Intertester and Intratester Reliability of a Dynamic Balance Protocol Using the Biodex Stability System

Randy Schmitz and Brent Arnold

Evaluating balance can be an important part of the rehabilitation protocol of an athletic injury. One purpose of this study was to determine the intertester and intratester reliability scores of single-leg stability on a platform of gradually decreasing stability using the Biodex Stability System (BSS). The second purpose was to determine intertester and intratester reliability scores of subject foot placement on the BSS. Subjects (N = 19) underwent a familiarization session on Day 1 that included five 30-s balance tests on the BSS. In each of the five tests, platform stability gradually decreased over the 30 s. Subjects were tested without footwear at all times. On the second day, each subject was tested twice by the same investigator and once by a second investigator using the same 30-s test. Investigator tests were counterbalanced to eliminate order effects. Intertester intraclass correlations (ICCs) ranged from .70 to .42 for stability index and from .93 to .54 for foot placement. Intratester ICCs ranged from .82 to .43 for stability index and from .81 to .55 for foot placement. The overall stability index scores were the most reliable stability scores (.82 for intratester and .70 for intertester). A 30-s, single-leg, gradually decreasing platform stability test appears to be highly reliable when performed on the BSS.

Evaluating balance characteristics can play an integral part in the rehabilitation of injury. Postural stability has been defined as the ability to maintain the center of body mass over the base of support (4). Ability to maintain postural stability under dynamic conditions is an important underlying component of physical activity/performance (2). The ability to maintain postural stability comes from the integration of visual, vestibular, and proprioceptive neural input to the central nervous system (3).

One device capable of quantifying postural stability measurements during single-legged stance is the Biodex Stability System (BSS) (Biodex, Shirley, NY). The platform of the BSS on which the individual stands can tilt 20° in any direction and can be used to measure overall stability index (OSI), anterior/posterior...
stability index (APSI), and medial/lateral stability index (MLSI). These scores are calculated from the amount of platform tilt (in degrees) from the preset centering of the subject. These measures are the average amount of tilt from baseline that occurred overall, in the frontal plane, and in the sagittal plane. Low scores indicate that a subject is very stable, while higher scores indicate that the subject is less stable. Formulas for calculating these scores are given below. The BSS samples the tilt data at 20 Hz. Additionally, the relative stability of the board can be set to decrease, increase, or remain constant within a testing period.

\[
\text{Overall stability index} = \sqrt{\frac{(0 - X)^2 + (0 - Y)^2}{\text{number of samples}}}
\]

\[
\text{Anterior/posterior stability index} = \sqrt{\frac{(0 - Y)^2}{\text{number of samples}}}
\]

\[
\text{Medial/lateral stability index} = \sqrt{\frac{(0 - X)^2}{\text{number of samples}}}
\]

Previous investigators have reported good reliability of the BSS (5). Pincivero et al. (5) reported BSS overall stability index reliability values using an intratester/within-days design. Healthy subjects were tested while holding a single- and double-leg stance using a relatively stable platform and an unchanging, relatively unstable platform setting. However, no results were reported for variable stability levels or foot placement. Foot placement is important because where the foot is placed in reference to the center of the BSS platform may change how the subject maintains balance and the resulting stability scores.

Thus, the purpose of this study was to determine the intertester and intratester reliability values of changing stability levels and foot placement for the single-leg stance using the BSS.

**Methodology**

**Subjects**

Nineteen healthy university students (8 male, 11 female) participated in this investigation (age = 24.4 ± 4.2 years, weight = 70.5 ± 20.0 kg, height = 171.2 ± 11.7 cm). None of the subjects were currently engaged in a varsity sport, and none had sustained an injury to the lower extremity or experienced any known vestibular system dysfunction within 6 months of testing. Leg dominance was determined by asking the subject which leg he or she would use to kick a ball. Before testing, each subject read and signed an informed consent form on the potential risks and benefits of the study.
Setup

A familiarization session was performed on the first day. Subjects were given an overview of the testing procedure, removed their footwear from both feet, and were positioned on the BSS to begin the setup protocol. A safety harness was used to protect subjects from falling (see Figure 1). Initially, the subjects stood on their dominant foot over the approximate center of the BSS platform. The BSS platform was then released to the highest level of stability used during the testing process (Level 8). The highest level of stability allows the platform to be least easily tilted and makes it easier for the subject to maintain stability. As the BSS approaches Level 1, it becomes more difficult for the subject to maintain stability.

Subjects were then asked to place their test foot on the platform where they could best maintain their balance while standing on a single leg without using the handrails. The amount of platform tilt from level was then entered into the BSS.

