Neurocognitive Testing and Sports Concussion: What are we Learning?

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Disclosure Statement
Micky Collins, PhD is Vice President, Chief Clinical Officer, and Co-Founder of ImPACT Applications, a computerized neurocognitive test battery designed to assess sports concussion and Mild Traumatic Brain Injury.

Objectives
- Discuss pathophysiology of concussion and need for functional assessment to determine outcomes
- Discuss psychometric properties of computerized neurocognitive testing, including sensitivity, reliability, and “added value” of testing
- Present sensitivity/specificity of neurocognitive testing in predicting protracted recovery from sports concussion
- Present case study of concussion management.
Neurometabolic Cascade Following Cerebral Concussion/MTBI

- Calcium
- Glucose
- Glutamate

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UCLA Brain Injury Research Center
Concussion Management: Areas of Focus

Acute Management
- Rule out more serious intracranial pathology
  - CT, MRI, neurologic examination primary diagnostic tests

Post Injury Management
- Prevent against Second Impact Syndrome
- Prevent against cumulative effects of injury
  - Less biomechanical force causing extension of injury
- Prevent presence of Post-Concussion Syndrome

Determination of asymptomatic status essential for reducing repetitive and chronic morbidity of injury

Factor Analysis, Post-Concussion Symptom Scale
(Pardini, Lovell, Collins et al. 2004)

Neuropsychiatric
- More emotional
- Sadness
- Nervousness
- Irritability

Migraine (Physical sx)
- Headaches
- Visual Problems
- Dizziness
- Noise/Light Sensitivity
- Nausea

Cognitive Symptoms
- Attention Problems
- Memory Dysfunction
- "Fogginess"
- Fatigue
- Cognitive slowing

Sleep Disturbance
- Difficulty falling asleep
- Sleeps less than usual

N=327, High School and University Athletes Within 7 Days of Concussion

Symptom Evaluation/Clinical Interview:
What is Asymptomatic?

IS NOT "How are you feeling?" or "Do You Have a Headache?"

IS a series of questions inquiring about subtleties of injury

"Do you have a pressure in your head that increases as day progresses?"
"Are you more sensitive to lights and noises than normal?"
"Do you become dizzy when looking up/down, turning head, standing quickly?"
"Do you feel more fatigued than normal at the end of the day?"
"Do you have blurred or fuzzy vision while reading or difficulty reading?"
"Do you feel more distractible in school than normal?"
"Do you feel a sense of fogginess during the day?"
"Do you have difficulty falling/staying asleep?"
"Have you or your parents noticed that you are more irritable than normal?"

"Asymptomatic" is not an easily defined term, though is at the core of proper concussion management.
The Evolving Definition of Concussion
CDC Physicians Toolkit 2007
REGARDING CEREBRAL CONCUSSION......
A concussion (or mild traumatic brain injury) is a complex pathophysiological process affecting the brain, induced by traumatic biomechanical forces secondary to direct or indirect forces to the head. Disturbance of brain function is related to neurometabolic dysfunction, rather than structural brain injury, and is typically associated with normal structural imaging findings (CT Scan, MRI). Concussion may or may not involve a loss of consciousness. Concussion results in a constellation of physical, cognitive, emotional, and sleep-related symptoms. Recovery is a sequential process and symptoms may last from several minutes to days, weeks, months, or even longer in some cases.

Management of MTBI:
Topics of Concern
- Grading systems ineffective/not data-based.
- CT and MRI insensitive to subtleties of injury.
- Variability in clinician recommendations.
- Lack of education and awareness of injury.
- Coaches, Parents, Clinicians/Physicians
- Inadequate/Improper recommendations from ED/Trauma Departments.
- Relying on subjective status of child with brain injury to determine clinical management.
“When it comes to concussion, don’t believe me when I tell you that I’m OK”

NFL Athlete, 2010

Pressure to Play in Sports: Can we trust what the athlete is telling us?

