Sports Concussion Management with ImPACT

Neal McGrath, Ph.D.

SPORTS CONCUSSION NEW ENGLAND
1. Rationale and techniques for effective baseline testing.
2. Principal components of ImPACT.
3. Experience relationship between test modules and composite scores.
4. Results analysis
5. Case studies
EVIDENCE-BASED
RETURN-TO-PLAY PROTOCOL

Value of neurocognitive testing...
- Can confirm presence of typical cognitive deficits.
- Can help identify symptoms that may not be revealed in clinical interview.
- Can track recovery of cognitive function at rest.
- Can confirm stability of cognitive recovery with exertion.
BASELINE TESTING ADVANTAGES

- Controls for individual factors such as...
  - Learning disabilities
  - ADHD
  - Medications

- Can be done in large groups with educational seminars

- Orients athletes to concussion information, risks and procedures at start of season
BASELINE TESTING

- Not foolproof.........it’s not an X-ray
  - Motivation
  - Failure to read or listen to instructions
  - Distraction by peers, environment, cell phone
  - Sandbagging: purposeful poor performance to set the bar low in case of a subsequent concussion
BASELINE TESTING

- Ideally yields synchronized scores in the expected range for an athlete
- Usually yields at least some valid "high water marks"
- Annual baseline if history of concussion in last year or multiple concussions
- Baseline every 2 years for all other students
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Practice effects?

- 5 alternate versions of ImPACT
  - Different words on Word Memory
  - Different shapes on Design Memory
  - Randomized stimuli on other subtests

>>Make sure to rotate Word Groups
- Must select on desktop version
- Automatically rotated on online version (if not overridden)
UNDERSTANDING NORMS

- **Symptom Scale**
  - Males 0-10
  - Females 0-15
  - Correlate baseline symptoms with known conditions or situations (bad night’s sleep, not taking medication for ADHD, sick with cold, etc.)

- **Impulse Control (< 20)**
  - Errors of inhibition
    - R/L errors on X’s & O’s
    - Color Match errors

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UNDERSTANDING NORMS

- Verbal Memory
- Visual Memory
- Visual Motor Speed
- Reaction Time

- Percentiles...comparison to 100 in your peer group

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PERCENTILE RANGES

- **Superior/Very Superior** 90 – 99th %ile
- **High Average** 75 – 89th %ile
- **Average** 26 – 74th %ile
- **Low Average** 16 – 25th %ile
- **Poor** 6 – 15th %ile
- **Impaired** < 5th %ile
BASELINE TESTING
RECOMMENDATIONS

- Combine education and baseline test
  - 45-60 minutes
  - Rotate larger teams through talk & test
  - Work with players and their coaches
- Have all the coaches test first.
- Have coach present for testing.
- Pre-season results
  - Before teams start contact
  - Eliminate the mad rush: End of school year testing.
BASELINE TESTING
RECOMMENDATIONS

- Keep group size manageable. (10-15)
  - Start with very small groups
  - Depends on the conduct of your athletes, room set-up, etc.

- Space athletes out in the room.
  - Empty seat between is best.
BASELINE TESTING RECOMMENDATIONS

- Explain that this is a challenging performance test.
  - Not an intelligence test
  - Some may have to return to re-take test if scores suggest they did not give their best effort.

- Tell them not to interfere or talk with others.
  - No joking, off-hand comments, or talking out loud.
BASELINE TESTING RECOMMENDATIONS

- Have staff (ATC, AD, coaches, teachers, etc.) who remain in room throughout the test.
- Watch door to prevent late arrivals from interrupting test.
- Have all athletes and staff turn off cell phones before starting.
- Turn off classroom phones and PA system if possible.
Mouse must be used!
  - ... with preferred hand.
  - Touchpad use will invalidate the test!

Mac
  - Use keyboard buttons for the X’s and O’s right/ left clicking.
Lower window shades.

