Strategies for Assessment and Management of the Concussed Patient

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Arizona Neuropsychological Society
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No Disclosures
Learning Objectives

1. Identify key components of a post-concussion evaluation appropriate to your setting.

2. Describe current knowledge and controversies on the role of cognitive and physical rest versus exercise in the management of concussion.

3. Identify empirically supported treatments for common persisting deficits following concussion.
Outline

• Assessment Strategies
• Recovery Patterns in Sport versus Non-Sport Concussion
• Cognitive and Physical Rest versus Activity
• Managing Acute versus Chronic Concussion Symptoms
Assessment Strategies
Assessment Strategies - Acute

• Common acute cognitive deficits
  • Processing speed and reaction time
  • Attention
  • Memory

• Certain aspect of “executive systems functioning”

• Fatigue and symptom exacerbation with mental exertion
Assessment Strategies - Acute

- Computerized Neurocognitive Testing
  - ImPACT
  - Axon CCAT
  - CNS Vital Signs
  - Others

- Helpful if you have a valid baseline
- Athlete populations
- Post-concussion symptom inventory if not embedded in test
Assessment Strategies - Acute

<table>
<thead>
<tr>
<th>Test Item</th>
<th>Total sample, mean (S.D.)</th>
<th>Males, mean (S.D.)</th>
<th>Females, mean (S.D.)</th>
<th>Males vs. females</th>
<th>P</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>(N = 100)</td>
<td>(n = 60)</td>
<td>(n = 40)</td>
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<td>WAIS-III Digit Span</td>
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<tr>
<td>Forward—raw score</td>
<td>11.0 (1.9)</td>
<td>10.9 (1.9)</td>
<td>11.1 (1.9)</td>
<td>0.51</td>
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<td>Backward—raw score</td>
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<td>7.0 (2.5)</td>
<td>6.5 (1.8)</td>
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<tr>
<td>Total—raw score</td>
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<td>17.9 (3.4)</td>
<td>17.7 (3.1)</td>
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<td>WAIS-III Processing Speed Index</td>
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<tr>
<td>Digit Symbol—raw score</td>
<td>106.7 (14.8)</td>
<td>104.6 (11.4)</td>
<td>109.8 (18.4)</td>
<td>1.73</td>
<td>.086</td>
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<td>Symbol Search—raw score</td>
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<td>80.1 (12.6)</td>
<td>91.9 (10.4)</td>
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<td>.001</td>
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<tr>
<td></td>
<td>38.8 (6.4)</td>
<td>37.8 (6.4)</td>
<td>40.3 (6.0)</td>
<td>1.94</td>
<td>.055</td>
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<td>Trailmaking Test</td>
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<tr>
<td>Part A (seconds)</td>
<td>22.5 (6.7)</td>
<td>23.2 (7.6)</td>
<td>21.4 (4.9)</td>
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<td>Part B (seconds)</td>
<td>52.5 (17.1)</td>
<td>56.1 (18.9)</td>
<td>47.1 (12.4)</td>
<td>2.60</td>
<td>.010</td>
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<td>COWAT—total words</td>
<td>35.3 (9.8)</td>
<td>33.1 (8.8)</td>
<td>38.1 (10.3)</td>
<td>2.93</td>
<td>.004</td>
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<td>HVLT</td>
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<td>Total Learning (Trials 1–3)</td>
<td>25.8 (4.8)</td>
<td>25.7 (4.3)</td>
<td>25.9 (5.5)</td>
<td>0.25</td>
<td>.805</td>
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<td>Delayed Recall</td>
<td>9.4 (1.9)</td>
<td>9.2 (2.1)</td>
<td>9.7 (1.7)</td>
<td>1.21</td>
<td>.228</td>
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<tr>
<td>Discrimination Index</td>
<td>11.7 (0.7)</td>
<td>11.6 (0.7)</td>
<td>11.7 (0.6)</td>
<td>0.62</td>
<td>.537</td>
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Assessment Strategies - Acute


