.

PMID: 22144000

ABSTRACT: OBJECTIVES: To compare new versus recurrent concussions with respect to constellation of symptoms, symptom severity, symptom resolution; evaluate potential subset differences with respect to gender and sport; and to compare mechanisms and activities associated with new versus recurrent concussions. METHODS: Sports-related injury and exposure data were collected for nine sports from

2005 to 2010 from 100 nationally representative US high schools. RESULTS: Nationally, an estimated 732,805 concussions occurred. Of these reported concussions, 13.2 percent were recurrent. The rate of new concussions was 22.2 per 100,000 athletic exposures while the rate of recurrent concussions was 3.1 per 100,000 athletic exposures (RR 7.23, 95 percent CI 6.39 to 8.17, $p < 0.001$). While 0.6 percent of new concussion symptoms took >1 month to resolve, 6.5 percent of recurrent concussion symptoms took >1 month to resolve (IPR 10.35; 95 percent CI 4.62 to 23.16; $p < 0.001$). Loss of consciousness was reported more often with recurrent (7.7 percent) than new concussions (4.4 percent) (IPR 1.76; 95 percent CI 1.02 to 3.03; $p = 0.043$). A greater proportion of athletes sustaining recurrent concussions returned to play in >3 weeks (7.5 percent) or were medically disqualified (16.2 percent) than athletes sustaining new concussions (3.8 percent; IPR 1.95; 95 percent CI 1.01 to 3.77; $p = 0.047$ and 2.9 percent; IPR 5.58; 95 percent CI 3.50 to 8.88; $p < 0.001$, respectively). The majority of new and recurrent concussions resulted from contact with another person (73.4 percent and 77.9 percent, respectively). CONCLUSIONS: Athletes sustaining recurrent concussions had longer symptom resolution times, were kept out of play longer and reported loss of consciousness more frequently than athletes sustaining new concussions. With the possibility of long-term impairment and other negative sequelae, proper management and prevention of concussions at the high school level is imperative.

Comstock, R.D., Fields, S.K., Marar, M., & McIlvain, N.M. (2012). **Epidemiology of concussions among United States high school athletes in 20 sports.** *The American Journal of Sports Medicine*, 40(4), 747-55. PMID: 22287642

ABSTRACT: BACKGROUND: In the United States (US), an estimated 300,000 sports-related concussions occur annually. Among individuals 15 to 24 years of age, sports are second only to motor vehicle crashes as the leading cause of concussions. PURPOSE: To investigate the epidemiology of concussions in high school athletes by comparing rates and patterns of concussion among 20 sports. STUDY DESIGN: Descriptive epidemiology study. METHODS: Using an Internet-based data collection tool, RIO, certified athletic trainers from a large, nationally dispersed

sample of US high schools reported athlete exposure and injury data for 20 sports during the 2008-2010 academic years. RESULTS: During the study period, 1936 concussions were reported during 7,780,064 athlete-exposures (AEs) for an overall injury rate of 2.5 per 10,000 AEs. The injury rate was higher in competition (6.4) than practice (1.1) (rate ratio [RR], 5.7; 95 percent confidence interval [CI], 5.2-6.3). The majority of concussions resulted from participation in football (47.1 percent, n = 912), followed by girls' soccer (8.2 percent, n = 159), boys' wrestling (5.8 percent, n = 112), and girls' basketball (5.5 percent, n = 107). Football had the highest concussion rate (6.4), followed by boys' ice hockey (5.4) and boys' lacrosse (4.0). Concussions represented a greater proportion of total injuries among boys' ice hockey (22.2 percent) than all other sports studied (13.0 percent) (injury proportion ratio [IPR], 1.7; 95 percent CI, 1.4-2.1; P < .01). In gender-comparable sports, girls had a higher concussion rate (1.7) than boys (1.0) (RR, 1.7; 95 percent CI, 1.4-2.0). The most common mechanisms of injury were player-player contact (70.3 percent) and player-playing surface contact (17.2 percent). In more than 40 percent of athletes in sports other than girls' swimming and girls' track, concussion symptoms resolved in 3 days or less. Athletes most commonly returned to play in 1 to 3 weeks (55.3 percent), with 22.8 percent returning in less than 1 week and 2.0 percent returning in less than 1 day. CONCLUSION: Although interest in sports-related concussions is usually focused on full-contact sports like football and ice hockey, concussions occur across a wide variety of high school sports. Concussion rates vary by sport, gender, and type of exposure. An understanding of concussion rates, patterns of injury, and risk factors can drive targeted preventive measures and help reduce the risk for concussion among high school athletes in all sports.

Conidi, F.X. (2012). **Sports-related concussion: The role of the headache specialist.** *Headache*, 52 Suppl 1, 15-21.

PMID: 22540200

ABSTRACT: Over the past few years, sports-related concussion has received significant media attention making it one of the most, if not highest profile neurological disorder. Thirty-one states now have passed sports concussion laws, with 14 states pending legislation. Most concussions are managed by primary care physicians, i.e., family practice trained sports

medicine physicians and pediatricians. Symptoms are usually short lived and do not require treatment. The one exception is headache, which is usually present from onset and is often the last symptom to resolve. Headache is the most common reason for referral to a specialist, and therefore it is imperative that the headache specialist have at least a basic understanding of all aspects of sports concussion as they are likely going to be called upon to evaluate these athletes, especially the more refractory cases.

Day, D.D., Doolan, A.W., Goforth, M., Gunnar Bro-linsson, P., & Maerlender, A.C. (2012). **A review of return to play issues and sports-related concussion.** *Annals of Biomedical Engineering*, 40(1), 106-13. PMID: 21997390

ABSTRACT: Mild traumatic brain injury in sports has become a significant public health concern which has not only received the general public's attention through multiple news media stories involving athletic concussions, but has also resulted in local, state, and national legislative efforts to improve recognition and management. The purpose of this article is to review the current literature for return to play (RTP) guidelines. State, regional, national, and professional legislation on sport-related concussion RTP management issues will be reviewed. This article will be helpful in developing a generalized systematic approach to concussion management and highlight specific RTP guidelines. The article will also touch upon specific contraindications to RTP, the role of neuropsychological testing in RTP, and other considerations and complications that affect an athlete's ability to return to competition. Finally, considerations for terminating an athlete's competitive season or ending a career after sustaining a concussion resulting in prolonged and protracted symptomatology or repeated concussions will be reviewed. PubMed and Google were searched using the key terms mentioned below. In addition, the author's library of concussion-related articles was reviewed for the relevant literature.

Deignan, P.J. (2012). **Point of view: National guidelines to manage sports-related concussions and New Jersey legislation extended to cheerleaders: Important wins for student-athletes.** *MD Advisor: A Journal for New Jersey Medical Community*, 5(1), 41-2.

PMID: 22318303

No abstract is available.

Dewan, M.C., Forbes, J.A., Kuhn, A., Morone, P.J., Sills, A.K., Solomon, G.S., & Zuckerman, S.L. (2012). **Structural brain injury in sports-related concussion.** *Neurosurgical Focus*, 33(6), E6: 1-12. PMID: 23199429

Full-text is available at <http://thejns.org/doi/pdf/10.3171/2012.10.FOCUS12279>

ABSTRACT: **OBJECT:** Sports-related concussions (SRCs) represent a significant and growing public health concern. The vast majority of SRCs produce mild symptoms that resolve within 1-2 weeks and are not associated with imaging-documented changes. On occasion, however, structural brain injury occurs, and neurosurgical management and intervention is appropriate. **METHODS:** A literature review was performed to address the epidemiology of SRC with a targeted focus on structural brain injury in the last half decade. MEDLINE and PubMed databases were searched to identify all studies pertaining to structural head injury in sports-related head injuries. **RESULTS:** The literature review yielded a variety of case reports, several small series, and no prospective cohort studies. **CONCLUSIONS:** The authors conclude that reliable incidence and prevalence data related to structural brain injuries in SRC cannot be offered at present. A prospective registry collecting incidence, management, and follow-up data after structural brain injuries in the setting of SRC would be of great benefit to the neurosurgical community.

Edwards, J.C., Gosserand, J.K., Upshaw, J.E., & Williams, N. (2012). **Sports-related concussions.** *Pediatric Emergency Care*, 28(9), 926-32.

ABSTRACT: During the past decade, awareness of concussions has exploded as both the media and the medical literature have given more focus to this common problem. Concussions after recreational activities, especially athletics, are a frequent complaint in the emergency department. In the past few years, care of these patients has been simplified as grading systems and classifications have been abandoned. However, questions remain as to the best way to rehabilitate these patients to avoid long-term sequelae, especially in children and adolescents. The purpose of this review is to discuss the demographic characteristics, the pathophysiology, definition, clinical characteristics, and management of concussions in children and adolescents.

Foley, C.M., Wang, D.H. (2012). **Central diabetes insipidus following a sports-related concussion: A case report.** *Sports Health*, 4(2), 139-41.

PMID: 23016080

Full-text is available at http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3435907/pdf/10.1177_1941738111434275.pdf

ABSTRACT: A 24-year-old female swimmer presented to a sports medicine clinic with complaints of frequent urination and increased thirst. The patient admitted to progressive worsening of her symptoms over a 4-year period since suffering a concussion. A water deprivation test, antidiuretic hormone level, and diamino-8-D-arginine vasopressin challenge were completed, and the patient was diagnosed with persistent central diabetes insipidus. As concussion awareness increases, health care professionals will be faced with treatment of post-concussive patients more often. The aim of this case report is to increase awareness of possible pituitary dysfunction-specifically, central diabetes insipidus-following a concussion.

Forbes, J.A., Haase, R.F., Lovell, M.R., Sills, A.K., Solomon, G.S., & Zuckerman, S.L. (2012). **Response to acute concussive injury in soccer players: Is gender a modifying factor?** *Journal of Neurosurgery: Pediatrics*, 10(6), 504-10.

PMID: 23030348

ABSTRACT: **OBJECT:** Several studies have suggested a gender difference in response to sports-related concussion (SRC). The Concussion in Sport group did not include gender as a modifying factor in SRC, concluding that the evidence at that point was equivocal. In the present study the authors endeavored to assess acute neurocognitive and symptom responses to an SRC in equivalent cohorts of male and female soccer players. The authors hypothesized that female athletes would experience greater levels of acute symptoms and neurocognitive impairment than males. **METHODS:** Baseline symptom and neurocognitive scores were determined in 40 male and 40 female soccer players by using the Immediate Post-concussion Assessment and Cognitive Testing (ImPACT) scale prior to any SRC. After sustaining an SRC, each athlete completed post-concussion ImPACT tests and was carefully matched on a wide array of bio-psychosocial variables. Baseline symptom and neurocognitive test scores were compared, and their acute symptoms and

neurocognitive responses to concussive injury were assessed. **RESULTS:** Specific a priori hypotheses about differences between males and females at baseline and at post-concussion measurements of verbal and visual memory ImPACT scores were evaluated according to simple main effects of the gender variable and according to baseline-to-post-concussion main effect and interaction of 2×2 split-plot ANOVA. Neither the interaction nor the main effects nor the simple main effects for either ImPACT variable were found to be statistically significant. Exploratory ANOVAs applied to the remaining ImPACT variables of visual motor speed, reaction time, impulse control, and symptom total scores revealed only a single statistically significant baseline-to-post-concussion main effect for the symptom total. **CONCLUSIONS:** The results failed to replicate prior findings of gender-specific baseline neurocognitive differences in verbal and visual memory. The findings also indicated no differential gender-based acute response to concussion (symptoms or neurocognitive scores) among high school soccer players. The implications of these findings for the inclusion of gender as a modifying factor in this tightly matched cohort are addressed. Potential explanations for the null findings are discussed.

Forbes, J.A., Lee, Y.M., Odom, M.J., Sills, A.K., Solomon, G.S., & Zuckerman, S.L. (2012). **Recovery from sports-related concussion: Days to return to neurocognitive baseline in adolescents versus young adults.** *Surgical Neurology International*, 3, 130

PMID: 23227435

Full-text is available at <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3513851/?report=printable>

ABSTRACT: **BACKGROUND:** Sports-related concussions (SRC) among high school and collegiate athletes represent a significant public health concern. The Concussion in Sport Group (CIS) recommended greater caution regarding return to play with children and adolescents. We hypothesized that younger athletes would take longer to return to neurocognitive baseline than older athletes after a SRC. **METHODS:** Two hundred adolescent and young adult athletes who suffered a SRC were included in our clinical research cohort. Of the total participants, 100 were assigned to the 13-16 year age group and 100 to the 18-22 year age group and were matched on the number of prior

concussions. Each participant completed baseline and post-concussion neurocognitive testing using the Immediate Post-Concussion assessment and Cognitive Testing (ImPACT) test battery. Return to baseline was defined operationally as post-concussion neurocognitive and symptom scores being equivalent to baseline using reliable change index (RCI) criteria. For each group, the average number of days to return to cognitive and symptom baseline were calculated. Independent sample t-tests were used to compare the mean number of days to return to baseline. **RESULTS:** Significant differences were found for days to return to baseline between 13-16 year olds and 18-22 year olds in three out of four neurocognitive measures and on the total symptom score. The average number of days to return to baseline was greater for 13-16 year olds than for 18-22 year olds on the following variables: Verbal memory (7.2 vs. 4.7, $P = 0.001$), visual memory (7.1 vs. 4.7, $P = 0.002$), reaction time (7.2 vs. 5.1 $P = 0.01$), and post-concussion symptom scale (8.1 vs. 6.1, $P = 0.026$). In both groups, greater than 90 percent of athletes returned to neurocognitive and symptom baseline within 1 month. **CONCLUSIONS:** Our results in this clinical research study show that in SRC, athletes 13-16 years old take longer to return to their neurocognitive and symptom baselines than athletes 18-22 years old.

Gay, M., Johnson, B., Slobounov, S., & Zhang, K. (2012). **Concussion in athletics: Ongoing clinical and brain imaging research controversies.** *Brain Imaging & Behavior*, 6(2), 224-43.

PMID: 22669496

ABSTRACT: Concussion, the most common form of traumatic brain injury, proves to be increasingly complex and not mild in nature as its synonymous term mild traumatic brain injury (mTBI) would imply. Despite the increasing occurrence and prevalence of mTBI there is no universally accepted definition and conventional brain imaging techniques lack the sensitivity to detect subtle changes it causes. Moreover, clinical management of sports induced mild traumatic brain injury has not changed much over the past decade. Advances in neuroimaging that include electroencephalography, functional magnetic resonance imaging, resting-state functional connectivity, diffusion tensor imaging and magnetic resonance spectroscopy offer promise in aiding research into

understanding the complexities and nuances of mTBI which may ultimately influence clinical management of the condition. In this paper the authors review the major findings from these advanced neuroimaging methods along with current controversy within this field of research. As mTBI is frequently associated with youth and sports injury this review focuses on sports-related mTBI in the younger population.

Glatts, C., Moser, R.S., & Schatz, P. (2012). **Efficacy of immediate and delayed cognitive and physical rest for treatment of sports-related concussion.** *The Journal of Pediatrics*, 161(5), 922-6.

PMID: 22622050

ABSTRACT: **OBJECTIVES:** To evaluate the efficacy of cognitive and physical rest for the treatment of concussion. **STUDY DESIGN:** High school and collegiate athletes (N = 49) underwent post-concussion evaluations between April 2010 and September 2011 and were prescribed at least one week of cognitive and physical rest. Participants were assigned to groups on the basis of the time elapsed between sustaining a concussion and the onset of rest (1-7 days, 8-30 days, 31+ days). Main outcome measures included Concussion Symptom Scale ratings and scores on the 4 composite indices of the Immediate Post-Concussion Assessment and Cognitive Testing measure, both before and following rest. Mixed-factorial design ANOVA were used to compare changes on the dependent measures within and between groups. **RESULTS:** Participants showed significantly improved performance on Immediate Post-Concussion Assessment and Cognitive Testing and decreased symptom reporting following prescribed cognitive and physical rest ($P < .001$), regardless of the time between concussion and onset of rest ($P = .44$). **CONCLUSION:** These preliminary data suggest that a period of cognitive and physical rest may be a useful means of treating concussion-related symptoms, whether applied soon after a concussion or weeks to months later.