Turn down lights.
Explain that the test will be in 3 parts:

1. **Sport and Health History**: athletes enter background information including…
   - Name, Date of birth
   - Years of education; LD/ADHD history?
   - **Medications being taken**: list names (especially ADHD meds) and doses.
   - Number of prior concussions, etc.
2. **Current Symptoms and Conditions:**

   athletes rate 22 concussion symptoms over the last 24 hours.

- Have all athletes complete these first 2 sections together.
- Students can ask questions aloud.
- Answer questions for everyone’s benefit.
- **WAIT** for everyone to start the last section together.
3. **Neurocognitive testing:**
   - The real “test” section
   - 6 tests of memory, attention, and speed.
Maintain silence in room.

Instruct students to

- Read and understand directions of each module before proceeding.
- Raise hands if they have a question.
- Wait for staff person to come over and assist them.
- Respond as *quickly* as possible on timed tests.
BASELINE TESTING
RECOMMENDATIONS

- Use the baseline testing link:
  - www.impacttestonline.com/(ORGANIZATION)/
  - Name / Date of birth
  - No SS# required

- Click “LAUNCH BASELINE TEST” button.
- Staff must remain quiet too.
- Athletes will finish the test at different times. Instruct them to leave the room quietly when they are done.
EVALUATING BASELINE RESULTS

Screen for invalid tests

Please Pick the Organization You Want to Manage: ImPACT High School
Starting Date: 1 Mar 2008 Ending Date: 21 May 2008

Number of Tests: 57

<table>
<thead>
<tr>
<th>Name</th>
<th>Date of Birth</th>
<th>Sport</th>
<th>Test</th>
<th>Test Date</th>
<th>Organization</th>
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<tr>
<td>Plandor, Brannon</td>
<td>02/02/1989</td>
<td>Basketball</td>
<td>Baseline</td>
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<td>Stier, Lynn</td>
<td>12/01/1966</td>
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<td>Zidron, Jeff</td>
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<td>03/05/2008</td>
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<td>Nurse, Linda</td>
<td>03/05/1956</td>
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<td>Baseline</td>
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<td>Douglass, Aaron</td>
<td>03/10/1978</td>
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<td>Baseline</td>
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<td>ImPACT High School</td>
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<tr>
<td>Doe, Jane</td>
<td>02/01/1961</td>
<td>Cheerleading</td>
<td>Baseline</td>
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<td>Sela, Amber</td>
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<td>Doe, John</td>
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<td>Csonka, Larry</td>
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<td>Eddie, Davis</td>
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<td>Baseline</td>
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<td>Knoop, Brett</td>
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<td>Football – Varsity</td>
<td>Baseline</td>
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EVALUATING BASELINE RESULTS

- Baseline Flagging Criteria
  - X’s and O’s **Total Incorrect** > 30
    OR
  - Impulse Control Composite > 30
    OR
  - Word Memory Learning Pct Correct < 69%
    OR
  - Design Memory Learning Pct Correct < 50%
    OR
  - Three Letters Total Letters Correct < 8
**EVALUATING BASELINE RESULTS**

- Repeat invalid tests
  - Use another form of the test ("Post-injury 1,2,3,4")
  - Do not repeat test same day
  - Cue student about weak areas of test to make sure instructions are understood.
- LD/ADHD students may not achieve “normal” test results.
- If baseline NOT repeated…
  - Use norms to estimate baseline taking clinical history into account.
Principal components of Immediate Postconcussion Assessment and Cognitive Testing
Enter the subject's identification number and date of birth below. If available, use the social security or social insurance number as the identification number. Otherwise, assign a unique identification number to the subject.

SSN/identification #: 
Date of Birth: / / (MM/DD/YYYY)

Check any of the following that apply:
- Received speech therapy
- Attended special education classes
- Repeated one or more years of school
- Diagnosed ADD or Hyperactive
- Diagnosed learning disability