- Can we trust the athletes self report?
- Athletes are naive to the subtleties of the injury
- Young athletes lack insight into self-assessment of MTBI symptoms
- Studies suggest that up to 50% of athletes experience concussion symptoms per year but only 10 percent report having an injury

Computer-Based Neurocognitive Testing

Currently Available Programs

- Cogsport
- Headminders (CRI)
- ANAM
- CNS Vital Signs
- ImPACT

Extensive research since 2001
Computerized Neurocognitive Testing

- Demographic / Concussion History Questionnaire
- Concussion Symptom Scale
  - 21 item Likert Scale (e.g. headache, dizziness, nausea, etc)
- 8 Neurocognitive Measures
  - Verbal Memory, Visual Memory, Reaction Time, Processing Speed Summary Scores
- Detailed Clinical Report
  - Outlines Demographic, Symptom, Neurocognitive Data
  - Automatically Computer Scored
- Desktop and On-Line Versions Available
  - Extensive normative data available from ages 11-60
  - Pediatric Version Developed - Ages 5-11
- Over 100 peer-reviewed research articles, books/chapters, abstracts published since 2000
  - Reliability, validity, sensitivity/specificity of test established

Concussion Evaluation Timeline

Pre-season
- Baseline Testing
  - Supervised at School Or clinic

1-3 Days
- Concussion
  - Remove From Play
- First Follow-Up Evaluation

Follow-up Testing as needed
- Re-evaluation
- Return to Play

Test Validity and Sensitivity/Specificity

Is neurocognitive testing valid?
Can testing detect impairment (sensitivity)?
Can testing identify non-impairment (specificity)?
Sensitivity and Specificity of Computerized Neurocognitive Testing


Discriminate Function Analysis

- Statistical classification of Concussed/control subjects
- No Clinician Input

Positive Predictive Value (90%)
(Probability that that a concussion is present when test is positive)

Negative Predictive Value (82%)
(Probability that a concussion is not present when test is negative)

Sensitivity of Computer Based Testing


N = 75 concussed athletes; Physician Dx Concussion
No control group; Change relative to baseline dictated success rate

<table>
<thead>
<tr>
<th>Test</th>
<th>Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>ImPACT</td>
<td>79.2%</td>
</tr>
<tr>
<td>Headminder</td>
<td>78.6%</td>
</tr>
<tr>
<td>Symptoms</td>
<td>68.0%</td>
</tr>
<tr>
<td>Postural Control</td>
<td>61.9%</td>
</tr>
<tr>
<td>Paper and Pencil NP</td>
<td>43.5%</td>
</tr>
<tr>
<td>Complete Battery</td>
<td>90.0%</td>
</tr>
</tbody>
</table>

Is Neurocognitive Testing Reliable?

- Are data stable over time in control population?
- What is meaningful statistical change?
- What are false positive rates of testing?
### Two Year Test-Retest Reliability for Computer NP Testing in Collegiate Athletes (Desktop)

#### Intra-class correlation coefficient

Shatz P. *AJSM*, 2009

<table>
<thead>
<tr>
<th>Domain Mean ICC*</th>
<th>Domain Mean ICC*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Verbal Memory Score</strong></td>
<td><strong>Time 1</strong> 87.6 .459 <strong>Time 2</strong> 87.8</td>
</tr>
<tr>
<td><strong>Visual Memory Score</strong></td>
<td><strong>Time 1</strong> 75.6 .653 <strong>Time 2</strong> 78.1</td>
</tr>
<tr>
<td><strong>Processing Speed Score</strong></td>
<td><strong>Time 1</strong> 41.2 .742 <strong>Time 2</strong> 42.0</td>
</tr>
<tr>
<td><strong>Reaction Time Score</strong></td>
<td><strong>Time 1</strong> .54 .676 <strong>Time 2</strong> .53</td>
</tr>
<tr>
<td><strong>Symptom Score</strong></td>
<td><strong>Time 1</strong> 9.3 .431 <strong>Time 2</strong> 9.8</td>
</tr>
</tbody>
</table>

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### Test-Retest Reliable Change Index Scores for ImPACT Test Battery