Goldman, R., Khan, I.S., Nanda, A., & Testa, M. (2012). **Sports-related concussions and the Louisiana Youth Concussion Act.** *The Journal of the Louisiana State Medical Society: Official Organ of the Louisiana State Medical Society*, 164(5), 246-50.

PMID: 23362587

ABSTRACT: Concussion, also referred to as mild

traumatic brain injury (TBI), is defined as a “complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces.” Various symptoms may be observed in patients with concussions. All of these might not be evident at the time of the injury and be intermittent in their nature. It is estimated that 300,000 of the yearly TBIs in the United States are sports-related, the second leading cause for TBIs after motor vehicle accidents among people aged 15 to 24 years old. Due to some recently reported high profile injuries and deaths of sports personalities, sports-related concussion has seen increasing media and public interest in the last decade. We review the role of football in youth concussions and analyze the Nationwide Inpatient Sample from 2007 to 2009 to elucidate the outcome and costs associated with sports-related concussions of the youth in the United States. We also review the latest state legislative efforts to decrease the incidence of dangerous sports-related concussions in youth--the Louisiana Youth Concussion Act.

Gray, A., Handcock, P., McCrory, P.R., Schneiders, A.G., & Sullivan, S.J. (2012). **Sports concussion assessment: The effect of exercise on dynamic and static balance.** *Scandinavian Journal of Medicine & Science in Sports*, 22(1), 85-90.

PMID: 20561282

ABSTRACT: This study determined the effect of exercise on measures of static and dynamic balance used in the assessment of sports-related concussion (SRC). A balanced three-group cross-over randomized design was used with three levels of exercise verified by blood-lactate, heart rate and “perceived-exertion”: no exercise/rest (NE), moderate-intensity exercise (ME), and high-intensity exercise (HE). Participants performed two timed balance tasks: tandem gait (TG) and single-leg stance (SLS); pre- and post-exercise and 15 min after exercise. Linear mixed-models with adjusted means and contrasts compared exercise effects. Ninety asymptomatic participants (45♂:45♀) were recruited. When times were contrasted with NE; HE resulted in a significant decrease in SLS ($P < 0.001$) and TG ($P < 0.001$) performance immediately following exercise. Fifteen minutes of recovery improved SLS ($P < 0.001$) and TG ($P = 0.011$) from post-exercise performance. ME caused a significant decrease in performance in SLS ($P = 0.038$) but not TG ($P = 0.428$).

No statistically significant change occurred following ME in any tasks after 15-min recovery (SLS $P=0.064$; TG $P=0.495$). Test-retest reliability was considerably higher for the dynamic task compared with the static task. The reliability of static and dynamic balance tasks, and the change in performance following exercise have implications for the immediate assessment of SRC, as these measures are utilized in concussion assessment instruments.

Hinton-Bayre, A.D. (2012). **Choice of reliable change model can alter decisions regarding neuropsychological impairment after sports-related concussion.** *Clinical Journal of Sport Medicine: Official Journal of the Canadian Academy of Sport Medicine*, 22(2), 105-8.

PMID: 22343968

ABSTRACT: **OBJECTIVE:** Impaired neuropsychological test performance after concussion has been used to guide restraint from play, in particular using reliable change indices (RCI). It remains unclear which of the RCI is most appropriate. **DESIGN:** Athletes were assessed prospectively before and after cerebral concussion and compared with control athletes. **SETTING:** Athletes were assessed in a clinical office environment after referral from a Sports Physician. **PARTICIPANTS:** One hundred ninety-four Australian rugby league athletes were assessed pre-season (time 1). **INTERVENTIONS:** Twenty-seven concussed athletes were assessed 2 days after trauma (time 2) and compared with 26 distribution-matched volunteer uninjured controls. **MAIN OUTCOME MEASURES:** Cognitive performance was assessed on 5 neuropsychological measures of speed of information processing, psychomotor speed, and response inhibition. Four previously reported RCI models used in sports concussion were contrasted, as described by Barr and McCrea (2001) and Maassen et al (2006). **RESULTS:** Reliable change index models were marginally comparable in classifying the control sample. In the concussed sample, no one model seemed to be consistently more or less sensitive. Moreover, the same model could be most sensitive for one individual and least sensitive for another, even on the same test. **CONCLUSIONS:** Reliable change index models can yield different outcomes regarding whether an athlete has experienced cognitive impairment after concussion. Reliable change index model sensitivity

to impairment depends on multiple test and situational factors, including test-retest reliability, differences in test and retest variances, and the individual's relative position on initial testing. In the absence of consensus, the clinician must use highly reliable measures with suitably matched controls if using an RCI.

Marshall, C.M. (2012). **Sports-related concussion: A narrative review of the literature.** *The Journal of the Canadian Chiropractic Association*, 56(4), 299-310.

PMID: 23204574

Full-text is available at http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3501917/pdf/jcca_56_4_299.pdf

Sports-related concussion has gained widespread interest and media attention in recent years due to the potential dangers and long-term consequences. Despite several international consensus statements there remains a great deal of uncertainty surrounding these injuries. This paper is a review of recent literature on the topic of concussion, consisting of: biomechanics, pathophysiology, diagnosis, and sideline management.

Moser, R.S., & Schatz, P. (2012). **A case for mental and physical rest in youth sports concussion: It's never too late.** *Frontiers in Neurology*, 3, 171.

PMID: 23248612

Full-text is available at <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3518809/pdf/fneur-03-00171.pdf>

ABSTRACT: Over the past decade, there has been a considerable increase in research on, and media attention to, sports-related concussion. However, despite accurate diagnosis, effective treatment and management of sports-related concussion have remained a challenge. There are approximately 1.8 million traumatic brain injuries in the United States annually (Faul et al., 2010) and emergency department pediatric visits for suspected concussion have doubled in the past decade (Bakhos et al., 2010). However, health care providers and medical researchers have yet to offer an effective, reliable evidence-based treatment for concussive brain injury. The Zurich 2008 Consensus Statement on Concussion in Sport codified the prescription for cognitive and physical rest immediately following a concussion based on clinical acumen and common sense (McCroory et al., 2009). Currently, rest is the considered

the best immediate treatment for concussion. Other supportive and anecdotal treatments are often applied throughout the post-concussive recovery process to address persistent symptoms. The need for empirical research to translate current guidelines for rest into evidence-based treatment protocols is essential. A recent study evaluated the efficacy of comprehensive rest and concluded that such rest may be helpful whether applied soon after a concussion or weeks to months later (Moser et al., 2012). Here, we present a case illustrating the effectiveness of rest in a youth athlete, commenced after experiencing 13 months of post-concussion symptoms. There appears to be value in applying a specific period of cognitive and physical rest following concussion, whether immediately or later in the recovery phase.

White, A. (2012). **Sports-related head injuries.** *Journal of Emergency Nursing (JEN): Official Publication of the Emergency Department Nurses Association*, 38(5), 463-5.
PMID: 22766143 [PubMed - indexed for MEDLINE]
No abstract is available.

2011

Agnihotri, S., Green, S., Keightley, M., Lobaugh, N., Reed, N., & Wilkinson, A. (2011). **An investigation of the effects of sports-related concussion in youth using functional magnetic resonance imaging and the head impact telemetry system.** *Journal of Visualized Experiments: JoVE* (47), pii: 2226.
PMID: 21248710

Full-text is available at <http://europepmc.org/articles/PMC3182638?pdf=render>

Watch this video of this article on JoVE:

<http://www.jove.com/video/2226/an-investigation-effects-sports-related-concussion-youth-using>

ABSTRACT: One of the most commonly reported injuries in children who participate in sports is concussion or mild traumatic brain injury (mTBI). Children and youth involved in organized sports such as competitive hockey are nearly six times more likely to suffer a severe concussion compared to children involved in other leisure physical activities. While the most common cognitive sequelae of mTBI appear similar for children and adults, the recovery profile and breadth of consequences in children remains

largely unknown, as does the influence of pre-injury characteristics (e.g. gender) and injury details (e.g. magnitude and direction of impact) on long-term outcomes. Competitive sports, such as hockey, allow the rare opportunity to utilize a pre-post design to obtain pre-injury data before concussion occurs on youth characteristics and functioning and to relate this to outcome following injury. Our primary goals are to refine pediatric concussion diagnosis and management based on research evidence that is specific to children and youth. To do this we use new, multi-modal and integrative approaches that will: 1. Evaluate the immediate effects of head trauma in youth. 2. Monitor the resolution of post-concussion symptoms (PCS) and cognitive performance during recovery. 3. Utilize new methods to verify brain injury and recovery. To achieve our goals, we have implemented the Head Impact Telemetry (HIT) System. (Simbex; Lebanon, NH, USA). This system equips commercially available Easton S9 hockey helmets (Easton-Bell Sports; Van Nuys, CA, USA) with single-axis accelerometers designed to measure real-time head accelerations during contact sport participation. By using telemetric technology, the magnitude of acceleration and location of all head impacts during sport participation can be objectively detected and recorded. We also use functional magnetic resonance imaging (fMRI) to localize and assess changes in neural activity specifically in the medial temporal and frontal lobes during the performance of cognitive tasks, since those are the cerebral regions most sensitive to concussive head injury. Finally, we are acquiring structural imaging data sensitive to damage in brain white matter.

Allen, M., Balcer, L.J., Brandes, L.E., Devick, S., Dziemianowicz, M.S., Galetta, K.M., Galetta, S.L., Laudano, E., Lawler, K., Maki, K., Messner, L.V., Sennett, B., & Wiebe, D. (2011). **The King-Devick test and sports-related concussion: Study of a rapid visual screening tool in a collegiate cohort.** *Journal of the Neurological Sciences*, 309(1-2), 34-9.
PMID: 21849171

ABSTRACT: **OBJECTIVE:** Concussion, defined as an impulse blow to the head or body resulting in transient neurologic signs or symptoms, has received increasing attention in sports at all levels. The King-Devick (K-D) test is based on the time to perform rapid number naming and captures eye movements

and other correlates of suboptimal brain function. In a study of boxers and mixed martial arts (MMA) fighters, the K-D test was shown to have high degrees of test-retest and inter-rater reliability and to be an accurate method for rapidly identifying boxers and mixed martial arts fighters with concussion. We performed a study of the K-D test as a rapid sideline screening tool in collegiate athletes to determine the effect of concussion on K-D scores compared to a pre-season baseline. **METHODS:** In this longitudinal study, athletes from the University of Pennsylvania varsity football, sprint football, and women's and men's soccer and basketball teams underwent baseline K-D testing prior to the start of the 2010-11 playing season. Post-season testing was also performed. For athletes who had concussions during the season, K-D testing was administered immediately on the sidelines and changes in score from baseline were determined. **RESULTS:** Among 219 athletes tested at baseline, post-season K-D scores were lower (better) than the best pre-season scores (35.1 vs. 37.9s, $P=0.03$, Wilcoxon signed-rank test), reflecting mild learning effects in the absence of concussion. For the 10 athletes who had concussions, K-D testing on the sidelines showed significant worsening from baseline (46.9 vs. 37.0s, $P=0.009$), with all except one athlete demonstrating worsening from baseline (median 5.9s). **CONCLUSION:** This study of collegiate athletes provides initial evidence in support of the K-D test as a strong candidate rapid sideline visual screening tool for concussion. Data show worsening of scores following concussion, and ongoing follow-up in this study with additional concussion events and different athlete populations will further examine the effectiveness of the K-D test.

Allen, M., Balcer, L.J., Barrett, J., Branas, C.C., Delicata, D., Devick, S., Galetta, K.M., Galetta, S.L., Madda, F., Maguire, M.G., Messner, L.V., & Tennant, A.T. (2011). **The King-Devick test as a determinant of head trauma and concussion in boxers and MMA fighters.** *Neurology*, 76(17), 1456-62.

PMID: 21288984

Full-text is available at <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3087467/pdf/znl1456.pdf>

ABSTRACT: **OBJECTIVE:** Sports-related concussion has received increasing attention as a cause of short- and long-term neurologic symptoms among

athletes. The King-Devick (K-D) test is based on measurement of the speed of rapid number naming (reading aloud single-digit numbers from 3 test cards), and captures impairment of eye movements, attention, language, and other correlates of suboptimal brain function. We investigated the K-D test as a potential rapid sideline screening for concussion in a cohort of boxers and mixed martial arts fighters. **METHODS:** The K-D test was administered prefight and post-fight. The Military Acute Concussion Evaluation (MACE) was administered as a more comprehensive but longer test for concussion. Differences in post-fight K-D scores and changes in scores from prefight to post-fight were compared for athletes with head trauma during the fight vs those without. **RESULTS:** Post-fight K-D scores ($n = 39$ participants) were significantly higher (worse) for those with head trauma during the match (59.1 ± 7.4 vs 41.0 ± 6.7 seconds, $p < 0.0001$, Wilcoxon rank sum test). Those with loss of consciousness showed the greatest worsening from prefight to post-fight. Worse post-fight K-D scores ($r(s) = -0.79$, $p = 0.0001$) and greater worsening of scores ($r(s) = 0.90$, $p < 0.0001$) correlated well with post-fight MACE scores. Worsening of K-D scores by ≥ 5 seconds was a distinguishing characteristic noted only among participants with head trauma. High levels of test-retest reliability were observed (intra-class correlation coefficient 0.97 [95 percent confidence interval 0.90-1.0]). **CONCLUSIONS:** The K-D test is an accurate and reliable method for identifying athletes with head trauma, and is a strong candidate rapid sideline screening test for concussion.

Almquist, J.L., Caswell, S.V., Dunn, R.E., Hinton, R.Y., Lincoln, A.E., & Norris, J.B. (2011). **Trends in concussion incidence in high school sports: A prospective 11-year study.** *The American Journal of Sports Medicine*, 39(5), 958-63.

PMID: 21278427

ABSTRACT: **BACKGROUND:** Understanding the risk and trends of sports-related concussion among 12 scholastic sports may contribute to concussion detection, treatment, and prevention. **PURPOSE:** To examine the incidence and relative risk of concussion in 12 high school boys' and girls' sports between academic years 1997-1998 and 2007-2008. **STUDY DESIGN:** Descriptive epidemiology study. **METHODS:** Data were prospectively gathered for 25 schools in

a large public high school system. All schools used an electronic medical record-keeping program. A certified athletic trainer was on-site for games and practices and electronically recorded all injuries daily. RESULTS: In sum, 2651 concussions were observed in 10 926 892 athlete-exposures, with an incidence rate of 0.24 per 1000. Boys' sports accounted for 53 percent of athlete-exposures and 75 percent of all concussions. Football accounted for more than half of all concussions, and it had the highest incidence rate (0.60). Girls' soccer had the most concussions among the girls' sports and the second-highest incidence rate of all 12 sports (0.35). Concussion rate increased 4.2-fold (95 percent confidence interval, 3.4-5.2) over the 11 years (15.5 percent annual increase). In similar boys' and girls' sports (baseball/softball, basketball, and soccer), girls had roughly twice the concussion risk of boys. Concussion rate increased over time in all 12 sports. CONCLUSION: Although the collision sports of football and boys' lacrosse had the highest number of concussions and football the highest concussion rate, concussion occurred in all other sports and was observed in girls' sports at rates similar to or higher than those of boys' sports. The increase over time in all sports may reflect actual increased occurrence or greater coding sensitivity with widely disseminated guidance on concussion detection and treatment. The high-participation collision sports of football and boys' lacrosse warrant continued vigilance, but the findings suggest that focus on concussion detection, treatment, and prevention should not be limited to those sports traditionally associated with concussion risk.

Bailes, J.E., Orphanos, J., & Sedney, C.L. (2011). **When to consider retiring an athlete after sports-related concussion.** *Clinics in Sports Medicine*, 30(1), 189-200, xi.

PMID: 21074092

Full-text is available at <http://download.journals.elsevierhealth.com/pdfs/journals/0278-5919/PIIS0278591910000578.pdf>

ABSTRACT: The pathophysiology of concussion may lead to a variety of both short- and long-term effects, which may lead to a decision to retire from contact sports. These effects follow a recognizable progression and may cause an athlete to opt out of

play at any point along this progression. To elucidate the effect of concussion or mild traumatic brain injury and weigh in on a decision to retire, the treating physician needs to take into account the history, neurologic examination, brain imaging, and neuropsychological testing. In addition, myriad social factors surrounding play must be taken into consideration.