Figure 1 — Subject setup on the Biodex Stability System.
automatically using the BSS setup program. This amount of platform tilt served as the basis for calculating stability scores (OSI, APSI, and MLSI). The placement of the heel in the medial/lateral (HPX) and anterior/posterior (HPY) directions was recorded manually using a grid that was broken into 1.8-cm intervals on the BSS platform. The angle of the third metatarsal in reference to the y-axis was also recorded manually. Upon completion of the centering process, subjects were instructed not to move their test foot on or away from the platform. In addition, subjects were encouraged to bear weight on the contralateral extremity during the intertest rest session, in an effort to minimize fatigue of the test limb.

Testing

After subject setup during the familiarization session, the BSS platform was released and the subjects were given five practice tests in which they attempted to maintain balance for 30 s. Each of the five practice tests started at the highest level of platform stability (Level 8) and gradually decreased to the lowest level (Level 1). The stability level decreased every 3.75 s and was automatically decreased by function of the computerized protocol. The time to decrease one stability level was less than 1 s. The subjects were instructed to keep the opposite extremity off the ground in a comfortable position, hold the arms at the side, extend the knee of the testing limb, and look straight ahead at a wall approximately 1 m away with eyes open. Subjects were also told that in case they lost balance, they should to catch themselves by using the handrails or allowing the safety harness to catch them. This postural protocol was designed to allow the subjects freedom to make corrections to maintain postural stability. At the end of the 30-s test, subjects rested for an additional 30 s before starting the next practice test.

The testing session commenced on Day 2. Each subject performed three 30-s tests. Investigator A administered one of the subject’s three tests and Investigator B administered the other two tests. The order of the three tests was counterbalanced in an effort to negate learning effects. The subjects once again went through the setup procedure outlined in the familiarization session. During the course of the 30-s testing protocol, the platform gradually became less stable (Level 8 to Level 1). A 45-s rest was given between tests. At the beginning of the second and third tests, the respective investigator asked the subject to step off the BSS platform. The subject was then recentered on the platform using the patient setup protocol. At the end of the testing protocol, subjects were allowed to leave.

Data Extraction

Stability scores (OSI, APSI, and MLSI) were calculated by the BSS computer interface and then manually copied and entered into a statistical software package. Heel position scores (HPX, HPY, and ANGLE) were also manually recorded and entered into the statistical software package.
Statistical Analyses

Statistical analyses were designed to calculate the reliability of stability scores and foot placement. Repeated-measures ANOVAs were performed on OSI, APSI, and MLSI. Repeated-measures ANOVAs were also performed on heel placement on the BSS platform in the x and y direction (HPX and HPY) and angle of the third metatarsal in respect to the y-axis. From the ANOVA data, the intraclass correlation coefficient (ICC) formula (2,1) (6) was used to calculate the intertester and intratester reliability of each dependent variable.

Results and Discussion

Means, standard deviations (SD), ICCs, and standard errors of measure (SEM) are reported for intertester (Table 1) and intratester (Table 2) scores. Intertester ICCs for stability scores ranged from .70 to .42. Intratester ICCs for stability scores ranged from .80 to .43. Foot placement reliability scores ranged from .93 to .54 and from .81 to .55 for intertester and intratester, respectively.

Measuring stability under dynamic conditions has numerous functions in the athletic training setting. Potential uses for stability scores include determining the extent of an injury, progression of rehabilitation protocols, and the effect of external bracing techniques (3). If such stability scores are to be used in the clinical setting, it is important to determine the reproducibility of these scores.

As would be expected for OSI, the intratester ICC was slightly higher than the intertester ICC. This may be due to slight changes in instructions to subjects or a slight change in how the subject was positioned and/or set up on the device. However, both were well within acceptable clinical ranges (.82 and .70, respec-

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Investigator A</th>
<th></th>
<th>Investigator B</th>
<th></th>
<th>ICC</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSI</td>
<td>3.58</td>
<td>1.65</td>
<td>3.82</td>
<td>1.63</td>
<td>.70</td>
<td>0.90</td>
</tr>
<tr>
<td>APSI</td>
<td>3.29</td>
<td>1.52</td>
<td>3.51</td>
<td>1.59</td>
<td>.68</td>
<td>0.86</td>
</tr>
<tr>
<td>MLSI</td>
<td>1.62</td>
<td>0.85</td>
<td>1.57</td>
<td>0.81</td>
<td>.42</td>
<td>0.65</td>
</tr>
<tr>
<td>HPX</td>
<td>4.68</td>
<td>1.06</td>
<td>4.37</td>
<td>1.34</td>
<td>.93</td>
<td>0.28</td>
</tr>
<tr>
<td>HPY</td>
<td>10.58</td>
<td>0.61</td>
<td>10.53</td>
<td>0.84</td>
<td>.54</td>
<td>0.41</td>
</tr>
<tr>
<td>Angle</td>
<td>16.32</td>
<td>5.23</td>
<td>13.42</td>
<td>5.02</td>
<td>.77</td>
<td>2.51</td>
</tr>
</tbody>
</table>