Current sport
- Current position/event/class
- Current Level
- Years experience
Number of times diagnosed with a concussion
- Total number of concussions that resulted in loss of consciousness
- Total number of concussions that resulted in confusion
- Total number of concussions that resulted in difficulty with memory for events occurring immediately after injury
- Total number of concussions that resulted in difficulty with memory for events occurring immediately before injury
- Total games were missed as a direct result of all concussions combined.
- List the 5 most recent concussions
- Indicate whether you have experienced the following:
  - Treatment for headaches by physician
  - Treatments for migraine headaches
  - Treatment for epilepsy/seizures
  - History of brain surgery
  - History of meningitis
  - Treatment for substance/alcohol abuse
  - Treatment for psychiatric condition (depression, anxiety, etc.)
CURRENT SYMPTOMS

- Headache
- Nausea
- Vomiting
- Balance Problems
- Dizziness
- Fatigue
- Trouble falling asleep
- Sleeping more than usual
- Sleeping less than usual
- Drowsiness
- Sensitivity to light
- Sensitivity to noise
- Irritability
- Sadness
- Nervousness
- Feeling more emotional
- Numbness or tingling
- Feeling slowed down
- Feeling mentally foggy
- Difficulty concentrating
- Difficulty remembering
- Visual problems (blurry or double vision)
Module 1 (Word Discrimination)

- Evaluates attentional processes/verbal recognition memory
- Utilizes a word discrimination paradigm.
- Twelve target words are presented for 750 milliseconds (twice to facilitate learning of the list)
- The subject is then tested for recall via the presentation of the 24-word list that is:
  - comprised of 12 target words and 12 non-target words
  - Words chosen from the same semantic category as the target word.
  - EX: the word “ice” is a target word, while the word “snow” represents the non-target word.
  - The subject responds by mouse-clicking the “yes” or “no” buttons
  - Individual scores are provided both for correct “yes” and “no” responses - In addition, a total percent correct score is provided.
- There are five different forms of the word list.

Was Small one of the words displayed?

Yes  No
Module 1 (Word Discrimination)

• Counts toward Verbal Memory Composite
• Has no speed demands
Module 2 (Design Memory)

- Evaluates attentional processes and visual recognition memory
- Utilizes a design discrimination paradigm.
- Twelve target designs are presented for 750 milliseconds (twice to facilitate learning)
- The subject is then tested for recall via the presentation of the 24-designs

✓ comprised of 12 target designs and 12 non-target designs

✓ EX: target designs that have been rotated in space

✓ The subject responds by mouse-clicking the “yes” or “no” buttons

✓ Individual scores are provided both for correct “yes” and “no” responses

✓ In addition, a total percent correct score is provided

- There are five different forms of this task
Module 2 (Design Memory)

- Counts toward Visual Memory Composite
- Has no speed demands
Module 3 (X’s and O’s)

- Measures visual working memory, visual processing speed, and visual memory paradigm
- Encorporates a distractor task.
- The subject can practice the distractor task prior to presentation of the memory task
- The distractor is a choice reaction time test: the subject is asked to click the left mouse button if a blue square is presented and the right mouse button if a red circle is presented.
- Once the subject has completed this task, the memory task is presented.

✓ Memory task: a random assortment of X’s and O’s is displayed for 1.5 seconds
✓ For each trial: three of the X’s or O’s are illuminated in YELLOW (the subject has to remember the location of the illuminated objects).
✓ Immediately after the presentation of the 3 X’s or O’s, the distractor task re-appears on the screen.
✓ Following the distractor task, the memory screen (X’s and O’s) re-appears and the subject is asked to click on the previously illuminated X’s and O’s.
✓ Scores are provided for correct identification of the X’s and O’s (memory), reaction time for the distractor task, and number of errors on the distractor task.

- For each administration of ImPACT, the subject completes 4 trials.
Module 3 (X’s and O’s)

- Counts toward Visual Memory Composite
- 4 rounds of 3 = 12 possible

# Correct clicks > Visual Motor Speed Composite

# R/L errors >> Impulse Control
Module 4 (Symbol Matching)

- Evaluates visual processing speed, learning and memory
- Initially, the subject is presented with a screen that displays 9 common symbols (triangle, square, arrow, etc).
- Directly under each symbol is a number button from 1 to 9
- Below this grid, a symbol is presented.