Baker, R., Giebel, S., Koestner, A., Kothari, R., & Mohny, G. (2011). **Factors influencing emergency medicine physicians' management of sports-related concussions: A community-wide study.** *The Journal of Emergency Medicine*, 41(6), 649-54. PMID: 21550754

ABSTRACT: BACKGROUND: Numerous guidelines to grade and manage sports-related concussions have been published. However, little is known about how frequently they are implemented in the emergency department. This study evaluates the current practices of emergency physicians (EPs) in managing sports-related concussions. OBJECTIVES: To evaluate the current practice of EP evaluation and management of sports-related concussions. METHODS: All EPs and emergency medicine residents in Kalamazoo County were surveyed regarding their management of sports-related concussions. The surveys obtained demographic data, participants' use of guidelines, and the importance of clinical and non-clinical factors in deciding when to allow a player to return to play. RESULTS: Of the 73 EP respondents, only 23 percent used a nationally recognized guideline, with no significant difference between attending and resident EPs. The symptomatic complaints of loss of consciousness, amnesia of the event, and difficulty concentrating were ranked most important by EPs in assessing patients with sports-related concussions. Among non-clinical factors, residents were significantly more likely than attendings to report that medical-legal, parental, and players' concerns were more likely to influence their decision in allowing a patient to return to play. CONCLUSION: EPs take into consideration important clinical factors in assessing patients with sports-related concussion. However, almost 75 percent do not use any nationally recognized guideline in their evaluation. Residents are more likely than attendings to be influenced by non-clinical factors.

Boyer, C., Cubon, V.A., Dettwiler, A., & Putukian, M. (2011). **A diffusion tensor imaging study on the white matter skeleton in individuals with sports-related concussion.** *Journal of Neurotrauma*, 28(2), 89-201.

PMID: 21083414

Full-text is available at <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3037804/pdf/neu.2010.1430.pdf>

ABSTRACT: Recognizing and managing the effects of cerebral concussion is very challenging, given the discrete symptomatology. Most individuals with sports-related concussion will not score below 15 on the Glasgow Coma Scale, but will present with rapid onset of short-lived neurological impairment, demonstrating no structural changes on traditional magnetic resonance imaging (MRI) and computed tomography (CT) scans. The return-to-play decision is one of the most difficult responsibilities facing the physician, and so far this decision has been primarily based on neurological examination, symptom checklists, and neuropsychological (NP) testing. Diffusion tensor imaging (DTI) may be a more objective tool to assess the severity and recovery of function after concussion. We assessed white matter (WM) fiber tract integrity in varsity level college athletes with sports-related concussion without loss of consciousness, who experienced protracted symptoms for at least 1 month after injury. Evaluation of fractional anisotropy (FA) and mean diffusivity (MD) of the WM skeleton using tract-based spatial statistics (TBSS) revealed a large cluster of significantly increased MD for concussed subjects in several WM fiber tracts in the left hemisphere, including parts of the inferior/superior longitudinal and fronto-occipital fasciculi, the retrolenticular part of the internal capsule, and posterior thalamic and acoustic radiations. Qualitative comparison of average FA and MD suggests that with increasing level of injury severity (ranging from sports-related concussion to severe traumatic brain injury), MD might be more sensitive at detecting mild injury, whereas FA captures more severe injuries. In conclusion, the TBSS analysis used to evaluate diffuse axonal injury of the WM skeleton seems sensitive enough to detect structural changes in sports-related concussion.

Collins, M.W., Kontos, A.P., Lau, B.C., Lovell, M.R., & Mucha, A. (2011). **Which on-field signs/symptoms predict protracted recovery from sport-**

related concussion among high school football players? *The American Journal of Sports Medicine*, 39(11), 2311-8.

PMID: 21712482

ABSTRACT: **BACKGROUND:** There has been increasing attention and understanding of sport-related concussions. Recent studies show that neurocognitive testing and symptom clusters may predict protracted recovery in concussed athletes. On-field signs and symptoms have not been examined empirically as possible predictors of protracted recovery. **PURPOSE:** This study was undertaken to determine which on-field signs and symptoms were predictive of a protracted (≥ 21 days) versus rapid (≤ 7 days) recovery after a sports-related concussion. On-field signs and symptoms included confusion, loss of consciousness, posttraumatic amnesia, retrograde amnesia, imbalance, dizziness, visual problems, personality changes, fatigue, sensitivity to light/noise, numbness, and vomiting. **STUDY DESIGN:** Cohort study (prognosis); Level of evidence, 2. **METHODS:** The sample included 107 male high school football athletes who completed computerized neurocognitive testing within an average 2.4 days after injury, and who were followed until returned to play as determined by neuropsychologists using international clinical concussion management guidelines. Athletes were then grouped into rapid (≤ 7 days, $n = 62$) or protracted (≥ 21 days, $n = 36$) recovery time groups. The presence of on-field signs and symptoms was determined at the time of injury by trained sports medicine professionals (i.e., ATC [certified athletic trainer], team physician). A series of odds ratios with χ^2 analyses and subsequent logistic regression were used to determine which on-field signs and symptoms were associated with an increased risk for a protracted recovery. **RESULTS:** Dizziness at the time of injury was associated with a 6.34 odds ratio (95 percent confidence interval = 1.34-29.91, $\chi^2 = 5.44$, $P = .02$) of a protracted recovery from concussion. Surprisingly, the remaining on-field signs and symptoms were not associated with an increased risk of protracted recovery in the current study. **CONCLUSION:** Assessment of on-field dizziness may help identify high school athletes at risk for a protracted recovery. Such information will improve prognostic information and allow clinicians to manage and treat concussion more effectively in these at-risk athletes.

Collins, M.W., Lau, B.C., & Lovell, M.R. (2011). **Sensitivity and specificity of subacute computerized neurocognitive testing and symptom evaluation in predicting outcomes after sports-related concussion.** *The American Journal of Sports Medicine*, 39(6), 1209-16.

PMID: 21285444

ABSTRACT: **BACKGROUND:** Concussions affect an estimated 136 000 high school athletes yearly. Computerized neurocognitive testing has been shown to be appropriately sensitive and specific in diagnosing concussions, but no studies have assessed its utility to predict length of recovery. Determining prognosis during sub-acute recovery after sports concussion will help clinicians more confidently address return-to-play and academic decisions. **PURPOSE:** To quantify the prognostic ability of computerized neurocognitive testing in combination with symptoms during the sub-acute recovery phase from sports-related concussion. **STUDY DESIGN:** Cohort study (prognosis); Level of evidence, 2. **METHODS:** In sum, 108 male high school football athletes completed a computer-based neurocognitive test battery within 2.23 days of injury and were followed until returned to play as set by international guidelines. Athletes were grouped into protracted recovery (>14 days; n = 50) or short-recovery (\leq 14 days; n = 58). Separate discriminant function analyses were performed using total symptom score on Post-Concussion Symptom Scale, symptom clusters (migraine, cognitive, sleep, neuropsychiatric), and Immediate Post-concussion Assessment and Cognitive Testing neurocognitive scores (verbal memory, visual memory, reaction time, processing speed). **RESULTS:** Multiple discriminant function analyses revealed that the combination of 4 symptom clusters and 4 neurocognitive composite scores had the highest sensitivity (65.22 percent), specificity (80.36 percent), positive predictive value (73.17 percent), and negative predictive value (73.80 percent) in predicting protracted recovery. Discriminant function analyses of total symptoms on the Post-Concussion Symptom Scale alone had a sensitivity of 40.81 percent; specificity, 79.31 percent; positive predictive value, 62.50 percent; and negative predictive value, 61.33 percent. The 4 symptom clusters alone discriminant function analyses had a sensitivity of 46.94 percent; specificity, 77.20 percent; positive predictive value, 63.90 percent; and negative predictive value, 62.86 percent. Discriminant

function analyses of the 4 computerized neurocognitive scores alone had a sensitivity of 53.20 percent; specificity, 75.44 percent; positive predictive value, 64.10 percent; and negative predictive value, 66.15 percent. **CONCLUSION:** The use of computerized neurocognitive testing in conjunction with symptom clusters results improves sensitivity, specificity, positive predictive value, and negative predictive value of predicting protracted recovery compared with each used alone. There is also a net increase in sensitivity of 24.41 percent when using neurocognitive testing and symptom clusters together compared with using total symptoms on Post-Concussion Symptom Scale alone.

Difiori, J.P., & Giza, C.C. (2011). **Pathophysiology of sports-related concussion: An update on basic science and translational research.** *Sports Health*, 3(1), 46-51.

PMID: 23015990

Full-text is available at http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3445184/pdf/10.1177_1941738110391732.pdf

ABSTRACT: **CONTEXT:** Concussions that occur during participation in athletic events affect millions of individuals each year. Although our understanding of the pathophysiology of concussion has grown considerably in recent years, much remains to be elucidated. This article reviews basic science and relevant translational clinical research regarding several aspects of concussion. **EVIDENCE ACQUISITION:** A literature search was conducted using PubMed from 1966 to 2010, with an emphasis on work published within the past 10 years. Additional articles were identified from the bibliography of recent reviews. **RESULTS:** Basic science and clinical data both indicate that there is a period of increased vulnerability to repeated injury following a concussion and that its duration is variable. Growing evidence indicates that post-injury activity is likely to affect recovery from brain injury. Data suggest that long-term sequelae may result from prior concussion-particularly, repeated injuries. The unique aspects of cerebral development may account for differences in the effects of concussion in children and adolescents when compared with adults. **CONCLUSIONS:** The available pathophysiologic data from basic science and clinical studies have increased the evidence base for concussion management strategies-the approaches to which may differ between young athletes and adults.

Dubourg, J., & Messerer, M. (2011). **Sports-related chronic repetitive head trauma as a cause of pituitary dysfunction.** *Neurosurgical Focus*, 31(5), E2. PMID: 22044101

Full-text is available at <http://thejns.org/doi/pdf/10.3171/2011.8.FOCUS11182>

ABSTRACT: Traumatic brain injury (TBI) is recognized as a cause of hypopituitarism even after mild TBI. Although over the past decade, a growing body of research has detailed neuroendocrine changes induced by TBI, the mechanisms and risk factors responsible for this pituitary dysfunction are still unclear. Around the world, sports-especially combative sports-are very popular. However, sports are not generally considered as a cause of TBI in most epidemiological studies, and the link between sports-related head trauma and hypopituitarism has not been investigated until recently. Thus, there is a paucity of data regarding this important concern. Because of the large number of young sports participants with near-normal life expectancy, the implications of undiagnosed or untreated post-concussion pituitary dysfunction can be dramatic. Understanding the pathophysiological mechanisms and risk factors of hypopituitarism caused by sports injuries is thus an important issue that concerns both medical staff and sponsors of sports. The aim of this paper was to summarize the best evidence for understanding the pathophysiological mechanisms and to discuss the current data and recommendations on sports-related head trauma as a cause of hypopituitarism.

Gay, M., Hallett, M., Horovitz, S., Johnson, B., Pennell, D., Sebastianelli, W., Slobounov, S.M., & Zhang, K. (2011). **Alteration of brain functional network at rest and in response to YMCA physical stress test in concussed athletes: RsfMRI study.** *NeuroImage*, 55(4), 1716-27. PMID: 21255654

Full-text is available at <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3062748/pdf/nihms266625.pdf>

ABSTRACT: There is still controversy in the literature whether a single episode of mild traumatic brain injury (mTBI) results in short- and/or long-term functional and structural deficits in the concussed brain. With the inability of traditional brain imaging techniques to properly assess the severity of brain damage induced by a concussive blow, there is hope

that more advanced applications such as resting state functional magnetic resonance imaging (rsfMRI) will be more specific in accurately diagnosing mTBI. In this rsfMRI study, we examined 17 subjects 10±2 days post-sports-related mTBI and 17 age-matched normal volunteers (NVs) to investigate the possibility that the integrity of the resting state brain network is disrupted following a single concussive blow. We hypothesized that advanced brain imaging techniques may reveal subtle alterations of functional brain connections in asymptomatic mTBI subjects. There are several findings of interest. All mTBI subjects were asymptomatic based upon clinical evaluation and neuropsychological (NP) assessments prior to the MRI session. The mTBI subjects revealed a disrupted functional network both at rest and in response to the YMCA physical stress test. Specifically, inter-hemispheric connectivity was significantly reduced in the primary visual cortex, hippocampal and dorsolateral prefrontal cortex networks ($p < 0.05$). The YMCA physical stress induced nonspecific and similar changes in brain network connectivity patterns in both the mTBI and NV groups. These major findings are discussed in relation to underlying mechanisms, clinical assessment of mTBI, and current debate regarding functional brain connectivity in a clinical population. Overall, our major findings clearly indicate that functional brain alterations in the acute phase of injury are overlooked when conventional clinical and neuropsychological examinations are used.

Guskiewicz, K.M., Valovich McLeod, T.C. (2011). **Pediatric sports-related concussion.** *PM & R: The Journal of Injury, Function, and Rehabilitation*, 3(4), 353-64; quiz 364.

PMID: 21497322

ABSTRACT: This article aims to examine pediatric concussion literature with respect to epidemiology, etiology, return to play, and recurrent concussions, and to provide recommendations for future research. We conducted a review of pediatric concussion literature regarding incidence, etiology, return to play, and recurrent concussive injury by using MEDLINE, CINAHL, Sport-Discus, and PsychInfo databases from 1995-2010. A review of reference lists in the aforementioned articles was also performed. We discovered that the research on sports-related concussion specific to children and adolescents is rather limited.

Results of existing studies of concussion incidence in this population indicate that concussion is relatively rare compared with most musculoskeletal injuries; however, the potential consequences of mismanagement and of subsequent injury warrant significant attention regarding injury recognition and recovery, and the challenge of determining readiness to return to play. Evidence exists that children and adolescents take longer to recover than adults after a concussion, which underscores the need for a more conservative approach to management and return to physical and cognitive activities. Concussion in the young athlete is of specific concern because of the continuing cognitive maturation, therefore, the recovery may be more difficult to track when using the standard assessment tools currently available. Until future studies can better delineate the mechanisms of, response to, and recovery from concussion in the young athlete, it is prudent to act in a conservative manner when dealing with pediatric athletes with concussion.

d'Hemecourt, P. (2011). **Subacute symptoms of sports-related concussion: outpatient management and return to play.** *Clinics in Sports Medicine*, 30(1), 63-72, viii.

PMID: 21074082

Full-text is available at <http://download.journals.elsevierhealth.com/pdfs/journals/0278-5919/PIIS0278591910000608.pdf>

ABSTRACT: Most concussion symptoms resolve within the first week after injury. Athletes with persistent symptoms may manifest subtle behavioral and cognitive changes. The astute clinician uses various information to determine when these symptoms have cleared before allowing the athlete to return to athletic competition.

Lovell, M.R., Ott, S.D., & Solomon, G.S. (2011). **Long-term neurocognitive dysfunction in sports: What is the evidence?** *Clinics in Sports Medicine*, 30(1), 165-77, x-xi.

PMID: 21074090

Full-text is available at <http://download.journals.elsevierhealth.com/pdfs/journals/0278-5919/PIIS0278591910000761.pdf>

ABSTRACT: Although the immediate neurocognitive effects of sports-related concussion are well known, less is known about the intermediate or long-

term effects of sports-related concussions. A sample of selected studies of high-school and collegiate athletes is reviewed and the intermediate effects of concussive injuries are discussed, because no long-term empiric data are available with these populations. The evidence for intermediate neurocognitive effects is mixed and not convincing at present in these groups of athletes. Selected studies of professional boxers and American professional football players are also reviewed, and the available data regarding long-term neurocognitive and neuropathologic effects are assessed. The evidence for long-term adverse neurocognitive effects in professional boxers is compelling. Suggestions for future research on relevant biopsychosocial variables affecting response to concussive injury are presented.

Moser, R.S., & Schatz, P. (2011). **Current issues in pediatric sports concussion.** *The Clinical Neuro-psychologist*, 25(6), 1042-57.

