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Examination of a Clinical Method of Assessing Postural Control During a Functional Performance Task

Bryan L. Riemann, Nancy A. Caggiano, and Scott M. Lephart

Postural control and functional performance tests are often used separately during orthopedic postinjury assessments. The purpose of this investigation was to examine a clinical method of assessing postural control during a functional performance task. Thirty participants were divided into two groups. The first group was tested three times, the second group only once. The same tester evaluated each participant's performance during all testing sessions, and during the first two testing sessions (Group 1) two additional testers evaluated each performance. Intraclass correlational coefficients between the three testers ranged from .70 to .92. Session 1 (Group 1) scores were pooled with Group 2 scores, and correlational analyses were conducted between participant height and performance; no significant relationships were revealed. The scores from Group 1 were analyzed using between-days repeated-measures ANOVAs. Results revealed significant improvement between Sessions 1 and 3 for the static portion of the test. The results suggest that the multiple single-leg hop-stabilization test offers a method of assessing postural control during a functional performance task.

Key Words: equilibrium, balance, measurement, reliability

Since the work of Freeman (10), postural control testing has gained widespread attention in the field of sports and orthopedic medicine (3, 5, 8, 9, 11, 15–18, 22, 25, 30, 31, 33). The results of investigations directly considering postural control following knee and ankle articular injury, however, are largely inconclusive. The majority of these studies were conducted during static single-leg stance on firm surfaces under both eyes-open and eyes-closed conditions (3, 11, 15, 29, 33). Through incorporating strain-gauge force platforms into these assessments, changes in center of pressure and variability in the horizontal and vertical reaction forces are often calculated to provide quantitative data on postural steadiness (13, 14).

The authors are with the Neuromuscular and Sports Medicine Research Laboratory, Musculoskeletal Research Center, Department of Orthopedic Surgery, at the University of Pittsburgh, Pittsburgh, PA 15261.

Considering the dynamic nature of both activities of daily living and athletic participation, the relevance of static (fixed base of support; firm, unmoving support surface) testing conditions to functional activity remains largely unknown. Static conditions might potentially fail to present enough of a challenge to elicit postural control deficiencies in physically active individuals. Furthermore, because forceplate systems largely depend on center-of-pressure changes and forces exerted against the platform from motor activities surrounding the ankle (20, 32), they might fail to reveal alterations and compensations occurring at proximal limb segments. The reports of increased proximal segment reliance during stance and perturbation through advanced kinematic and kinetic measurements in patients with ankle injury support this notion (24, 31).

The development of various functional tests, mainly surrounding anterior cruciate ligament injuries, is also a popular topic in the orthopedic literature. By attempting to recreate the forces encountered during functional activity in a controlled environment (1, 2, 21), these tests have been advocated for evaluating functional joint stability (1, 12, 27, 28), monitoring recovery (28), and determining timing of return to participation (4). It has been suggested that single-leg hopping is associated with the requirements necessary for sports-related function (27). Single-leg hop tests performed by patients with unilateral pathology enable bilateral comparisons or calculations of symmetry scores (1, 23). The outcome measures used for the majority of these tasks are distance and/or time (1, 27, 28).

Although a major advantage of these tests is their ease and the minimal equipment necessary to rate performance (2), they have been widely questioned with respect to their sensitivity in assessing lower extremity performance following injury or during the rehabilitation process (1, 23). One explanation for their lack of sensitivity could be their heavy dependence on a maximal effort(s), without regard to the control that individuals maintain over their bodily equilibrium before, during, and after the movement.

The purpose of this investigation was to examine a clinical method of assessing postural control during a functional performance task in normal participants. More specifically, this study aimed to (1) establish the intertester reliability of using a comprehensive error-scoring system for measuring test performance, (2) determine whether customizing the dimensions of the floor pattern to participant height would reduce any apparent bias associated with a standardized floor pattern, and (3) establish the learning curves associated with repeated exposure to the test.

