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

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## Context

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 sports-related concussions, may be associated with disturbances 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] Athletic trainers (ATs) and other healthcare professionals have access to a variety of clinical tests to assess postural stability. Recently, mobile technology, including applications for smartphone/tablets (iPad, Apple, Inc., Cupertino, CA) that use the accelerometer of the device and pressure-sensing platforms have been created to assess postural stability. These devices have become increasingly popular in evaluating balance, however their reliability 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 educated return-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®, Biodex Stability System, Shirley, NY), as well as the common clinically used modified Balance Error Scoring System.

The research questions that guided this investigation were as follows:

1. Are ATs using reliable tools for assessing concussion in sport?
2. How do new mobile postural stability tests compare to the gold-standard device?

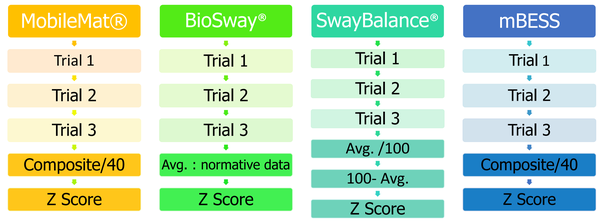
## Methods

### 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 stances (double leg, single leg, and tandem stances) on both a firm and 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)**, which omits the double leg stances.[3,4]
- **SwayBalance®, the mobile smartphone/tablet application:** participants completed five different stances (double leg, both single legs and both tandem directions) for 10 seconds each on a tile surface while holding the tablet with both arms against their chest and while closing their eyes.
- **BioSway®, the Forceplate device:** participants completed double leg eyes open and double leg eyes closed stances 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).

**Figure 1.** Research design with Main Outcome measures




### Participants

- 31 uninjured, college-aged healthy individuals of both genders participated in our study (19 females, 12 males, age= 20.4±1.2 yrs, mass=69.3±13.2 kg, height=170.4±11.3 cm).
- Participants were recruited through presentation in classes at Chapman University.
- Participants were excluded if they sustained a head or lower extremity injury in the last six months or if they suffered from any visual, vestibular or balance disorders. ATs cleared participants to participate based on a health history questionnaire and graded symptom checklist (if athletes reported being symptomatic, the discretion of the AT determined their participation).
- Participants read and signed an inform consent form. The study was approved by the Institutional Review Board.
- All participants received a $10 gift card for participating in this study.
- All data were collected anonymously without patient identifiers and remained on a password-protected computer in encrypted files.

### Main Outcome Measures

Each mobile postural stability test generated objective scores of participant performance:

- MobileMat® generated a score representing the number of times the patient deviated from the given stance with a maximum of 10 errors per stance. The double-leg stances were not included in data analysis. The maximum score was 40 points/errors.
- SwayBalance® produced a score between 0 and 100 for each stance as well as an average of all stances, with 100 representing perfect balance. The composite score was subtracted from 100 to elicit a score that was higher with worse balance.
- BioSway® generated a score in comparison to the mean normative range for the participant's demographic profile. The composite sway index was used for data analysis.

Modified BESS was used as the subjective clinical comparison device. Three clinicians with pre-established interrater reliability separately scored each participant on a video recording of the pressure-sensing platform performance. There was a maximum of 10 errors per stance with composite maximum of 40 errors. Scores were averaged between scorers. Further statistics on the comparison of MobileMat® to mBESS can be found on our companion poster, "Relationship Between Pressure-Sensing Platforms and Subjective mBESS Tests in Diagnosing Mild Traumatic Brain Injuries."

### Statistical Analyses

- Composite scores of all tests were transformed into Z scores using Statistical Package for the Social Sciences (SPSS) Version 19 (IBM, Chicago, IL).
- Internal consistency was calculated using Cronbach's α, with $p<.05$ for all analyses.
- Z scores were calculated into Interclass correlation coefficients (ICCs) and confidence intervals (CI) to determine intra-device reliability and concurrent validity.

