

**Concussion and neuropsychological testing (literature search) – Dr Ryan Kohler –  
December 2011**

**The Influence of Musculoskeletal Injury on Cognition: Implications for Concussion Research**

Hutchison, Michael; Comper, Paul; Mainwaring, Lynda; Richards, Doug, American Journal of Sports Medicine Nov2011, Vol. 39 Issue 11, p2331

Abstract: Background: Safe return-to-play decisions after concussion can be challenging for sports medicine specialists. Neuropsychological testing is recommended to objectively measure concussion-related cognitive impairments. Purpose: The objective of this study was to measure cognitive functioning among 3 specific athletic groups: (1) athletes with no injuries (n = 36), (2) athletes with musculoskeletal injuries (n = 18), and (3) athletes with concussion (n = 18). Study Design: Case-control study; Level of evidence, 3. Methods: Seventy-two intercollegiate athletes completed preseason baseline cognitive testing and follow-up assessment using the Automated Neuropsychological Assessment Metrics (ANAM) test battery. Injured athletes were tested within 72 hours of injury. A 1-way analysis of covariance adjusted for baseline scores was performed to determine if differences existed in cognitive test scores among the 3 groups. Results: A group of athletes with concussion performed significantly worse than a group of athletes with no injuries on the following subtests of the ANAM at follow-up: Code Substitution Learning, Match to Sample, and Simple Reaction. Athletes with musculoskeletal injuries performed significantly worse than those with no injury on the Match to Sample subtest. No significant differences between athletes with concussion and athletes with musculoskeletal injuries were found on all ANAM subtests. Conclusion: Concussion produces cognitive impairment in the acute recovery period. Interestingly, athletes with musculoskeletal injuries also display a degree of cognitive impairment as measured by computerized tests. Clinical Relevance: Although these findings support previous research that neuropsychological tests can effectively measure concussion-related cognitive impairment, this study provides evidence that athletic injury, in general, also may produce a degree of cognitive disruption. Therefore, a narrow interpretation of scores of neuropsychological tests in a sports concussion context should be avoided.

**Neuropsychological Testing as It Relates to Recovery From Sports-related Concussion.**

Putukian M, PM & R: The Journal Of Injury, Function, And Rehabilitation 2011 Oct; Vol. 3 (10 Suppl 2), pp. S425-32

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.

**Sensitivity and Specificity of Subacute Computerized Neurocognitive Testing and Symptom Evaluation in Predicting Outcomes After Sports-Related Concussion.**

Lau, Brian C.; Collins, Michael W.; Lovell, Mark R., American Journal of Sports Medicine Jun2011, Vol. 39 Issue 6, p1209 (English Abstract Available) 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 subacute 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 subacute 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 Postconcussion 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%), specificity (80.36%), positive predictive value (73.17%), and negative predictive value (73.80%) in predicting protracted recovery. Discriminant function analyses of total symptoms on the Post-Concussion Symptom Scale alone had a sensitivity of 40.81%; specificity, 79.31%; positive predictive value, 62.50%; and negative predictive value, 61.33%. The 4 symptom clusters alone discriminant function analyses had a sensitivity of 46.94%; specificity, 77.20%; positive predictive value, 63.90%; and negative predictive value, 62.86%. Discriminant function analyses of the 4 computerized neurocognitive scores alone had a sensitivity of 53.20%; specificity, 75.44%; positive predictive value, 64.10%; and negative predictive value, 66.15%. 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% when using neurocognitive testing and symptom clusters together compared with using total symptoms on Post-Concussion Symptom Scale alone.

#### **Psychometric data for the NFL neuropsychological test battery.**

Lovell MR, Solomon GS, Applied Neuropsychology 1532-4826, 2011 Jul; Vol. 18 (3), pp. 197-209

As part of a comprehensive league-wide study of concussion, the National Football League's Committee on Mild Traumatic Brain Injury sponsored a neuropsychological testing program from 1996 through 2001. Nearly 1,000 athletes participated voluntarily in the study. Traditional paper-and-pencil neuropsychological tests were used for baseline assessment. Neuropsychological tests used in the study included the Hopkins Verbal Learning Test-Revised, the Brief Visuospatial Memory Test-Revised, Trail-Making Tests (Parts A and B), and the Controlled Oral Word Association Test. We present a factor analysis of these baseline data on 513 athletes who completed all of the neuropsychological tests and present normative psychometric data on the multiple baseline tests employed.