<table>
<thead>
<tr>
<th>Test</th>
<th>Function</th>
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<tbody>
<tr>
<td>Post Concussive Symptom Checklist</td>
<td>Symptoms associated with brain injury</td>
</tr>
<tr>
<td>Hopkins Verbal Learning Test/List Learning</td>
<td>Verbal learning and memory</td>
</tr>
<tr>
<td>Symbol Digit Modalities Test</td>
<td>Short term memory, visual motor speed</td>
</tr>
<tr>
<td>Symbol Digit Modalities Memory</td>
<td>Incidental memory</td>
</tr>
<tr>
<td>Digit Span Test</td>
<td>Working memory, attention/concentration</td>
</tr>
<tr>
<td>Penn State Cancellation Test</td>
<td>Visual scanning, visual attention</td>
</tr>
<tr>
<td>Trail Making Test</td>
<td>Visual sequencing, visual motor speed</td>
</tr>
<tr>
<td>Controlled Oral Word Association Test</td>
<td>Verbal fluency</td>
</tr>
<tr>
<td>Stroop Test</td>
<td>Speed of processing, divided attention</td>
</tr>
<tr>
<td>Vigil Continuous Performance Test</td>
<td>Reaction time, sustained attention</td>
</tr>
</tbody>
</table>
Assessment Strategies - Chronic

- Chronic (> 3-6 months) or complicating factors
  - Full traditional neuropsychological evaluation
  - Psychological functioning
  - Psychosocial factors and stressors

- Concussion symptom inventory

- Details on their course of recovery, activities, symptoms, and when they occur

- Rehabilitation?
  - Vestibular/balance?
  - Cognitive?
Effect sizes of MTBI on overall functioning

Iverson, 2005

Justin E. Karr, Corson N. Areshenkoff, and Mauricio A. Garcia-Barrera
University of Victoria

Mild Traumatic Brain Injury (mTBI), also known as concussion, has become a growing public health concern, prevalent in both athletic and military settings. Many researchers have examined post-mTBI neuropsychological outcomes, leading to multiple meta-analyses amalgamating individual study results. **Objective:** Considering the plethora of meta-analytic findings, the next logical step stands as a systematic review of meta-analyses, effectively reporting key moderators that predict post-mTBI neuropsychological outcomes. **Method:** A systematic review of reviews yielded 11 meta-analyses meeting inclusion criteria (i.e., English-language systematic reviews/meta-analyses covering post-mTBI observational cognitive research on late adolescents/adults), with their findings qualitatively synthesized based on moderator variables (i.e., cognitive domain, time since injury, past head injury, participant characteristics, comparison group, assessment technique, and persistent symptoms). **Results:** The overall effect sizes ranged for both general (range: .07–.61) and sports-related mTBI (range: .40–.81) and differed both between and within cognitive domains, with executive functions appearing most sensitive to multiple mTBI. Cognitive domains varied in recovery rates, but overall recovery occurred by 90 days postinjury for most individuals and by 7 days postinjury for athletes. Greater age/education and male gender produced smaller effects sizes, and high school athletes suffered the largest deficits post-mTBI. Control-group comparisons yielded larger effects than within-person designs, and assessment techniques had limited moderating effects. **Conclusions:** Overall, meta-analytic review quality remained low with few studies assessing publication or study quality bias. Meta-analyses consistently identified adverse acute mTBI-related effects and fairly rapid symptom resolution. Future meta-analyses should better operationally define cognitive constructs to produce more consistent effect estimates across domains.
Recovery Patterns
Recovery from mTBI

• For the majority of individuals, symptoms will resolve within minutes to hours to days
  • Adolescents may take longer to recover than [young] adults

• “Metabolic cascade” takes 7-10 days to resolve

• Functional neuroimaging studies show differences extending beyond 1 month in at least a subset of patients (reviewed in Williams, Potter & Ryland, 2010; Moser, Glatts & Schatz, 2012)

• Symptoms are expected to resolve in 1-3 months
McCrea et al 2009: Integrated model of recovery after [single] uncomplicated MTBI

**Acute Period (immediately after injury to ~5 days post):**

- Symptoms and cognitive impairments can be severe and significantly disrupt normal daily function
- The brain is sufficiently injured to create a neurometabolic crisis. Functional neuroimaging studies can reveal a dysregulation of normal and consistent recruitment of neuronal resources (e.g., decreased activation)
- Exertion while the brain is in a state of neurometabolic crisis may slow down recovery and, theoretically, could have other secondary pathophysiological effects
McCrea et al 2009: Integrated model of recovery after uncomplicated MTBI

**Subacute Period (~5–30 days post)**
- Symptoms and cognitive/functional impairments follow a gradual, overlapping course of improvement.
- Clinically, an overwhelming majority of cases achieve full symptom and neuropsychological recovery.
- Neurophysiologically, the brain continues on a course of recovery to a normal metabolic state and cerebral functioning, during which over-recruitment of neuronal resources may be required to achieve customary functional and performance standards (e.g., increased activation on functional neuroimaging).
- Once asymptomatic, a protocol of gradual, sequential exertion is appropriate, initially focusing on cardiovascular challenge before transitioning to more vigorous exercise.