## Results

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

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

| | Mean | Std. Deviation |
|---|---|---|
| **SwayBalance®** | 6.46 | 6.376 |
| **BioSway®** | 0.95 | 0.170 |
| **MobileMat®** | 20.39 | 5.916 |
| **mBESS** | 10.24 | 3.002 |

### Internal Consistency of Devices

- The internal consistency of the devices within trials yielded Cronbach's α for SwayBalance® =0.952, BioSway® =0.895, mBESS =0.868, and MobileMat® =0.849. (Figure 2).
- Comparisons of the four devices yielded single measure $ICC_{30,90}$ =0.269 (95% CI =0.096-0.479, $p\leq0.001$) and average measure $ICC_{30,90}$ =0.595 (95% CI =0.299-0.786, $p\leq0.001$).

### Reliability of Devices

- Average measure intra-device reliability scores were excellent for MobileMat® $ICC_{30,60}$ =.849 (95% CI =.727-.922, $p\leq.001$), mBESS $ICC_{30,60}$ =.868 (95% CI =.760-.932, $p\leq.001$), BioSway® $ICC_{30,60}$ =.895, (95% CI =.809-.946, $p\leq.001$), and SwayBalance® $ICC_{30,60}$ =.952 (95% CI =.913-.975, $p\leq.001$) (Figure 2).
- Single measure intra-device reliability scores were moderate for MobileMat® $ICC_{30,60}$ =.653 (95% CI =.470-.799, $p\leq.001$) and mBESS $ICC_{30,60}$ =.686 (95% CI =.513-820, $p\leq.001$), substantial for BioSway® $ICC_{30,60}$ =.739 (95% CI =.586-.853, $p\leq.001$), and excellent for SwayBalance® $ICC_{30,60}$ =.869 (95% CI =.772-930, $p\leq.001$) (Figure 2).

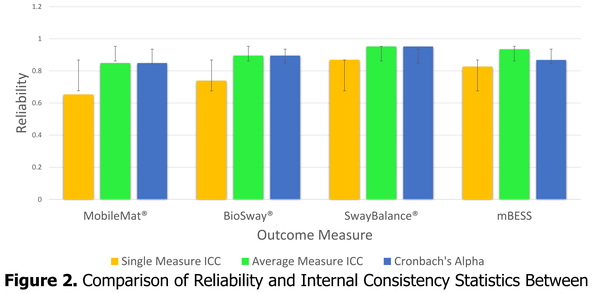



**Figure 2.** Comparison of Reliability and Internal Consistency Statistics Between Tests

### Concurrent Validity of Devices

- Individual comparisons of composite means for the four tests were poor for mBESS to BioSway® $ICC_{30,90}$ =0.011, MobileMat® to BioSway® $ICC_{30,90}$ =0.023, and SwayBalance® to BioSway® $ICC_{30,90}$ =0.106, and moderate for MobileMat® to SwayBalance® $ICC_{30,90}$ =0.418, mBESS to SwayBalance® $ICC_{30,90}$ =0.451, and MobileMat® to mBESS $ICC_{30,90}$ =0.541 (Table 2).

**Table 2.** Inter-Item Correlation Matrix for Four Device's Z-scores for means of all trials (N=31)

| | BioSway® | MobileMat® | mBESS |
|---|---|---|---|
| **SwayBalance®** | .106 | .418 | 0.451 |
| **BioSway®** | | .023 | 0.011 |
| **MobileMat®** | | | 0.541 |

## 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 measure intra-device reliability (ICC ≥ 0.849) and moderate to excellent single measure intra-device reliability (ICC =0.653-0.827).
- We hypothesized that no test correlated strongly to the BioSway® device which was limited in that it only tested double leg stances. In 2009, the BESS test was modified into mBESS to omit the double leg stances because of lack of errors. By omitting the double leg stances, greater reliability was achieved.[4] Similarly, we hypothesized that there was a lack of significant errors on the double-leg BioSway® stances, resulting in poor correlations to other tests.
- One limitation of this study is that participants are from a highly homogenous group. Other limitations include differences between stances 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 where as with SwayBalance® they are not), 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 stances. A future study should investigate how individual stances compare to each other between devices.
- In future research, a similar study should be completed using the BESS protocol on the BioSway® device instead of the mCTSIB protocol which was used in this investigation.

## Conclusion

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. If 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 choose one test to implement in their setting and complete both baseline and post-injury testing with the same device.
4. Due to the lack of validity when comparing the individual tests to one another, results from one test cannot and should not be transferred from device to device.

## References

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