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DIAGNOSTIC METHODS: Original Research

# Studying the correlation between balance assessment by Biodex Stability System and Berg Scale in stroke individuals

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ABSTRACT

*Introduction:* Balance disorders are considered to be a serious clinical manifestation after stroke. Therefore, to assess stroke patients' balance performance, use of a quantitative method appears essential. A fundamental step would be the approval of the efficiency of the measurement instruments. The current study aimed to investigate correlations between balance assessment as examined by Biodex Stability System (BSS) and the clinical Berg Balance Scale (BBS) in post-stroke hemiparesis.
*Methods:* Twenty-five stroke survivors and 25 healthy age-sex matched subjects were recruited. The subjects were assessed using BSS during 3 days, with a 24-h interval. The high interclass correlation coefficient (ICC) values showed that the system was reliable enough to continue the study. The clinical evaluation was performed by the standard BBS.
*Results:* There was a significant moderate negative correlation between the Biodex overall indices and BBS scores in the stroke groups ($r_{avg} = -0.68$) and in the healthy cohort ($r_{avg} = -0.55$). Also, a significant moderate negative correlation was found between the Biodex antero-posterior stability indices and BBS scores in the stroke groups ($r_{avg} = -0.67$) and in healthy cohort ($r_{avg} = -0.55$). The correlation between the Biodex mediolateral stability indices and BBS scores was moderate to low in the stroke and healthy groups ($r_{avg} = -0.67$ and $-0.39$ respectively).
*Discussion and conclusion:* Moderate negative correlation between the stability indices of the Biodex Stability System and BBS scores indicates that dynamic balance status of the participants partially reflects their functional balance status.



## 1. Introduction

Balance is a vital component for performing many activities of daily living (ADL) (Matjačić et al., 2003; Lajoie and Gallagher, 2004; Cho et al., 2014). All individuals must therefore be able to maintain and adopt different postures, react to external perturbations, and use automatic postural responses in daily living tasks (Walker et al., 2000; Matjačić et al., 2003). Stroke disrupts almost all of these abilities. Patients with stroke exhibit abnormal postural responses (Walker et al., 2000), increased sway during quiet standing, uneven weight distribution with increased weight-bearing on the unaffected limb (Nichols, 1997; Geurts et al., 2005), and decreased weight-shifting ability in stance (Nichols, 1997; Walker et al., 2000). Therefore, an asymmetrical pattern is observed in muscle forces of the lower extremities (Geurts et al., 2005).

To maintain static and dynamic stability, integrated activity of sensorimotor systems is required (Liston and Brouwer, 1996; Cheng et al., 2004; Pereira et al., 2013; Cho et al., 2014). In patients with stroke, balance ability is often diminished due to weakness, sensory loss (Liston and Brouwer, 1996; Cheng et al., 2004), impaired righting reflexes, and visuospatial distortion (Cheng et al., 2004). Hence, balance deficit leads to an impaired ability to perform typical ADL and consequently increases the risk of falls (Schmitz and Arnold, 1998; Pereira et al., 2013). On the basis of these facts, efficient and precise balance assessment in patients with stroke can not only enable comprehensive recovery evaluation and fall prevention in stroke rehabilitation (Schmitz and Arnold, 1998) but also help the clinicians to select an appropriate intervention and evaluate treatment outcomes.

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The Biodex Stability System (BSS) is one of the instruments that is currently used for the evaluation of stability, including both dynamic stability and limit of stability. As the BSS has been recently introduced to the market, few investigations have been conducted thus far to evaluate its efficacy in stability assessment, particularly in neurologic patients. Pickerill et al. demonstrated that the BSS can assess functional stability because the size of the base of support on the unstable Biodex platform continuously changes (Pickerill and Harter, 2011); however, Cho and colleagues showed that stability indices acquired using the BSS represent dynamic stability (Cho et al., 2014). The validity of an instrument can be assessed by examining the correlation between its results and a standard outcome measure, whose reliability and validity have been previously established. Although there are few studies on BSS reliability (Schmitz and Arnold, 1998; Cheng et al., 2004), its intertester interclass correlation coefficient (ICC) and intratester ICC were calculated as 0.43 to 0.82 and 0.42 to 0.70, respectively (Schmitz and Arnold, 1998).

