Validity and Reliability of Mobile Postural Stability Testing Devices for use in Clinical Concussion Assessment

Haley C. Seymour, Nicole B. Brashears, Kho T. Roberts, Amanda A. Mock, Michelle A. Cleary PhD, ATC, CSCS; Tricia M. Kasamatsu PhD, ATC,* Athletic Training Education Program, Chapman University, Orange, CA; *University of La Verne, La Verne, CA

Postural stability, or the ability of a person to maintain, achieve or restore a specific state of balance without falling, has been shown to be a chief indicator of musculoskeletal health.1 Consequently neurologic conditions, such as stroke-related concussion, may be associated with changes in postural stability. At the third International Conference on Concussion in Sport, clinicians established that postural stability can be used to determine the motor domain of neurologic function.2 Athlete training (ATs) and other healthcare professionals have access to a variety of clinical tests assessing postural stability. Recently, mobile technology, including applications for smartphones/tablets (iPod, Apple, Inc., Cupertino, CA) that use the accelerometer and gyroscope of the device, has been proposed to assess postural stability. These devices have become increasingly popular in evaluating balance, however, internal validity and assessment is limited. It is important for ATs to have access to valid and reliable clinical tests for postural stability evaluation to assist in the diagnosis of sports-related concussion and implementation of educational resources to play decisions.

Objective
The purpose of our study was to:
1. Explore the reliability of mobile postural stability tests including a pressure-sensing platform (MobileMat®, Tekscan, Inc., Boston, MA) and a mobile smartphone/tablet application (SwayBalance®, SwayMedical LLC, Tulsa, OK).
2. Establish validity of the mobile postural stability tests in comparison to the laboratory gold-standard forceplate device (a forceplate device, BioSway®, BioSway® System, Shirling, NY) as well as the commonly clinically used modified Balance Error Scoring System (mBESS).

The research questions that guided this investigation were as follows:
1. Are ATs using reliable tools for assessing concussion in sport?
2. How do mobile postural stability tests compare to the gold-standard device?

Methods
Research Design
Each participant completed three different testing stations: the pressure sensing platform, the mobile smartphone/tablet application, and the forceplate device. Participants were assigned a randomized and counterbalanced order of stations. All participants completed three trials of each station. The tests are as described as below and the research design may be found in Figure 1.

- MobileMat®, the pressure sensing platform: participants performed the Balance Error Scoring System (mBESS) on the mobile and balance tasks (tandem stance) on both a firm and a foam surface for 20 seconds with eyes closed on top of the platform. Participants were video recorded while performing this test. Then, three clinicians with pre-established interrater reliability scored each participant on the modified Balance Error Scoring System (mBESS). All 30 participants were scored by the double leg stance.1,4

- SwayBalance®, the mobile smartphone/tablet application: participants completed five different stations (double leg, both single legs and both tandem positions) for 10 seconds each on a surface while holding the tablet with both arms against their chest and while closing their eyes.

- BioSway®, the forceplate device: participants completed double leg stance, single leg and double leg on both a firm and foam surface on top of the forceplate device for 30 seconds each (modified Clinical Test of Sensory Integration on Balance, mCTSIB).

Results
Means and standard deviations for three devices is provided in Table 1.

<table>
<thead>
<tr>
<th>Device</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SwayBalance</td>
<td>6.46</td>
<td>6.376</td>
</tr>
<tr>
<td>BioSway®</td>
<td>0.95</td>
<td>0.170</td>
</tr>
<tr>
<td>MobileMat®</td>
<td>20.39</td>
<td>5.916</td>
</tr>
</tbody>
</table>

Table 1. Item Statistics for Four Devices Composite Mean (N=31)

Intrarater Consistency of Devices
- The internal consistency of the devices within trials yielded Cronbach’s α = 0.91, 0.93, 0.86. The SwayBalance® test yielded a Cronbach’s α = 0.939. (Figure 2).

- Comparisons of the four devices yielded single measure ICC = 0.269 (95% CI = 0.096-0.479, p<0.001) and average measure ICC = 0.595 (95% CI = 0.299-0.786, p<0.001).

Reliability of Devices
- Average measure intra-device reliability scores were excellent for MobileMat® ICCAA = .849 (95% CI = .727-.922, p<0.001), mBESS ICC = 0.809 (95% CI = 0.795-0.824, p<0.001), SwayBalance® ICC = 0.805 (95% CI = 0.806-0.886, p<0.001), and SwayBalance® ICC = 0.805 (95% CI = 0.795-0.815, p<0.001) (Table 2).

- Single Measure Intra-device reliability scores were moderate for MobileMat® ICCAA = .653 (95% CI = .470-.799, p<0.001) and mBESS ICC = 0.586 (95% CI = 0.413-0.730, p<0.001), moderate for BioSway® ICC = 0.739 (95% CI = 0.586-0.851, p<0.001), and excellent for SwayBalance® ICC = 0.869 (95% CI = 0.772-0.925, p<0.001) (Figure 2).

Figure 1. Research design with Main Outcome measures

Discussion
- The major findings of this investigation were that each mobile postural stability test was reliable within itself however was not valid compared to the BioSway® forceplate device, nor strongly correlated to any other test. All devices demonstrated excellent average intra-device reliability (ICC ≥ 0.849) and moderate to excellent single measure intra-device reliability (ICC ≥ 0.849).

- We hypothesized that no test correlated strongly to the BioSway® device which was limited in that it only tested double leg stance. In 2009, the BESS test was modified into mBESS to omit the double leg stance because of lack of errors. By omitting the double leg stance, greater reliability was achieved. This study demonstrated that there were lack of errors with mBESS and SwayBalance® which makes sense because there was no errors on the double-leg BioSway® stance, resulting in poor correlations to other devices.

- One limitation of this study is that participants are from a highly homogeneous group. Other limitations include differences between devices, in the three tests, differences for stance directions within a test (i.e. with MobileMat® participant is directed to keep legs straight in tandem stance and with SwayBalance® they are 90°), and different densities of the foam pad used.

- It is important to note that all comparisons being made are from the composite/average scores of all stance. A future study should investigate how individual stances compare to each other between devices.

- In future research, a similar study should be conducted using the BESS protocol on the BioSway® device instead of the mCTSIB protocol which was used in this investigation.

Conclusions
All the devices were found to have moderate to excellent intra-device reliability, however, scores generated by these tests did not significantly correlate with the gold standard forceplate device. Clinicians should use caution when interpreting data from these mobile postural stability tests. All these tests are used in the clinical setting, baseline testing should utilize the same test that will be used post-injury.

Based on our findings, we have arrived at the following conclusions:
1. All of the tested mobile postural stability testing devices are reliable within themselves.
2. The postural stability tests have not been demonstrated to be valid compared to each other.
3. Clinicians should use caution when changing between postural stability tests. Ideally a clinician will use post-test that is compatible with their clinical population.
4. Determining the device of validity when comparing the individual devices to each another, results from one test cannot and should not be transferred from device to device.

References