- Period of vulnerability – symptom recovery and normal cognition, but brain still compensating.
- It may not be necessary to wait until someone is completely asymptomatic to begin exercise.
McCrea et al 2009: Integrated model of recovery after uncomplicated MTBI

**Chronic Period (>30 days post)**
- A relatively small percentage of patients report persistent symptoms and cognitive or other complaints, which may be influenced by injury (e.g., more severe grades of complicated MTBI with abnormal structural imaging findings) or non-injury related factors (e.g., depression, PTSD, chronic pain, life stress, or secondary gain).
- The brain returns to a normal state of cerebral function (e.g., normal activation on functional neuroimaging) in the overwhelming majority of cases.
- Persistent post-concussion symptoms may be observed in a small percentage (<5%) of MTBI cases, significantly influenced by non-injury-related factors.
- If identified, co-morbidities (e.g., depression, anxiety, PTSD, chronic pain, etc.) should be treated. Psychological and educational interventions can be effective in improving functional outcome and reducing persistent disability from MTBI and these associated conditions.

This theoretical model applies to a single, uncomplicated MTBI without focal, structural injury visualized on conventional neuroimaging (e.g., CT, MRI) and is less relevant in more severe forms of MTBI or repeat MTBI. This model does not apply to moderate or severe TBI.

Model only applies to adult MTBI and may be incomplete. Higher percentage of cases with persistent symptoms in clinical practice. A variety of factors (e.g., ADHD, LD, gender) may influence recovery times and risk of persistent symptoms.
Influences on Recovery Patterns

• Age: Child v. adult; younger v. older adult
  • Children take longer & may be more vulnerable

• Population: Sport v. Trauma
  • Biomechanics of the injury
  • Physical differences in the patients
  • Psychological difference
Sport and Nonsport Etiologies of Mild Traumatic Brain Injury: Similarities and Differences

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\(^2\)Physical Medicine and Rehabilitation Alliance, Baylor College of Medicine and the University of Texas-Houston Medical School, Houston, Texas 77030

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Influences on Recovery Patterns

• Personal History
  • LD, ADHD
  • Migraine
  • Prior injury & time between them
  • Psychiatric history

• Other biological (e.g., gender, ApoE) & external (e.g., secondary gain), and situational (e.g., pain, other stress) factors
Cognitive & Physical Rest v. Activity
Rest as treatment for concussion

• Moser, Glatts & Schatz, 2012
  ✴ Retrospective study of 49 high school & collegiate athletes
  ✴ Presented 1-7 days, 8-30 days, or 31+ days post concussion
  ✴ All were prescribed at least 1 week of total cognitive and physical rest
  ✴ Evaluated results on ImPACT and symptoms ratings
Table II. Post-concussion ImPACT and total symptom scores by time and group (n = 49)