Methods

The Multiple Single-Leg Hop-Stabilization Test

The multiple single-leg hop-stabilization test was developed by adopting and adapting the modified Bass test described by Johnson and Nelson (19). A numbered floor pattern (see Figure 1) was marked with 11 pieces of white athletic tape, each

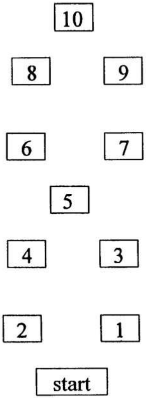


Figure 1 — Numbered floor pattern used for the test. Intertape distances were adjusted for each participant according to his or her height (see text).

2.5 cm square. Rather than using the standardized dimensions provided by Johnson and Nelson, we modified intertape distances according to the height of each participant. The largest distances that participants are required to hop in the pattern are for the diagonals between Tape Marks 2 and 3 and Tape Marks 7 and 8. Our pilot study using 20 participants revealed that most participants could maximally hop approximately 95% of their height in a purely anterior direction. Using these data as a reference, we chose to use 45% of a participant's height for the diagonal dimensions, the largest intertape distance of the pattern. For example, for a participant height of 170 cm the diagonal dimension would be 76.5 cm, with the distances between adjacent pieces computed using the Pythagorean theorem (54 cm).

Another major modification we made from the original test involved the participants using only one limb to complete the entire test, rather than alternating limbs between tape marks, as Johnson and Nelson described. In an attempt to reduce or control upper limb and body movements during the test, we included a requirement that participants keep their hands on their iliac crests at all times.

Participants were also told that in addition to completely covering each tape mark on landing, their foot needed to be pointed forward. We incorporated these adjunct requirements into the error-scoring system (see Table 1).

Participants

Thirty recreationally active participants (19 men, 11 women; age = 21.23 ± 2.9 years, height = 173.37 ± 9.42 cm, weight = 73.36 ± 13.92 kg) were used in this investigation. *Recreationally active* was defined as participating in physical activity for a minimum of 20 min, three times per week. All of the participants had no history of balance or lower extremity neurological disorders, and no participant had sustained a musculoskeletal or head injury within the past 12 months. The dominant leg, being defined as the preferred leg to use to kick a ball, was used for all data collection. Informed consent was obtained from all participants in accordance with the University of Pittsburgh Institutional Review Board.

Procedures

Participants were randomly assigned to one of two groups. The first group of 15 participants underwent the testing procedures three times (48 hr apart). During the first two sessions, intertester reliability data for each participant's performance were collected using three trained testers. This sample size was chosen based on an a priori power analysis for ρ = .8, three testers, and power equal to .8 (7). Training for each tester was conducted during a single, 1-hr session and included collective evaluations and discussions of several pilot participants completing the test. One of the co-investigators (NAC) controlled the counting and progression of each hop-stabilization sequence. During each test, testers were blinded to the results of the other tester evaluations. The same co-investigator (NAC) evaluated performance during the third testing session.

The second group of 15 participants underwent only one testing session. Administration of the test and evaluation of each participant's performance was conducted by the same co-investigator (NAC).

Table 1 Error-Scoring System

Landing errors	Not covering tape mark
	Stumbling on landing
	Foot not facing forward with 10° of inversion or eversion
	Hands off hips
Balance errors	Touching down with nondominant limb
	Nondominant limb touching dominant limb
	Nondominant limb moving into excessive flexion, extension, or abduction
	Hands off hips

Before beginning the test, participants were given an overview of the test and the scoring system and standardized instructions. The instructions emphasized the error-scoring system and test procedures. Each of the participants was given the opportunity to try several practice hop-stabilization sequences prior to data collection. The test began with the participant standing at the start location on the test limb, facing forward with head level and hands on iliac crests (see Figure 2). When a participant was ready to begin, he or she was allowed to briefly look at the target location before hopping to Tape Mark 1 (see Figure 3). On landing, participants controlled their balance to remain in single-leg stance position with hands remaining on the iliac crests and head level and facing forward. It was important to a successful landing to completely cover the tape mark, with the head and foot pointed straight ahead, without the support foot moving from the original point of floor contact, the contralateral limb touching down, or removing the hands from the iliac crests.