✓ The subject is required to click the matching number as quickly as possible and to remember the symbol/number pairings
✓ Correct performance is reinforced through the illumination of a correctly clicked number in GREEN. Incorrect performance illuminates the number button in RED.
✓ Following the completion of 27 trials, the symbols disappear from the top grid.
✓ The symbols again appear below the grid and the subject is asked to recall the correct symbol/number pairing by clicking the appropriate number button.

- This module provides an average reaction time score and a score for the memory condition.
Module 4 (Symbol Matching)

- Clicking speed >> Reaction Time Composite

- Total Correct hidden (Trial 4) (____ of 9) >> Verbal Memory Composite
Module 5 (Color Match)

- Represents a choice reaction time task and measures impulse control/response inhibition
- First, the subject is required to respond by clicking a red, blue or green button as they are presented on the screen. This procedure is completed to assure that subsequent trials would not be affected by color blindness
- Next, a word is displayed on the screen in the same colored ink as the word (e.g. RED), or in a different colored ink (GREEN or BLUE)

✓ The subject is instructed to click in the box as quickly as possible only if the word is presented in the matching ink.

- In addition to providing a reaction time score, this task also provides an error score.

Color Word Match

This is a test of SPEED or REACTION TIME.

On the next screen, you will see the words RED, GREEN and BLUE presented one at a time. Click the word inside the box when it shown in the same color in which it is written. Do not click the word when it is shown in a different color.

For example:

Click as fast as you can when you see:  RED or  GREEN or  BLUE
Do not click when you see:  RED or  GREEN or  BLUE

Click this button when you are ready to begin:
Module 5 (Color Match)

- Avg. Correct RT >> Reaction Time Composite
- Any errors >> Impulse Control Composite

This is a test of SPEED or REACTION TIME.

On the next screen, you will see the words RED, GREEN and BLUE presented one at a time. Click the word inside the box when it shown in the same color in which it is written. Do not click the word when it is shown in a different color.

For example:

Click as fast as you can when you see: RED or GREEN or BLUE
Do not click when you see: RED or GREEN or BLUE

Click this button when you are ready to begin: Continue >>
Module 6 (Three letters)

- Measures **working memory** and **visual-motor response speed**
- First, the subject is allowed to practice a distractor task
  - Consists of 25 numbered buttons (5 x 5 grid).
  - The subject is instructed to click as quickly as possible on the numbered buttons in backward order starting with “25.” (has an initial practice task)
  - Then they are presented with three consonant letters displayed on the screen.
  - Immediately following display of the 3 letters, the numbered grid re-appears and the subject is instructed to click the numbered buttons in backward order, again
  - After a period of 18 seconds, the numbered grid disappears and the subject is asked to recall the three letters by typing them from the keyboard.
  - Both the number placement on the grid and letters displayed are randomized for each trial.
- Yields a **memory score** (total number of correctly identified letters) and a score for the average number of correctly clicked numbers per trial from the distractor test.
- Five trials of this task are presented for each administration of the test.
Module 6 – Three Letters

• Total correct letters (5/15)

>> Verbal Memory Composite

Average Counted Correctly >>

Visual Motor Speed Composite

C R J

Three-Letters (Pass 1 of 5)

Click each of these buttons in BACKWARD ORDER.

Start with 25 and count down to 1 AS FAST AS YOU CAN.

If you make a mistake, use the "Go back" button to clear the buttons you have already clicked, one at a time.
Module 1 (Word Memory)

Delay Condition: Following the administration of all other test modules (approximately 20 minutes), the subject is again tested for recall via the same method described above. The same scores that are described above are provided for the delay condition.
**Module 2 (Design Memory)**

**Delay Condition:** Following the administration of all other test modules (approximately 20 minutes), the subject is again tested for recall via the same method described above. The same scores that are described above are provided for the delay condition.
**ImPACT COMPOSITE SCORES**

- **Verbal Memory**
  - Word Memory Total % Correct
  - Symbol Match Total correct hidden symbols
  - Three Letters Total % Correct

- **Visual Memory**
  - Design Memory Total % Correct
  - X’s and O’s Total Correct