#### **Baseline neuropsychological testing in managing sport-related concussion: does it modify risk?**

Randolph C, Current Sports Medicine Reports [2011 Jan-Feb; Vol. 10 (1), pp. 21-6

Baseline neuropsychological testing is mandated at various levels of play for hundreds of thousands of athletes each year. This paper reviews the risks associated with sport-related concussion, and the clinical validity and reliability data for the most commonly used baseline test, the ImpACT program. There is no evidence to suggest that the use of baseline testing alters any risk from sport-related concussion, nor is there even a good rationale as to how such tests might influence outcome. Given the poor sensitivity and low reliability of these measures, they have an associated high false negative rate (i.e., classifying a player's neurocognitive status is normal, when in fact, it is not). The use of

baseline neuropsychological testing, therefore, is not likely to diminish risk, and to the extent that there is a risk associated with "premature" return-to-play, the use of these measures even may increase that risk in some cases.

### **Neuropsychological Assessment of Sport- Related Concussion.**

Johnson, Eric W.; Kegel, Nathan E.; Collins, Michael W., *Clinics in Sports Medicine* Jan2011, Vol. 30 Issue 1, p73

Abstract: The article explores the use of neuropsychological testing in the management of sports-related concussion. The history of neurocognitive testing in sports is traced, along with an examination of literature on the reliability, validity, sensitivity and prognostic value of neurocognitive testing. A case study on the use of neurocognitive testing in sports-related concussion is also presented.

### **Evaluating the methodological quality of sports neuropsychology concussion research: A systematic review.**

Comper, Paul; Hutchison, Michael; Magrys, Sylvia; Mainwaring, Lynda; Richards, Doug. *Brain Injury*, Oct2010, Vol. 24 Issue 11, p1257-1271, 15p, 1 Diagram, 4 Charts, 1 Graph

Abstract: Primary objective: Sports-related concussion is a frequently-occurring, serious neurological event that can produce a spectrum of potentially debilitating primary and secondary problems. Many investigators—particularly neuropsychologists—have focused their efforts on identifying cognitive changes that accompany such injuries. As such, the present review evaluated the methodological quality of neuropsychological sports-related concussion research using a comprehensive, systematic method. Research design: Of 349 studies initially selected by search criteria, a total of 43 studies were evaluated using a Cochrane-style review format. Research methods: Studies were assigned a Level of Evidence using the Centre for Evidence-based Medicine (CEMB) framework. Relevant information related to the methods of each study were extracted and rated for methodological quality using a standardized form-based evaluation tool. Results: The review revealed heterogeneity among the studies in terms of research design, as well as a number of methodological weaknesses and inconsistencies. Conclusion: 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 rigour. 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.

### **Do UK university football club players suffer neuropsychological impairment as a consequence of their football (soccer) play?**

Rutherford, Andrew; Stephens, Richard; Fernie, Gordon; Potter, Douglas. *Journal of Clinical & Experimental Neuropsychology*, Aug2009, Vol. 31 Issue 6, p664-681, 18p, 5 Charts, 1 Graph

Abstract: Male players from football and rugby clubs and sportsmen from a variety of noncontact sports clubs at a UK university were compared on biographical and neuropsychological test measures. A data analysis paradigm was developed and employed to control the inflation of Type 1 error rate due to multiple hypotheses testing. Rugby players sustained most head injuries in their chosen sport, but neuropsychological tests of attention, memory, and executive function provided no evidence of performance impairment attributable to the number of head injuries sustained or the

football, rugby, or noncontact sport groups. Footballers' heading frequency was related to the number of football head injuries sustained, but no relationship was detected between footballers' heading frequency and their neuropsychological test performance. Following discussion of pertinent methodological limitations it is concluded that there was no evidence in this dataset of neuropsychological impairment consistent with either mild head injury incidence or football heading frequency. However, a need for further research examining the long-term neuropsychological consequences of such head injuries was identified.

### **Examining the stability of Automated Neuropsychological Assessment Metric (ANAM) baseline test scores.**

Kaminski TW, Groff RM, Glutting JJ, Journal Of Clinical And Experimental Neuropsychology 2009 Aug; Vol. 31 (6), pp. 689-97

