Validation of Postural Stability Assessment Using Accelerometer and Gyroscopic Measures

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Background

Based on the 2012 Consensus Statement on Concussion in Sport, neuropsychological testing is a valuable tool in concussion management. However, “the presentation of symptoms and rate of recovery can be variable, which reinforces the value of assessing all three areas (symptoms, balance, and cognition) as part of a comprehensive sport concussion program” (McCrory et al., 2013).

The primary aim of this project was to develop a reliable, portable and cost-effective method of objectively quantifying balance and postural stability. The C3 Logix Application was developed on the Apple iPad™ platform to determine the feasibility of using accelerometer and gyroscope data for the assessment of postural stability.

The secondary aim was to determine the feasibility of using the C3 Logix App to support concussion management by ATCs and clinicians within the Cleveland Clinic Health System.

Methods and Hardware

Forty-nine (22 male, 27 female) healthy subjects between 14-25 years of age (19.5 ± 3.1) completed the Sensory Organization Test (SOT) and the Balance Error Scoring System (BESS) with an Apple iPad affixed at mid-sagittal level via a customized belt. Data was collected at a sampling rate of 100 Hz using the iPad’s native hardware provide a precise and reliable assessment of postural stability with iPad motion sensors (±250 g, ±2.0° resolution).

Application code was written in objective C for use across multiple mobile device platforms.

Validation of Postural Stability Assessment with iPad

Validation Conclusions

Accelerometer and gyroscope data provided by the iPad’s native hardware provide a precise and reliable assessment of postural stability relative to the “gold standard” SOT. The developed measures can be used to objectively quantify postural stability during the performance of a clinical balance test (BESS) specifically designed and validated for concussion assessment.

Three-dimensional volume metric may be useful for identifying postural instability, determining need for secondary referral for rehabilitation or intervention, and tracking post-injury recovery.

The objectivity of this approach combined with the portability and accessibility of the iPad platform may make this solution ideal for clinical and in-the-field use in the evaluation and monitoring of athletes post-concussion.

ATC Utilization of C3 Logix Application

C3 Logix Test Battery

1. Graded Symptom Checklist
2. Simple Reaction Time
3. Trail Making Test A & B
4. Memory & Processing Speed
5. Balance Assessment

C3 Logix App provides ATCs with a portable and quantitative method of assessing postural stability with iPad motion sensors.

Field Utilization Conclusions

- The C3 Logix App provides ATCs with a portable and quantitative method of assessing balance, dynamic visual acuity, and neuropsychological domains including set switching, information processing, working memory and learning.
- C3 Logix provides a standardized method of assessing the multifactorial manifestation of concussion across a system with multiple providers of care.
- We are currently assessing the efficacy of using C3 Logix in return-to-play decision-making and in guiding care in cases of a complicated recovery.

Acknowledgements

Supported by the Lincy Foundation and the Bell Family. We thank Patrick Cummings PTA, ATC for initial discussions regarding the clinical utility of this approach and all of the Cleveland Clinic Athletic Trainers and Staff who participated in data collection.

| Field Utilization | C3 Logix App | Other
|-------------------|-------------|------|
| Balance Assessment | C3 Logix App | Other methods available
| Memory & Processing Speed | C3 Logix App | Other methods available
| Simple Reaction Time | C3 Logix App | Other methods available
| Trail Making Test A & B | C3 Logix App | Other methods available
| Graded Symptom Checklist | C3 Logix App | Other methods available

Statistical Analysis

- 3-D Postural Stability metric showed significant differences between surfaces during double-leg stance, while BESS Errors show no difference in performance (zero errors recorded across entire test population).
- Normalized volumes are significantly different between surfaces within each stance (***p<0.001).
- Floor effect and subjectivity of Error Count removed by 3-D Postural Stability assessment in double-leg stance.

Rater Error Count

- iPad sensor data was fit to center-of-gravity (COG) sway output from NeuroCom using a non-linear, mixed effects model comprised of a 5-knot restricted cubic spline and a sine function.

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<th>Rater Error Count</th>
<th>iPad sensor data</th>
<th>NeuroCom data</th>
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Normalized 3-D Volume

- 3-D Postural Stability assessment in double-leg stance

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Graded Symptom Checklist

- Symptom tracking and management (by domain)

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- 36 Cleveland Clinic Certified Athletic Trainers, 46 high schools and colleges
- 4921 Fall 2012 Baseline Tests (3834 M, 1087 F): Football, Soccer, Volleyball
- 482 well-characterized concussions: when injury suspected, Incident Report filed and Follow Up Assessments completed until athlete is returned to play
- Comprehensive visualization of performance on follow-up assessments compared to baseline highlights impairments in specific domains and allows more timely referral to specialists for intervention