Iverson et al. *PCN* 2005

<table>
<thead>
<tr>
<th>ImPACT Domain Mean RCI 90% Confidence Interval</th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>ImPACT Verbal Memory Score</strong></td>
<td><strong>Time 1</strong> 88.6 8.75 <strong>Time 2</strong> 88.8</td>
</tr>
<tr>
<td><strong>ImPACT Visual Memory Score</strong></td>
<td><strong>Time 1</strong> 78.7 13.5 <strong>Time 2</strong> 77.5</td>
</tr>
<tr>
<td><strong>ImPACT Processing Speed Score</strong></td>
<td><strong>Time 1</strong> 40.54 4.98 <strong>Time 2</strong> 42.24</td>
</tr>
<tr>
<td><strong>ImPACT Reaction Time Score</strong></td>
<td><strong>Time 1</strong> .543 .06 <strong>Time 2</strong> .536</td>
</tr>
<tr>
<td><strong>ImPACT Symptom Score</strong></td>
<td><strong>Time 1</strong> 5.23 9.6 <strong>Time 2</strong> 5.79</td>
</tr>
</tbody>
</table>

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### One Year Stability of Computer NP Testing in a High School Sample (On-Line Version)

Schatz, in preparation, 2011

<table>
<thead>
<tr>
<th>Verbal Memory</th>
<th>Visual Memory</th>
<th>Process Speed</th>
<th>RT</th>
<th>Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time 1</strong> 85.6</td>
<td>72.0</td>
<td>37.5</td>
<td>.59</td>
<td>4.7</td>
</tr>
<tr>
<td><strong>Time 2</strong> 86.4</td>
<td>75.5</td>
<td>39.8</td>
<td>.56</td>
<td>4.4</td>
</tr>
<tr>
<td>r</td>
<td>.619</td>
<td>.703</td>
<td>.851</td>
<td>.761</td>
</tr>
</tbody>
</table>

Inter-class correlation coefficients.
N=369, DF=368, Bonferroni correct alpha p<.01

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Two-Year Stability Computerized Neurocognitive Testing

<table>
<thead>
<tr>
<th>Domain</th>
<th>Improved</th>
<th>Declined</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal Memory</td>
<td>3%</td>
<td>2%</td>
<td>5%</td>
</tr>
<tr>
<td>Visual Memory</td>
<td>7%</td>
<td>2%</td>
<td>9%</td>
</tr>
<tr>
<td>Processing Speed</td>
<td>2%</td>
<td>2%</td>
<td>4%</td>
</tr>
<tr>
<td>Reaction Time</td>
<td>3%</td>
<td>2%</td>
<td>5%</td>
</tr>
<tr>
<td>Symptom Score</td>
<td>3%</td>
<td>3%</td>
<td>6%</td>
</tr>
</tbody>
</table>

Percentages of healthy sample that would be classified as reliably improved or declined based upon existing reliable change methodology.  

Shatz P. AJSM, 2009

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Table 1: Prevalence of Low Composite Scores in a healthy population

<table>
<thead>
<tr>
<th>Scores Below Cutoff</th>
<th>Boys, Ages 13-15 (N=183)</th>
<th>Boys, Ages 16-18 (N=158)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;25th %ile</td>
<td>44.4%</td>
<td>4.4%</td>
</tr>
<tr>
<td>25th-50th %ile</td>
<td>2.5%</td>
<td>2.5%</td>
</tr>
<tr>
<td>&gt;50th %ile</td>
<td>4%</td>
<td>4%</td>
</tr>
<tr>
<td>&lt;16th %ile</td>
<td>41.6%</td>
<td>1.6%</td>
</tr>
<tr>
<td>16th-50th %ile</td>
<td>0.6%</td>
<td>0.6%</td>
</tr>
<tr>
<td>&gt;50th %ile</td>
<td>4%</td>
<td>4%</td>
</tr>
<tr>
<td>&lt;10th %ile</td>
<td>4-</td>
<td>2-</td>
</tr>
<tr>
<td>10th-50th %ile</td>
<td>25.5%</td>
<td>9.3%</td>
</tr>
<tr>
<td>&gt;50th %ile</td>
<td>2-</td>
<td>2-</td>
</tr>
<tr>
<td>≤5th %ile</td>
<td>30.5%</td>
<td>0.5%</td>
</tr>
<tr>
<td>6th-10th %ile</td>
<td>0.5%</td>
<td>0.6%</td>
</tr>
<tr>
<td>&gt;10th %ile</td>
<td>4%</td>
<td>4%</td>
</tr>
<tr>
<td>≤2nd %ile</td>
<td>20.5%</td>
<td>0.5%</td>
</tr>
<tr>
<td>2nd-5th %ile</td>
<td>6.5%</td>
<td>7.6%</td>
</tr>
<tr>
<td>&gt;5th %ile</td>
<td>1-</td>
<td>1-</td>
</tr>
<tr>
<td>≤5th %ile</td>
<td>93.4%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Comparison of Preseason, Midseason and Post-Season Neurocognitive Scores in Uninjured Collegiate Football Players