<table>
<thead>
<tr>
<th>Time since concussion (in days)</th>
<th>1-7 (N = 14)</th>
<th>8-30 (N = 22)</th>
<th>31+ (N = 13)</th>
<th>F</th>
<th>P</th>
<th>$\eta^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal memory</td>
<td></td>
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</tr>
<tr>
<td>Pre-rest (N = 14)</td>
<td>80.9 (10.9)</td>
<td>82.6 (11.5)</td>
<td>76.9 (11.2)</td>
<td>17.13</td>
<td>.001</td>
<td>.27</td>
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<tr>
<td>Post-rest</td>
<td>90.3 (8.9)</td>
<td>85.3 (7.9)</td>
<td>83.9 (11.9)</td>
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<tr>
<td>Visual memory</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Pre-rest (N = 14)</td>
<td>65.9 (12.4)</td>
<td>69.7 (12.7)</td>
<td>70.0 (16.8)</td>
<td>16.03</td>
<td>.001</td>
<td>.26</td>
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<tr>
<td>Post-rest</td>
<td>76.4 (11.8)</td>
<td>75.2 (10.9)</td>
<td>79.9 (13.0)</td>
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<td></td>
<td></td>
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<tr>
<td>Processing speed</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Pre-rest (N = 14)</td>
<td>33.9 (10.6)</td>
<td>33.8 (7.4)</td>
<td>35.5 (10.1)</td>
<td>20.18</td>
<td>.001</td>
<td>.31</td>
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<tr>
<td>Post-rest</td>
<td>38.0 (8.1)</td>
<td>36.9 (7.5)</td>
<td>38.5 (8.3)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Reaction time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-rest (N = 14)</td>
<td>.698 (.18)</td>
<td>.634 (.09)</td>
<td>.652 (.11)</td>
<td>7.59</td>
<td>.008</td>
<td>.14</td>
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<tr>
<td>Post-rest</td>
<td>.631 (.09)</td>
<td>.614 (.12)</td>
<td>.599 (.11)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Total symptom</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-rest (N = 14)</td>
<td>22.0 (21.1)</td>
<td>23.6 (21.5)</td>
<td>28.1 (18.9)</td>
<td>50.15</td>
<td>.001</td>
<td>.52</td>
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<tr>
<td>Post-rest</td>
<td>6.8 (7.4)</td>
<td>11.4 (17.6)</td>
<td>7.9 (5.5)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Verbal: time: $F(1,46) = 17.13; P = .001$, group: $F(2,46) = 1.17; P = .32$.
Visual: time: $F(1,46) = 16.03; P = .001$, group: $F(2,46) = 0.46; P = .63$.
Motor: time: $F(1,46) = 20.18; P = .001$, group: $F(2,46) = 0.16; P = .85$.
React: time: $F(1,46) = 7.59; P = .008$, group: $F(2,46) = 0.76; P = .47$.
Symptoms: time: $F(1,46) = 50.15; P = .001$, group: $F(2,46) = 0.23; P = .79$. 
Effect of Cognitive Activity Level on Duration of Post-Concussion Symptoms

**Authors:** Naomi J. Brown, MD, Rebekah C. Mannix, MD, MPH, Michael J. O'Brien, MD, David Gostine, BS, Michael W. Collins, PhD, and William P. Meehan III, MD

**Division of Sports Medicine, Children’s Hospital of Philadelphia, Philadelphia, Pennsylvania; Division of Emergency Medicine, Brain Injury Center, and Sports Concussion Clinic, Division of Sports Medicine, Children’s Hospital Boston, Boston, Massachusetts; The Michelli Center for Sports Injury Prevention, Waltham, Massachusetts; and Sports Concussion Program, University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania**

**What’s Known on This Subject:** Cognitive rest is recommended for the management of sport-related concussions. There are limited data to support this recommendation.

**What This Study Adds:** This study adds empirical data supporting the recommendation for cognitive rest after a sport-related concussion.

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**Kaplan-Meier Curve of Symptoms**

![Kaplan-Meier Curve](image)

- 1st quartile activity score
- 2nd quartile activity score
- 3rd quartile activity score
- 4th quartile activity score

**proportion still symptomatic**

<table>
<thead>
<tr>
<th>time (days)</th>
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<tbody>
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</table>
Exercise as treatment of PCS

- Baker et al, 2012
  - Physiological theory of concussion—altered autonomic function and impaired autoregulation of cerebral blood flow
  - Exercise assessment and subsymptom threshold aerobic exercise rehabilitation
  - Physiologic PCS and PCS patients who completed the exercise program were more likely to return to full functioning
Exercise as treatment of PCS

- Leddy et al (2013) pilot fMRI study
  - PCS exercise treatment group, PCS placebo stretching group, Healthy controls (each group n=4)
- Math processing task in fMRI before & after 12 weeks
- Time 1: healthy controls had greater activation in the posterior cingulate gyrus, lingual gyrus & cerebellum
- Time 2: No difference between exercise PCS & controls. Placebo stretching group had less activity in the cerebellum, anterior cingulate gyrus, and thalamus than controls. Exercise group had fewer sx.
- Controlled aerobic exercise may help restore normal cerebral blood flow regulation
Leddy & Willer, 2013

**Figure 2:** Use of the BCTT and exercise prescription for RTA in physiologic PCD. APMHR, age-predicted maximum HR. *After 3 wk of symptoms. **5 bpm for nonathletes; 10 bpm for athletes. To obtain a more precise target HR, consider repeating the BCTT every 2 wk.