- **Visual Motor Speed**
  - X’s and O’s Total Number Correct / 4 (Interference)
  - Three Letters Avg. Counted Correctly X3

- **Reaction Time**
  - X’s and O’s Avg. Correct Interference RT
  - Symbol Match Avg. Correct RT
  - Color Match Avg. Correct RT

- **Impulse Control**
  - X’s and O’s Avg. Correct Interference RT
  - Color Match Total Commissions

- **Total Symptom Score**
  - 22 Symptoms (0-132)
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SYMPTOM ANALYSIS

- COMPARE
  - Clinical interview
  - ImPACT Total Symptom Score
- Analyze discrepancies
  - Hiding symptoms?
  - Prompted by questions?
  - Concussed and not thinking clearly?
Unreported Concussion in High School Football Players: Implications for Prevention

- Confidential survey completed after football season in Milwaukee area high schools
- 1,532 varsity football players from 20 high schools
- 29.9% reported a previous history of concussion
- 15.3% reported sustaining a concussion during the current football season.
- Of that 15.3%, 47.3% reported their injury.
Why were concussions not reported?

- Player did not think the injury was serious enough to warrant medical attention (66.4%)
- Did not want to be withheld from competition (41.0%)
- Not aware the injury was a probable concussion (36.1%).

# Clinical Report

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Impulse Control Analysis

- Validity measure (if > 20) ???
- Errors of disinhibition (control) under conditions of speed pressure ???
  - Right/Left confusion on X’s and O’s (Check if instructions reversed)
  - Color Match errors (mismatches)

- LD?
- ADHD?
- Inability to respond both quickly and accurately?
## Memory Speed

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ImPACT COMPOSITE SCORES

**Verbal Memory** – (left hemisphere)

1. Word Memory Total % Correct
   - **Immediate** (0-100%)
     - 12 Targets
     - 12 Foils *(some related meanings)*
   - **Delayed** (0-100%)
     - 12 Targets
     - 12 Foils *(some related meanings)*

2. Symbol Match Total correct hidden
   - 0 - 9

3. Three Letters Total % Correct
   - 0 – 15 *(after delay/interference)*
**ImPACT COMPOSITE SCORES**

- **Visual Memory** – (right hemisphere)
  1. Design Memory Total % Correct
     - **Immediate (0-100%)**
       - **12 Targets**
       - **12 Foils** (some rotated targets)
     - **Delayed (0-100%)**
       - **12 Targets**
       - **12 Foils** (some rotated targets)
  2. X’s and O’s Total Correct
     - % of 12 (4 rounds of 3 targets)
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ImPACT COMPOSITE SCORES

• **Visual Motor Speed**
  • *X’s and O’s Total Number Correct / 4 (Interference)*
  • *Three Letters Avg. Counted Correctly X3*

• **Affected by errors**
  • *Right-left errors reduce Total Correct*
  • *Counting 1 >> 25*
ImPACT COMPOSITE SCORES

• **Reaction Time**
  • *X’s and O’s Avg. Correct Interference RT*
    • Clicking to  
  • *Symbol Match Avg. Correct RT*
    • *Mouse/ click to matching numbers*
  • *Color Match Avg. Correct RT*
    • *Click when matched words appear*
    • **RED**  **BLUE**  **GREEN**
What is “significant” change?

- **RCI** – Reliable Change Index
  - Factors in regression to the mean and practice effects
  - Includes certain standard level of statistical probability

<table>
<thead>
<tr>
<th>Composite</th>
<th>Declined</th>
<th>Improved</th>
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<tbody>
<tr>
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<td>9 points</td>
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<tr>
<td>Visual Memory</td>
<td>14 points</td>
<td>14 points</td>
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<tr>
<td>Visual Motor Speed</td>
<td>3 points</td>
<td>7 points</td>
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<tr>
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<td>.06 seconds</td>
<td>.06 seconds</td>
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<tr>
<td>Post-Concussion Scale</td>
<td>10 points</td>
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</table>
What is “significant” change?

“However, scores that do not exceed the RCI Index may still be clinically significant.”