Miller, Adamson, Pink, Sweet, AJSM, 2007

- Compared computerized neurocognitive test results for 58 non-concussed collegiate football players at preseason, midseason and post season.
- All athletes engaged in contact practices/games.
- Found no statistical differences in test performance across the three evaluations.
- "Test scores are not significantly altered by a season of repetitive contact in uninjured collegiate football athletes.”
- “Impairment of neurocognitive scores in concert with clinical symptoms/findings should be interpreted as evidence of a post-concussive event.”

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What is “Added Value” of Neurocognitive Testing

Does testing identify deficits in asymptomatic athletes?

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How well can young athletes estimate their level of cognitive functioning? (not very well)

<table>
<thead>
<tr>
<th>Neurocognitive Domain</th>
<th>Patient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verbal Memory</td>
<td>.45</td>
</tr>
<tr>
<td>Visual Memory</td>
<td>.48</td>
</tr>
<tr>
<td>Processing Speed</td>
<td>.45</td>
</tr>
<tr>
<td>Reaction Time</td>
<td>-.53</td>
</tr>
<tr>
<td>Symptom Score</td>
<td>-.70</td>
</tr>
</tbody>
</table>

Correlation of estimate of “back to normal” (0-100%) with post-injury ImPACT Scores. (N=97). Sandel et a. INS, 2011

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Unique Contributions of Neurocognitive Assessment to Concussion Management

Testing reveals cognitive deficits in asymptomatic athletes within 4 days post-concussion

N=215, MANOVA p<.000000

(Fazio, Loved, Collins et al., Neurehabilitation, 2007)
Unique Contribution of Neurocognitive Testing to Concussion Management

MANOVA p<.000000

Value Added of Neurocognitive Evaluation

Neurocognitive Testing Increases Diagnostic Yield to 93%

201 concussed high school and collegiate athletes tested with 2 days of injury.
Abnormal performance determined by RCI's (van Kampen, 2004).

The Value Added of Memory Assessment

- 11% of athletes have abnormal RT but normal memory
- 32% of athletes have abnormal memory but normal RT
- Evaluating memory identifies 21% more impairment than RT measurement in isolation
- 84% of athletes exhibit deficits on one composite score

Determined by comparison to pre-injury baseline testing. Concussed athletes include high school and college athletes tested within 4 days of injury. Abnormal performance determined by RCI scores.

Recovery in Athletes:
How long does it Take?