Note. OSI = overall stability index; APSI = anterior/posterior stability index; MLSI = medial/lateral stability index; HPX = heel position in x-axis; HPY = heel position in y-axis; angle = angle of third metatarsal.
Table 2 Intertester Stability Means ± SD and Reliability Coefficients

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Trial 1</th>
<th></th>
<th></th>
<th>Trial 2</th>
<th></th>
<th></th>
<th></th>
<th>ICC</th>
<th>SEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSI</td>
<td>3.82</td>
<td>1.63</td>
<td></td>
<td>3.38</td>
<td>1.71</td>
<td></td>
<td>.82</td>
<td>0.69</td>
<td></td>
</tr>
<tr>
<td>APSI</td>
<td>3.51</td>
<td>1.59</td>
<td></td>
<td>3.07</td>
<td>1.58</td>
<td></td>
<td>.80</td>
<td>0.71</td>
<td></td>
</tr>
<tr>
<td>MLSI</td>
<td>1.57</td>
<td>0.81</td>
<td></td>
<td>1.58</td>
<td>0.92</td>
<td></td>
<td>.43</td>
<td>0.61</td>
<td></td>
</tr>
<tr>
<td>HPX</td>
<td>4.37</td>
<td>1.34</td>
<td></td>
<td>4.21</td>
<td>1.18</td>
<td></td>
<td>.75</td>
<td>0.67</td>
<td></td>
</tr>
<tr>
<td>HPY</td>
<td>10.53</td>
<td>0.84</td>
<td></td>
<td>10.78</td>
<td>0.71</td>
<td></td>
<td>.55</td>
<td>0.56</td>
<td></td>
</tr>
<tr>
<td>Angle</td>
<td>13.42</td>
<td>5.02</td>
<td></td>
<td>13.42</td>
<td>6.68</td>
<td></td>
<td>.81</td>
<td>2.19</td>
<td></td>
</tr>
</tbody>
</table>

Note. OSI = overall stability index; APSI = anterior/posterior stability index; MLSI = medial/lateral stability index; HPX = heel position in x-axis; HPY = heel position in y-axis; angle = angle of third metatarsal.

These values are similar to those reported by Pincivero et al. (5), who reported dominant, single-limb stance, intratester OSI scores at the highest level of stability (Level 8) of the BSS (ICC = .95) and at a relatively unstable level (Level 2) (ICC = .60). However, Pincivero et al. used an unchanging level of stability, while in the current investigation, the BSS platform was gradually made more unstable during the course of each 30-s trial. Therefore, comparisons with present findings are limited.

APSI intertester and intratester ICCs (.68 and .80, respectively) closely paralleled the OSI ICC scores. The amplitude of tilt was greater in the sagittal plane (APSI) than the frontal plane (MLSI) (see Tables 1 and 2). The OSI is calculated from the amount of platform tilt in the frontal and sagittal planes (see the equations), thus the influence of the APSI score on the OSI score.

MLSI had poor intertester and intratester ICCs (.42 and .43, respectively). We attribute this to the small amount of variance that occurred in the between-subject effects. This decrease in value will decrease the numerator of the ICC formula (2,1), thereby decreasing the ICC score. This demonstrates that there was little difference among the subjects for the MLSI score or there was a large uniform correction.

ICC scores were highest for placement of the foot in the medial/lateral axis and angle of the foot during the centering protocol. Foot placement ICC scores were lowest for placement of the foot in the anterior/posterior axis. This may be due to increased available motion of the ankle and knee in the sagittal plane. If the subject’s foot is centered too far medial or lateral from the center of gravity, there may not be enough range of motion available in the frontal plane to allow for postural corrections. Therefore, it may be more important to properly place the foot closely under the center of gravity in the frontal plane. In this study we did not determine the center of gravity, but we feel that the foot was placed near the center of gravity. If the foot is not...
properly placed near the center of gravity the subject will not be able maintain postural stability in the single-leg stance. As described in the methodology, the BSS accounts for this during the setup procedure when the subject attempts to find a foot placement on the platform where he or she can best maintain balance while single-leg standing without the aid of the handrails.

It has been reported that the majority of the corrections in postural stability during quiet standing occur in the anterior/posterior direction (1). Little is known about the characteristics of balance and resulting postural corrections when a platform is unstable in 360° (such as the BSS) as opposed to platform instability in one plane. Wilkerson and Nitz (7) suggested that when the center of gravity is kept within the base of support during static standing postural, balance is maintained. It has not been demonstrated how the center of gravity is related to base of support on a platform that is unstable in any direction.

**Conclusion**

We conclude that the OSI of the Biodex Stability System and subject repositioning in the medial/lateral axis are reliable within clinical ranges for the testing of a single-leg dynamic balance protocol. The above measures should help clinicians in comparing normative data. The concept of maintaining balance during dynamic conditions is not well understood. It is our hope that future research will further investigate the manner in which dynamic balance is controlled.

**References**