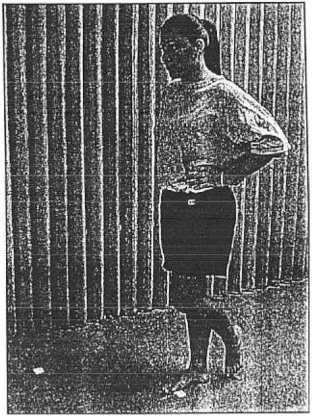


Figure 2 — The stance position used at the beginning of the test, as well as during each of the balance periods.

Once a participant established control, the tester began counting 5 s aloud to mark the beginning of the balance period. During this period, the participant had to maintain a stable position, looking forward, without touching down or moving the contralateral limb into excessive (>30°) flexion, abduction, or extension. At the end of 5 s, the participant was again allowed to look at the target location and hop to the next tape mark, landing in the standardized position. The tester determined the success of each landing and balancing period using the criteria listed in Table 1. Committing one of the errors during a period counted as a failure for that entire period. At the conclusion of the test, 10 error points were given for each period in which there was a landing error, and 3 error points were given for each period in which a balance error was committed. The sum of error points was designated as the total score.

Figure 3 — While hopping and landing, participants were required to keep their hands on their iliac crests while looking straight ahead.

Data Analysis

The landing and balancing scores served as the two dependent variables for all statistical analyses. All analyses were conducted using SPSS, version 6.1 (SPSS, Inc., Chicago), with statistical significance (when applicable) set at .05 a priori. To determine intertester reliability, separate repeated-measures analyses of variance (ANOVAs) were conducted on each of the dependent variables for each session. Intraclass correlational coefficients (ICCs) using the (2,1) Shrout and Fleiss methods outlined by Denegar and Ball (6) were calculated. In addition, standard errors of measurement (*SEMs*) were calculated. The landing and balance scores from the second group of participants were pooled with the Session 1 data collected by the same co-investigator (NAC) for the first group of participants. To determine whether a relationship existed between height and performance, Pearson's bivariate correlational analyses were conducted between the variables of height, landing score, and balance score. The three sessions of landing and balance scores from the first group of participants were analyzed using a between-days repeated-measures ANOVA for each variable.

Results

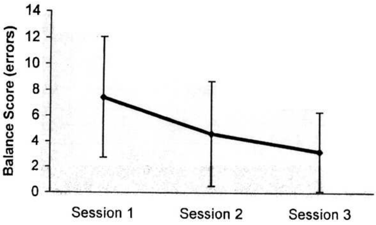
Means, standard deviations, and ranges for the error and balance scores for the pooled data (*N* = 30) are given in Table 2. Results of the reliability analyses are summarized in Table 3. The correlational analyses failed to reveal significant

Table 2 *Ms*, *SDs*, and Ranges for the Error and Balance Scores (*N* = 30)

Score	*M* (± *SD*)	Range
Balance	7.3 ± 5.9	0–27
Landing	43.7 ± 23.3	0–90

Table 3 Intertester Reliability Measures for the Two Testing Sessions (*N* = 15)

	Landing Score		Balance Score	
Session	ICC	*SEM*	ICC	*SEM*
Session 1	.92	.57	.70	.55
Session 2	.92	.56	.74	.54



*Significantly different than session one score.
Tukey's HSD = 3.59, $p < .05$.

Figure 4 — **Balance error score means (± *SD*) for each of three testing sessions ($n = 15$).**

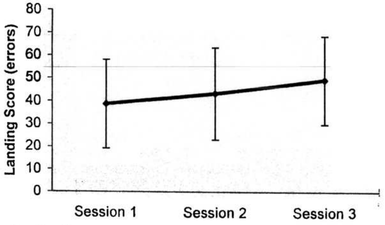


Figure 5 — **Landing error score means (± *SD*) for each of three testing sessions ($n = 15$).**

relationships between height and landing score ($r = -.1401, p = .460$) and height and balance score ($r = .2652, p = .157$). Results of the repeated-measures ANOVA revealed a significant difference between the repeated testing sessions for balance scores (see Figure 4), $F(2, 28) = 4.32$, $p = .023$, but not the landing scores (see Figure 5), $F(2, 28) = 1.58$, $p = .224$. Tukey's post hoc analysis revealed the difference between Sessions 1 and 3 as being significant (Tukey's HSD = 3.59, $p < .05$).