Among all ordinal balance scales, the Berg Balance Scale (BBS) (Berg et al., 1992; Liston and Brouwer, 1996; Tyson and DeSouza, 2002) is the most commonly used balance assessment for older adults (Tyson and DeSouza, 2002). The BBS is thought to be an assessment measure for dynamic and functional stability (Pickerill and Harter, 2011). The BBS has also been found to be one of the two “standing balance core outcome sets in adults” according to a study by a group of experts in the field of balance measurement (Sibley et al., 2015). It is also considered one of the most precise and reliable outcome measures to assess balance in patients with stroke as its inter-rater ICC is 0.98 and test-retest ICC is 0.97 (Liston and Brouwer, 1996; Tyson and DeSouza, 2002). The content validity of BBS has been investigated previously (Tyson and DeSouza, 2002). Berg et al. also studied its concurrent validity by using a computerized postural sway test on a moving force plate (Berg et al., 1992). This scale has 98% sensitivity and 96% specificity in fall prediction (Tyson and DeSouza, 2002; Lajoie and Gallagher, 2004).

Taking all studies on validity of similar instruments into consideration, it is clear that there is a weak correlation between static computerized posturography and the BBS scores (Nichols et al., 1996; Karlsson and Frykberg, 2000; Lajoie et al., 2002; Tyson and DeSouza, 2002; Lajoie and Gallagher, 2004; Geurts et al., 2005; Leroux et al., 2006; Cho et al., 2014), although in some cases, it seems that there is a significant correlation in the antero-posterior (AP) direction (Berg et al., 1992; ELWISHY, 2012; Cho et al., 2014). In contrast, there are some conflicting findings that are suggestive of a lower efficacy of the BSS. For instance, Pickerill et al. studied the correlation between limits of stability (LOS) measures generated by the BSS and NeuroCom Balance Master. The authors reported that construct validity of the Biodex LOS tests was not definitively established, and hence, they were unable to recommend the use of LOS measures as the gold standard (Pickerill and Harter, 2011). Conversely, Villafane et al. observed a weak significant correlation between the BBS and the fall risk test (FRT) performed using the BSS (Villafañe et al., 2015). Although it seems that dynamic stability is more representative of functional stability, few studies have investigated the correlation between dynamic posturography and BBS scores (Liston and Brouwer, 1996; Nichols, 1997). Elwishy and Preira et al. also described that laboratory dynamic balance assessment using the BSS showed a significant correlation with the BBS in their studied population (Elwhisy, 2012; Pereira et al., 2013). According to all the above-mentioned studies, it appears that studying the correlation between balance assessment using the BSS and functional BBS in hemiparetic participants with stroke and their healthy age- and sex-matched counterparts is an effective means to assess the efficacy of the BSS for balance assessment in a selected population.

## 2. Methods and materials

### 2.1. Subjects

This cross-sectional, observational study comprised 25 stroke survivors (with mean age of 57 ± 14 years) and 25 healthy age- and sex-matched subjects (with mean age of 57 ± 13 years) who were enrolled using a simple, non-random sampling strategy. The subjects (14 males and 11 females in each group) were selected from patients with stroke and healthy subjects who were referred to Physiotherapy Research Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran. The inclusion criteria in the healthy group were as follows: not suffering from any orthopedic, neurologic, neoplastic, or major internal diseases. The inclusion criteria for the stroke group were as follows: first incidence of stroke; no history of orthopedic, neoplastic, or neurological diseases, except for stroke; no other impairments that disturb balance; possessed the ability to stand independently for 2 min. Exclusion criteria were as follows: not achieving a score of 1–3 on the Modified Ashworth Scale, achieving more than ±1 standard deviation in Line Bisection Test, achieving a score of less than 18 in Mini–Mental State Examination (MMSE) Questionnaire (Folstein et al., 1975), achieving a score of less than 60 in Modified Barthel Index (Shah et al., 1989), achieving a score of less than 30 in Fugl-Meyer Assessment (Duncan et al., 1983), and not using any drugs that could affect the balance.

### 2.2. Tools

Balance was measured using the BSS (Biodex Medical Systems, Inc., Shirley, NY, USA) and the Persian version of the BBS (Salavati et al., 2012). The BSS has a circular platform that can freely move around the AP and medial-lateral (ML) axes simultaneously. Furthermore, the stability level of the test can be adjusted by changing the resistance force acting on the platform to make it more or less stable. Thus, the platform of the BSS can tilt in any direction and measure overall stability index (OSI), AP stability index (APSI), and ML stability index (MLSI). The average amount of tilt from the baseline that occurred overall, in the sagittal plane and in the frontal planes, is used to calculate the abovementioned indices, respectively. The lower the scores obtained in the test, the higher is the stability of the subjects and vice versa. Intratester ICC of the OSI was calculated to be 0.43–0.82, and its intertester ICC was 0.42–0.70 (Schmitz and Arnold, 1998).

