Comparison of a Mobile Technology Application with the Balance Error Scoring System

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Context: The most widely used method for postural balance assessment relies on the subjective observations of a test administrator. Accelerometry has been shown to provide a valid and reliable method for assessment of balance, and recent advances in microelectromechanical systems have made the technology available in mobile electronic devices. **Objective**: To compare a mobile technology application with a commonly used subjective balance assessment. **Setting**: Biomechanics laboratory. **Participants**: Twenty-one nonathlete college-aged individuals (7 men, 14 women; mean age 23 ± 3 years) volunteered to participate. Subjects were excluded if they reported any preexisting condition that might affect postural balance. **Results:** A strong inverse correlation was found between the scores for the two balance assessment methods ($r = -.767$, $p < .01$). **Conclusions:** Advances in technology have provided an attractive means to objectively quantify postural balance with off-the-shelf mobile consumer electronic devices.

Keywords: accelerometer, postural balance, balance error scoring system

A variety of postural balance assessment techniques are currently used that include both subjective and objective methods. Subjective balance assessment methods involve tasks that range in difficulty from simple static standing to conditions that alter peripheral sensory feedback. Such assessments can generally be administered in a few minutes, require little or no equipment, and impose no cost. The Balance Error Scoring System (BESS), Berg Balance Scale, and Tinetti Balance Assessment have been shown to be valid and reliable methods for various populations,[1–5] but they rely on the test administrator's knowledge and clinical experience to properly score the assessment.[6]

Because of the subjective nature of many balance assessments, an instrumented method may provide a more objective representation of an individual's ability to maintain postural balance. One method for objective quantification of postural stability is accelerometry. Accelerometers are electromechanical sensors that produce an electrical output that is proportional to an acceleration input.[7] Accelerometers have been shown to provide valid and reliable measurements of postural balance.[8–10] Recent advances in microelectromechanical systems have reduced both the physical size and the manufacturing cost of accelerometers, which has allowed for incorporation into many different off-the-shelf mobile consumer electronic devices (e.g., smartphones, tablet computers, gaming systems).[11] A wireless accelerometry system for assessment of gait and balance has been used by Lemoyne et al.[12–16] Additionally, Amick et al.[17] have demonstrated that the triaxial accelerometer installed in iPod Touch devices provides highly consistent measurement precision.

BESS is a clinical assessment of three different standing conditions, including bipedal standing (feet together), nondominant single-leg stance, and tandem standing (heel to toe with nondominant foot behind

http://dx.doi.org/10.1123/ijatt.2013-0094

the dominant foot), that are assessed on both firm and compliant surfaces. During each 20-s trial, a test administrator records the number of predefined errors committed by the test subject (Table 1). A BESS score is calculated by summing the total number of errors observed (i.e., a high score indicates poor balance).[1]

The BESS assessment has been reported to provide a score with moderate to good overall reliability,[1] but values reported in the literature have varied widely. Hunt et al.[18] reported an intraclass correlation coefficient (ICC) of .60 for interrater reliability, and Finnoff et al.[19] reported a corresponding ICC of .74. However, reported ICC values for interrater reliability have ranged from .50 to .88 for the different stance conditions. Riemann and Guskiewicz.[20] reported interrater ICC values that ranged from .96 to .87, but Finnoff et al.[19] reported an overall interrater ICC value of .57 and values that ranged from .44 to .83 for the different stance conditions. For both intrarater and interrater reliability, more consistency was found for the more stable stance conditions and less consistency was found for the less stable stance conditions. Variability in BESS scoring is likely because of the subjective nature of the assignment of test errors.

Table 1. Balance Error Scoring System Errors (BESS)
Moving the hands off of the hips
Opening the eyes
Step, stumble, or fall
Hip flexion or abduction greater than 30°
Lifting the forefoot or heel off of the testing surface
Remaining out of testing position for more than 5 seconds

SWAY Balance (SWAY Medical, Tulsa, OK) is a mobile device application that uses triaxial accelerometer output to quantify postural sway during the performance of a series of tasks. The SWAY Balance test consists of five stance conditions (Figure 1), each of which is performed for 10 s on a firm surface and with the eyes closed. Deflections of the triaxial accelerometer are recorded throughout each of the tasks, and units that correspond to the accelerations are used to calculate a final balance score. The purpose of this study was to compare the SWAY Balance mobile application balance score with the BESS score.

Procedures and Findings

Twenty-one nonathlete college-aged individuals (7 men, 14 women; mean age 23 ± 3 years) volunteered to participate in this study (Table 2), which was approved by the Wichita State University Institutional Review Board for Research Involving Human Subjects. Subjects were excluded from participation if they reported any preexisting condition that might affect postural balance.

