Interesting Concussion Case Studies

Kevin Guskiewicz, PhD, ATC
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Case 2 – Collegiate Football Player
Accelerometry Instrumentation

- Head Impact Telemetry System (HITS)
- Sensors embedded in the padding of helmet
- Measures and records blows to the head:
  - Impact location
  - Impact magnitude
  - Impact duration
  - Linear and angular acceleration components
  - Exact times of impacts
HIT System™
Impact Algorithm

- Determines **magnitude** and **direction** of head c.g. acceleration \( (H) \) from 6 single axis accelerometers

- Determines 2 of 3 rotational accelerations depending on impact location (no z-axis rotation)

\[
\sum_{i=1}^{n} \left( \frac{\| \vec{H} \| \left( \cos \alpha_i \cos \alpha_H \cos (\theta_i - \theta_H) + \sin \alpha_i \sin \alpha_H \right) - \left\| \vec{a}_i \right\|}{\left\| \vec{a}_i \right\|^2} \right)^2
\]

Head Coordinate System
Azimuth = \( \alpha \)
Elevation = \( \theta \)
The HIT System™ Hardware
Accelerometry Instrumentation

HIT System™
Hardware in the Helmet

Telemetry, Data Acquisition, and Sensor Components

Player Units

HIT System™ Equipped
HIT System

- In-helmet units (6 single axis accelerometers, battery, and radio) communicate with a signal receiver and laptop computer system on the sideline (coverage: approx 150 yard radius).
- Positioned around the 50 yard line for games; centrally located between fields for practices
- 128 on-board memory – *can store up to 128 impacts during one session*
- Battery life – approx. 3-5 days
Case Study:
UNC Football Player

- 20-year-old Division I football defensive end
- Concussion #1: August 14, 2004
- Concussion #2: October 16, 2004
Concussion #1: August 14, 2004

Clinical Findings

- At the time of injury player reported experiencing 16 of 18 concussion symptoms on the Graded Symptom Checklist (GSC).

- SAC and BESS performed on the sideline revealed moderate deficits. Follow-up computerized neuropsychological (NP) and postural stability (PS) testing revealed moderate deficits through postinjury day 3.
### Post Concussion Symptom Checklist

<table>
<thead>
<tr>
<th>SYMPTOM</th>
<th>NONE</th>
<th>MILD</th>
<th>MODERATE</th>
<th>SEVERE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Headache</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Nausea/Vomiting</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td></td>
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<tr>
<td>Balance Problems</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Dizziness</td>
<td></td>
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<tr>
<td>Sensitivity to Light</td>
<td></td>
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<tr>
<td>Blurred Vision</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Sensitivity to Noise</td>
<td></td>
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<td></td>
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<tr>
<td>Nervousness</td>
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<tr>
<td>Numbness/Tingling</td>
<td></td>
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<tr>
<td>Feeling Slowed Down</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feeling Like “In a Fog”</td>
<td></td>
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<td></td>
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<tr>
<td>Difficulty Concentrating</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Difficulty Remembering</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neck Pain</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Fatigue/Drowsiness</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Difficulty sleeping</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sadness</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irritability</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Balance Error Scoring System (BESS)

Clinical Test Battery
- Six 20 sec trials using 3 different stances (double, single, tandem) on 2 different surfaces (firm, foam)

Recorded errors
- Hands lifted off iliac crests
- Opening eyes
- Step, stumble, or fall
- Moving into >30 deg. of hip flexion or abduction
- Remaining out of testing position for >5 secs.
Repeated measures ANOVA:
Group x Day interaction; $F(7, 142) = 7.52; p < .0001$
(significant differences through day 1 postinjury)

Balance Error Scoring System (BESS)
94 Injured & 56 Control NCAA FB players

McCrea et al (JAMA 2003)
**SAC**
Standardized Assessment of Concussion

**FORM A**

Name: ____________________________
Age: _______ Sex: ___________ Examiner: ______________________
Nature of Injury: __________________
Date of Exam: ___________ Time: ___________ Exam No. ___________

1) **ORIENTATION:**
Month: _______ 0 1 1
Date: ___________ 0 1 1
Day of week: ___________ 0 1 1
Year: ___________ 0 1 1
Time (within 1 hr.): ___________ 0 1 1
Orientation Total Score _______ / 5

2) **IMMEDIATE MEMORY:** (all 3 trials are completed regardless of score on trial 1 & 3; score equals sum across all 3 trials)

<table>
<thead>
<tr>
<th>List</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elbow</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Apple</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Carpet</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Saddle</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Bubble</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

Immediate Memory Total Score _______ / 15

Note: Do not inform the subject that delayed recall will be tested.

