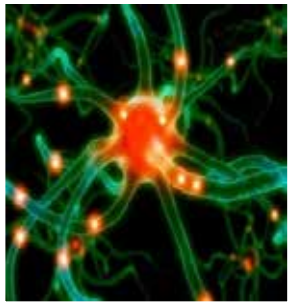
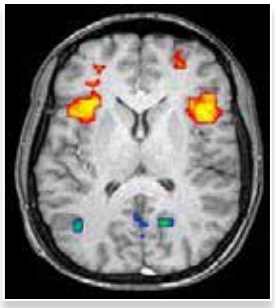
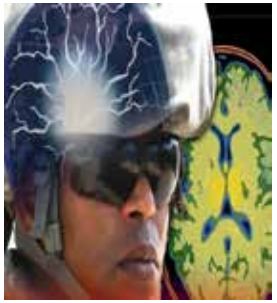
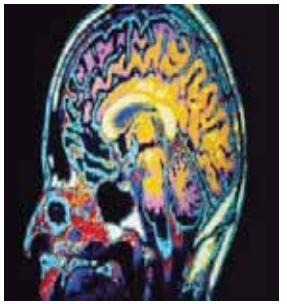
# A Multidimensional Approach to Studying Predictors of Recovery from Sport-Related Concussion:

## *What is the relevance of age in recovery?*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MEDICAL COLLEGE OF WISCONSIN

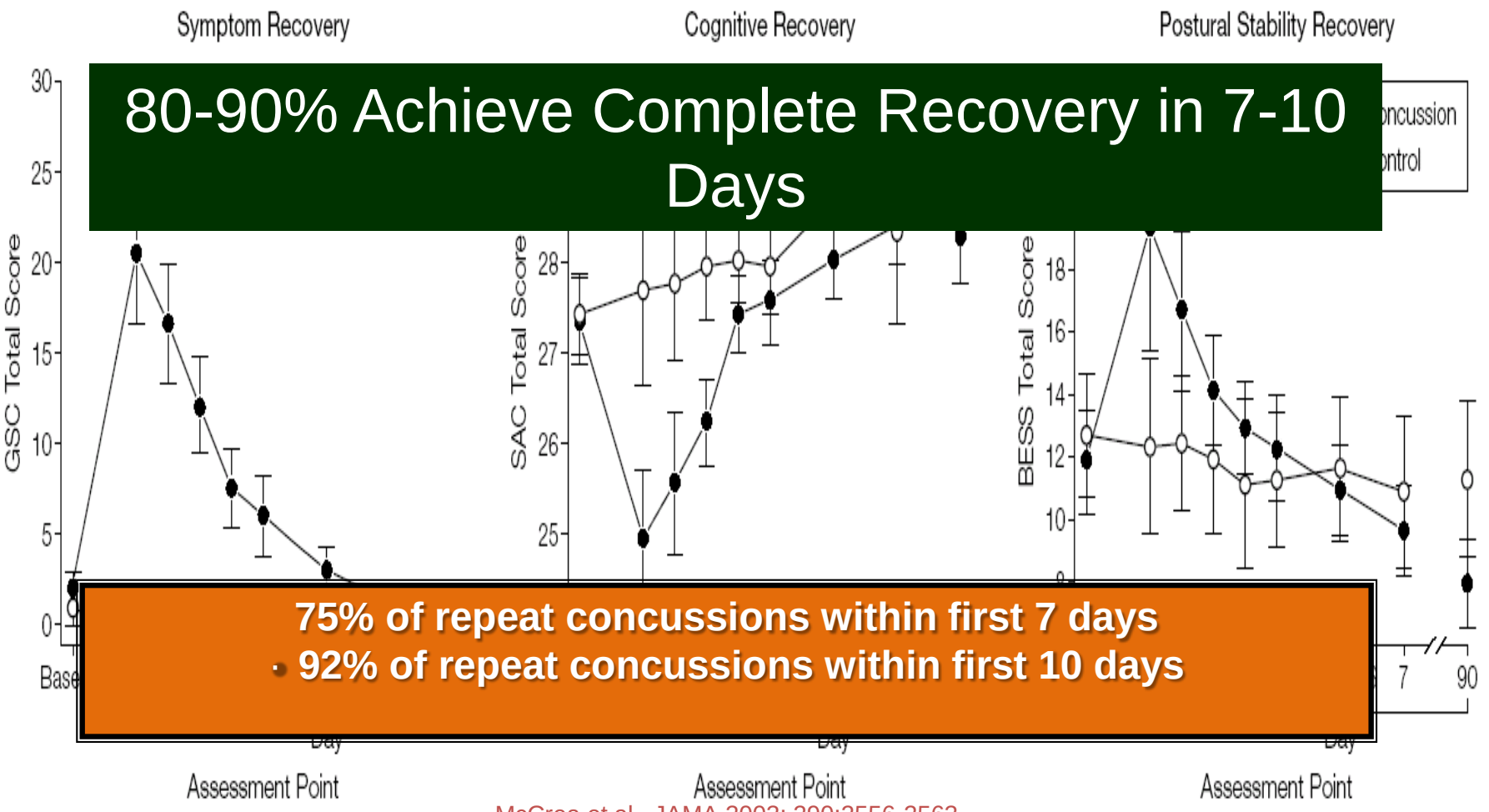
Brain Injury Research

# SRC: What's All The Fuss About?


- Up to 3.8 million concussions due to sport and recreation per year
- Among most frequent injuries in contact and collision sports
- More than just "bell rung"
- Serious acute effects that effect function
- Urgency to "get back out there"
- Concern about lasting effects
- Clinical challenges…