The subjects performed both the BESS and the SWAY Balance mobile application testing protocols, which were administered in a randomized order. The SWAY Balance test was administered using an Apple iPod Touch (Apple Computer Inc., Cupertino, CA) with

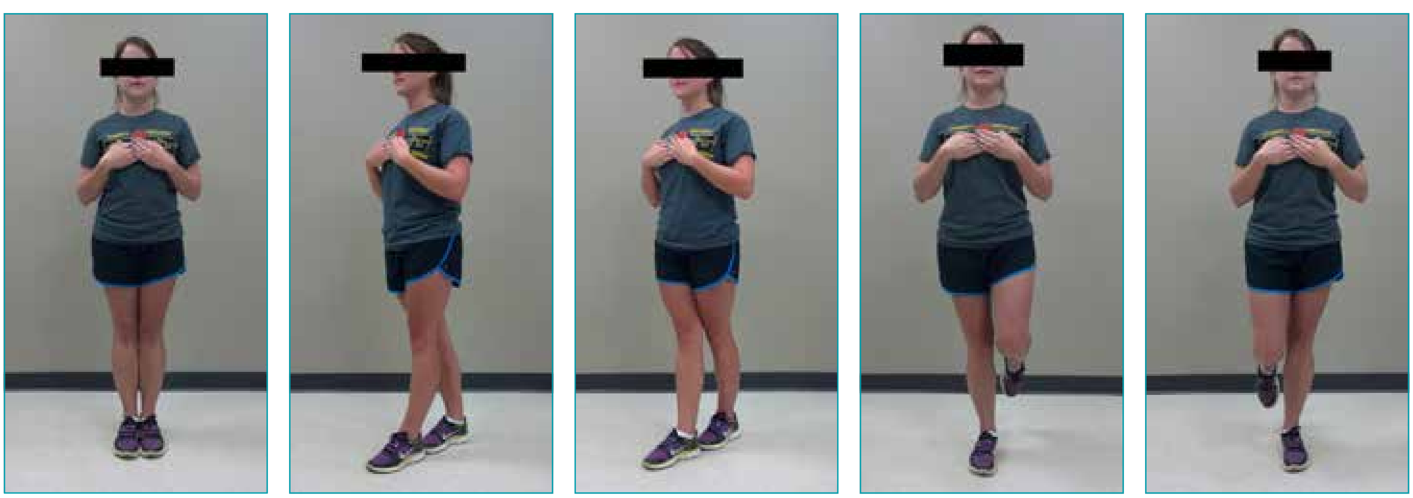

Figure 1 SWAY Mobile Application Balance Assessment Stances

Table 2. Subject Demographic Information		
	Mean ± Standard Deviation	Range
Age (years)	23.04 ± 3.34	19 - 32
Weight (kg)	82.76 ± 25.69	52.62 - 156.94
Height (cm)	171.66 ± 10.20	151.4 - 191.8
BMI (kg/m^2)	27.78 ± 6.91	20.19 – 49.81

the SWAY software. Subjects were instructed to use both hands to press the face of the device against the midpoint of the sternum and to hold the device upright with its top edge maintained below a line horizontal with the clavicles. All subjects completed a familiarization trial, which was immediately followed by an experimental trial. On completion of each balance task, instructions for the next balance task were provided on the device screen. After all balance tasks were completed, a balance score was calculated and recorded (i.e., a high score indicates good balance). The BESS assessments were conducted by two test administrators experienced in assessing balance. Subjects performed three balance tasks on a solid support surface, followed by performance of the same three tasks on a compliant foam surface. The standard BESS procedure was modified by having the subjects replicate the position of the hands during the SWAY Balance test. The BESS scoring criteria were modified to accommodate the alteration in the position of the hands. The overall BESS score was the average of the total error scores recorded by the two test administrators.

The mean BESS score was 10.4 (± 5.98), and the mean SWAY Balance score was 79.62 (± 18.28). A strong[21] inverse correlation was found between the BESS and SWAY Balance scores (r = -.767, p < .01).

Discussion

Personal electronic devices such as smartphones, media players, and tablet computers now incorporate triaxial accelerometers. Consequently, such devices have the potential to be used for biomechanical analyses of postural balance and movement.[13–16,22–24] Initial testing has demonstrated that reliable measurements can be obtained.[17,24] The BESS assessment was chosen for comparison because of its widespread use as a clinical assessment. The BESS has been found to provide values that have moderate to good reliability,[1] and it has been shown to be a valid method for assessment of postural balance impairment associated with concussion,[20,25] exertional fatigue,[26–28] ankle instability,[29] and advanced age.[30] Additionally, normative data are available for qualitative assessment of an individual's BESS performance. The BESS scores we recorded were between the 25th and 75th percentiles reported for the same age category by Iverson et al.[30]

Our results demonstrated a strong inverse correlation between the SWAY Balance and BESS values. The inverse nature of the correlation is readily explained by the difference in the structure of the two scoring systems. An elevated BESS score reflects a high number of balance errors, whereas the SWAY Balance score assigns a higher value to a more stable performance. Mobile electronic devices are widely accessible, relatively inexpensive, and easy to use, all of which make the SWAY Balance application a potentially valuable method for objective documentation of postural stability that does not require a skilled test administrator. However, further research is needed to establish the clinical utility of the postural stability measurement derived from this method for management of specific types of injury.

Conclusion

Advances in technology have provided an attractive means to objectively quantify postural balance with off-the-shelf mobile consumer electronic devices. The SWAY Balance mobile technology application provides a postural balance score that demonstrated a moderately strong inverse correlation to the score derived from the BESS method. ▮

Acknowledgment

We acknowledge the support of Sway Medical LLC, Tulsa, OK, for supplying the mobile devices and providing access to SWAY Balance software.

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