PMID: 21391151

ABSTRACT: This article reviews current issues in the following areas of pediatric sports-related concussion: incidence of concussion, potential long-term effects, return to play, and the emergence of legislation regarding concussion education and management programs. Incidence of concussion is presented in context of emergency room visits, as well as under-reporting of concussions. The literature on history of concussion is reviewed, for high school, collegiate, and professional athletes, with respect to potential long-term effects of cerebral concussion. Specific discussions of effects include: decreased cognition and increased symptom reporting following multiple concussions, and recent diagnoses of chronic traumatic encephalopathy in non-professional and youth athletes. Recent legislative and advocacy efforts are reviewed, including mandated programs in specific states.

Nierengarten, M.B. (2011). **Neurologists weigh in on sports-related concussions.** *Lancet Neurology*, 10(4), 302-3.

PMID: 21435596

No abstract is available.

Putukian, M. (2011). **Neuropsychological testing as it relates to recovery from sports-related concussion.** *PM & R: The Journal of Injury, Function, & Rehabilitation*, 3(10 Suppl 2), S425-32.

PMID: 22035685

ABSTRACT: Concussion is a challenging injury for the sports medicine team, and neuropsychological testing has been used as an adjunct to other clinical measures for assessment and management, and to guide return-to-play decisions. Understanding the limitations as well as the role of neuropsychological testing in the evaluation and management of sports-related concussion is important for the sports medicine team. This article will review the evidence regarding the utility of neuropsychological testing as it relates to concussion in sports.

Zafonte, R. (2011). **Diagnosis and management of sports-related concussion: A 15-year-old athlete with a concussion.** *JAMA: The Journal of the American Medical Association*, 306(1), 79-86.

PMID: 21632470

ABSTRACT: Concussion in youth athletes is a growing problem worldwide. During the past decade, significant progress has been made in standardization of the assessment of young athletes, and a growing appreciation of metabolic vulnerability, activity, and cognitive challenges has led to guidelines and suggestions for rest from the field as well as cognitive rest from school. Outcome data have begun to establish groups linked to symptom class, genetics, and sex who are at risk of worse outcomes from concussions. Decisions regarding return to activity are now based on at-rest symptoms, graded increases in activity, and neuropsychological testing. Using the case of Ms X, a 15-year-old otherwise healthy high school student who fell while skiing, evaluation, prognosis, and management of concussion are discussed.

2010

Bailey, C.M., Barth, J.T., Broshek, D.K., Freeman, J.R., & Samples, H.L. (2010). **The relationship between psychological distress and baseline sports-related concussion testing.** *Clinical Journal of Sport Medicine*, 20(4), 272-7.

PMID: 20606512

ABSTRACT: **OBJECTIVE:** This study examined the effect of psychological distress on neurocognitive performance measured during baseline concussion testing. **DESIGN:** Archival data were utilized to examine correlations between personality test-

ing and computerized baseline concussion testing. Significantly correlated personality measures were entered into linear regression analyses, predicting baseline concussion testing performance. Suicidal ideation was examined categorically. **SETTING:** Athletes underwent testing and screening at a university athletic training facility. **PARTICIPANTS:** Participants included 47 collegiate football players 17 to 19 years old, the majority of whom were in their first year of college. **INTERVENTIONS:** Participants were administered the Concussion Resolution Index (CRI), an internet-based neurocognitive test designed to monitor and manage both at-risk and concussed athletes. Participants took the Personality Assessment Inventory, a self-administered inventory designed to measure clinical syndromes, treatment considerations, and interpersonal style. **MAIN OUTCOME MEASURES:** Scales and subscales from the PAI were utilized to determine the influence psychological distress had on the CRI indices: simple reaction time, complex reaction time, and processing speed. **RESULTS:** Analyses revealed several significant correlations among aspects of somatic concern, depression, anxiety, substance abuse, and suicidal ideation and CRI performance, each with at least a moderate effect. When entered into a linear regression, the block of combined psychological symptoms accounted for a significant amount of baseline CRI performance, with moderate to large effects ($r = 0.23-0.30$). When examined categorically, participants with suicidal ideation showed significantly slower simple reaction time and complex reaction time, with a similar trend on processing speed. **CONCLUSIONS:** Given the possibility of obscured concussion deficits after injury, implications for premature return to play, and the need to target psychological distress outright, these findings heighten the clinical importance of screening for psychological distress during baseline and post-injury concussion evaluations.

Baker, J., Cubos, J., Duggan, C., Faight, B., Keightley, M., McAuliffe, J., McPherson, M., Montelpare, W., Reed, N., & Taha, T. (2010). **Measurement of head impacts in youth ice hockey players.** *International Journal of Sports Medicine*, 31(11), 826-33. PMID: 20830655

ABSTRACT: Despite growing interest in the biomechanical mechanisms of sports-related concussion,

ice hockey and the youth sport population has not been studied extensively. The purpose of this pilot study was: 1) to describe the biomechanical measures of head impacts in youth minor ice hockey players; and, 2) to investigate the influence of player and game characteristics on the number and magnitude of head impacts. Data was collected from 13 players from a single competitive Bantam boy's (ages 13-14 years) AAA ice hockey team using telemetric accelerometers implanted within the players' helmets at 27 ice hockey games. The average linear acceleration, rotational acceleration, Gadd Severity Index and Head Injury Criterion of head impacts were recorded. A significantly higher number of head impacts per player per game were found for wingers when compared to center and defense player positions ($df=355$, $t=3.087$, $p=0.00218$) and for tournament games when compared to regular season and playoff games ($df=355$, $t=2.641$, $p=0.086$). A significant difference in rotational acceleration according to player position ($F_{2,1812}=4.9551$, $p=0.0071$) was found. This study is an initial step towards a greater understanding of head impacts in youth ice hockey.

Batchelor, J., Gardner, A., & Shores, E.A. (2010). **Reduced processing speed in rugby union players reporting three or more previous concussions.** *Archives of Clinical Neuropsychology*, 25(3), 174-81. PMID: 20202986

ABSTRACT: The issue pertaining to the effect of multiple self-reported sports-related concussions on cognitive function is controversial. Although this topic has received increased attention in the literature recently, the issue remains unresolved. Evidence supporting a detrimental cognitive effect has been reported at a sub-concussive level and following one, two, and three or more previous concussions. However, numerous studies have been unable to replicate these findings. Additionally, discrepancies between neuropsychological testing formats have been identified, where studies utilizing traditional tests tend to support the notion of detrimental cognitive effects whereas studies with computerized tests have tended to demonstrate no effect. The present study sought to examine possible detrimental cognitive effects in a sample of adult male rugby union players who reported a history of three or more concussions ($n =$

34) compared with those who reported no previous concussions ($n = 39$). A computerized neuropsychological battery and a traditional neuropsychological measure of processing speed were administered for this purpose. Findings revealed that there were differences between groups on two processing speed measures from both traditional and computerized tests. Athletes with a history of multiple concussions performed significantly lower on these measures than those with no history of concussion. These results provide further evidence to suggest that a history of three or more self-reported concussions in active athletes may have a detrimental effect on cognitive function. Future research may focus on identifying moderating factors in an attempt to resolve some of the conflicting findings and identify potential athletes at risk for sustaining cognitive deficits.

Bottari, C., Chen, J.K., Gosselin, N., Johnston, K., Ptito, A., & Saluja, R.S. (2010). **Brain functions after sports-related concussion: insights from event-related potentials and functional MRI.** *The Physician & Sportsmedicine*, 38(3), 27-37. PMID: 20959693

ABSTRACT: The high incidence of concussions in contact sports and their impact on brain functions are a major cause for concern. To improve our understanding of brain functioning after sports-related concussion, advanced functional assessment techniques, namely event-related potentials (ERPs) and functional magnetic resonance imaging (fMRI), have been recently used in research studies. Contrary to neuropsychological tests that measure verbal and/or motor responses, ERPs and fMRI assess the neural activities associated with cognitive/behavioral demands, and thus provide access to better comprehension of brain functioning. In fact, ERPs have excellent temporal resolution, and fMRI identifies the involved structures during a task. This article describes ERP and fMRI techniques and reviews the results obtained with these tools in sports-related concussion. Although these techniques are not yet readily available, they offer a unique clinical approach, particularly for complex cases (i.e., athletes with multiple concussions, chronic symptoms) and objective measures that provide valuable information to guide management and return-to-play decision making.

Covassin, T., & Elbin, R.J. (2010). **The cognitive effects and decrements following concussion.** *Open Access Journal of Sports Medicine*, 1, 55-61.

PMID: 24198543

ABSTRACT: Sports-related concussion is an injury that continues to receive attention from both the popular media and sports medicine community. The many different symptom presentations and cognitive decrements that follow concussions have made this injury difficult to detect and manage. Furthermore, concussed athletes should not always be entrusted to appropriately self-report their concussion symptoms; therefore the burden falls on the clinician and coach. Recent management recommendations call for using a multi-faceted approach to managing concussion, which consists of neurocognitive testing before (i.e., baseline/preseason) and after injury. In addition age, sex, and previous history of concussion have been found to influence the risk and recovery from this injury.

Eckner, J.T., & Kutcher, J.S. (2010). **At-risk populations in sports-related concussion.** *Current Sports Medicine Reports*, 9(1), 16-20.

PMID: 20071916

ABSTRACT: Concussion is a physiological injury to the extremely complex and dynamic human brain. Individual variability adds to the challenge of concussion management, and sports medicine practitioners recently have begun to realize the need for an individualized approach. Adequately assessing an athlete with concussion requires consideration of many risk factors, including age, gender, and certain comorbid conditions. Understanding how these factors may affect concussion risk and outcome is becoming an essential aspect of management. This article reviews what is known or assumed about how some of these risk factors affect concussion. We conclude by providing several key concepts that we feel are important to keep in mind when managing an athlete with concussion.

Eckner, J.T., & Kutcher, J.S. (2010). **Concussion symptom scales and sideline assessment tools: A critical literature update.** *Current Sports Medicine Reports*, 9(1):8-15.

PMID: 20071915

ABSTRACT: Sports-related concussion remains a

diagnostic and management challenge for the sports medicine practitioner. Numerous symptom scales and sideline assessment tools are available for team physicians and athletic trainers to objectively assess this difficult injury. The purpose of this article is to update the reader on literature published within the past year relevant to concussion symptom scales and sideline assessment tools. A critical evaluation of pertinent articles is presented. We conclude that multiple symptom scales and assessment tools are available, with no single tool showing clear superiority. Many tools remain based more on expert opinion than rigorous scientific evaluation. A multifaceted approach to sports concussion is advised. The sports medicine practitioner must not rely on any one tool in managing concussion and must be aware of the strengths and limitations of whichever method is chosen to incorporate into a concussion evaluation and management plan.

Garland, K., Garton, J., Green, S., Keightley, M.L., McAuliffe, J., Reed, N., Taha, T., & Yule, A. (2010). **Sports-related mild traumatic brain injury in female youths.** *BMJ Case Reports*, 2010, doi:10.1136/bcr.09.2009.2309.

PMID: 22791784

Full-text is available at <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3027911/pdf/bcr.09.2009.2309.pdf>

ABSTRACT: Sports-related concussion or mild-traumatic brain injury (mTBI) is common in children who participate in organized sports. We describe two case studies involving 14-year-old girls who each sustained a mTBI during ice hockey competition. Neurocognitive functioning post-injury is compared to baseline pre-injury assessment on the same measures. Results from Immediate Post-Concussion Assessment and Cognitive Testing (ImPACT), Conners' Continuous Performance Test II (CPT-II) and the Attention Network Test (ANT) revealed decreased performance in attention, memory functioning and reaction time. Furthermore, some measures had not returned to baseline at midseason testing sessions approximately 30-40 days post-injury. The results are discussed with respect to the difference in recovery profiles and the need for thorough and ongoing evaluation following mTBI in the paediatric population, and for girls in particular.

Makdissi, M. (2010). **Sports-related concussion: Management in general practice.** *Australian Family Physician*, 39(1-2), 12-7.

ABSTRACT: **BACKGROUND:** Concussive injuries are common in many sports and recreational activities, especially those involving body contact, collisions or high speed. Over the past 8 years, international experts met on three occasions to address key issues in the understanding and management of concussion in sport; most recently in Zurich in November 2008. The consensus statement produced from this meeting provides an outline of up-to-date knowledge and best practice management guidelines on concussion in sport. **OBJECTIVE:** The aim of this article is to provide an overview of the key concepts from the Zurich consensus statement, including an understanding of concussion and an outline of potential risks and recommended management as applicable to the general practice setting. **DISCUSSION:** Concussion is thought to reflect a functional injury to the brain. Clinical features are typically short lived and resolve spontaneously, with the majority of affected individuals recovering within 10-14 days. However, complications can occur including prolonged symptoms or cognitive deficit, depression, and cumulative deterioration in brain function. The potential for adverse outcomes and the absence of direct measures of recovery following a concussive injury, make decisions regarding return to play a challenge. Clinical management includes confirming the diagnosis, differentiating concussion from structural head injury, estimating the severity of injury, and determining when the patient can return safely to competition. Players should return to play in a graded fashion after clinical features have resolved and cognitive function has returned to 'normal' on neuropsychological testing.

2009

Atabaki, S., Cohen, J.S., Gioia, G., & Teach, S.J. (2009). **Sports-related concussions in pediatrics.** *Current Opinion in Pediatrics*, 21(3), 288-93.

PMID: 19390439

ABSTRACT: **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 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.

Bailes, J.E. (2009). **Sports-related concussion: What do we know in 2009—A neurosurgeon's perspective.** *Journal of the International Neuropsychological Society*, 15(4), 509-11.

PMID: 19573268

No abstract is available.

Bailes, J., Echemendia, R.J., & Herring, S. (2009). **Who should conduct and interpret the neuropsychological assessment in sports-related concussion?** *British Journal of Sports Medicine*, 43 Suppl 1, i32-5.

PMID: 19433423

ABSTRACT: **OBJECTIVE:** This paper seeks to (i)

describe the education and training of clinical neuropsychologists, (ii) discuss the significant differences between test administration and clinical assessment, (iii) outline the complex factors involved in psychometric test theory and test interpretation, and (iv) provide a framework for the role of clinical neuropsychologists in the interpretation and administration of neuropsychological instruments within the sports context. DESIGN: Review of pertinent professional practice, empirical and theoretical literature. INTERVENTION: Pubmed, Medline and Psych Info databases were reviewed. In total, 35 articles and 2 books were reviewed. RESULTS: The decision to return an athlete to play following sports-related brain injury is complex and requires the analysis of several sources of data. The decision is determined by a team physician; ideally within the context of a multidisciplinary team that employs comprehensive concussion surveillance and management, including baseline and post-injury neuropsychological assessment. Neuropsychologists possess the training and skill sets necessary to provide unique expertise in the assessment of cognitive functioning and post-injury neurocognitive and psychological assessment. CONCLUSIONS: Baseline neuropsychological testing is a technical procedure that can be conducted by technicians under the supervision/guidance of a neuropsychologist. Post-injury assessment requires advanced neuropsychological expertise that is best provided by a clinical neuropsychologist. Significant international differences exist with respect to the training and availability of clinical neuropsychologists, which require modification of these views on a country by country basis.

Bailey, C.M., Barth, J.T., & Bender, S.D. (2009). **SLAM on the stand: How the sports-related concussion literature can inform the expert witness.** *The Journal of Head Trauma Rehabilitation, 24*(2), 123-30.

PMID: 19333067

ABSTRACT: Mild head injury is a controversial topic because patients may have subtle deficits and widely varied outcomes. Accordingly, neuropsychologists are frequently asked to provide expert testimony about the nature of mild head injury. This article discusses how the sports-related concussion literature, including the concept of baseline assessment, can inform expert witnesses who are asked to provide such testimony. We first provide a review of several of the controversies surrounding mild head injury, both within and outside

of the forensic context. This is followed by a review of the sports as a laboratory assessment model literature, which demonstrates consistent and meaningful evidence of cognitive sequelae following mild head injury. We conclude with a description of how the sports as a laboratory assessment model literature may be utilized in a forensic neuropsychology context to address some of the identified controversies. We end with a call for more research that will further inform the forensic neuropsychologist about mild head injury and those factors that may result in poor recovery.