# Not Just the Big Boys

# How Long Does it Take to Recover?

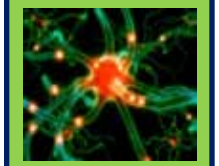



McCrea et al., JAMA 2003; 290:2556-2563

# Integrated Recovery Model

**PRE-INJURY:**

Normal Cerebral Function



**CONCUSSIVE EVENT**

**ACUTE**

*IMPAIRED:*
*Elevated symptoms, functional impairment, physiological dysfunction*

**Clinical Recovery**

**POST-ACUTE**

*COMPENSATORY:*
*Full clinical recovery, but persistent physiological dysfunction*

**Physiological Recovery**

(Common Time Point for Return to Play)

**FULL**

*COMPLETE:*
*Full clinical recovery, normal physiological function*

**Full Clinical & Physiological Recovery**

Window of Cerebral Vulnerability

**Prevention-based Return to Activity**

# Science Driving Evidence-based Management

# How Far We've Come…

Journal of Athletic Training 2013;48(4):554–575
doi: 10.4085/1062-6050-48.4.05

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consensus statement

## Consensus Statement on Concussion in Sport: The 4th International Conference on Concussion in Sport, Zurich, November 2012

Paul McCrory, MBBS, PhD*; Willem H. Meeuwisse, MD, PhD†; Mark Aubry, MD‡; Robert C. Cantu, MD§; Jiří Dvořák, MDǁ; Ruben J. Echemendia, PhD¶; Lars Engebretsen, MD, PhD#; Karen Johnston, MD, PhD**; Jeffrey S. Kutcher, MD††; Martin Raftery, MBBS‡‡; Allen Sills, MD§§; Brian W. Benson, MD, PhDǁǁ; Gavin A. Davis, MBBS¶¶; Richard Ellenbogen, MD##; Kevin M. Guskiewicz, PhD***; Stanley A. Herring, MD†††; Grant L. Iverson, PhD‡‡‡; Barry D. Jordan, MD§§§; James Kissick, MDǁǁǁ; Michael McCrea, PhD¶¶¶; Andrew S. McIntosh, PhD###; David Maddocks, LLB, PhD****; Michael Makdissi, MBBS, PhD††††; Laura Purcell, MD‡‡‡‡; Margot Putukian, MD§§§§; Kathryn Schneider, PhDǁǁǁǁ; Charles H. Tator, MD, PhD¶¶¶¶; Michael Turner, MD####

Journal of Athletic Training 2014;49(2):245–265
doi: 10.4085/1062-6050-49.1.07

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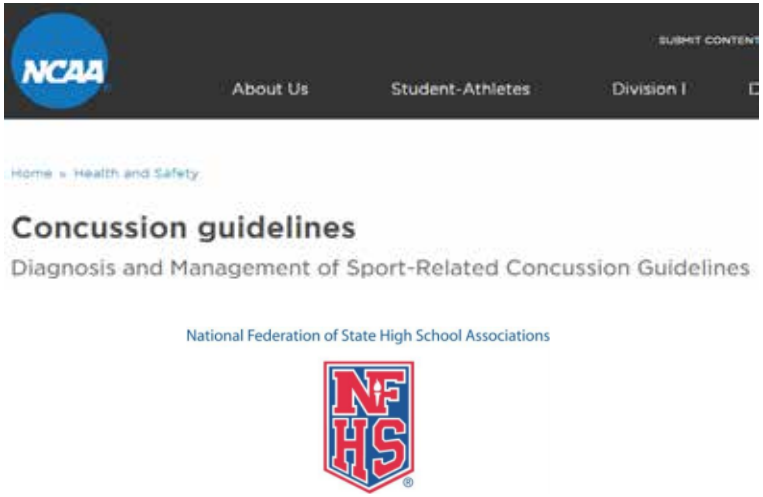
position statement

## National Athletic Trainers' Association Position Statement: Management of Sport Concussion

Steven P. Broglio, PhD, ATC*; Robert C. Cantu, MD†; Gerard A. Gioia, PhD‡; Kevin M. Guskiewicz, PhD, ATC, FNATA, FACSM§; Jeffrey Kutcher, MD*; Michael Palm, MBA, ATCǁ; Tamara C. Valovich McLeod, PhD, ATC, FNATA¶


National Federation of State High School Associations

**Recommendations and Guidelines for Minimizing Head Impact Exposure and Concussion Risk in Football**

**National Federation of State High School Associations (NFHS)**
**Report from the July 2014 NFHS Concussion Summit Task Force**

# Multimodal Assessment of Sport Concussion

## SCAT3™

**Sport Concussion Assessment Tool – 3rd Edition**

For use by medical professionals only

## SYMPTOM EVALUATION

### How do you feel?

*"You should score yourself on the following symptoms, based on how you feel now".*

| | none | mild | | moderate | | severe | |
|---|---|---|---|---|---|---|---|
| Headache | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| "Pressure in head" | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Neck Pain | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Nausea or vomiting | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Dizziness | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Blurred vision | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Balance problems | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Sensitivity to light | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Sensitivity to noise | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Feeling slowed down | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| Feeling like "in a fog" | 0 | 1 | 2 | 3 | 4 | 5 | 6 |

### Cognitive assessment

**Standardized Assessment of Concussion (SAC)[4]**

**Orientation** (1 point for each correct answer)

| | | |
|---|---|---|
| What month is it? | 0 | 1 |
| What is the date today? | 0 | 1 |
| What is the day of the week? | 0 | 1 |
| What year is it? | 0 | 1 |
| What time is it right now? (within 1 hour) | 0 | 1 |
| **Orientation score** | | of 5 |

**Immediate memory**

### Balance examination

Do one or both of the following tests.