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Sample Size</th>
<th>Tests Utilized</th>
<th>Total Days</th>
<th>Cognitive Resolution</th>
<th>Total Days</th>
<th>Symptom Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lovell et al., 2005</td>
<td>95 (NFL)</td>
<td>Paper and Pencil NP</td>
<td>1 day</td>
<td>1 day</td>
<td></td>
<td></td>
</tr>
<tr>
<td>McCrea et al., 2003</td>
<td>94 College</td>
<td>SAC</td>
<td>&lt;1 day</td>
<td>7 days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>McCrea et al., 2003</td>
<td>94 College</td>
<td>Paper and Pencil NP</td>
<td>5-7 days</td>
<td>7 days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Echemendia, 2001</td>
<td>29 College</td>
<td>Paper and Pencil NP</td>
<td>3 days</td>
<td>3 days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gladstein et al., 2001</td>
<td>94 College</td>
<td>Balance, BESS</td>
<td>5-5 Days</td>
<td>7 Days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blalock et al., 2009</td>
<td>64 College</td>
<td>Computer ANAM</td>
<td>3-7 days</td>
<td>Did Not Evaluate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iverson et al., 2006</td>
<td>50 High School</td>
<td>Computer, ImPACT</td>
<td>10 days</td>
<td>7 Days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>McCrea et al., 2006</td>
<td>104 High School</td>
<td>Computer, ImPACT</td>
<td>14 days</td>
<td>7-10 Days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lovell, Collins et al., 2008</td>
<td>208 High School</td>
<td>Computer, ImPACT</td>
<td>26 days</td>
<td>17 Days</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Three-year prospective study in Western PA.
  17 high school football teams (2,141 total sample)

- 134 athletes with diagnosed concussion (6.2%)
  All athletes referred for evaluation at UPMC

- Recovery determined by “Back to Baseline” on computerized neurocognitive test scores and symptom inventory
  Determined by Reliable Change Index Scores-RCI’s

Collins, Lovell, Iverson, Ida, Maroon et al., Neurosurgery, 2006:58,276-283
Individual Recovery From Sports MTBI: How Long Does it Take?

Predicting Protracted Recovery Following Sports Concussion: Syndrome: What are we Learning?

Established (?) Constitutional Risk Factors For More Complicated Recovery

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Field, Lovell, Collins et al, J of Pediatrics, 2003</td>
</tr>
<tr>
<td></td>
<td>Pellman, Lovell et al, Neurosurgery, 2006</td>
</tr>
<tr>
<td>Learning Disability</td>
<td>Collins, Lovell et al, JAMA, 1999</td>
</tr>
<tr>
<td></td>
<td>Guskiewicz et al, CJSM, 2003</td>
</tr>
</tbody>
</table>
Sensitivity/Specificity of Symptoms and Neurocognitive Testing in Predicting “Protracted” Recovery from Sports Concussion


Computerized Neurocognitive Testing
To Test or Not to Test When Symptomatic?
- Is there “added value” in completing neurocognitive testing during symptomatic phase of recovery?
- What is prognostic value of doing testing?
- What is sensitivity/specificity of subacute testing in predicting protracted recovery?

Sensitivity-Specificity of computerized neurocognitive testing in Diagnosing Concussion

 Discriminant Function Analysis
 Statistical Classification of Concussed and Control Subjects
 No clinician Input

✓ Positive Predictive Value (90%)
(Probability that that a concussion is present when test is positive)

✓ Negative Predictive Value (82%)
(Probability that a concussion is not present when test is negative)
What is Sensitivity/Specificity of Neurocognitive and Symptom Scores in Predicting Protracted Recovery?

- 108 concussed high school football players (Mean Age=16.0)
  - Athletes had baseline computerized neurocognitive testing and were reevaluated within 3 days of injury (Mean = 2.2 days)
  - All followed until clinical recovery
  - 46% of sample recovered ≤ 14 days = “Quick”
  - Mean = 6.9 days
  - 54% of sample recovered >14 days = “Protracted”
  - Mean = 33.0 days
- T-Test conducted on differences of PCSS total score, Individual Symptom Clusters, and ImPACT Cognitive Composite Scores between “Quick” and “Protracted” Recovery Groups
- Discriminant Function Analysis conducted on examining Sensitivity and Specificity of these subacute variables in predicting group recovery


Variables Assessed at 2 Days Post Injury

<table>
<thead>
<tr>
<th>PCSS Total Score</th>
<th>Four Symptom Clusters from Factor Analysis of PCSS</th>
<th>Four Neurocognitive Composite Scores from ImPACT</th>
</tr>
</thead>
<tbody>
<tr>
<td>22 items from ImPACT PCSS</td>
<td>Migraine Cluster</td>
<td>Verbal Memory</td>
</tr>
<tr>
<td></td>
<td>Cognitive Cluster</td>
<td>Visual Memory</td>
</tr>
<tr>
<td></td>
<td>Neuropsychiatric Cluster</td>
<td>Visual-Motor Speed (i.e. Processing Speed)</td>
</tr>
<tr>
<td></td>
<td>Sleep Cluster</td>
<td>Reaction Time</td>
</tr>
</tbody>
</table>

First study to combine and quantify how well Computerized Neurocognitive testing and Symptom Profiles Predict Length of recovery following sports related concussion

Predicting Outcome Following Sports MTBI: Which Variables at 2 days post-injury differ b/w Groups?