Baker, J., Duggan, C.T., Faught, B., Keightley, M., McAuliffe, J., McPherson, M., Montelpare, W., Reed, N., & Taha, T. (2009). **Paediatric sports-related mild traumatic brain injury.** *BMJ Case Reports, 2009*. [Epub].

PMID: 21686913

Full-text is available at <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3029340/?report=printable>

ABSTRACT: Mild traumatic brain injury (mTBI) is a common but relatively understudied childhood injury that can impact cognitive functioning and development. The present report describes a case study of a 14-year-old boy who sustained two consecutive sports-related mTBIs within a 24 hour period. Neurocognitive functioning at 2, 6, 8, 55 and 225 days after injury is compared to baseline prior to injury assessment on the same measures. Results from Immediate Post-Concussion Assessment and Cognitive Testing (ImpACT), Conner Continuous Performance Test 2 (CPT-II) and the Attention Network Test (ANT) revealed decreased performance in attention, visual memory functioning and impulsivity, with some measures still not returning to baseline at 225 days post injury. The results are discussed with respect to return to normal activities at 4 days post injury. This case study highlights the need for increased research regarding the clinical management of mTBI in the paediatric population, particularly the potential deleterious effects of cumulative injuries.

Broglio, S.P., Ellemberg, D., Guskiewicz, K.M., Henry, L.C., & Macciocchi, S.N. (2009). **Advances in sport concussion assessment: From behavioral to brain imaging measures.** *Journal of Neurotrauma, 26*(12), 2365-82.

PMID: 19715396

ABSTRACT: Given that the incidence of sports-related concussion is considered to have reached

epidemic proportions, in the past 15 years we have witnessed an explosion of research in this field. The purpose of the current review is to compare the results provided by the different assessment tools used in the scientific literature in order to gain a better understanding of the sequelae and recovery following a concussion. Until recently, the bulk of the literature has focused on the immediate outcome in the hours and days post-injury as a means to plan the safest return-to-play strategy. This has led to the development of several assessment batteries that are relatively easy and rapid to administer and that allow for multiple testing sessions. The main conclusion derived from that literature is that cognitive symptoms tend to resolve within one week. However, accumulating evidence indicates that cognitive testing should be viewed as one of several complementary tools necessary for a comprehensive assessment of concussion. Including an objective measure of postural stability increases the sensitivity of the return-to-play decision-making process and minimizes the consequences of mitigating factors (e.g., practice effects and motivation) on neuropsychological test results. This is consistent with findings that symptom severity, neuropsychological function, and postural stability do not appear to be related or affected to the same degree after a concussion. Furthermore, recent evidence from brain imaging, including event-related potentials and functional and metabolic imaging, suggest abnormalities in the electrical responses, metabolic balance, and oxygen consumption of neurons that persist several months after the incident. We explain this apparent discrepancy in recovery by suggesting an initial and rapid phase of functional recovery driven by compensatory mechanisms and brain plasticity, which is followed by a prolonged neuronal recovery period during which subtle deficits in brain functioning are present but not apparent to standard clinical assessment tools.

Broglio, S.P., & Guskiewicz, K.M. (2009). **Concussion in sports: The sideline assessment.** *Sports Health*, 1(5), 361-9.

PMID: 23015894

ABSTRACT: CONTEXT: The vast differences between individual athletes can make identifying and evaluating sports-related concussion one of the most complex and perplexing injuries faced by medical personnel. EVIDENCE ACQUISITION: This review

summarizes the existing literature supporting the use of a multifaceted approach to concussion evaluation on the sideline of the athletic field. Information was drawn from a PubMed search (MEDLINE) for the terms sport concussion for the most recent and relevant literature. CONCLUSIONS: By using a standardized clinical examination that is supported by objective measures of concussion-related symptoms, mental status, and postural control, the medical professional becomes well equipped to make an informed diagnosis.

Lovell, M. (2009). **The management of sports-related concussion: Current status and future trends.** *Clinics in Sports Medicine*, 28(1), 95-111. PMID: 19064168

ABSTRACT: This article provides a review of current trends in the management of sports-related concussion. An evidence-based approach to concussion management is presented with a specific focus on return-to-play issues. The use of neuropsychological testing and other diagnostic tools is presented and reviewed.

Lovell, M. (2009). **The neurophysiology and assessment of sports-related head injuries.** *Physical Medicine and Rehabilitation Clinics of North America*, 20(1), 39-53, vii-viii. PMID: 19084762

Full-text is available at <http://tinyurl.com/q4nv58r>

ABSTRACT: This article provides a review of contemporary standards for the management of athletes who have sustained a sports-related head injury. Recent research regarding concussion management is reviewed with specific reference to clinical care. The use of neuropsychologic testing in sports also is reviewed, and a systematic protocol for the management of sports-related concussion is presented.

2008

Gray, A., Maruthayanar, S., McCrory, P.R., Ranhotiggamge, P., Schneiders, A.G., Singh, P., Sullivan, S.J., & Van der Salm, R. (2008). **The effect of exercise on motor performance tasks used in the neurological assessment of sports-related concussion.** *British Journal of Sports Medicine*, 42(12), 1011-3. PMID: 18308895

ABSTRACT: Sports-related concussion is assessed using both cognitive and motor performance tasks. There is limited understanding of how exercise affects these measures. The purpose of this study was to investigate the effect of moderate-intensity exercise on three selected measures of motor performance. A repeated measures design was used to compare baseline motor performance scores with post-exercise scores with an exercise intervention modelled on the physiological demands of a team sport. 30 physically active subjects performed timed motor performance tasks: Finger-to-Nose (FTN), Tandem Gait (TG) and Single Leg Stance (SLS). The tasks were administered twice pre-exercise and twice post-exercise. FTN, TG and SLS demonstrated high test-retest reliability (ICC values >0.8). 15 minutes of moderate-intensity exercise caused a significant improvement in FTN (T2 = 2.66 (SD 0.38), T3 = 2.49 (0.32); $p < 0.001$) and TG (T2 = 13.08 (2.84), T3 = 12.23 (2.22); $p = 0.001$), but not in SLS (T2 = 5.94 (4.99), T3 = 5.91 (5.54); $p = 0.507$). Improvement in the performance of motor tasks after exercise has implications for the immediate assessment of sports-related concussion, given that measures of motor performance are utilized in concussion assessment instruments.

Guskiewicz, K.M., Mihalik, J.P., & Register-Mihalik, J.K. (2008). **Balance deficits after sports-related concussion in individuals reporting post-traumatic headache.** *Neurosurgery*, 63(1), 76-80; discussion 80-2.

PMID: 18728571

ABSTRACT: OBJECTIVE: Posttraumatic headache (PTH) may affect neurocognition after sports-related concussion. To our knowledge, no studies have examined how PTH affects balance after concussion using dynamic posturography. The purpose of this study is to compare balance after concussion between athletes reporting PTH and athletes not reporting PTH. **METHODS:** We conducted a retrospective, repeated-measures design with participants grouped by presence of post-injury report of headache. Balance testing was conducted on 108 concussed collegiate athletes (age, 18.83 +/- 1.27 year; height, 180.92 +/- 10.01 cm; mass, 83.29 +/- 19.62 kg). Presence of PTH during the first post-injury test session (group) and test time (baseline, post-injury) served as the independent variables. The composite equilibrium score and the somatosensory, vestibular, and visual ratio scores served as dependent variables. A 2 x 2

mixed model analysis of variance was used to analyze each outcome measure. **RESULTS:** Significant decreases in all four measures assessed were noted after concussion compared with preseason baseline measures ($P < 0.05$). Significant group by test-time interactions were observed, suggesting that composite equilibrium (F1106 = 6.6089; $P = 0.012$) and vestibular ratio (F1106 = 7.156; $P = 0.009$) scores are affected by the presence of PTH. Athletes reporting PTH also demonstrated worse visual ratio scores compared with individuals not experiencing PTH (F1106 = 4.26; $P = 0.041$). No other significant findings were observed for the somatosensory ratio score. **CONCLUSION:** Current literature proposes that PTH is associated with cognitive deficits. Our study indicates that PTH may also contribute to increased balance deficits. We believe the deficits may be a result of increased sensory organization challenges after injury. Clinicians should be mindful of these findings when managing concussed athletes reporting headache.

Haase, R.F., & Solomon, G.S. (2008). **Biopsychosocial characteristics and neurocognitive test performance in National Football League players: An initial assessment.** *Archives of Clinical Neuropsychology*, 23(5), 563-77.

PMID: 18614333

ABSTRACT: The use of neurocognitive testing in the assessment of professional athletes sustaining sports-related concussions has become widespread over the past decade. Baseline neurocognitive testing is now a requirement for athletes in the National Football League (NFL). We present preliminary normative data on a computer based neurocognitive test (Immediate Post Concussion Assessment and Cognitive Testing; ImPACT) for 159 NFL athletes. Also included are summary data on basic biopsychosocial characteristics, including medical, psychiatric, chemical dependency, concussion, learning disability/attention deficit disorder, and symptom variables, and the relevance of each to baseline neurocognitive test scores.

Sim, A., Terryberry-Spohr, L., & Wilson, K.R. (2008). **Prolonged recovery of memory functioning after mild traumatic brain injury in adolescent athletes.** *Journal of Neurosurgery*, 108(3), 511-6.

PMID: 18312098

ABSTRACT: OBJECT: The current body of sports-related concussion literature is hampered by a lack of

research conducted in high school athletes. Accordingly, the authors sought to examine the neuropsychological deficits and recovery patterns after concussive injuries in this population. **METHODS:** Participants included 419 male and female athletes with a mean age of 15.69 years who underwent baseline testing of their neuropsychological functioning prior to their sports season. Fourteen participants sustained an in-season concussion and were serially reassessed at ~2.5, 6, and 10 days post-injury. Fourteen uninjured matched control participants were also reassessed at the end of the school year. **RESULTS:** Individuals who sustained in-season concussions demonstrated impairments in reaction time, processing speed, and had delayed memory functioning. Although reaction time and processing speed deficits returned to baseline levels by ~6 days post-injury, participants continued to show memory impairments up to 7 days post-injury. Memory impairments were found to resolve by Day 10, however. **CONCLUSIONS:** The results of the present study suggest that high school athletes demonstrate prolonged memory dysfunction compared with college athletes, and should therefore be treated more conservatively.

2007

Barth, J.T., Echemendia, R.J., Iverson, G.L., Lovell, M.R., Moser, R.S., Ruff, R.M., Schatz, P., & Webbe, F.M. (2007). **Neuropsychological evaluation in the diagnosis and management of sports-related concussion.** *Archives of Clinical Neuropsychology*, 22(8), 909-16.

PMID: 17988831

Full-text is available at <http://tinyurl.com/npazkee>
ABSTRACT: A mild traumatic brain injury in sports is typically referred to as a concussion. This is a common injury in amateur and professional athletics, particularly in contact sports. This injury can be very distressing for the athlete, his or her family, coaches, and school personnel. Fortunately, most athletes recover quickly and fully from this injury. However, some athletes have a slow recovery, and there are reasons to be particularly concerned about re-injury during the acute recovery period. Moreover, some athletes who have experienced multiple concussions are at risk for long-term adverse effects. Neuropsychologists are uniquely qualified to assess the neurocognitive and psychological effects of con-

cussion. The National Academy of Neuropsychology recommends neuropsychological evaluation for the diagnosis, treatment, and management of sports-related concussion at all levels of play.

Broglio, S.P., Ferrara, M.S., & Macciocchi, S.N. (2007). **Sensitivity of the concussion assessment battery.** *Neurosurgery*, 60(6), 1050-7; discussion 1057-8.

PMID: 17538379

Full-text is available at <http://tinyurl.com/ntnyyvg>
ABSTRACT: **OBJECTIVE:** Sports medicine clinicians commonly use multiple tests when evaluating patients with concussion. The specific tests vary but often include symptom inventories, posturography, and neurocognitive examinations. The sensitivity of these tests to concussion is vital in reducing the risk for additional injury by prematurely returning an athlete to play. Our study investigated the sensitivity of concussion-related symptoms, a postural control evaluation, and neurocognitive functioning in concussed collegiate athletes. **METHODS:** From 1998 to 2005, all high-risk athletes completed a baseline concussion-assessment battery that consisted of a self-reported symptom inventory, a postural control evaluation, and a neurocognitive assessment. Post-concussion assessments were administered within 24 hours of injury to 75 athletes who had physician-diagnosed concussion. Individual tests and the complete battery were evaluated for sensitivity to concussion. **RESULTS:** The computerized Immediate Post-Concussion Assessment and Cognitive Testing and HeadMinder Concussion Resolution Index (neurocognitive tests) were the most sensitive to concussion (79.2 and 78.6 percent, respectively). These tests were followed by self-reported symptoms (68.0 percent), the postural control evaluation (61.9 percent), and a brief pencil-and-paper assessment of neurocognitive function (43.5 percent). When the complete battery was assessed, sensitivity exceeded 90 percent. **CONCLUSION:** Currently recommended concussion-assessment batteries accurately identified decrements in one or more areas in most of the athletes with concussion. These findings support previous recommendations that sports-related concussion should be approached through a multifaceted assessment with components focusing on distinct aspects of the athlete's function.

Cantu, R.C., Herring, S.A., & Standaert, C.J. (2007). **Expert opinion and controversies in sports and musculoskeletal medicine: Concussion in the young athlete.** *Archives of Physical Medicine & Rehabilitation*, 88(8), 1077-9.

PMID: 17678673

Full-text is available at <http://tinyurl.com/pxfkuhh>

ABSTRACT: Concussion is a common injury in young athletes and can be very challenging for clinicians to diagnose and manage. Debate exists over not only the incidence of long-term risks of multiple concussions but also the potential for catastrophic outcomes after sports-related head injury. Decisions on returning athletes to competition can be difficult, and there are limited prospective data on which to make these decisions. This has resulted in the existence of a number of published guidelines and consensus statements on the management of concussion in athletes. Athletes sustaining a concussion need appropriate on-field care and structured follow-up. Baseline cognitive assessments can be helpful, but clinicians must be aware that head trauma may result in a wide array of clinical signs and symptoms. Delivery of care and decisions on return to play need to be based on an individual assessment of the affected athlete.

Bleiberg, J., Chew, K.T., Lew, H.L., & Thomander, D. (2007). **Review of sports-related concussion: Potential for application in military settings.** *Journal of Rehabilitation Research & Development*, 44(7), 963-74.

PMID: 18075953

ABSTRACT: This article reviews current issues and practices in the assessment and clinical management of sports-related concussion. An estimated 300,000 sports-related concussions occur annually in the United States. Much of what has been learned about concussion in the sports arena can be applied to the diagnosis and management of concussion in military settings. Current military guidelines for assessing and managing concussion in war zones incorporate information and methods developed through sports-concussion research. We discuss the incidence, definition, and diagnosis of concussion; concussion grading scales; sideline evaluation tools; neuropsychological assessment; return-to-action criteria; and complications of concussion.

Brooks, D.A. (2007). **Use of computer based testing of youth hockey players with concussions.** *NeuroRehabilitation*, 22(3), 169-79.

PMID: 17917167

ABSTRACT: Concussion is a potentially serious injury for athletes. Recent statistics suggest that approximately 300,000 sports-related traumatic brain injuries occur annually in the United States. Soccer, rugby, football, and ice hockey are all considered high-risk team sports for concussion. Hockey-related concussions are of particular concern in Canada, where over 500,000 players compete annually in ice hockey. The United States is now registering similar numbers of players. Return to play issues are one of the most difficult issues for physicians caring for concussed athletes. The advent of computerized neuropsychological testing adds another tool to assist in this process. It also appears to enhance the education process for players, coaches, and parents on the potential seriousness of concussion for these young athletes.

Couture, S., Daigle, C., ElleMBERG, D., & Leclerc, S. (2007). **Prolonged neuropsychological impairments following a first concussion in female university soccer athletes.** *Clinical Journal of Sport Medicine*, 17(5), 369-74.