Footwear (shoes, barefoot, braces, tape, etc.) _____

**Modified Balance Error Scoring System (BESS) testing[5]**

Which foot was tested (i.e. which is the **non-dominant** foot) ☐ Left ☐ Right

Testing surface (hard floor, field, etc.) _____

**Condition**

| | |
|---|---|
| Double leg stance: | Errors |
| Single leg stance (non-dominant foot): | Errors |
| Tandem stance (non-dominant foot at back): | Errors |

# Current Questions in SRC:

## *Acute Effects & Recovery*

Acute Effects and Recovery Time Following Concussion in Collegiate Football Players

The NCAA Concussion Study

Michael McCrea, PhD
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Jingzhen Yang, MPH
James P. Kelly, MD

**Context** Lack of empirical data on recovery time following sport-related concussion hampers clinical decision making about return to play after injury.

**Objective** To prospectively measure immediate effects and natural recovery course relating to symptoms, cognitive functioning, and postural stability following sport-related concussion.

**Design, Setting, and Participants** Prospective cohort study of 1631 football players from 15 US colleges. All players underwent preseason baseline testing on concussion assessment measures in 1999, 2000, and 2001. Ninety-four players with concussion (based on American Academy of Neurology criteria) and 56 noninjured controls underwent assessment of symptoms, cognitive functioning, and postural stability immediately, 3 hours, and 1, 2, 3, 5, 7, and 90 days after injury.

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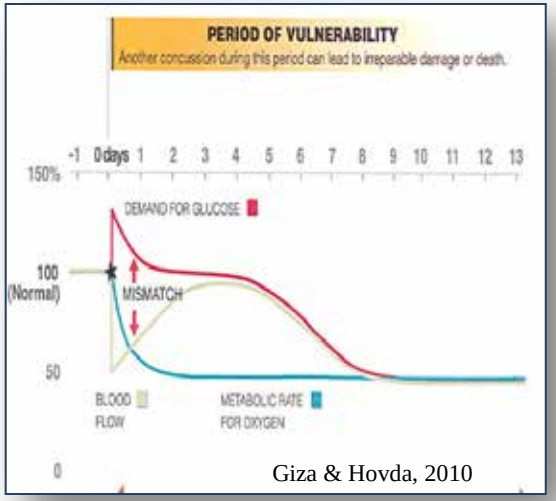



Giza & Hovda, 2010

**Clinical Recovery**:
Why do individuals vary in recovery?

**Physiological Recovery**:
How long does it take for the *brain* to recover?

**Individual Variability:**
Who is at risk for prolonged clinical and physiological recovery?

# What about Youth Athletes?

Which symptom assessments and approaches are uniquely appropriate for paediatric concussion?

G A Gioia,[1] J C Schneider,[1] C G Vaughan,[1] P K Isquith[2]

## Pediatric Sport-Related Concussion: A Review of the Clinical Management of an Oft-Neglected Population

**Michael W. Kirkwood, PhD[a,b], Keith Owen Yeates, PhD[c,d], Pamela E. Wilson, MD[a,b]**

[a]Department of Physical Medicine and Rehabilitation, Children's Hospital, Denver, Colorado; [b]University of Colorado Health Sciences Center, Denver, Colorado; [c]Department of Pediatrics, Ohio State University, Columbus, Ohio; [d]Center for Biobehavioral Health, Columbus Children's Research Institute, Columbus, Ohio

The authors have indicated they have no financial relationships relevant to this article to disclose.

*Journal of Athletic Training* 2006;41(4):399–408

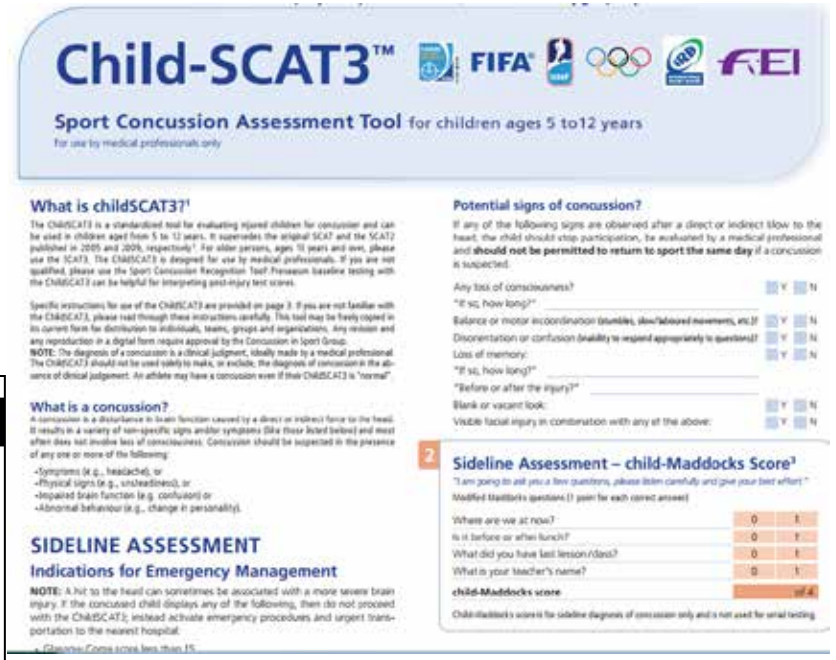
www.journalofathletictraining.org

*original research*

## Psychometric and Measurement Properties of Concussion Assessment Tools in Youth Sports

**Tamara C. Valovich McLeod*; William B. Barr†; Michael McCrea‡; Kevin M. Guskiewicz§**

*Arizona School of Health Sciences, A.T. Still University, Mesa, AZ; †New York University School of Medicine, New York, NY; ‡Waukesha Memorial Hospital, Waukesha, WI, and Medical College of Wisconsin, Milwaukee, WI; §University of North Carolina at Chapel Hill, Chapel Hill, NC



Child-SCAT3™ FIFA FEI

Sport Concussion Assessment Tool for children ages 5 to12 years

For use by medical professionals only

**What is childSCAT3?**

The ChildSCAT3 is a standardized tool for evaluating injured children for concussion and can be used in children aged from 5 to 12 years. It supersedes the original SCAT and the SCAT2 published in 2005 and 2009, respectively. For older persons, ages 13 years and over, please use the SCAT3. The ChildSCAT3 is designed for use by medical professionals. If you are not qualified, please use the Sport Concussion Recognition Tool. Preseason baseline testing with the ChildSCAT3 can be helpful for interpreting post-injury test scores.