### 2.3. Procedures

After the subjects agreed to participate in the study, they signed a written informed consent form prior to the collection of the essential demographic and clinical data. The study was approved by the local institutional ethics committee of Shahid Beheshti University of Medical Sciences (approval no. 4392). The BBS test and a familiarization session were performed on the first day. First, the subjects were given an overview of the testing procedure; then, they removed their footwear from both feets and placed their feets on the BSS to start the setup protocol. On the second day, after 24 h, stability assessment was conducted by instructing the subject to stand on the platform at the defined feet placement. Three 20-s trials were performed with a 30-s rest interval. The system has 8 stability levels. Level 8 has the highest platform stability, whereas level 1 has the lowest stability. Practice trials were started at the highest level of platform stability (Level 8) and then gradually decreased to a lower level (Level 5) every 20 s. On the third day, after 24 h, another two practice trials were performed in a similar way.

**Table 1**
The demographic data of the subjects participated in this study.

| Variable | Mean ± SD | | p-values in mean comparison between two groups |
|---|---|---|---|
| | Patients | Healthy | |
| Age | 56.96 ± 14.15 | 56.92 ± 13.82 | 0.992 |
| Height | 159.72 ± 10.43 | 164.08 ± 9.91 | 0.136 |
| Weight | 65.04 ± 15.61 | 67.84 ± 12.12 | 0.482 |
| BBS Score | 50.40 ± 7.16 | 55.28 ± 1.02 | 0.001* |
| OSI Score | 3.44 ± 1.52 | 2.52 ± 1.00 | 0.015* |
| APSI Score | 2.60 ± 1.23 | 2.01 ± 0.79 | 0.048* |
| MLSI Score | 2.34 ± 0.97 | 1.56 ± 0.63 | 0.005 |

OSI, APSI and MLSI are average values of three times assessment.
*The significance level was considered $p < 0.05$.

### 2.4. Statistical analysis

The Kolmogorov-Smirnov (K–S) test was performed to determine the normality of distribution. Independent *t*-test and the Mann-Whitney *U* test were performed to compare the basic mean values between the two groups, while Spearman rank correlation coefficient was used to assess the relationship between the BBS scores and stability indices. To confirm the reliability of the BSS, ICCs were calculated in 15 patients with stroke in two successive days and at two times of assessment on the same day. All statistical analyses were performed using SPSS statistical version 20.0 software package. A p-value of <0.05 was considered statistically significant.

## 3. Results

A comparison of the mean basic values showed no statistically significant difference in demographic characteristics such as age, height, and weight between the two groups ($p > 0.05$), while there was a significant difference between the clinical and laboratory values of balance assessment ($p < 0.05$) (see Table 1). Table 2 presents some additional information about subjects with stroke. The K–S test exhibited a normal distribution in all values, except for the BBS scores ($p < 0.05$).

Results of computing Spearman rank correlation coefficient indicated significant negative correlations between the BBS and OSI values in all three times of assessments and their average value in the stroke group ($r_{avg} = -0.68$, $p < 0.05$). Significant negetive correlations were also observed in the three times of assessment and their average value in the healthy group ($r_{avg} = -0.55$, $p < 0.05$). Moreover, there was a significant negative correlation between the BBS and APSI values in the stroke group ($r_{avg} = -0.67$, $p < 0.05$) and the healthy group ($r_{avg} = -0.55$, $p < 0.05$) (Tables 3 and 4). The MLSI and BBS scores were significantly correlated in the stroke group ($r_{avg} = -0.67$, $p < 0.05$), whereas this correlation was found in only one time of assessment and the average value in the healthy group ($r_{avg} = -0.39$, $p = 0.049$) (Table 5). ICCs with 95% confidence interval were calculated for different indices on two successive days and at two times of assessment on the same day. The ICCs for OSI, APSI, and MLSI were 0.84 and 0.89, 0.80 and 0.88, and 0.86 and 0.80, respectively.