PMID: 17873549

ABSTRACT: OBJECTIVE: Although research is accumulating on the cognitive sequelae from sports-related concussions in men, little to nothing is known about the prolonged cognitive outcome after a concussion in women. This point is important because recent evidence suggests that female athletes are at greater risk of sustaining a concussion. DESIGN: We assessed cognitive functioning after a first concussion in female soccer players, 6 to 8 months after their injury. The first-time concussed athletes were compared with a group of age-matched teammates who had never experienced a concussion. SETTING AND PARTICIPANTS: A total of 22 female university-level soccer players participated in the study. MAIN OUTCOME MEASUREMENTS: Paper-and-pencil and computerized tasks were used to assess different neuropsychological functions. RESULTS: Short- and long-term verbal memory, attention, and simple reaction time were normal. In contrast, compared with the control group, the concussed athletes were

significantly slower on tasks that required decision making (complex reaction time), inhibition and flexibility (Stroop), and planning (Tour of London task). CONCLUSIONS: The results of this study suggest that cognitive functions related to cognitive processing speed are most vulnerable to a sports-related concussion and are still impaired for a half year after injury in university-level female soccer players.

2006

Brolinson, G., Duma, S., Greenwald, R., Manoogian, S., & McNeely, D. (2006). **Head acceleration is less than 10 percent of helmet acceleration in football impacts.** *Biomedical Sciences Instrumentation*, 42, 383-8.

PMID: 16817638

ABSTRACT: Sports-related concussions constitute 20 percent of brain injuries each year in the United States. Concussion research has included a variety of instrumentation and techniques to measure head accelerations. Most recently, the Head Impact Telemetry (HIT) System (Simbex, Lebanon, NH), a wireless system that provides real-time data from impacts, is used to measure in-situ head accelerations in collegiate football. The purpose of this study is to compare helmet shell acceleration to head center of gravity acceleration using two measures of linear head acceleration. A study of 50 helmet to helmet impact tests using a pendulum provided a range of head accelerations from 5 g to 50 g. The primary measure of head acceleration is accelerometers mounted at the center of gravity of the Hybrid III head. A secondary measure is the in-helmet HIT System. The series of 50 pendulum impacts included three impact velocities of 2.0 m/s, 3.5 m/s and 5.0 m/s at four different impact locations. The impact locations were on the side, back, top and just above the facemask on the front. By comparing these two measured head accelerations and the helmet acceleration during a pendulum impact, it is shown that the response of the head and the helmet vary greatly and the in-helmet system matches the head and not helmet acceleration. Specifically, head acceleration is less than 10 percent of helmet acceleration in football impacts; moreover, the HIT System is able to accurately measure the head acceleration.

Collins, M.W., Iverson, G.L., Johnston, K.M., Lovell,

M.R., Maroon, J.C., Norwig, J., Pardini, D., Pardini, J., & Podell, K. (2006). **Measurement of symptoms following sports-related concussion: Reliability and normative data for the post-concussion scale.** *Applied Neuropsychology*, 13(3), 166-74.

PMID: 17361669

ABSTRACT: It is important to carefully evaluate self-reported symptoms in athletes with known or suspected concussions. This article presents data on the psychometric and clinical properties of a commonly used concussion symptom inventory-the Post-Concussion Scale. Normative and psychometric data are presented for large samples of young men (N = 1,391) and young women (N = 355). In addition, data gathered from a concussed sample of athletes (N = 260) seen within 5 days of injury are presented. These groups represent samples of both high school and collegiate athletes. Data from a subsample of 52 concussed athletes seen 3 times post-injury are presented to illustrate symptom reporting patterns during the initial recovery period. General guidelines for the clinical use of the scale are provided.

Dimeff, R.J., & Goldberg, L.D. (2006). **Sideline management of sport-related concussions.** *Sports Medicine & Arthroscopy Review*, 14(4), 199-205.

PMID: 17135969

ABSTRACT: Concussions remain one of the most troublesome injuries sports physicians face. Studies suggest recovery takes hours to weeks, but at what point is the concussed brain no longer at increased risk for re-injury is unknown. Physicians must be alert to the symptoms of concussion and be familiar with the available tools to assess neurocognitive dysfunction. Prospectively validated signs and symptoms include amnesia, loss of consciousness, headache, dizziness, blurred vision, attention deficit, memory, postural instability, and nausea. A player with any signs or symptoms of a concussion should not be allowed to return to the current game or practice and should be monitored closely for deterioration of symptoms. Return-to-play should be individually based and proceed in a step-wise manner. The ongoing risk-benefit analysis of return-to-play must currently be based on experience, corollary data from traumatic brain injuries in animals and humans, and limited prospective data with sports-related concussions.

Katayama, Y., Kawamata, T., & Mori, T. (2006). **Acute hemispheric swelling associated with thin subdural hematomas: Pathophysiology of repetitive head injury in sports.** *Acta Neurochirurgica. Supplement*, 96, 40-3.

PMID: 16671421

ABSTRACT: INTRODUCTION: The most common head injury in sports is concussion, and repeated concussions occurring within a short period occasionally can be fatal. Acute subdural hematoma is the most common severe head injury and can be associated with severe neurologic disability and death in sports. We investigated severe brain damage resulting from repetitive head injury in sports, and evaluated the pathophysiology of sports-related repetitive injury. **METHODS:** We reviewed the literature containing detailed descriptions of repetitive severe sports-related head injury. In total, 18 cases were analyzed with regard to age, gender, type of sports, symptoms before second injury, and pathology of brain CT scans. **RESULTS:** The majority of cases involved young males aged 16 to 23 years old, who sustained a second head injury before symptoms from the first head injury had resolved. Ten of 15 cases did not suffer loss of consciousness at insult. Eight cases were confirmed on brain CT scans after the second injury, and all 8 cases revealed brain swelling associated with a thin subdural hematoma. **CONCLUSIONS:** Second impact syndrome is thought to occur because of loss of auto-regulation of cerebral blood flow, leading to vascular engorgement, increased intracranial pressure, and eventual herniation. Our investigation suggests that the existence of subdural hematoma is a major cause of brain swelling following sports-related, repetitive head injury.

2005

Barth, J.T., Broshek, D.K., Erlanger, D., Freeman, J.R., Kaushik, T., & Webbe, F. (2005). **Sex differences in outcome following sports-related concussion.** *Journal of Neurosurgery*, 102(5), 856-63.

PMID: 15926710

ABSTRACT: OBJECT: Females comprise an increasing percentage of the athlete population across all age groups, and analysis of recent literature reveals that they sustain more concussions in collegiate sports. Results of human and animal studies

indicate that females may have poorer outcomes after traumatic brain injury; however, no return-to-play guideline takes sex or other individual differences into account. In the present study the authors evaluated the influence of patient sex on objective neurocognitive performance and subjective reporting of symptoms following sports-related concussion. **METHODS:** According to preseason baseline neurocognitive computerized testing in 2340 male and female high school and collegiate athletes, individuals who sustained sports-related concussions (155 persons) were reevaluated using an alternate form of the cognitive test. Sex differences in the magnitude of cognitive change from baseline levels and the subjective experience of symptoms were analyzed. To account for the possible protective effects of helmets, comparisons were performed among females, males with helmets, and males without helmets; none of the female athletes wore helmets. Female athletes had significantly greater declines in simple and complex reaction times relative to preseason baseline levels, and they reported more post-concussion symptoms compared with males. As a group, females were cognitively impaired approximately 1.7 times more frequently than males following concussions. Furthermore, females experienced more objective and subjective adverse effects from concussion even after adjusting for the use of helmets by some groups of male athletes (for example, in football). **CONCLUSIONS:** Return-to-play decisions and concussion management must be objective and made on an individual basis, including consideration of factors such as patient sex rather than relying on a one-size-fits-all guideline.

Belanger, H.G., & Vanderploeg, R.D. (2005). **The neuropsychological impact of sports-related concussion: A meta-analysis.** *Journal of the International Neuropsychological Society*, 11(4), 345-57.

PMID: 16209414

ABSTRACT: There is increasing interest in the potential neuropsychological impact of sports-related concussion. A meta-analysis of the relevant literature was conducted to determine the impact of sports-related concussion across six cognitive domains. The analysis was based on 21 studies involving 790 cases of concussion and 2014 control cases. The overall effect of concussion ($d = 0.49$) was comparable to the effect found in the non-sports-related mild trau-

matic brain injury population ($d = 0.54$; Belanger et al., 2005). Using sports-concussed participants with a history of prior head injury appears to inflate the effect sizes associated with the current sports-related concussion. Acute effects (within 24 hours of injury) of concussion were greatest for delayed memory, memory acquisition, and global cognitive functioning ($d = 1.00, 1.03, \text{ and } 1.42$, respectively). However, no residual neuropsychological impairments were found when testing was completed beyond seven days post-injury. These findings were moderated by cognitive domain and comparison group (control group versus pre-concussion self-control). Specifically, delayed memory in studies utilizing a control group remained problematic at seven days. The implications and limitations of these findings are discussed.

Collins, M.W., Iverson, G.L., & Lovell, M.R. (2005). **Validity of ImPACT for measuring processing speed following sports-related concussion.** *Journal of Clinical & Experimental Neuropsychology*, 27(6), 683-9.

PMID: 16019644

ABSTRACT: The purpose of this study was to examine the validity of ImPACT (Immediate Post-Concussion Assessment and Cognitive Testing), a computerized neuropsychological test battery, for measuring attention and processing speed in athletes with concussions. This was accomplished by comparing the computerized testing to a traditional neuropsychological measure, the Symbol Digit Modalities Test (SDMT). Participants were 72 amateur athletes who were seen within 21 days of sustaining a sports-related concussion (Mean = 9.4, SD = 5.4 days). As predicted, the SDMT correlated more highly with the Processing Speed and Reaction Time composites than the Verbal Memory and Visual Memory Composites from ImPACT. The composite scores from ImPACT and the SDMT were subjected to exploratory factor analysis, revealing a two-factor solution interpreted as Speed/Reaction Time and Memory. It appears as if the Processing Speed Composite, Reaction Time Composite, and SDMT are measuring a similar underlying construct in this sample of concussed amateur athletes.

Hurley, R.A., Lassonde, M., Mendez, C.V., Taber, K.H., & Zhang, L. (2005). **Mild traumatic brain**

injury: Neuroimaging of sports-related concussion. *The Journal of Neuropsychiatry & Clinical Neurosciences*, 17(3), 297-303.

PMID: 16179650

Full-text is available at <http://neuro.psychiatryonline.org/data/Journals/NP/3933/297.pdf>

No abstract is available.

2004

Bleiberg, J., Cameron, K., Cernich, A.N., Ecklund, P.J., Peck, K., Reeves, D., Sparling, M.B., Sun, W., Uhorchak, J., & Warden, D.L. (2004). **Duration of cognitive impairment after sports concussion.** *Neurosurgery*, 54(5), 1073-78; discussion 1078-80.

PMID: 15113460

ABSTRACT: OBJECTIVE: We sought to determine the duration of cognitive impairment after sports concussion. METHODS: We conducted a study with a prospective design in which 729 athletes underwent preseason baseline testing by being administered a computerized neuropsychological test battery, followed by retesting at regular intervals after they sustained sports-related concussions. A control group consisting of non-concussed athletes drawn from the same baseline population underwent testing at parallel intervals. RESULTS: Cognitive impairment in this primarily American Academy of Neurology Grade II sample of boxing concussions was apparent on the day of injury and at 1 to 2 days post-injury. Recovery of cognitive performance occurred during the 3- to 7-day interval. Comparison with control subjects showed that absent or attenuated practice effects, in addition to frank deterioration from baseline, were indications of recent concussion. CONCLUSION: The present findings of recovery during the 3- to 7-day interval post-injury are consistent with the American Academy of Neurology Grade II return-to-play practice parameters suggesting a 1-week time-out from participation in contact sports.

Bradley, J., Collins, M., & Lovell, M. (2004). **Return to play following sports-related concussion.** *Clinics in Sports Medicine*, 23(3), 421-41, ix.

PMID: 15262380

ABSTRACT: This article provides a review of current important issues in the management of athletes who have sustained a concussion during athletic

competition. Recent research in the area of concussion management is reviewed with specific reference to the side line evaluation of concussion and the follow-up of the athlete during the recovery period. The use of neuropsychological testing in sports is also reviewed. A systematic protocol for the management of sports related concussion is presented.

Mueller, K.A., & Theye, F. (2004). **“Heads up”:** Concussions in high school sports. *Clinical Medicine & Research*, 2(3), 165-71.

PMID: 15931353

Full-text is available at <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1069089/pdf/ClinMed-Res0203-0165.pdf>

ABSTRACT: In the United States, sports-related head injuries occur frequently. The Centers for Disease Control estimates more than 300,000 sports-related concussions occur each year in the United States. There are a number of myths and misunderstandings among health care professionals regarding concussions. In this article, we clarify some reasons for these misunderstandings and provide some of the possible causes for the increased susceptibility of the adolescent athlete, along with evidence-based assessment tools for assisting physicians in making return-to-play decisions. Finally, suggestions for a concussion safety program in the high school setting are also provided.

2003

Asthaqiri, A.R., Dumont, A.S., & Sheehan, J.M. (2003). **Acute and long-term management of sports-related closed head injuries.** *Clinics in Sports Medicine*, 22(3), 559-76.

PMID: 12852686

ABSTRACT: Aggressive participation in athletics is rewarded in many ways in our society. As long as there is such strong impetus for participation in athletics, the risks of head injuries for participants will remain. Important strides made in understanding of the pathophysiology of head injuries may lead to improved treatment strategies in the future. In light of the current lack of effective therapies, however, the best options remain injury prevention, early and appropriate recognition, and limitation of subsequent, further injury. Frequently the medical staff is encour-

aged to allow the athlete to return to play based on the desires of the coach, team, fans, parents, and even the athlete himself. A thorough understanding of the potentially serious risks of repetitive injury, however, mandates that only a proper conservative period of observation and evaluation will best serve the competitor.

Barr, W.B., Jordan, B., Lathan, W.E., Ravdin, L.D., & Relkin, N.R. (2003). **Assessment of cognitive recovery following sports related head trauma in boxers.** *Clinical journal of sport medicine*, 13(1), 21-7.

PMID: 12544160

ABSTRACT: OBJECTIVE: To prospectively examine recovery of cognitive function within one month following subconcussive sports related head trauma. DESIGN: A prospective study of New York State licensed professional boxers who underwent testing of cognitive functioning before and after (within days, one week, and one month) a professional bout. SETTING: Male professional athletes recruited from the New York State Athletic Commission and local boxing gyms. PARTICIPANTS: Twenty-six licensed professional boxers were enrolled in the protocol. Data is presented on the 18 participants who completed testing on at least three of the four time points. INTERVENTIONS: Serial neuropsychological assessment before and after the athletes engaged in competition. MAIN OUTCOME MEASURES: Neuropsychological measures of cognitive functioning, including new learning and memory, information processing speed, and mental flexibility. RESULTS: A series of repeated measures MANOVAS revealed significant within subject differences across testing on complex information processing and verbal fluency. Post hoc analyses indicated significant differences between time one (baseline) and time four (one month post), with scores one month following the bout indicating significantly improved performance. Memory scores did not change significantly across testing; however, prior boxing exposure measured by total number of professional bouts was associated with poorer memory performance. CONCLUSIONS: Cognitive testing one month following participation in a professional boxing bout yielded scores suggestive of recovery to a level above the baseline. We conclude that baseline assessment taken during periods of intense training are likely confounded by other

pre-bout conditions (i.e., sparring, rapid weight loss, pre-bout anxiety) and do not represent true baseline abilities. Instability of performance associated with mild head injury may complicate the interpretation of post-injury assessments. Practice effects may also confound the interpretation of serial assessments, leading to underestimation of the effects of sports related head trauma. Poorer cognitive performance was evident during the presumed recovery period in boxers with greater exposure to the sport (>12 professional bouts). This finding is consistent with reports of a cumulative effect of repetitive head trauma and the subsequent development of chronic traumatic brain injury. These data have implications for assessing recovery of function following head injury in players of other contact sports as well as determination of return-to-play following an injury.