Specific instructions for use of the ChildSCAT3 are provided on page 3. If you are not familiar with the ChildSCAT3, please read through these instructions carefully. This tool may be freely copied in its current form for distribution to individuals, teams, groups and organizations. Any revision and any reproduction in a digital form require approval by the Concussion in Sport Group.

**NOTE:** The diagnosis of a concussion is a clinical judgment, ideally made by a medical professional. The ChildSCAT3 should not be used solely to make, or exclude, the diagnosis of concussion in the absence of clinical judgement. An athlete may have a concussion even if their ChildSCAT3 is "normal".

**What is a concussion?**

A concussion is a disturbance in brain function caused by a direct or indirect force to the head. It results in a variety of non-specific signs and/or symptoms (like those listed below) and most often does not involve loss of consciousness. Concussion should be suspected in the presence of any one or more of the following:

- Symptoms (e.g., headache), or
- Physical signs (e.g., unsteadiness), or
- Impaired brain function (e.g. confusion) or
- Abnormal behaviour (e.g., change in personality).

**SIDELINE ASSESSMENT**

**Indications for Emergency Management**

**NOTE:** A hit to the head can sometimes be associated with a more severe brain injury. If the concussed child displays any of the following, then do not proceed with the ChildSCAT3; instead activate emergency procedures and urgent transportation to the nearest hospital:

- Glasgow Coma score less than 15

**Potential signs of concussion?**

If any of the following signs are observed after a direct or indirect blow to the head, the child should stop participation, be evaluated by a medical professional and **should not be permitted to return to sport the same day** if a concussion is suspected.

| | |
|---|---|
| Any loss of consciousness? | Y N |
| "If so, how long?" | |
| Balance or motor incoordination (stumbles, slow/laboured movements, etc.)? | Y N |
| Disorientation or confusion (inability to respond appropriately to questions)? | Y N |
| Loss of memory: | Y N |
| "If so, how long?" | |
| "Before or after the injury?" | |
| Blank or vacant look: | Y N |
| Visible facial injury in combination with any of the above: | Y N |

**2 Sideline Assessment – child-Maddocks Score[3]**

"I am going to ask you a few questions, please listen carefully and give your best effort."

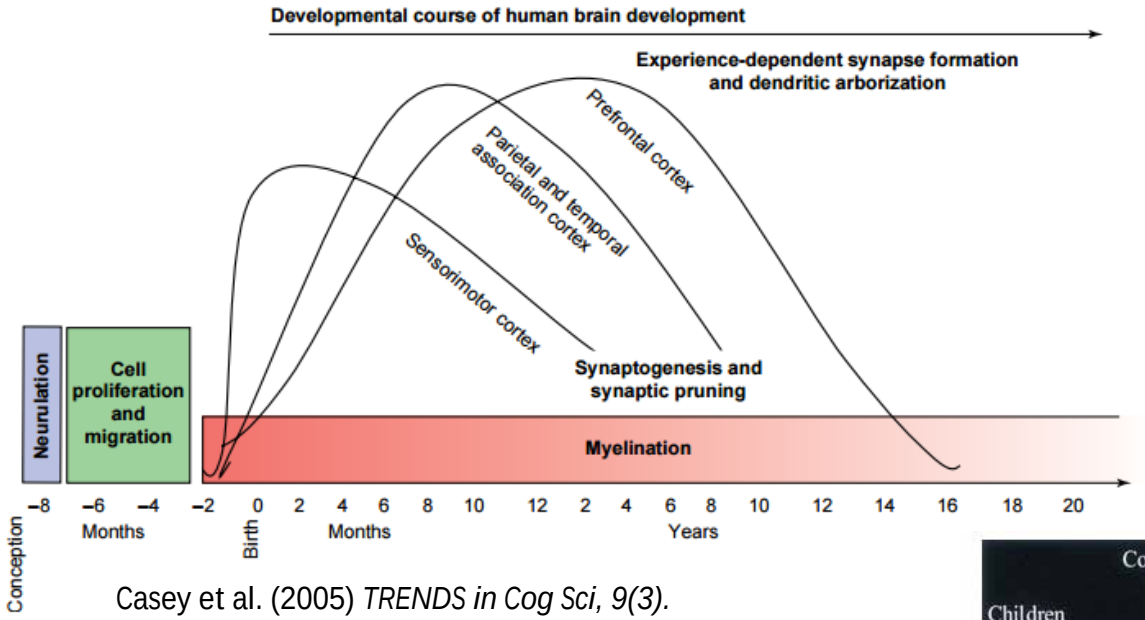
Modified Maddocks questions (1 point for each correct answer)

| | | |
|---|---|---|
| Where are we at now? | 0 | 1 |
| Is it before or after lunch? | 0 | 1 |
| What did you have last lesson/class? | 0 | 1 |
| What is your teacher's name? | 0 | 1 |
| **child-Maddocks score** | | of 4 |

Child-Maddocks score is for sideline diagnosis of concussion only and is not used for serial testing

**Box 2. Structural architecture of the developing brain**

The human brain undergoes dramatic changes in both its structural architecture and functional organization that reflect a dynamic interplay of simultaneously occurring progressive and regressive events. Although the total brain size is about 90% of adult size by age 6 years, the brain continues to undergo dynamic changes throughout adolescence and well into young adulthood [61]. Figure I illustrates some of these developmental changes, including proliferation and migration of cells mostly during fetal development [62,63], regional changes in synaptic density during postnatal development [11,12,64], and protracted development of myelination well into adulthood [65]. Current non-invasive neuroimaging methods do not have the resolution to delineate which of these processes underlies observed developmental changes beyond gray and white matter subcomponents.