- Downward change of 15-20 %ile points or more with loss in most or all subtests of a composite.
- Drops after exertion, especially if area(s) were affected initially and had recovered.
- Larger changes in one composite or medium-size changes in 2 or more composites.
“Are we there yet?”

- Keeping all the balls in the air
  - Memory
  - Speed
  - Accuracy
  - Symptoms
Time course of recovery

Collins, et al. Neurosurgery 58:275-286,
64 high school athletes with “mild” concussion

Two groups compared on ImPACT performance
- Athletes with <5 min of signs/symptoms
- Athletes with 5-15 min of signs/symptoms
  » No athlete in sample sustained LOC

No athlete returned to contest

ImPACT evaluation obtained
- at Baseline
- Day 2, Day 4, and Day 7 post-injury

ImPACT MEMORY COMPOSITE SCORES
Brief versus Prolonged On-field Mental Status Changes

N = 64 High School Athletes

ImPACT Memory-Percent Correct

ImPACT SYMPTOM SCALE SCORES
Brief versus Prolonged On-field Mental Status Changes

N = 64 High School Athletes

Lovell, Collins, Iverson, Field, Podell, Cantu, Fu; J Neurosurgery; Feb, 2003

- **78 concussed symptomatic** athletes
- **44 concussed asymptomatic** athletes  
  (Mostly football players)
- **70 non-concussed control** athletes  
  (mostly non-contact sports)
- High school and college athletes
- All subjects pre-season baseline
- Concussed athletes tested about 2 days post
- Controls tested about 13 days post
* Neuropsychological test performance on ImPACT, a computer based test battery—Processing Speed Composite. Higher scores indicate better performance.
Univariate $F=33.6$ $p<.00000$.

*Neuropsychological test performance on ImPACT, a computer-based test battery- Reaction Time Composite. A lower score reflects better (faster) performance.*
EVIDENCE-BASED RETURN-TO-PLAY PROTOCOL

1. Symptom-free at rest
2. Recovery of ImPACT scores to baseline at rest
3. ImPACT scores remain stable following exertion.
4. Non-contact workouts without symptoms
   (1 WEEK SX-FREE)
   • Light contact without symptoms
   • Full contact without symptoms
Office Evaluation

- Two concussions in the last calendar year
- Three or more concussions in their lifetime
- Any prior neurological illness or condition
  - Seizures, ADHD, medications, etc.
- Substantial symptoms two weeks after injury
- Problems with completing school work.

- Extended neuropsychological evaluation
  - 3+ months of persisting symptoms and
  - Problems in academic work.
CASE #1: Using ImPACT

- Football kickoff receiver – age 15
- No prior concussions
- No history LD, ADHD, neurological, medications, medical issues
- Multiple hits in first half; hit twice blocking on one play >> left game 1 minute before halftime
- Initial Sx: arm tingling
CASE #1: Using ImPACT

- No Concussion Signs or Symptoms noted when initially seen for neck injury.
- Players and coach told ATC player was “not right” at halftime; emotional and crying.
- SAC = 23/30
- Minor headache, trouble remembering across first 6 days (reported by father).
CASE 1:
KICK-OFF RETURNER

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**CASE 1: KICK-OFF RETURNER**

**ImPACT Clinical Report**

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### ImPACT® Clinical Report

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*Note: The table highlights abnormal findings in red (Memory composite (verbal) and Reaction time composite) and highly abnormal findings in blue (Total Symptom Score).*
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Exertion

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* Composite Scores: Baseline scores are compared to post-concussion scores to evaluate recovery.
CASE #1 Issues

- Athletes minimize symptoms
  - ImPACT Symptom Score < report to father.
  - Returned to practice before cleared.
- Pressure for star player to return ASAP
- Need for parent & coach education
- Neurocognitive testing sometimes shows consistent focal deficits (Verbal Memory).
- Baseline testing valuable for showing some of the athlete’s normal capabilities.
MORE CASE STUDIES...
SPORTS CONCUSSION NEW ENGLAND

Smarter, Safer Concussion Management for the Student Athlete

www.sportsconcussion.net