Computerized neuropsychological (NP) testing has evolved into an important tool for clinicians in the assessment of sport-related concussions. The importance of having a reliable baseline test score for comparison post concussion is critical; yet, the stability of these baseline measurements has not been well established. The purpose of this study was to examine the consistency of the measurements derived from the Automated Neuropsychological Assessment Metric (ANAM) test battery over a series of repeated trials, in an attempt to determine at what point the test scores stabilized. A cohort of 25 recreationally active collegiate students, free from mild head injury, volunteered for the study. Throughput score (measures of performance efficiency) stability was assessed for the computerized NP tests using intraclass correlation coefficients (ICCs). Average throughput scores for all five test trials were simple reaction time (SRT) = 235, matching to sample (MSP) = 41, continuous performance test (CPT) = 108, math processing (MTH) = 24, and Sternberg memory (STN) = 89, and these are within the range of those previously reported. Results show that all four of the ICCs were in the excellent range of agreement (i.e., > or = .75), and more importantly, the statistical comparisons of the ICCs show that there was no significant difference between the ICCs. Consequently, results serve to show that two time periods are sufficient to obtain stable NP results, and thus clinicians can feel comfortable relying on a two-score baseline test for follow-up comparison.

### **What are the real risks of sport-related concussion, and are they modifiable?**

Randolph C, Kirkwood MW, Journal Of The International Neuropsychological Society: JINS 2009 Jul; Vol. 15 (4), pp. 512-20

Over the past two decades, the management of sport-related concussion has been the topic of increased attention in the scientific literature and in the popular media. Despite a proliferation of competing guidelines for concussion management, the widespread use of neuropsychological "baseline" testing designed to monitor postinjury recovery, and several prospective controlled studies of the natural history of concussion, there has been virtually no attempt to quantify the risks associated with sport-related concussion or to determine whether these risks are modifiable via management strategies. Using American football as a model, the short- and long-term risks of sport-related concussion are reviewed. It is concluded that serious short-term consequences of sport-related concussion are extremely rare and unlikely to be significantly modified via management strategies that rely on baseline testing. Other less serious short-term adverse outcomes are also quite rare, transient, and not likely to be altered by specific management guidelines. The long-term consequences of multiple sport-related head trauma remain unclear but are potentially of greater public health concern and should be the focus of increased research. Based on available evidence, there is little rationale for the use of rigid strategies or guidelines in the place of individual clinical decision-making in the management of these injuries.

### **Application of Reliable Change Indices to Computerized Neuropsychological Measures of Concussion.**

Parsons, Thomas D.; Notebaert, Andrew J.; Shields, Edgar W.; Guskiewicz, Kevin M.. International Journal of Neuroscience, Apr2009, Vol. 119 Issue 4, p492-507, 16p, 3 Charts

Abstract: Serial assessments of neurocognitive functioning in athletes with concussion are commonly used for return to play decisions. This study provides reliable change indices (RCIs) for computerized tests from 40 NCAA Division I collegiate athletes that suffered a sports-related concussion. The normative data that resulted from the RCIs and subsequent analyses of differences between improved and not improved athletes may aid both clinicians and researchers to assess whether observed change on neuropsychological measures is reliable change or change due simply to practice effects. Hence, the RCIs presented herein provide information that may be used judiciously by a clinician for assessing meaningful change.

### **The management of sports-related concussion: current status and future trends.**

Lovell M, Clinics In Sports Medicine 2009 Jan; Vol. 28 (1), pp. 95-111

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.

### **Reliability and validity of a computerized neurocognitive test battery, CNS Vital Signs.**

Gualtieri CT, Johnson LG, Archives Of Clinical Neuropsychology: The Official Journal Of The National Academy Of Neuropsychologists 2006 Oct; Vol. 21 (7), pp. 623-43

CNS Vital Signs (CNSVS) is a computerized neurocognitive test battery that was developed as a routine clinical screening instrument. It is comprised of seven tests: verbal and visual memory, finger tapping, symbol digit coding, the Stroop Test, a test of shifting attention and the continuous performance test. Because CNSVS is a battery of well-known neuropsychological tests, one should expect its psychometric properties to resemble those of the conventional tests upon which it is based. 1069 subjects age 7-90 participated in the normative database for CNSVS. Test-retest reliability (TRT) was evaluated in 99 Ss who took the battery on two separate occasions, separated, on the average, by 62 days; the results were comparable to those achieved by equivalent conventional and computerized tests. Concurrent validity studies in 180 subjects, normals and neuropsychiatric patients, indicate correlations that are comparable to the concurrent validity of similar tests. Discriminant validity is supported by studies of patients with mild cognitive impairment and dementia, post-concussion syndrome and severe traumatic brain injury, ADHD (treated and untreated) and depression (treated and untreated). The tests in CNSVS are also sensitive to malingers and patients with conversion disorders. The psychometric characteristics of the tests in the CNSVS battery are very similar to the characteristics of the conventional neuropsychological tests upon which they are based. CNSVS is suitable for use as a screening instrument, or as a serial assessment measure. But it is not a substitute for formal neuropsychological testing, it is not diagnostic, and it will have only a limited role in the medical setting, absent the active participation of consulting neuropsychologists.