Casey et al. (2005) *TRENDS in Cog Sci, 9(3).*

Casey et al. (2000) *Bio Psychol, 54,* 241-257.

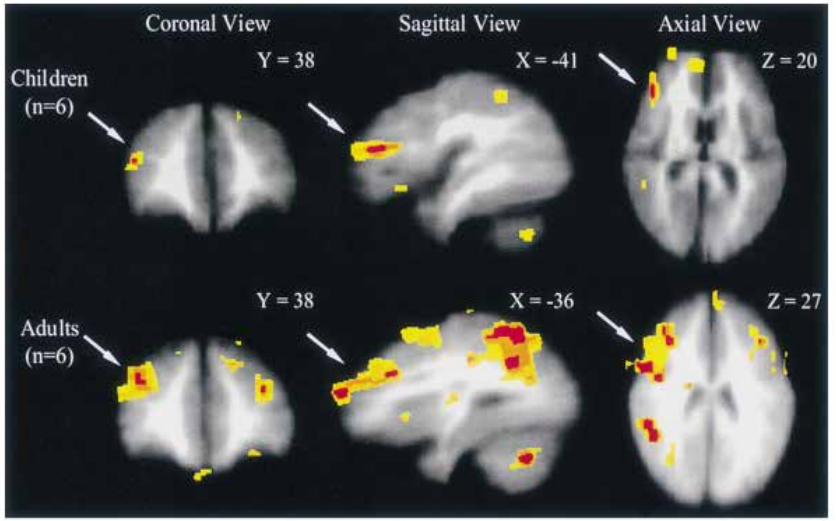


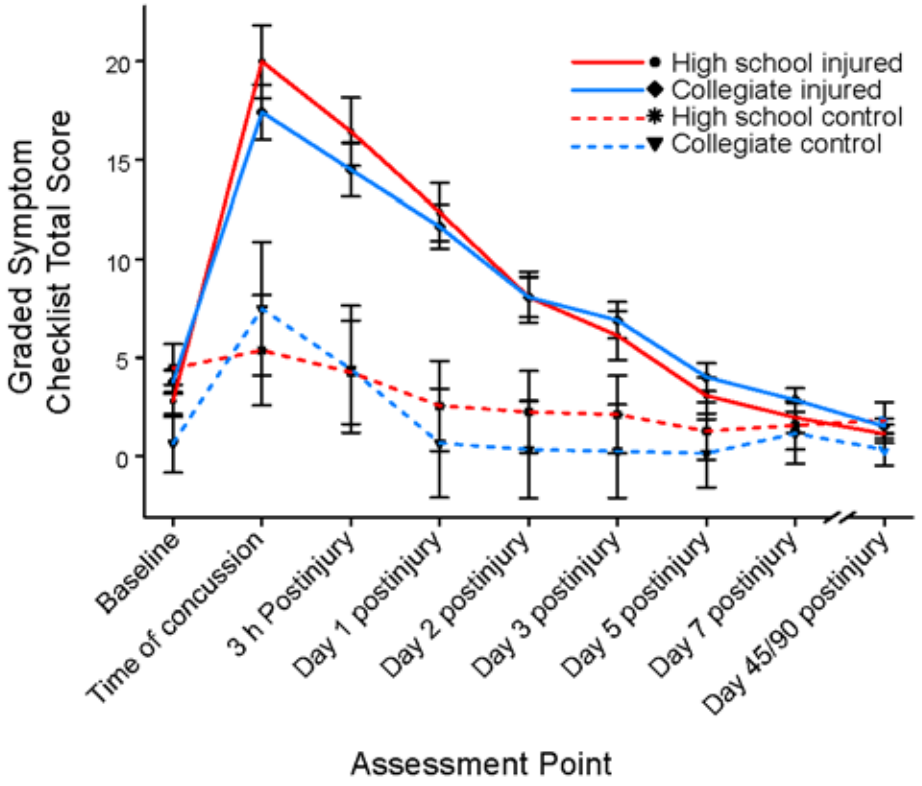

Fig. 4

Fig. 4. Coronal, sagittal, and axial views of brain activity for children and adults during performance of a spatial working memory task.

