The Predictive Value of Treadmill Exercise Testing versus Computerized Neuropsychological Testing for Return to Sport in Adolescents with Concussion

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Background

• Athletes in the United States sustain 1.5 to 3.8 million sport related concussions yearly. Langlois JA et al 2006

• The return to sport (RTS) decision is challenging because symptom reports are subjective and have poor specificity. Boake C et al 2005

• Establishing asymptomatic at-rest status may also be difficult given the prevalence of daily symptoms reported by healthy people. Lovell MR et al 2006
Computer NP Testing

- ANAM and ImPACT computerized NP testing are among the most widely used programs.
- Ease of administration to large numbers.
- Test interpretation may be enhanced if baseline testing has been performed.
  - *Recent study - normative data (specific to age and gender) just as valid as baseline test data for interpreting post-injury tests. Schmidt JD et al 2012*
But…

- Computer NP testing has been shown to be affected by age, sex, symptoms, sleep, effort, testing conditions and concussion history.  
  Randolph C et al 2005; Schmidt JD et al 2012

- NP testing may be unavailable or limited by a lack of staff to reliably administer and interpret test results.

- Despite its growing popularity, the reliability and utility of computerized NP testing for concussion assessment has been questioned.  Randolph C et al 2005
• Computerized NP testing can be useful but RTS decisions should not be based solely upon its results.

• Athletes should not RTS until they have demonstrated the ability to perform to the maximum level of sport without recurrent symptoms.

• Progressive step-wise RTS protocol.
2009 Zurich Guidelines

### TABLE 1. Graduated Return to Play Protocol

<table>
<thead>
<tr>
<th>Rehabilitation Stage</th>
<th>Functional Exercise at Each Stage of Rehabilitation</th>
<th>Objective of Each Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. No activity</td>
<td>Complete physical and cognitive rest</td>
<td>Recovery</td>
</tr>
<tr>
<td>2. Light aerobic exercise</td>
<td>Walking, swimming or stationary cycling keeping intensity &gt;70% MPFR; no resistance training</td>
<td>Increase HR</td>
</tr>
<tr>
<td>3. Sport-specific exercise</td>
<td>Skating drills in ice hockey, running drills in soccer; no head impact activities</td>
<td>Add movement</td>
</tr>
<tr>
<td>4. Non-contact training drills</td>
<td>Progression to more complex training drills, eg, passing drills in football and ice hockey; may start progressive resistance training</td>
<td>Exercise, coordination, and cognitive load</td>
</tr>
<tr>
<td>5. Full contact practice</td>
<td>Following medical clearance, participate in normal training activities</td>
<td>Restore confidence and assess functional skills by coaching staff</td>
</tr>
<tr>
<td>6. Return to play</td>
<td>Normal game play</td>
<td></td>
</tr>
</tbody>
</table>

No scientific evidence to support this protocol
Is provocative exercise testing useful in the RTS decision?
Buffalo Concussion Treadmill Test (BCTT)

• Modification of the Balke Cardiac Treadmill test
  Leddy JJ et al 2010

• Safe and reliable for the evaluation of concussion in athletes with ongoing symptoms
  Leddy JJ et al 2011

• Exercise below symptom threshold is safe and effective in returning these athletes to sport
  Leddy JJ et al 2010
Buffalo Concussion Treadmill Test (BCTT)
Baker JG et al. “Return to full functioning after graded exercise assessment and progressive exercise treatment of postconcussive syndrome.” Rehabilitation Research and Practice 2012; 705309

• BCTT - Useful in the differential diagnosis of concussion patients with prolonged symptoms and in establishing a safe level of exercise for these patients.

  – 2/3 of those with ongoing symptoms had physiologic PCS. Most of rest were Cervicogenic.
Purpose

• Primary - evaluate the outcome of RTS decisions for concussed adolescents when based on the BCTT.

• Secondary - determine whether computerized NP testing has predictive value for RTS and return to school for adolescents.
Purpose

• Primary outcome - safe and successful return to sport without symptom recurrence.

• Secondary outcome - symptoms and/or complications upon return to school in adolescents after concussion.
Participants

• 82 athletes (78% male) with sport-related concussion who presented to the University at Buffalo Concussion Management Clinic.

• Age 19 or younger at the time of injury (mean 15.4 years; range 13-19 years)

• 32% reported having experienced prior concussions.

• Initial evaluation within 10 days of injury.
Procedures

• ANAM (n=66) or ImPACT (n=16) and the SCAT-2 symptom checklist.

• Once athletes reported being asymptomatic at rest (Median days from concussion = 22.6 days), they underwent final testing:
  – Computerized NP testing
  – SCAT-2
  – BCTT to exhaustion
Procedures

• Athletes who were able to exercise to voluntary exhaustion on the BCTT without exacerbation of symptoms were allowed to start the Zurich step-wise progression for RTS.