### **Value of neuropsychological testing after head injuries in football.**

McCorry, P.; Makdissi, M.; Davis, G.; Collie, A., *British Journal of Sports Medicine* Aug 2005: Vol. 39 Issue Suppl 1. p. i58-i63

Abstract: This paper reviews the pros and cons of the traditional paper and pencil and the newer computerized neuropsychological tests in the management of sports concussion. The differences between diagnosing concussion on the field and neuropsychological assessment at follow up and decision making with regard to return to play are described. The authors also discuss the issues involved in interpreting the results of neuropsychological testing (comparison with population norms versus player's own baseline test results) and potential problems of such testing in football. Finally, suggested recommendations for neuropsychological testing in football are given.

### **Validity of ImPACT for Measuring Processing Speed Following Sports-Related Concussion.**

Iverson, Grant L.; Lovell, Mark R.; Collins, Michael W.. *Journal of Clinical & Experimental Neuropsychology*, Aug2005, Vol. 27 Issue 6, p683-689, 7p, 1 Chart

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. [ABSTRACT FROM AUTHOR]DOI: 10.1080/13803390490918435 (AN 17540149)

### **Computerised neuropsychological testing.**

Collie A, Maruff P, *British Journal Of Sports Medicine* 2003 Feb; Vol. 37 (1), pp. 2-3

### **Return to Play Following Sports-Related Mild Traumatic Brain Injury: The Role for Neuropsychology.**

Echemendia, Ruben J.; Cantu, Robert C.. *Applied Neuropsychology*, 2003, Vol. 10 Issue 1, p48-55, 8p

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.

### Tracking neuropsychological recovery following concussion in sport.

Iverson GL, Brooks BL, Collins MW, Lovell MR, Brain Injury: 2006 Mar; Vol. 20 (3), pp. 245-52

The purpose of this study was to illustrate the serial use of computerized neuropsychological screening with ImPACT to monitor recovery in a clinical case series of injured athletes.

### Methodologic issues in neuropsychological testing.

Barr, W.B., Journal of Athletic Training July/Sept 2001: Vol. 36 Issue 3. p. 297-302

Abstract: To familiarize athletic trainers with methodologic issues regarding the development and implementation of neuropsychological tests used in programs for monitoring sport-related cerebral concussion. Knowledge base and MEDLINE and PsychLit searches from 1980-2000 using the terms sports, athletes, concussion, and brain. Neuropsychological testing is a proven method for evaluating symptoms of concussion that results from a variety of different causes. These tests have been shown to be effective in evaluating symptoms of subtle cognitive dysfunction in a number of patient groups. Applying these tests in an athletic population has required some procedural modifications, including the use of brief test batteries, collection of preseason baseline data, and evaluation of subtle postconcussive changes in test scores over time. New methods are now being used for improved evaluation of the reliability and validity of neuropsychological tests in athletes. Proper scientific analysis of the psychometric properties of neuropsychological tests and the ultimate value of their use in the sport setting will require years of detailed study on large numbers of athletes with and without symptoms of concussion. Athletic trainers and related personnel need to be aware of the training and methodologic issues associated with neuropsychological testing. Knowledge of the scientific properties of these tests, their advantages, and current limitations will ultimately enhance the athletic trainer's ability to use information from neuropsychological testing in an effective manner.

### Implementation of neuropsychological testing models for the high school, collegiate, and professional sport settings.

Randolph, C., Journal of Athletic Training July/Sept 2001: Vol. 36 Issue 3. p. 288-296 (English Abstract Available)

Abstract: To review models for the use of neuropsychological testing in the management of sport-related concussion at various levels of competition. As we come to understand the natural history of sport-related concussive brain injury, it is increasingly evident that significant neurologic risks are associated with this type of injury. These risks include (1) acute intracranial pathology, (2) catastrophic brain swelling from second-impact syndrome, and (3) the potential risk for markedly prolonged recovery or permanent cognitive dysfunction associated with multiple concussions. Neuropsychological testing has proved to be a useful tool in the medical management of sport-related concussion. In this paper, I describe a systematic model for the implementation of neuropsychological assessment of athletes at various levels of competition. The systematic model was designed to incorporate state-of-the-art techniques for the detection and tracking of neurocognitive deficits associated with concussion into recently formulated guidelines for the medical management of sport-related concussion. Current applications of the model are discussed, as well as ongoing studies designed to elaborate the empirical underpinnings of the model and refine clinical decision making in this area.