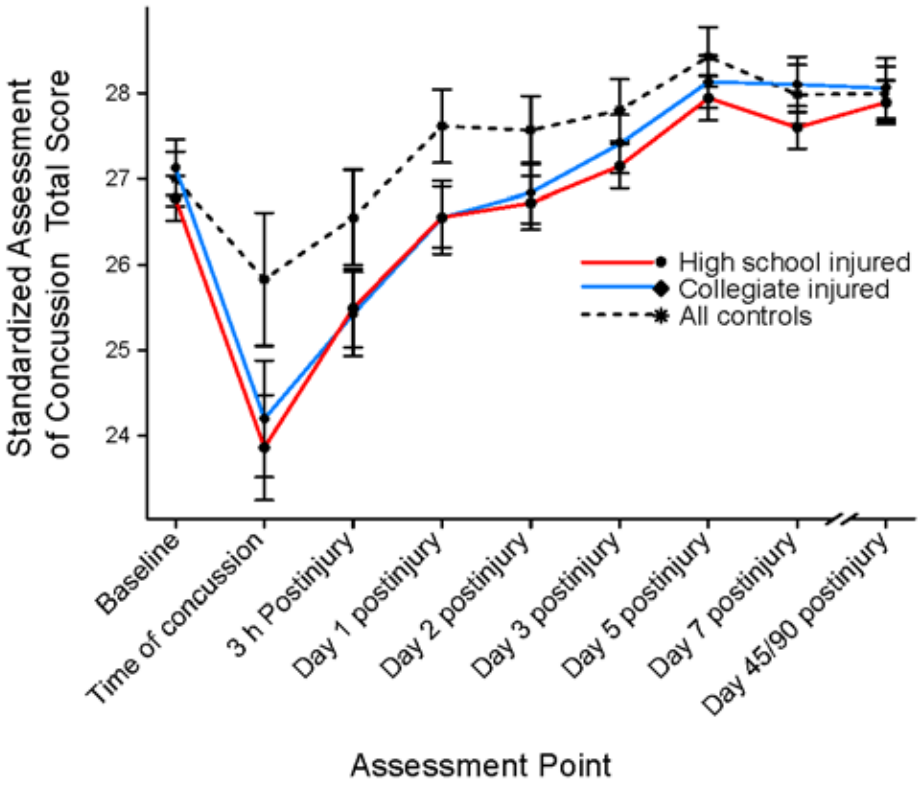
# NCAA, PrSL, CPI Combined Dataset: High School vs. College Recovery