## 4. Discussion

Postural control impairment is one of the key components of mobility problems in individuals with stroke that may result from complicated interactions of impaired motor, sensory, and cognitive systems. It is well known that following stroke, paretic lower extremity loading is impaired, postural sway during quiet standing is increased, and equilibrium reactions and anticipatory postural adjustments to body perturbations are disrupted, particularly in the affected leg (de Haart et al., 2004). Therefore, it is expected that subjects with stroke experience significant deficits in the ability to control their functional and dynamic balance. Furthermore, dynamic and functional balance is a multidimensional motor skill. It has been suggested that regulation of frontal plane stability is more challenging than that of sagittal plane stability and needs active control (Vistamehr et al., 2016). Thus, the current study aimed to investigate the correlation between dynamic balance assessment using the BSS, which assesses balance in all directions individually, and the functional BBS in subjects with stroke and their healthy age- and sex-matched controls.

**Table 2**
Demographic data of the stroke subjects.

| Variable | frequencies | | |
|---|---|---|---|
| | | numbers | percentages |
| Type of stroke | ischemic | 17 | 68% |
| | hemorrhagic | 5 | 20% |
| | Not clear | 3 | 12% |
| Paretic side | right | 10 | 40% |
| | left | 15 | 60% |

**Table 3**
*P*-values and Spearman Correlation Coefficients (r) between the BBS scores and OSI index in two groups.

| Group | Stroke | | Healthy | |
|---|---|---|---|---|
| variable | P | R | P | R |
| $OSI_1$ | 0.001* | −0.602 | 0.014* | −0.486 |
| $OSI_2$ | 0.001* | −0.629 | 0.008* | −0.518 |
| $OSI_3$ | 0.001* | −0.630 | 0.006* | −0.533 |
| $OSI_{avg}$ | 0.001* | −0.688 | 0.004* | −0.555 |

$OSI_1$: frist assessment of overall stability index.
$OSI_2$: second assessment of overall stability index.
$OSI_3$: third assessment of overall stability index.
$OSI_{avg}$: average value of overall stability index.

**Table 4**
P-values and Spearman Correlation Coefficients (R) between the BBS scores and APSI index in the two groups.

| Group | Stroke | | Healthy | |
|---|---|---|---|---|
| variable | P | R | P | R |
| $APSI_1$ | 0.001* | −0.609 | 0.005* | −0.547 |
| $APSI_2$ | 0.001* | −0.603 | 0.014* | −0.484 |
| $APSI_3$ | 0.002* | −0.592 | 0.004* | −0.551 |
| $APSI_{avg}$ | 0.001* | −0.676 | 0.004* | −0.554 |

$APSI_1$: first assessment of anterior-posterior stability index.
$APSI_2$: second assessment of anterior-posterior stability index.
$APSI_3$: third assessment of anterior-posterior stability index.
$APSI_{avg}$: average value of anterior-posterior stability index.

**Table 5**
P-values and Spearman Correlation Coefficients (R) between the BBS scores and MLSI index in two groups.

| Group | Stroke | | Healthy | |
|---|---|---|---|---|
| variable | P | R | P | R |
| $MLSI_1$ | 0.004* | −0.561 | 0.071 | −0.368 |
| $MLSI_2$ | 0.001* | −0.623 | 0.096 | −0.340 |
| $MLSI_3$ | 0.001* | −0.627 | 0.046* | −0.402 |
| $MLSI_{avg}$ | 0.001* | −0.675 | 0.049* | −0.398 |

$MLSI_1$: first assessment of medial-lateral stability index.
$MLSI_2$: second assessment of medial-lateral stability index.
$MLSI_3$: third assessment of medial-lateral stability index.
$MLSI_{avg}$: average value of medial-lateral stability index.