Barth, J., Broshek, D., Erlanger, D., Feldman, D., Festa, J., Freeman, J., Kaushik, T., Kroger, H., & Kutner, K. (2003). **Development and validation of a web-based neuropsychological test protocol for sports-related return-to-play decision-making.** *Archives of Clinical Neuropsychology*, 18(3), 293-316. PMID: 14591461

Full-text is available at <http://tinyurl.com/onzzvrf>
 ABSTRACT: The Concussion Resolution Index (CRI) is an online assessment tool designed to track resolution of symptoms following sports-related concussion. The CRI is composed of six subtests measuring reaction time, visual recognition, and speed of information processing. Three factors are derived from the subtests: Simple Reaction Time (SRT), Complex Reaction Time (CRT), and Processing Speed (PS). Multiple alternate forms within subtests afford simple, reliable, assessment of change, relative to a baseline test completed by an athlete. The test also assesses self-reported neurophysiological symptoms at the time of injury and tracks resolution of these symptoms. The data demonstrate the CRI is a valid and reliable measure of cognitive performance in a relatively heterogeneous group of athletes aged 13-35. Two methods of statistical analysis for assessing change from baseline were compared to establish a psychometric basis for return-to-play decision-making: the Reliable Change Index (RCI) and multiple regression. Multiple regression was more accurate than the RCI in determining a decline in performance relative to the baseline.

Cantu, R.C., & Echemendia, R.J. (2003). **Return to play following sports-related mild traumatic brain injury: The role for neuropsychology.** *Applied Neuropsychology*, 10(1), 48-55.

PMID: 12734075

ABSTRACT: Cerebral concussions frequently occur at all levels of athletic competition. The effects from these concussions can be transient or may lead to chronic, debilitating symptoms. A growing literature has established that neuropsychological tests are useful in detecting the subtle neurocognitive changes that occur following concussions. The identification of these deficits and subsequent recovery of function can be important components in making return-to-play (RTP) decisions. This article describes the emergence of neuropsychology in sports medicine, discusses the context in which RTP decisions are made, outlines factors that are important to RTP decisions, and presents a model that views the RTP decision as a dynamic risk-benefit analysis that involves complex interactions among variables. It is argued that neuropsychology has a unique, but not exclusive, role in the decision making process. Implications for future research are discussed.

Collins, M.W., Field, M., Fu, F.H., Iverson, G., Johnston, K.M., Lovell, M.R., & Maroon, J. (2003). **Relationship between post-concussion headache and neuropsychological test performance in high school athletes.** *The American Journal of Sports Medicine*, 31(2), 168-73.

PMID: 12642248

ABSTRACT: BACKGROUND: The relevance of headache to outcome after sports-related concussion is poorly understood. HYPOTHESES: High school athletes reporting headache approximately one week after injury will have significantly more other concussion symptoms and will perform more poorly on neuropsychological tests compared to athletes not experiencing headache. STUDY DESIGN: Prospective cohort study. METHODS: Study participants included 109 high school athletes who had sustained concussion and who were divided into two groups: those reporting headache seven days after injury and those reporting no headaches. The two groups were compared regarding on-field markers of concussion severity at the time of injury and symptoms and neurocognitive test results collected via ImPACT, a

computerized neuropsychological test battery and post-concussion symptom scale, at a mean of 6.8 days after injury. RESULTS: Athletes reporting post-traumatic headache demonstrated significantly worse performance on reaction time and memory ImPACT neurocognitive composite scores. These athletes also reported significantly more symptoms other than headache and were more likely to have demonstrated on-field anterograde amnesia. CONCLUSIONS: Findings suggest that any degree of post-concussion headache in high school athletes 7 days after injury is likely associated with an incomplete recovery after concussion.

Collins, M.W., Field, M., Lovell, M.R., & Maroon, J. (2003). **Does age play a role in recovery from sports-related concussion? A comparison of high school and collegiate athletes.** *The Journal of Pediatrics*, 142(5), 546-53.

PMID: 12756388

ABSTRACT: OBJECTIVE: To evaluate symptoms and neurocognitive recovery patterns after sports-related concussion in high school and college athletes. STUDY DESIGN: College athletes (n = 371) and high school athletes (n = 183) underwent baseline neuropsychological evaluation between 1997 and 2000. Individuals who received a concussion during athletic competition (n = 54) underwent serial neuropsychologic evaluation after injury and were compared with a non-injured within-sample control group (n = 38). Main outcome measures included structured interview, four memory measures, and Concussion Symptom Scale ratings. Baseline to post-injury change scores and multiple analyses of variance were used to compare recovery curves within and between groups. RESULTS: High school athletes with concussion had prolonged memory dysfunction compared with college athletes with concussion. High school athletes performed significantly worse than age-matched control subjects at seven days after injury (F = 2.90; P < .005). College athletes, despite having more severe in-season concussions, displayed commensurate performance with matched control subjects by day three after concussion. Self-report of post-concussion symptoms by student athletes was not predictive of poor performance on neuropsychologic testing. CONCLUSIONS: Caution and systematic evaluation should be undertaken before returning athletes with concussion to competition.

Sole reliance on the self-report of the athlete may be inadequate. Preliminary data may suggest a more protracted recovery from concussion in high school athletes.

Collins, M.W., Iverson, G.L., Lovell, M.R., Maroon, J., McKeag, D.B., & Norwig, J. (2003). **On-field predictors of neuropsychological and symptom deficit following sports-related concussion.** *Clinical Journal of Sport Medicine*, 13(4), 222-9.

PMID: 12855924

ABSTRACT: OBJECTIVE: Investigate the relationship between on-field markers of concussion severity and post-injury neuropsychological and symptom presentation in an athlete-specific population. DESIGN: Case control study. SETTING: Multicenter analysis of high school and college athletes. PARTICIPANTS: A total of 78 athletes sustaining sports-related concussion were selected from a larger sample of 139 concussed athletes. ASSESSMENT OF PREDICTOR VARIABLES: On-field presence of disorientation, posttraumatic amnesia, retrograde amnesia, and loss of consciousness. MAIN OUTCOME MEASURES: ImPACT, a computerized neuropsychological test battery, was administered pre-season and, on average, 2 days post-injury. Good post-injury presentation (n = 44) was defined as no measurable change, relative to baseline, in terms of both ImPACT memory and symptom composite scores. Poor presentation (n = 34) was defined as a 10-point increase in symptom reporting and 10-point decrease in memory functioning (exceeding the 80 percent confidence interval for measurement error on ImPACT). Athletes failing to meet good or poor selection criteria (n = 61) were not included in the analysis. RESULTS: Odds ratios revealed that athletes demonstrating poor presentation at 2 days post-injury were over 10 times more likely (P < 0.001) to have exhibited retrograde amnesia following concussive injury when compared with athletes exhibiting good presentation. Similarly, athletes with poor presentation were over four times more likely (P < 0.013) to have exhibited posttraumatic amnesia and at least five minutes of mental status change. There were no differences between good and poor presentation groups in terms of on-field loss of consciousness. CONCLUSIONS: The presence of amnesia, not loss of consciousness, appears predictive of symptom and neurocognitive deficits following concussion in athletes. Athletes presenting

with on-field amnesia should undergo comprehensive and individualized assessment prior to returning to sport participation. Continued refinement of sports concussion grading scales is warranted in lieu of consistent findings that brief loss of consciousness is not predictive of concussion injury severity.

McKeever, C.K., & Schatz, P. (2003). **Current issues in the identification, assessment, and management of concussions in sports-related injuries.** *Applied Neuropsychology*, 10(1), 4-11.

PMID: 12734070

ABSTRACT: The recent literature has focused on the need for appropriate identification, assessment, and management of sports-related concussion. This article addresses current issues in the prevalence and assessment of sports-related concussion. Despite a paucity of research on female athletes and youth athletes, there is evidence that female athletes are at higher risk for injury than males and that concussions may affect children and young adolescents differently than older adolescents and adults. Sideline, baseline, and post-concussion assessments have become prevalent in documenting pre-injury and post-injury performance, tracking recovery rates, and assisting return-to-play decisions. New computerized assessment procedures are growing in popularity and use. Future directions in the assessment and management of sports-related concussion include increased research on prevalence rates and effects of concussions for females and youth athletes, educating parents of youth athletes as well as family physicians on the importance of baseline and post-concussion cognitive assessments, and further validation of computerized assessment measures.

Schatz, P., & Zillmer, E.A. (2003). **Computer-based assessment of sports-related concussion.** *Applied Neuropsychology*, 10(1), 42-7.

PMID: 12734074

ABSTRACT: Sports-related concussion has received considerable attention from neuropsychologists, athletic trainers, team coaches, physicians, families, and athletes. In this context, researchers have recently developed computer programs for the assessment of sports-related concussion. Computer-based assessment of sports-related concussion saves time, allows for team baseline testing, and can be easily incorporated into the sports medicine environment. This article reviews the advantages and limitations of computer-based assessment of sports-related

concussion. Within a well-coordinated concussion management program that includes input from a neuropsychologist, computer-based assessment of sports-related concussion will soon be the most common approach for assessing concussion in athletes.

2002

Cantu, R.C., Collins, M.W., Field, M., Iverson, G.L., Lovell, M.R., & Maroon, J.C. (2002). **Cumulative effects of concussion in high school athletes.** *Neurosurgery*, 51(5), 1175-9; discussion 1180-1.

PMID: 12383362

ABSTRACT: OBJECTIVE: A common assumption in sports medicine is that a history of concussion is predictive of a lower threshold for, as well as a worse outcome after, subsequent concussive injury. The current study was conducted to investigate the relationship between concussion history in high school athletes and the on-field presentation of symptoms after subsequent concussion. **METHODS:** One hundred seventy-three athletes who experienced sports-related concussion composed the initial study group. Binary groups were subsequently created on the basis of concussion history. Sixty athletes with no concussion history were compared with 28 athletes with a history of three or more concussions. The groups were compared in terms of the on-field presentation of symptoms after an in-study concussion. Dependent variables included the post-injury presence of loss of consciousness, anterograde amnesia, retrograde amnesia, and confusion. **RESULTS:** Athletes with three or more prior concussions were more likely to experience on-field positive loss of consciousness ($\chi^2 = 8.0, P = 0.005$), anterograde amnesia ($\chi^2 = 5.5, P = 0.019$), and confusion ($\chi^2 = 5.1, P = 0.024$) after a subsequent cerebral concussion. An odds ratio revealed that athletes with a history of three concussions were 9.3 times more likely than athletes with no history of concussion to demonstrate three to four abnormal on-field markers of concussion severity. **CONCLUSION:** This study is the first to suggest a cumulative effect of concussion in high school athletes. A more severe on-field presentation of concussion markers is evidenced in high school athletes with a pronounced history of concussion. This study's findings highlight the need for more long-term outcome studies in high school athletes who sustain sports-related concussions.

Collins, M.W., & Lovell, M.R. (2002). **New developments in the evaluation of sports-related concussion.** *Current Sports Medicine Reports*, 1(5), 287-92. PMID: 12831691

ABSTRACT: There have been a number of exciting advances in the clinical management of concussion over the past several years. This article reviews new developments in concussion diagnosis technologies.

Lovell, M.R. (2002). **The relevance of neuropsychologic testing for sports-related head injuries.** *Current Sports Medicine Reports*, 1(1), 7-11. PMID: 12831641

ABSTRACT: The utilization of neuropsychologic testing following sports-related concussion has dramatically increased over the past five years. The inclusion of neuropsychologic test results in the diagnosis of concussion has resulted in increasing questions into the specific role of these procedures in the return-to-play decision-making process. This article reviews the relevance of neuropsychologic testing for the sports medicine physician.

2001

Cable, A.M. (2001). **Recognizing sports-related concussion.** *Orthopedic Nursing*, 20(4), 87. PMID: 12025678

No abstract is available.

Collie, A., Darby, D., & Maruff, P. (2001). **Computerized cognitive assessment of athletes with sports related head injury.** *British Journal of Sports Medicine*, 35(5), 297-302. PMID: 11579059

Full-text is available at <http://bjsm.bmj.com/content/35/5/297.full.pdf+html>

ABSTRACT: Professional and amateur participants in many sports are at risk of brain injury caused by impact with other players or objects. In many cases, mild cognitive deficits may persist after the common neurological signs of brain injury have passed. In recent years, the athlete's cognitive status after concussion has been measured with conventional "paper and pencil" neuropsychological tests. However, such tests are not ideal for sporting settings, as they are designed for the detection of gross cognitive impairments at a single assessment, not for the identification

of mild cognitive deficits on repeated assessment. A number of computerized cognitive assessment tests and test batteries have been developed over the past two decades. These batteries offer major scientific and practical advantages over conventional neuropsychological tests which make them ideal for the assessment of cognitive function in sportspeople. This review first describes the problems associated with cognitive assessment of people with sports related cognitive deficits, and then critically examines the utility of conventional neuropsychological and computerized cognitive tests in sporting settings.

Delaney, J.S., Johnston, K.M., Lacroix, V.J., Lassonde, M., & Leclerc, S. (2001). **Recommendations for grading of concussion in athletes.** *Sports Medicine*, 31(8), 629-36. PMID: 11475324

ABSTRACT: Mild sports-related concussions, in which there is no loss of consciousness, account for >75 percent of all sports-related brain injury. Universal agreement on concussion definition and severity grading does not exist. Grading systems represent expertise of clinicians and researchers yet scientific evidence is lacking. Most used loss of consciousness and post-traumatic amnesia as markers for grading concussion. Although in severe head injury these parameters may have been proven important for prognosis, no study has done the same for sport-related concussion. Post-concussion symptoms are often the main features to help in the diagnosis of concussion in sport. Neuropsychological testing is meant to help physicians and health professionals to have objective indices of some of the neurocognitive symptoms. It is the challenge of physicians, therapists and coaches involved in the care of athletes to know the symptoms of concussion, recognize them when they occur and apply basic neuropsychological testing to help detect this injury. It is, therefore, recommended to be familiar with one grading system and use it consistently, even though it may not be scientifically validated. Then good clinical judgment and the ability to recognize post-concussion signs and symptoms will assure that an athlete never returns to play while symptomatic.

Echemendia, R.J., & Julian, L.J. (2001). **Mild traumatic brain injury in sports: Neuropsychology's**

contribution to a developing field. *Neuropsychology Review*, 11(2), 69-88.

PMID: 11572472

ABSTRACT: Mild traumatic brain injuries are common at all levels of athletic competition. Although once considered a "routine part of the game," a significant amount of attention has recently been placed on these injuries at the professional, college, and high school levels. This paper reviews the epidemiology of sports-related brain injuries, the pathophysiology of the injuries, and the role of neuropsychology in this newly emerging area. Issues related to the adequacy of neuropsychological test instruments and approaches are discussed in light of future directions for research.

Echemendia, R.J., Julian, L., Mackin, R.S., Putukian, M., & Shoss, N. (2001). **Neuropsychological test performance prior to and following sports-related mild traumatic brain injury.** *Clinical Journal of Sport Medicine*, 11(1), 23-31.

PMID: 11176142

ABSTRACT: **OBJECTIVE:** To examine the utility of neuropsychological tests in assessing college athletes prior to and following a sports-related mild Traumatic Brain Injury (mTBI). **DESIGN:** A prospective study of college athletes who sustained mTBI while engaged in sport. Pre-injury baseline neuropsychological test data were obtained for athletes at risk for mTBI. Following an mTBI, the athlete and his or her matched non-injured control were evaluated at 2 hours, 48 hours, 1 week, and 1 month post-injury. **SETTING:** Male and female athletes from a Division I college. **PARTICIPANTS:** Male and female athletes from the football, men's ice hockey, men's and women's soccer, and men's and women's basketball teams at Penn State University. A total of 29 injured and 20 non-injured athletes participated in the study. **INTERVENTIONS:** Neuropsychological test batteries were administered at baseline and serially following mTBI. **MAIN OUTCOME MEASURES:** Post-Concussion Symptom Checklist, Hopkins Verbal Learning Test, Symbol Digit Modalities Test, Stroop Color-Word Test, Trail Making Test, VIGIL/W, List Learning, Digit Span, Penn State Cancellation Test, and Controlled Oral Word Association. **RESULTS:** Neuropsychological test data yielded significant differences between injured athletes and controls at 2 hours and 48 hours following cerebral concussion;

injured athletes performing significantly worse than controls. Injured athletes reported a significantly greater number of post-concussion symptoms 2 hours following injury but not at the 48-hour assessment. No multivariate group differences were found at 1 week, but univariate analyses suggested significant differences on a few measures. At 1 month post-injury, a statistically significant difference was found on one measure with injured athletes marginally outperforming controls. **CONCLUSIONS:** Neuropsychological tests are useful in the detection of cognitive impairment following mTBI. The test data appear to be more effective than subjective report of symptoms in differentiating between injured and non-injured athletes at 48 hours post-injury. Although significant individual variability existed, most injured athletes recovered within 1 week of injury. A battery of tests, rather than any single test, is necessary to capture the variability that exists among injured athletes.