<table>
<thead>
<tr>
<th>Variables</th>
<th>Wilks’ Lambda</th>
<th>F Value</th>
<th>P Value</th>
<th>Canonical Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Migraine Cluster</td>
<td>.828</td>
<td>6.774</td>
<td>.012</td>
<td>.990</td>
</tr>
<tr>
<td>ImPACT Reaction Time</td>
<td>.807</td>
<td>4.233</td>
<td>.042</td>
<td>.682</td>
</tr>
<tr>
<td>ImPACT Visual Memory</td>
<td>.821</td>
<td>5.874</td>
<td>.017</td>
<td>.654</td>
</tr>
<tr>
<td>ImPACT Verbal Memory</td>
<td>.806</td>
<td>4.070</td>
<td>.047</td>
<td>.470</td>
</tr>
<tr>
<td>Neuropsychiatric Cluster</td>
<td>.792</td>
<td>2.420</td>
<td>.123</td>
<td>.431</td>
</tr>
<tr>
<td>Total PCS8 score</td>
<td>.785</td>
<td>2.160</td>
<td>.200</td>
<td>.425</td>
</tr>
<tr>
<td>ImPACT Visual Motor Speed</td>
<td>.785</td>
<td>1.622</td>
<td>.206</td>
<td>.416</td>
</tr>
<tr>
<td>Cognitive Symptom Cluster</td>
<td>.776</td>
<td>0.478</td>
<td>.491</td>
<td>.253</td>
</tr>
<tr>
<td>Sleep Symptom Cluster</td>
<td>.780</td>
<td>0.942</td>
<td>.334</td>
<td>.242</td>
</tr>
</tbody>
</table>

Predicting Outcomes Following Sports MTBI: Discriminant Function Analysis

<table>
<thead>
<tr>
<th>PCSS Total Score</th>
<th>Sensitivity</th>
<th>Specificity</th>
<th>Positive Predictive Value</th>
<th>Negative Predictive Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>40.81%</td>
<td>70.31%</td>
<td></td>
<td>62.5%</td>
<td>61.33%</td>
</tr>
<tr>
<td>PCSS Symptom Clusters</td>
<td>46.91%</td>
<td>77.2%</td>
<td>63.9%</td>
<td>62.86%</td>
</tr>
<tr>
<td>ImPACT Neurocognitive Composite Scores</td>
<td>53.20%</td>
<td>75.44%</td>
<td>64.10%</td>
<td>66.15%</td>
</tr>
</tbody>
</table>


Predicting Outcomes Following Sports MTBI: Discriminant Function Analysis

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<thead>
<tr>
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<td>PCSS Symptom Clusters</td>
<td>46.91%</td>
<td>77.2%</td>
<td>63.9%</td>
<td>62.86%</td>
</tr>
<tr>
<td>ImPACT Neurocognitive Composite Scores</td>
<td>53.20%</td>
<td>75.44%</td>
<td>64.10%</td>
<td>66.15%</td>
</tr>
<tr>
<td>Combined Migraine Cluster and Neurocognitive Scores</td>
<td>65.22%</td>
<td>80.36%</td>
<td>73.17%</td>
<td>73.8%</td>
</tr>
</tbody>
</table>


Iverson G. *CJS; 2008*

Predicting Simple versus Complex Concussion

At three days post-injury, if athlete exhibit three or more RCI changes on ImPACT composite scores (relative to baseline), there is a 94% chance that recovery will require >10 days.

Exhibiting a high symptom score did not improve classification accuracy over neurocognitive test scores in isolation.