• A prospective telephone survey of athletes and one parent (minors) was performed asking about return to school or sport difficulties.
Analyses

• NP functioning was compared with normative data and rated as
  – Average (\(10^{th}\) percentile or higher)
  – Below Average (\(9^{th}\) percentile or lower) or
  – Clearly Below Average (\(2^{nd}\) percentile or lower)

• Statistics: Chi Square and Fisher’s Exact tests
Results

• All athletes exercised to exhaustion without exacerbation of concussion symptoms on BCTT.

• All athletes returned to sport without recurrent symptoms during sport.

• Same day Computerized NP results…
## Overall ANAM performance (n=66)

<table>
<thead>
<tr>
<th>ANAM Performance</th>
<th>Below average &lt; 9 percentile</th>
<th>Clearly below average &lt; 2 percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 subtests</td>
<td>42%</td>
<td>70%</td>
</tr>
<tr>
<td>1 subtests</td>
<td>26%</td>
<td>18%</td>
</tr>
<tr>
<td>2 subtests</td>
<td>18%</td>
<td>6%</td>
</tr>
<tr>
<td>3 subtests</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td>4 subtests</td>
<td>6%</td>
<td>3%</td>
</tr>
<tr>
<td>5 subtests</td>
<td>3%</td>
<td>0</td>
</tr>
<tr>
<td>6 subtests</td>
<td>2%</td>
<td>0</td>
</tr>
</tbody>
</table>
### Overall ImPACT performance (n=16)

<table>
<thead>
<tr>
<th>Total Composite Scores</th>
<th>Below average &lt; 9 percentile</th>
<th>Clearly below average &lt; 2 percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 Composite scores</td>
<td>69%</td>
<td>81%</td>
</tr>
<tr>
<td>1 Composite scores</td>
<td>25%</td>
<td>13%</td>
</tr>
<tr>
<td>4 Composite scores</td>
<td>6%</td>
<td>6%</td>
</tr>
</tbody>
</table>
Results

- No athlete returned to clinic for difficulty with RTS.

- Phone contact follow up with 50 athletes collected 3-41 months (mean 18.8 ± 10.8 months) after RTS revealed that none had experienced recurrence of symptoms during sport.
Results

- 38% reported some symptoms with school activities.
- NP test performance did not predict symptoms reported on the day of the treadmill test or symptoms reported upon return to school.
## Symptoms upon Return to School

<table>
<thead>
<tr>
<th></th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>N=49</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal NP Test</td>
<td>9 (18%)</td>
<td>19 (39%)</td>
</tr>
<tr>
<td>≥1 Abnormal NP Subtest</td>
<td>5 (10%)</td>
<td>16 (33%)</td>
</tr>
</tbody>
</table>

Not significant, p > .05
New Symptoms

<table>
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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>N=49</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal NP Test</td>
<td>6 (12%)</td>
<td>22 (45%)</td>
</tr>
<tr>
<td>≥1 Abnormal NP Subtest</td>
<td>5 (10%)</td>
<td>16 (33%)</td>
</tr>
</tbody>
</table>

Not significant, p > .05
School Issues
Parent or Adult (over age 18) report of school issues

<table>
<thead>
<tr>
<th>N = 50</th>
<th>School Issues</th>
<th>No School Issues</th>
</tr>
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<tbody>
<tr>
<td>Normal NP Test</td>
<td>10 (20%)</td>
<td>14 (28%)</td>
</tr>
<tr>
<td>≥1 Abnormal NP Subtest</td>
<td>9 (18%)</td>
<td>17 (34%)</td>
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Not significant, p > .05
### New School Issues

<table>
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<tr>
<td>N = 50</td>
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<td></td>
</tr>
<tr>
<td>Normal NP Test</td>
<td>9 (18%)</td>
<td>19 (38%)</td>
</tr>
<tr>
<td>≥1 Abnormal NP Subtest</td>
<td>3 (6%)</td>
<td>19 (38%)</td>
</tr>
</tbody>
</table>

Not significant, p > .05
Limitations

• Sample size.

• Evaluation of the predictive nature of NP testing might have been enhanced if athletes had baseline data.
Limitations

• Follow up period was variable and memory of school adjustment issues may have faded.

• Safe and successful RTS (without symptom exacerbation) may not capture subtle cognitive issues represented by NP testing.
Conclusions

• The BCTT in combination with the application of the *Zurich guidelines* was 100% successful for safe RTS in adolescent athletes.

• Computerized NP test performance did not relate statistically to RTS and was not associated with symptoms on the day of the treadmill test or symptoms reported upon return to school.
Significance

• A standardized exercise stress test may be a useful indicator of readiness to RTS after concussion.

• Computerized NP testing performed at rest, at least in athletes who do not have a pre-injury “baseline” NP test, does not appear to be useful in the RTS decision process.
Thank you for your kind attention

SUNY Buffalo
Concussion Management Clinic