2000

Baker, R.J., & Patel, D.R. (2000). **Sports related mild traumatic brain injury in adolescents.** *Indian Journal of Pediatrics*, 67(5), 317-21.

PMID: 10885200

ABSTRACT: While head injuries are not common in youth sports, they may have catastrophic results. Concussion is also referred to as mild traumatic brain injury (MTBI). Although the occurrence of head injuries has been studied more extensively in American football, the findings have wider application for any MTBI. Recently, more attention has been directed at other sports in which both boys and girls participate. The diagnosis of MTBI is based on subjective findings and subtle changes in mental status. Other cerebral injuries requiring emergent or urgent neurosurgical attention should be ruled out. Objective tests such as CT scans and Magnetic Resonance Imaging (MRI) are usually without significant findings in MTBI. Neuropsychological testing may demonstrate areas of deficiencies; however, results may be difficult to interpret because of confounding factors. Complications following MTBI have been known to occur. The most catastrophic of these is second impact syndrome. There are a variety of guidelines for return to play following a concussion, which have been designed in an effort to avoid problems such as second impact

syndrome. These guidelines are based more on clinical experience than on scientific evidence. Education, good training and coaching techniques, improved equipment, and rule changes and enforcement, can all help in curbing the sports related head injuries in adolescents.

Cantu, R.C., & Proctor, M.R. (2000). **Head and neck injuries in young athletes.** *Clinics in Sports Medicine, 19*(4), 693-715.

PMID: 11019736

ABSTRACT: Careful study of the pathophysiology and epidemiology of sports-related spine injuries brings to light many common features. The incidence increases as the sport becomes increasingly violent and aggressive. Poor conditioning and lack of knowledge of the proper techniques of the sport put the athlete at significant risk for head and spine injury. Improper helmet fit and the use of the head as an offensive weapon also are common features of injury. Although recognition of these features has resulted in a dramatic reduction in catastrophic neurological injury, the athlete remains at risk for less severe head and spine injury, and concussion remains at epidemic proportions at high school, university, and professional levels. It is hoped that careful recognition of the signs of concussion and knowledge of return-to-play criteria will prevent catastrophic complications from minor head injuries, although the long-term effects of multiple concussions on cognition may be problematic.

Kelly, J.P. (2000). **Concussion in sports and recreation.** *Seminars in Neurology, 20*(2), 165-71.

PMID: 10946735

ABSTRACT: More than 800 sports-related concussions occur in the United States each day, sometimes involving high-profile athletes whose injuries reach public awareness through sports broadcasts and news media. Although non-physicians are often present and relied upon for the detection of concussion in the sports setting, the proper diagnosis and management of this neurological problem require a physician's thoughtful attention to the athlete's signs and symptoms. This article offers a diagnostic protocol and treatment recommendations as well as a useful grading scale and management strategy for return to competition.

Poirier, M.P., & Wadsworth, M.R. (2000). **Sports-related concussions.** *Pediatric Emergency Care, 16*(4), 278-83; quiz 284-6.

PMID: 10966352

ABSTRACT: Concussion is the most common head injury occurring in sports participation. Concussions range from a brief period of neural dysfunction to a prolonged period of unconsciousness with retrograde amnesia. It is imperative that the pediatric emergency medicine specialist be familiar with the proper initial assessment of the child or adolescent athlete who has sustained a sports-related concussion, the latest grading scales of concussions, and the current recommendations for returning the athlete to competition. A systematic approach to the athlete who has suffered a concussion will minimize the risk of further injury or mortality.

1999

Barnes, R., Barth, J.T., Erlanger, D.M., & Kutner, K.C. (1999). **Neuropsychology of sports-related head injury: Dementia Pugilistica to Post-Concussion Syndrome.** *The Clinical Neuropsychologist, 13*(2), 193-209.

PMID: 10949160

ABSTRACT: This article reviews the existing literature in the following areas of sports neuropsychology: Dementia Pugilistica, concussion and Post-Concussion Syndrome, Second Impact Syndrome, and the emerging role of the sports neuropsychologist regarding return to play decisions. Dementia Pugilistica is discussed as a condition that exists along a continuum: Although many boxers will develop mild neurocognitive deficits, it is not yet known what percent of these mild presentations will progress to diagnosable Dementia Pugilistica. Factors contributing to both increased and reduced risk are detailed. The role of neuropsychological assessment in research and clinical management is reviewed. Existing studies of concussion incurred during contact sports provide evidence of an important role for neuropsychology in assessment and management of mild head injuries. Issues in clinical assessment of concussion are reviewed. The importance of grading of concussions, monitoring of post-concussive symptom resolution, and the use of neuropsychological test results in return to play decisions is detailed. The

Second Impact Syndrome is discussed with regard to return to play decisions. Recommendations are proposed for research and for clinical application of findings in sports neuropsychology.

Barone, D.F., Ferguson, R.J., Mittenberg, W., & Schneider, B. (1999). **Postconcussion syndrome following sports-related head injury: Expectation as etiology.** *Neuropsychology*, 13(4), 582-9.

PMID: 10527067

ABSTRACT: Mild head trauma is often complicated by a persistent set of symptoms known as post-concussion syndrome (PCS). Past research has suggested that an expectancy-guided, retrospective-recall bias may account for much of the variance in PCS symptom reporting. The present study examined the influence of symptom expectations on mild head trauma symptom reports among participants in contact sports. Head-injured athletes reported symptom rates that did not differ from those of uninjured athletes but consistently underestimated the pre-injury incidence of symptoms. Athletes with no head trauma history overestimated the expected degree of pre- to post-injury change in symptom status. Results suggest that individuals with mild head injury tend to overestimate post-concussion symptom change in a manner consistent with their symptom expectations. A cognitive-behavioral model that explains the persistence of PCS is proposed.

Collins, M.W., Lovell, M.R., & Mckeag, D.B. (1999). **Current issues in managing sports-related concussion.** *JAMA: The journal of the American Medical Association*, 282(24), 2283-5.

PMID: 10612307

No abstract is available.

1998

Bleiberg, J., Daniel, J.C., Halpern, E.L., & Reeves, D. (1998). **Future directions for the neuropsychological assessment of sports concussion.** *The Journal of Head Trauma Rehabilitation*, 13(2), 36-44.

PMID: 9575255

ABSTRACT: This article argues in favor of using newly developed computerized, complex reaction time (RT)-based neuropsychological procedures for the study of sports-related concussion. Recent

studies show that by using these complex RT procedures, significant differences between concussed and control samples can be observed. The magnitude of RT differences is 110 ms or less, levels that are not meaningfully measured with stopwatch-based procedures. RT-based procedures also have the advantage of permitting analysis of variability of RT, and several recent studies have shown that brain dysfunction is accompanied by erratic and inconsistent RT. A currently ongoing sports concussion study using measures of complex RT and variability of RT is described.

Kelly, J.P., & Rosenberg, J.H. (1998). **The development of guidelines for the management of concussion in sports.** *The Journal of Head Trauma Rehabilitation*, 13(2), 53-65.

PMID: 9575257

ABSTRACT: Concussion in sports has caught the attention of the news media in recent years, primarily due to the high profile of certain athletes who have sustained traumatic brain injuries. Even though the management of concussion remains somewhat controversial, certain principles of neuroscience regarding mental status alterations and other symptoms resulting from concussion are well accepted by medical experts. Several authors have previously published management strategies for sports-related concussion based on their own experiences, but this article will describe the formal process of developing guidelines for the diagnosis and management of concussion in sports. The processes of literature review, evidence-based analysis, and consensus building are described. This article includes the grading scale, sideline evaluation, and management strategy adopted as a practice parameter by the American Academy of Neurology. Emphasis is placed on the need to detect mild forms of concussion through detailed observation and examination of athletes.

1997

Centers for Disease Control and Prevention (CDC). (1997). **Sports-related recurrent brain injuries—United States.** *MMWR. Morbidity & Mortality Weekly Report*, 46(10), 224-7.

PMID: 9082176

ABSTRACT: An estimated 300,000 sports-related traumatic brain injuries (TBIs) of mild to moderate

severity, most of which can be classified as concussions (i.e., conditions of temporarily altered mental status as a result of head trauma), occur in the United States each year. The proportion of these concussions that are repeat injuries is unknown; however, there is an increased risk for subsequent TBI among persons who have had at least one previous TBI. Repeated mild brain injuries occurring over an extended period (i.e., months or years) can result in cumulative neurologic and cognitive deficits, but repeated mild brain injuries occurring within a short period (i.e., hours, days, or weeks) can be catastrophic or fatal. The latter phenomenon, termed “second impact syndrome”, has been reported more frequently since it was first characterized in 1984. This report describes two cases of second impact syndrome and presents recommendations developed by the American Academy of Neurology to prevent recurrent brain injuries in sports and their adverse consequences.

1991

Filley, C.M., Kelly, J.P., Kleinschmidt-DeMasters, B.K., Lillehei, K.O., Nichols, J.S., & Rubinstein, D. (1991). **Concussion in sports: Guidelines for the prevention of catastrophic outcome.** *JAMA: The Journal of the American Medical Association*, 266(20), 2867-9.

PMID: 1942455

ABSTRACT: 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.



Quick Looks

Online Resources Related to Sport-Related Concussion

According to the Centers for Disease Control and Prevention (CDC), [emergency departments in the US treat more than 173,000 sports- and recreation-related TBIs in children and youth](#), with TBIs representing almost 9% of all high school sport injuries. Education and prevention are key to ensuring safe play for everyone. For more information about sports-related concussion education, prevention, and treatment, we recommend the following resources:

Returning to School After TBI – Factsheet from the Model Systems

www.msktc.org/tbi/factsheets/Returning-To-School-After-Traumatic-Brain-Injury

Sports Injuries from Brainline.org

www.brainline.org/landing_pages/categories/sportsinjuries.html

Four smartphone apps that check for sports-related concussion

www.brainline.org/content/2011/07/top-4-concussion-screener-apps-for-athletes.html

HeadsUp Football

usafootball.com/headsup

Youth Soccer Concussion Education

www.usyouthsoccer.org/ConcussionEducation/

Concussion Guidelines from the NCAA

www.ncaa.org/health-and-safety/concussion-guidelines

Search Terms for Sport-Related Concussion

- 📖 Access to Health Care
- 📖 Academics
- 📖 Accessibility
- 📖 Accident Prevention
- 📖 Accommodation
- 📖 Acute Disease
- 📖 Adolescents
- 📖 Adults
- 📖 Age Factors
- 📖 Alzheimers Disease
- 📖 Amnesia
- 📖 Anxiety
- 📖 At Risk Persons
- 📖 Athletes
- 📖 Athletic(s) Coaches/Equipment/Injuries
- 📖 Attention Deficit Disorders
- 📖 Attitudes Toward Disabilities
- 📖 Baseball Injuries
- 📖 Behavior/Problems
- 📖 Blast Injuries/Complications/Diagnosis
Physiopathology/Therapy
- 📖 Boxing Injuries
- 📖 Brain/Damage
- 📖 Brain Injury Closed/Open
- 📖 Children with Disabilities
- 📖 Chronic Illness
- 📖 Classification Systems
- 📖 Clinical Management
- 📖 Cognition/Disorders
- 📖 Cognitive Ability/Disabilities/Processes
- 📖 College Athletics/Students
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- 📖 Compliance
- 📖 Concussion
- 📖 Correlation
- 📖 Cultural Influences
- 📖 Curriculum Development
- 📖 Death
- 📖 Dementia
- 📖 Demography
- 📖 Depression
- 📖 Device(s) Evaluation
- 📖 Diagnosis
- 📖 Diagnostic Tests
- 📖 Disabilities/Management
- 📖 Dizziness
- 📖 Drug Abuse
- 📖 Education
- 📖 Electrophysiology
- 📖 Employment
- 📖 Epidemiology
- 📖 Equilibrium
- 📖 Equipment/Standards
- 📖 Equipment Failure Analysis
- 📖 Evaluation/Methods/Techniques
- 📖 Evidence-Based Medicine
- 📖 Exercise
- 📖 Football Injuries
- 📖 Functional Evaluation
- 📖 Gait/Disorder
- 📖 Gender Differences
- 📖 Guidelines
- 📖 Handbooks
- 📖 Head Injuries
- 📖 Head Protective Devices
- 📖 Headache
- 📖 Health Education/Policy/Promotion
- 📖 Health Status Indicators
- 📖 High School Students
- 📖 Higher Education
- 📖 Hockey Injuries
- 📖 Incidence
- 📖 Individual Characteristics
- 📖 Information Dissemination/Resources
- 📖 Injuries
- 📖 Injury Severity Score
- 📖 Interview Techniques
- 📖 Legislation
- 📖 Literature Reviews
- 📖 Long-Term Care
- 📖 Longitudinal Studies
- 📖 Magnetic Resonance Imaging
- 📖 Management
- 📖 Measurements
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- 📖 Memory/Disorders
- 📖 Mental Health
- 📖 Mild Traumatic Brain Injury
- 📖 Military/Medicine/Personnel
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- 📖 Mixed Methods Research
- 📖 Model Programs
- 📖 Mood Disorders
- 📖 Multiple Regression Analysis









Search Terms for Sport-Related Concussion continued ...

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| <ul style="list-style-type: none"> 📖 National Standards 📖 Nausea 📖 Nervous System 📖 Neurocognitive Status 📖 Neurodegenerative Diseases 📖 Neurologic Diagnosis/Examination 📖 Neurological Disorders/Impairments 📖 Neuropsychological Tests 📖 Neurosurgery 📖 Occupational Therapy 📖 Outcomes 📖 Pain 📖 Parent Role 📖 Participation 📖 Performance Based Assessment/Standards 📖 Personality Inventory 📖 Physical Activities 📖 Physical Activity Level 📖 Physical Disabilities 📖 Physical Education/Fitness/Health 📖 Physiology 📖 Play 📖 Post-Concussion Syndrome 📖 Post-Traumatic Headache 📖 Practice Guidelines 📖 Prevalence 📖 Prevention 📖 Primary Prevention/Methods 📖 Professional Associations 📖 Prognosis 📖 Program Development/Effectiveness/Evaluation Guides 📖 Psychological Evaluation/Tests 📖 Psychometrics 📖 Psychomotor Performance 📖 Public Agencies/Health 📖 Racial Differences 📖 Reaction Time 📖 Recovery of Function 📖 Recreation 📖 Recurrence 📖 Rehabilitation/Medicine/Research/Services 📖 Remote Service Delivery 📖 Research/Methodology/Reviews/Utilization 📖 Retrospective Studies 📖 Return to Play 📖 Risk/Assessment/Factors/Management | <ul style="list-style-type: none"> 📖 Role 📖 Safety/Education 📖 School/Nurses/Role 📖 Secondary Condition 📖 Secondary School 📖 Self Concept 📖 Sensitivity and Specificity 📖 Sensory Impairments 📖 Severity of Illness Index 📖 Sexuality 📖 Skiing/Injuries 📖 Smoking 📖 Soccer 📖 Social Influences 📖 Socioeconomic Influences 📖 Sociology 📖 Special Needs Students 📖 Sports 📖 Sports Concussion/Medicine 📖 State Legislation 📖 Statistical Analysis 📖 Statistics/Numerical Data 📖 Stress Disorder 📖 Student Interests/Needs 📖 Students 📖 Subacute Care 📖 Substance Abuse 📖 Suicide 📖 Surveys 📖 Symptoms 📖 Teacher Attitudes/Role 📖 Team Sports 📖 Testing 📖 Trainers 📖 Training Materials 📖 Trauma Severity Indices 📖 Treatment 📖 Trends 📖 Two Year College Students 📖 United States 📖 Universities 📖 Video Games 📖 Well Being 📖 Wheelchairs 📖 Women's Athletics 📖 Youth |
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