Athletes with prior history of concussion were not statistically more likely to have “protracted” recovery from concussion.
Predicting Outcomes Following Sports Concussion: Evidence Summary

- Neurocognitive and symptom evaluation during symptomatic phase of recovery “adds value” in prognosis and determining severity of injury

- Migraine symptom cluster and neurocognitive composite scores most predictive of outcome
  - Migraine= headache, photophobia, dizziness, nausea, vomiting, vision
  - ImPACT= Reaction Time, Verbal Memory, Visual Memory

- Testing while symptomatic allows for understanding of severity of injury, prognosis of outcome, considerations for academic accommodations, and consideration of physical exertion recommendations


Case Example:
Female High School Soccer Player (2010)

- 13 year old, 8th grader
- Academic Gifted program
- Superior academic functioning/standardized testing
- Medical History unremarkable
- Concussion sustained 09/11/10
Case Example:
Female High School Soccer Player
- September 11, 2010
  - Ball to face-attempting to head ball and lost in sun
  - Not prepared for hit
  - Kept playing with no overt symptoms
  - After game/at home reported extreme fatigue, mild bifrontal headache, photosensitivity, difficulty with concentration
  - Tried to do math homework after game-increased headache, concentration difficulty
  - Went to ER next day-no CT scan
  - Went to school for 5 days with increase in symptoms
- Referred for Evaluation at UPMC (by school ATC)

Case Example:
High School Football Player
- Evaluation 09/20/10 (9 days post injury)
  - Clinical/symptom interview
    - Mild headache reported (2/10)-lasting 1/16 hours, mild photosensitivity, mild blurred vision bilaterally, difficulty with concentration (particularly Math), mild fatigue
  - Vestibular screening indicated convergence insufficiency (18cm), provocative dizziness with horizontal/vertical gaze stability
    - Saccades WNL
    - Balance WNL
  - Computerized Neurocognitive Testing

Show ImPACT Data
Case Example:
Female High School Soccer Player
- Recommendations from 09/11/10 Evaluation
  - Off of school for 4 days, ½ days subsequently for 3 days
  - Full academic accommodations upon return
    - Books on tape, reduced work (half), extensions on assignments, tutoring if needed, leave class early to avoid busy hallways, go home from school after classes
  - Vestibular Referral-Evaluation/Therapy
  - Out of soccer and exertion
  - Reevaluation in 2 weeks

Case Example:
Female High School Soccer Player
- Return Evaluation 09/27/10 (16 days post injury)
  - Very mild concentration difficulties/fatigue-no headache or other sx
  - Continued convergence insufficiency (improved to 12 cm)
- Return Evaluation 10/11/10
  - 100% Normal-no symptoms reported
  - Vestibular screening normal
  - ImPACT data review

Case Example:
Female High School Soccer Player
- Return Evaluation 10/22/10
  - 100% Normal-no symptoms reported
  - Vestibular screening normal
Recommended Sports Concussion Management

Post-Injury Management
- Removal from contest if concussion suspected-no RTP in same game
- No return to play while symptomatic or if symptomatic with exertion
- Carefully monitored and graded increase in exertion over time
- Need to be mindful of cognitive exertion on role of recovery

Need for conservative management in children/adolescents
Neurocognitive testing recommended for athletes sustaining concussion

Criteria for Return to Play
1. Symptom-Free at Rest
2. Symptom-Free with Cognitive/Physical Exertion
3. Normal Neurocognitive Data/Clinical Evaluation
“Conservative” approach to management of concussion
- Out of play for game/practice with any LOC, amnesia, or confusion
- Out of play for game/practice if new and persistent dizziness, headache (particularly if accompanied by photophobia, dizziness, nausea, or vomiting) or any other persistent symptoms of concussion

Follow up evaluation to be conducted by team physician as well as independent “neurological consultant”
- Clearance for RTP required by both

Baseline and post-injury neurocognitive testing mandated by league
- No return to play until athlete exhibits normal neurological evaluation and is...
  1) asymptomatic at rest
  2) asymptomatic with progressive exertion, and
  3) neurocognitive test scores back to baseline (within RCI indices on NP Test)