405 High School, 216 Collegiate concussed athletes

**Symptoms (GSC)**

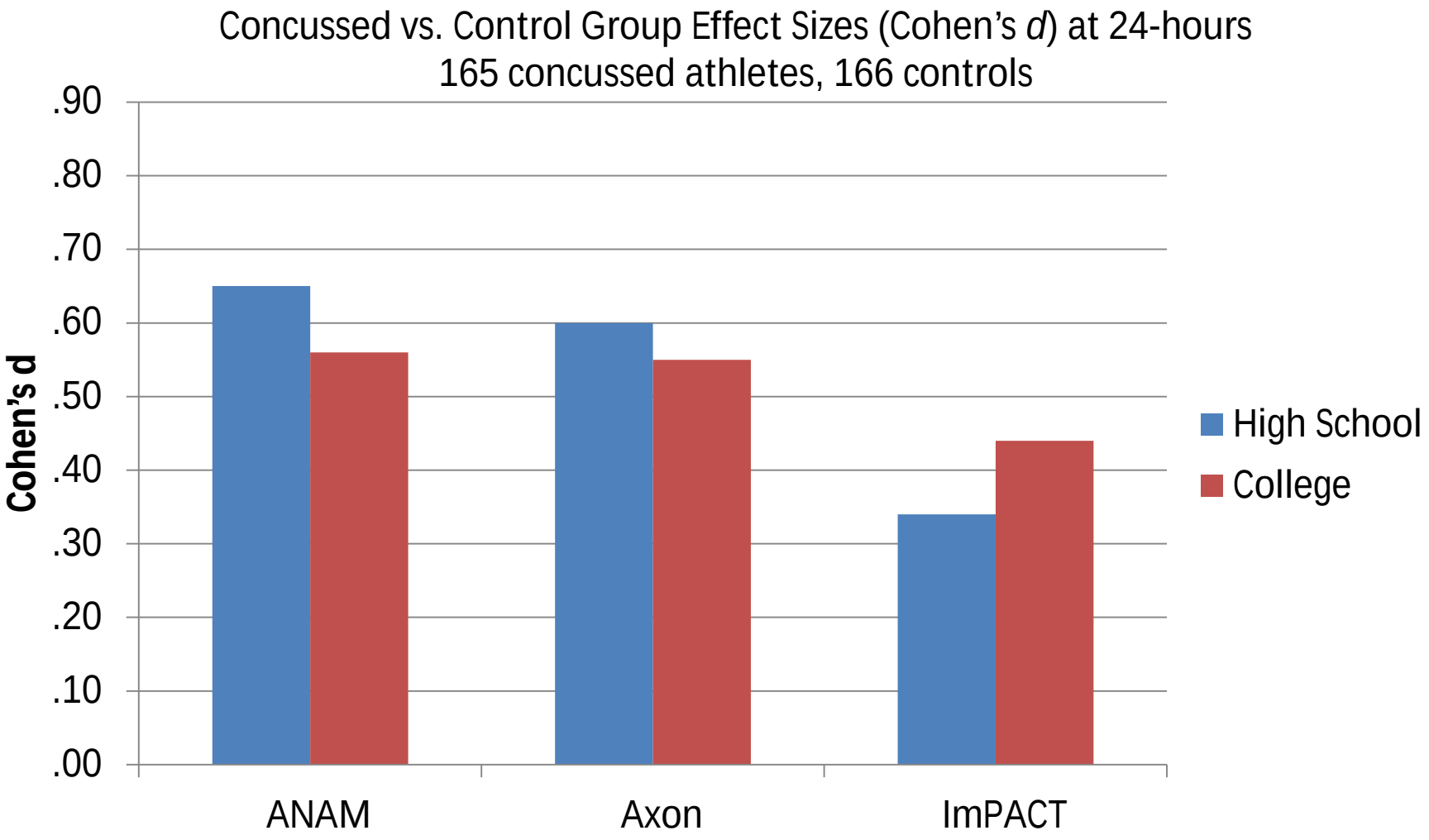



**Cognitive Performance (SAC)**



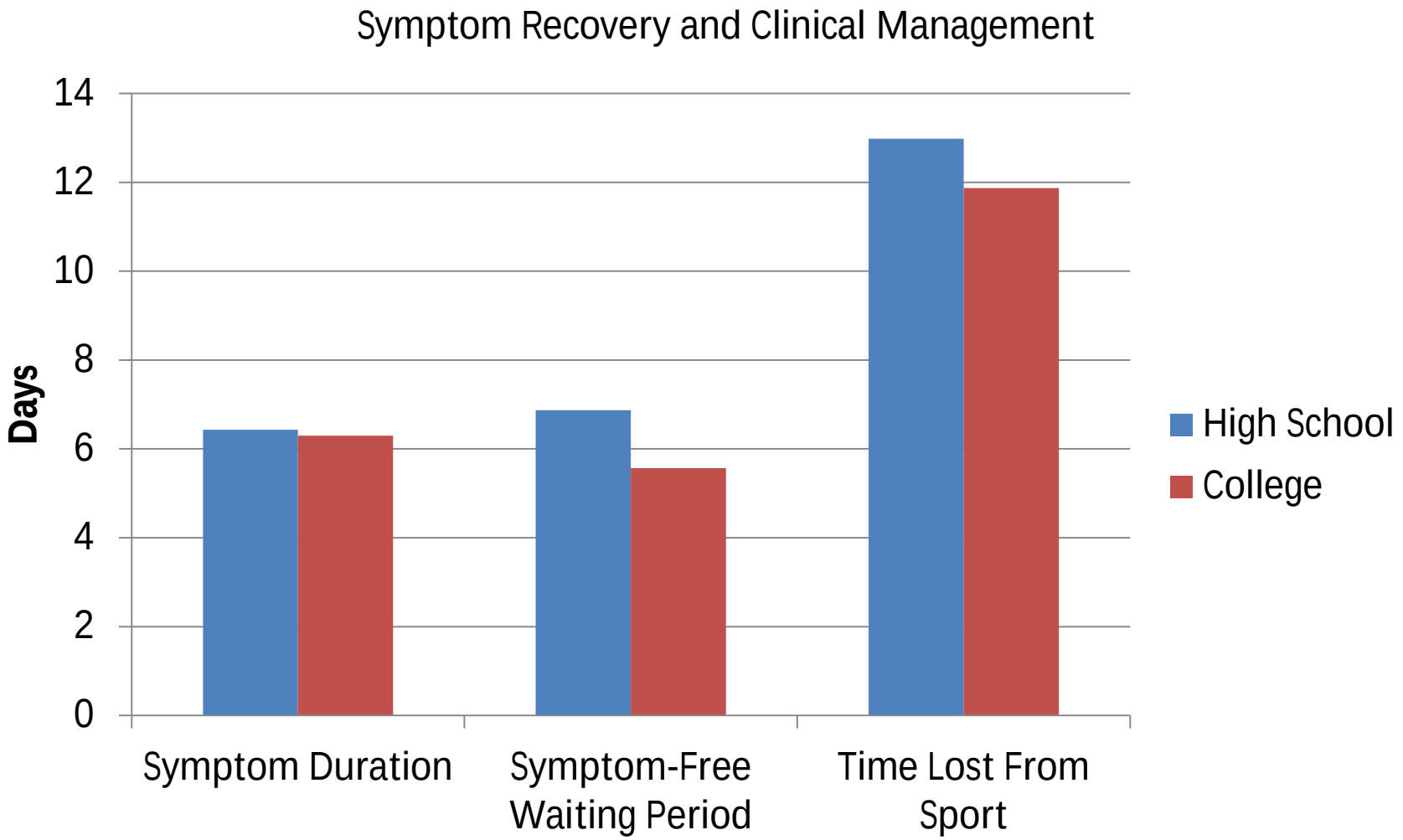

Nelson, Guskiewicz, Barr, Hammeke, Randolph, Ahn, Wang, & McCrea (2016). *J Athl Train, 51*(4).

# PROJECT HEADTOHEAD SPORTS ARM: High School vs. College




Nelson, LaRoche, Pfaller, Lerner, Hammeke, Randolph, Barr, Guskiewicz, & McCrea (2016) *J Int Neuropsychol Soc, 22*, 24-37.

PROJECT HEADTOHEAD SPORTS ARM : High School vs. College




Pfaller, Nelson, Apps, Walter, & McCrea *(under review)*.

# Changes in Clinical Management

| | 1999-2004 sample* | 2012-2014 sample |
|---|---|---|
| Duration of symptom-free waiting period (SFWP) | 3.21 | 5.95 |
| Days lost from sports participation | 7.41 | 12.31 |
| Symptom-Free Waiting Period | | |
| None | 39.7% | 1.4% |
| ≤ 1 day | 14.8% | 7.0% |
| > 1 day, ≤ 7 days | 30.9% | 67.8% |
| > 7 days | 14.6% | 23.8% |

*McCrea, Guskiewicz, Randolph, Barr, Hammeke, Marshall, & Kelly (2009). *Neurosurgery, 65,* 876-883.

# Hypothesized Modifiers of Recovery/Clinical Management

- Injury Severity (symptoms, prolonged loss of consciousness or amnesia)
- Convulsions
- Repeated injuries close in time
- Younger Age
- Migraine history, psychiatric history, ADHD
- Etc....