Our results demonstrated that the best moderate, negative correlation was found between the overall stability index and the BBS scores in both groups. However, better correlation coefficients were observed in the stroke group. It is anticipated that because the BBS is a functional scale, the subject has to overcome perturbations in different directions simultaneously to complete the actions. The OSI also reflects the stability of the subject in all directions. Several researchers have assessed positional perturbations in all sides and showed that there was no significant correlation between the laboratory static stability tests and the BBS scores that assess the functional balance (Liston and Brouwer, 1996; Nichols, 1997; Karlsson and Frykberg, 2000; Lajoie et al., 2002; Tyson and DeSouza, 2002; Lajoie and Gallagher, 2004; Leroux et al., 2006; Cho et al., 2014). The reason for the different findings of the current study may be due to the difference in the type of tested stability, assessment methods, and studied subjects. Conversely, some studies have reported a high correlation between the findings of positional static stability on the force platform and the BBS scores in elderly subjects and subjects with cerebrovascular accidents (CVA) (Berg et al., 1992; Niam et al., 1999; Murphy and Roberts-Warrior, 2003). Many investigations also found a significant correlation between the dynamic stability measures and the BBS scores (Liston and Brouwer, 1996; Nichols, 1997; Cho et al., 2014; Song et al., 2017). Consistent with our findings, these lines of evidence support that laboratory balance assessment is correlated with the BBS scores. Other studies also investigated subjects with multiple sclerosis (MS), Parkinson's disease, and a history of falling by using the BSS. In all studies, there was a significant correlation between the OSI and the BBS score (Elwishy, 2012; Pereira et al., 2013; Pasha et al., 2016). Considering previous studies, it appears that the dynamic assessment of balance in all directions shows a stronger correlation with the BBS scores in both healthy subjects and individuals with stroke.

The current study shows more correlation between the BBS scores and the AP stability index than between the ML index. A moderate, negative correlation was observed in both subjects with stroke and healthy controls in terms of the APSI. Similar to daily function, most of the activities tested in the BBS are accomplished in the AP direction. Hence, it is not surprising to find that the APSI correlates better with BBS scores than with the MLSI. Previous studies found a high correlation between the BBS scores and the AP dynamic stability index (Liston and Brouwer, 1996; Cho et al., 2014). A high correlation between the BBS and static stability index has already been reported by other researchers (Berg et al., 1992; Niam et al., 1999). Karlsson and colleagues also reported such correlations in their static stability tests (Karlsson and Frykberg, 2000). Although in the current study the indices were attributed to the center of pressure (CoP) displacement, the authors did not directly observe any correlation of the CoP displacement parameters in their study.

The lowest correlation was found between the MLSI and the BBS scores. The correlation was moderate in subjects with CVA and low in the healthy subjects. Berg et al. could not explain the preference of APSI over the MLSI (Berg et al., 1992). Other researchers found the same result for the MLSI in unhealthy groups. Lajoie et al. also reported the same correlation in healthy subjects (Liston and Brouwer, 1996; Lajoie and Gallagher, 2004; Pasha et al., 2016).

Altogether, the findings of the current study indicate that all three types of indices showed a significant negative correlation with the BBS scores in both groups, where higher Biodex indices were recorded and lower BBS scores were achieved as represents poorer stability. All indices correlated better in the stroke group than in the healthy group. This was more prominent for MLSI, where the correlation was not significant in two assessments and correlation coefficients were the lowest in the healthy group. As mentioned earlier, the only reason for lower correlation in the ML direction in healthy subjects appears to be that most of the functional activities tested in the BBS disturb balances in the AP direction rather than in the ML direction. As healthy subjects have no issues with balance in the ML direction, their positional changes in the ML direction are small and have no significant correlations with most of the parameters. Neurological deficits may change the results measured by either laboratory or functional assessment tests. However, more investigations are needed to address this point.

## 5. Conclusion

Comprehensive assessments of subjects with CVA may predispose early diagnosis and treatments for such patients to bring them general healthiness, independence, and social involvements. The BSS balance tool has shown to be very helpful in offering dynamic positional disturbances for assessment or treatment of stroke survivors dynamically. Various studies have shown that dynamic balance assessments may better reflect functional balance of the subjects. It should be noted that all static, dynamic, and functional tests must be carried out for a comprehensive assessment of stability.

Some researchers have also emphasized that both AP and ML stability indices and overall stability index should be measured separately; otherwise, many important data may be lost. Analysis of indices of all directions offers important somatosensory and biomechanical data, which may be necessary for further treatments. For instance, the AP direction mainly shows data for ankle strategy, which comes from the plantar -and dorsiflexor muscles. However, the ML direction is mainly controlled by the hip strategy, and it involves hip abductor muscles and fairly ankle invertor/evertor muscles.

### *5.1. Limitations*

Balance assessment using BSS in an independent standing position limits subject selection. Moreover, some participants were excluded from the study because of the fear of falling, which is common after stroke, and this can lead to abnormal responses. The BBS assessor was not blinded to Biodex balance indices. Therefore, more valid results can possibly be obtained by including a larger number of participants in each group.

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