### Table 2.
Differential diagnosis of PCD using the BCTT and the physical examination.

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Physiologic PCD</th>
<th>Cervicogenic PCD</th>
<th>Migraine PCD</th>
<th>Affective PCD</th>
<th>Vestibular/Ocular PCD</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCTT response</td>
<td>Distinct submaximal symptom-limited threshold characterized by complaints of sudden increase in lightheadedness, headache, head pressure, or &quot;fullness&quot; of the head.</td>
<td>No distinct symptom-limited threshold. Able to exercise to exhaustion. Posterior headache that improves early in exercise but often returns near exhaustion.</td>
<td>BCTT not performed if migraine present. If migraine not present, there is no distinct symptom-limited threshold. Able to exercise to exhaustion.</td>
<td>No distinct symptom-limited threshold. Able to exercise to exhaustion. Mood usually improves with exercise testing.</td>
<td>No distinct symptom-limited threshold. Able to exercise to exhaustion. Symptoms are usually visual (blurred vision, difficulty with focusing) or mild lightheadedness. Vertigo typically is not reported during the test.</td>
</tr>
<tr>
<td>Physical exam</td>
<td>May have orthostatic drop in BP and or rise in HR.</td>
<td>Cervical muscle tenderness and/or spasm, reduced motion, altered cervical proprioception, suboccipital tenderness</td>
<td>Exam usually normal when not symptomatic. May have photosensitivity.</td>
<td>May have flat or depressed affect.</td>
<td>Discomfort (and sometimes nystagmus) with ocular smooth pursuits and saccades, abnormal ocular convergence (~6 cm), abnormal VOR, positive Romberg and abnormal tandem gait.</td>
</tr>
</tbody>
</table>

* VOR, vestibulo-ocular reflex; BCTT, Buffalo Concussion Treadmill Test; PCD, post concussion disorders.
Cognitive & Physical Rest vs Exercise

- Acute (first few days) Cognitive & physical rest
- Subacute – moderation
  - Gradual return to activities (e.g., work / school)
  - Too much or too little could be bad
- Post-acute
  - Gradual increase aerobic exercise (J. Leddy)
Management Suggestions
Return to activity algorithm with exercise protocol for athletes

Leddy et al, 2012
Acute Management (1st month)

• Initial rest with information and reassurance – set appropriate expectations

• Coordinate and assist with return to school, work, or other activities (CDC ACE forms)
  • Initial time off (may be brief)
  • Moderation and pacing of activities
  • Gradual return to normal activities (symptom limited)

• If still symptomatic after 3-4 weeks, more active steps or support may be necessary
Psychological Approaches

• Benefit of early information and setting appropriate expectations

• Support for cognitive behavioral psychotherapy in the treatment of PPCS

• Negative mTBI perceptions, stress, anxiety, depression, and all-or-nothing behavior associated with PPCS

• Important to identify and address other conditions that may contribute to PCS

  • Williams et al, 2010; Sayegh et al, 2010; Mittenbreg, et al, 2001; Hou et al, 2012; Comper et al, 2005
Rehabilitation

- Vestibular Rehabilitation
  - Lightheaded/dizzy – could be autonomic dysfunction – refer to neurology
- Controlled Exercise Rehabilitation
- Cognitive Rehabilitation
- Psychotherapy
Cognitive Rehabilitation

- Attention
- Memory
- Executive Functioning
- Social Communication
- Metacognitive strategy training
“Demonstrated efficacy and utility for cognitive rehabilitation:” p. 243

- Direct attention training
- External memory / organizational aids
- Internal memory strategy training
- Metacognitive strategy training
- Social pragmatics training
- Environmental modification
- Brain injury education
- Aggressive support during gradual reentry into community and vocational/educational activities
Attention

• Individual Treatment
  • Attention Process Training (APT-III; Sohlberg & Mateer, 2010)
  • Working Memory Retraining (Cicerone, 2002)
  • Time Pressure Management Training (Winkens et al, 2009)

• Independent Computer Based -
  • CogMed
  • Lumosity
  • Brain HQ
Role of neuropsychology in concussion management

• Objectively assess cognitive functioning and monitor symptoms
  • Assist in return to activity decisions (school, work, play)
  • Recommend accommodations if necessary

• Assist in differential diagnosis

• Recommend treatment
  • Neurorehabilitation – Cognitive retraining
  • Psychotherapy

• Education & expectations
Questions & Discussion