3) **CONCENTRATION:**

- **Digits Forward:** (If correct, go to next string length. If incorrect, read trial 2. Stop after incorrect on both trials)
  - 4-9-3 6-2-9 0 1
  - 3-8-1-4 3-2-7-9 0 1
  - 6-2-9-7-1 1-5-2-8-6 0 1
  - 7-1-8-4-6-2 5-3-9-1-4-8 0 1

- **Months in Reverse Order:** (Identical reverse sequence correct for 3 pt.)
  - Dec-Nov-Oct-Sep-Aug-Jul
  - Jan-Feb-Mar-Apr-May-Jun
  Concentration Total Score _______ / 5

4) **DELAYED RECALL:**

- Elbow 0 1
- Apple 0 1
- Carpet 0 1
- Saddle 0 1
- Bubble 0 1

Delayed Recall Total Score _______ / 5

5) **EXERTIONAL MANEUVERS:** (when appropriate)

- 5 Jumping jacks
- 5 Push-ups
- 5 Sit-ups
- 5 Lunge-bends

**NEUROLOGICAL SCREENING:**

- Loss of Consciousness (presence, duration)
- Recollection of Injury (pre- or post-traumatic amnesia)
- Strength:
- Sensation:
- Coordination:

**SUMMARY OF TOTAL SCORES:**

- Orientation _______ / 5
- Immediate Memory _______ / 15
- Concentration _______ / 5
- Delayed Recall _______ / 5

Overall Total Score _______ / 30

©Copyright McCrea, Kelly, Randolph 1998
Cognitive Recovery: Standardized Assessment of Concussion (SAC)

Concussion #1: August 14, 2004

**Clinical Findings**

- An MRI conducted on postinjury day 2 revealed no abnormalities, so the player was instructed to rest and attend team meetings as tolerated until symptoms resolved.

- Symptoms resolved over the course of 5 days, and he was returned to restricted participation, followed by full participation at postinjury days 6 and 7 respectively.
Impact Data: Concussion #1

- First impact
  - 9:55 a.m.
  - 79.18 g acceleration
Impact Data: Concussion #1

- **Second impact**
  - 10:06 a.m.
  - 97.97 g acceleration
Impact Data: Concussion #1

- Third impact
  - 7:30 p.m.
  - 64.51 g acceleration
Impact Data: Concussion #1

- Fourth impact
  - 7:33 p.m.
  - 63.95 g acceleration
Impact Data: Concussion #1

- All 4 significant impacts
  - 2 in morning session (79.18 & 97.97 g)
  - 2 in evening session (64.51 & 63.95 g)
Impact Data: Concussion #1

- 31 total impacts for both sessions
- Between 2.87 g to 97.97 g (mean = 28.95 g)
Cumulative Effects: Concussion #1

The graph shows the cumulative effects over time, with the x-axis representing impact time and the y-axis representing magnitude (Mag). The data is color-coded: Peak Lin Acc(g) in blue, HIC in green, and GSI in red. The peaks indicate significant impacts, with notable clusters around specific times.
Concussion #2: October 16, 2004

Clinical Findings

- Reported 13 of 18 concussion symptoms at the time of injury. Symptoms lingered for 10 days, with drowsiness, fatigue, and dizziness being the most persistent symptoms.

- Sideline SAC and BESS scores were again moderately depressed, however, serial assessments of NP and PS tests were significantly depressed during the initial 4 days postinjury.
Concussion #2: October 16, 2004

Clinical Findings

• An MRI was not conducted as part of the treatment, however, the player was evaluated by the team physician daily to insure detection of any neurological deterioration.

• Player withheld for 15 days before being permitted to return to full participation.
Case Study con’t

Relationship Between Concussion Symptoms and Postural Stability

- Symptoms (GSC)
- Postural Stability (SOT)
Impact Data: Concussion #2

- Impact in warm-up
  - 9:35 p.m.
  - 76.13 g acceleration
Impact Data: Concussion #2

- Impact in game
  - 10:08 p.m.
  - 102.39 g acceleration
Impact Data: Concussion #2

- 6 total impacts
- Between 13.10 g to 102.39 g (mean = 40.78 g)
Cumulative Effects: Concussion #2

Linear Acceleration, HIC, and GSI

- ImpMag(g)
- HIC
- GSI

Time vs. Magnitude
Conclusions

*Raises several intriguing questions with respect to sport-related concussion:*

1) was there a cumulative effect on the initial injury day, since there were two significant impacts during the morning practice?

2) could the threshold for injury be lowered because of these repetitive loads to the brain? “*Acute cumulative effect of sub-concussive impacts*”

3) was the delayed symptom recovery and depressed NP and PS scores following the repeat concussion a result of a more chronic cumulative effect, or simply a result of the increased magnitude (102 g)?