*Journal of Athletic Training* 2013;48(4):554–575
doi: 10.4085/1062-6050-48.4.05

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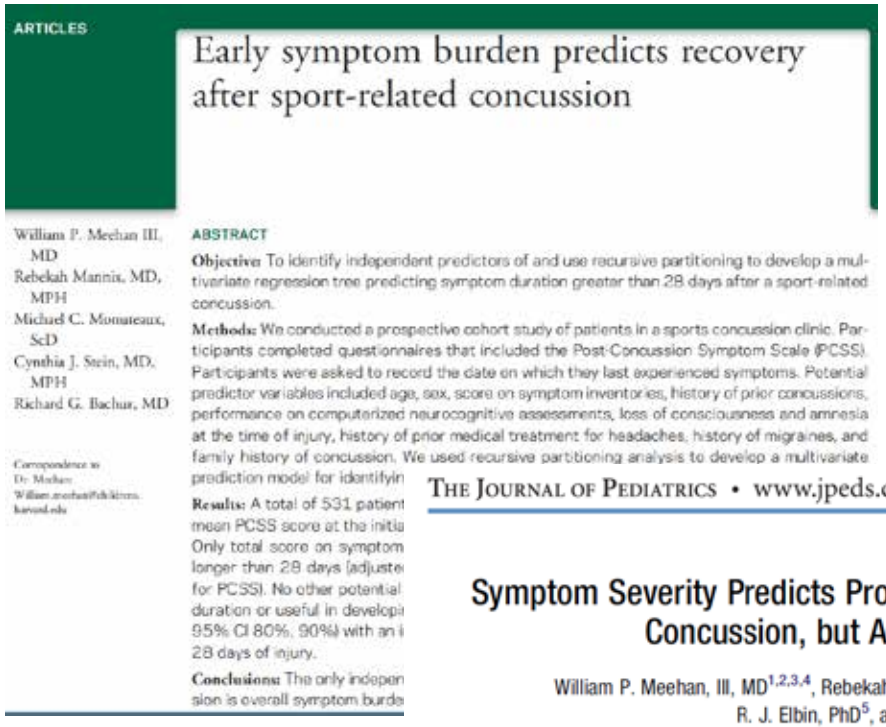
*consensus statement*

**Consensus Statement on Concussion in Sport: The 4th International Conference on Concussion in Sport, Zurich, November 2012**

Paul McCrory, MBBS, PhD*; Willem H. Meeuwisse, MD, PhD†; Mark Aubry,

# Predictors of Recovery



ARTICLES

Early symptom burden predicts recovery after sport-related concussion

William P. Meehan III, MD
Rebekah Mannix, MD, MPH
Michael C. Monuteaux, ScD
Cynthia J. Stein, MD, MPH
Richard G. Bachur, MD

ABSTRACT

**Objective** To identify independent predictors of and use recursive partitioning to develop a multivariate regression tree predicting symptom duration greater than 28 days after a sport-related concussion.

**Methods** We conducted a prospective cohort study of patients in a sports concussion clinic. Participants completed questionnaires that included the Post-Concussion Symptom Scale (PCSS). Participants were asked to record the date on which they last experienced symptoms. Potential predictor variables included age, sex, score on symptom inventories, history of prior concussions, performance on computerized neurocognitive assessments, loss of consciousness and amnesia at the time of injury, history of prior medical treatment for headaches, history of migraines, and family history of concussion. We used recursive partitioning analysis to develop a multivariate prediction model for identifyin

**Results** A total of 531 patient
mean PCSS score at the initia
Only total score on symptom
longer than 28 days (adjuste
for PCSS). No other potential
duration or useful in developi
95% CI 80%, 90%) with an i
28 days of injury.

**Conclusions** The only indepen
sion is overall symptom burde

*Journal of the International Neuropsychological Society* (2013), **19**, 22–33.

doi:10.1017/S1355617712000872

Incidence, Clinical Course, and Predictors of Prolonged Recovery Time Following Sport-Related Concussion in High School and College Athletes

Michael McCrea,[1] Kevin Guskiewicz,[2,3,4] Christopher Randolph,[5] William B. Barr,[6] Thomas A. Hammeke,[7] Stephen W. Marshall,[3,4,8] Matthew R. Powell,[9] Kwang Woo Ahn,[10] Yanzhi Wang,[10] AND James P. Kelly[11]

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ORIGINAL ARTICLES

## Symptom Severity Predicts Prolonged Recovery after Sport-Related Concussion, but Age and Amnesia Do Not

William P. Meehan, III, MD[1,2,3,4], Rebekah C. Mannix, MD, MPH[3,4], Andrea Stracciolini, MD[2], R. J. Elbin, PhD[5], and Michael W. Collins, PhD[5]

**Objective** To identify predictors of prolonged symptoms in athletes who sustain concussions.
**Study design** This was a multicenter prospective cohort study of patients in 2 sport concussion clinics. Possible predictors of prolonged symptoms from concussion were compared in 2 groups, those whose symptoms resolved within 28 days and those whose symptoms persisted beyond 28 days. Candidate predictor variables were entered into a logistic regression model that was used to generate aORs.
**Results** A total of 182 patients met the inclusion criteria during the study period. The mean patient age was 15.2 ± 3.04 years. More than one-third of the patients (n = 65) underwent computerized neurocognitive testing on their initial visit. On univariate analyses, Post-Concussion Symptom Scale (PCSS) score and all composite scores on computerized neurocognitive testing were apparently associated with prolonged symptom duration. Sex, age, loss of consciousness at time of injury, and amnesia at time of injury were not associated with prolonged symptom duration. After adjusting for potential confounding, only total PCSS score was associated with the odds of suffering prolonged symptoms.
**Conclusion** Further efforts to develop clinical tools for predicting which athletes will suffer prolonged recoveries after concussion should focus on initial symptom score. *(J Pediatr 2013;163:721-5).*

Nelson, Tarima, LaRoche, Hammeke, Barr, Guskiewicz, Randolph, & McCrea (in press). *Neurology*.