Discussion

The purpose of this investigation was to examine a clinical method of assessing postural control during a functional performance task—the multiple single-leg hop-stabilization test. Specifically, this study sought to determine intertester reliability, relationship between performance and height, and learning curves associated with repeated exposures to the test. The most important finding was the demonstration of consistent intertester reliability across the two sessions; it appears that the multiple single-leg hop-stabilization test offers a reliable clinical method of assessing postural control during a functional performance task.

Inherent in the published description of the modified Bass test (19) were several limitations on incorporating the test into clinical assessments. First, the dimensions of the floor pattern were standardized for all participants. Our experience with the test demonstrated that although shorter participants had extreme difficulty reaching some of the tape marks, taller participants did not appear to be challenged. In addition, the test did not attempt to control upper extremity and body compensation during periods of disequilibrium. Finally, the goal of the test was for participants to alternate the limb used to hop through the floor pattern, maintaining a steady position on the ball of the support foot for 5 s after each landing. Modeled after the modified Bass test, the multiple single-leg hop-stabilization test evolved from alterations to make the idea behind the Bass test into a clinically useful method of measuring functional postural control. Specifically, alterations were incorporated to reduce height–performance test bias, reduce the amount of compensatory actions arising from upper extremity and body movement, increase the sensitivity of isolating deficiencies between the lower extremities, and include a more functional balancing position (foot flat).

A major component of functional testing is providing an activity that recreates forces and challenges similar to those an athlete faces during actual participation in a controlled environment. The many derivatives of the single-leg hop test involve forward propulsion of the body using one leg. The test developed in this investigation involved unique combinations of controlled forward and/or lateral movements interspersed with periods of quiet, single-leg standing. Similar movements often occur during sports such as gymnastics, football, wrestling, and dance. Future research should investigate characteristic deficiencies associated with specific pathologies in moving laterally, medially, and anteriorly through the floor pattern. Additionally, the time required to complete the multiple single-leg hop-stabilization test taxes the muscular endurance of the test limb. This aspect of the test could give clinicians additional insight into the functional level of an injured athlete. With respect to task complexity, single-leg hop tests might be better suited for earlier postinjury evaluations, whereas the single-leg hop-stabilization test might be best suited for later stages of postinjury evaluation. Combining both forms of single-leg testing with other available functional performance tests such as the carioca test and cocontraction test offers clinicians a battery of assessments for determining functional status and assisting in return-to-play decisions.

Important to many sports medicine practitioners is the ability to make a functional evaluation of the severity of an injury and of postinjury status without the need for sophisticated or expensive equipment. The use of an error-scoring system to evaluate postural control during static stance has been previously demonstrated to correlate with measures provided by forceplate technology (18, 26). As mentioned previously, the reason for modifying the original error-scoring system was to attempt to make the test more sensitive to upper extremity and body compensatory actions. The error-scoring system used in our current study was similar to the Balance Error Scoring System (26), and therefore the comparable results concerning intertester reliability were not surprising. The absolute reliability (*SEM*) was less than one error for both the landing and the balance errors across the two testing sessions. These results, coupled with relative reliability results ranging from .70 to .92, suggest that the intertester reliability of the error-scoring system is within clinically acceptable standards.

In addition to comparing the results of single-leg hop tests bilaterally (injured vs. uninjured), clinicians and researchers often make interparticipant comparisons. Because physical characteristics, especially height, and activity levels influence hopping and postural control abilities, we strove to modify the original Bass test to reduce a height-related performance bias. Our pilot work using physically active participants revealed that most participants could maximally hop approximately 95% of their height in a purely anterior direction. Using these data as a guide, we chose to use 45% of a participant's height for the diagonal dimensions for several reasons. First, we wanted to have the participants perform the test barefoot to avoid confounding factors arising from different shoes during between-subject comparisons. We theorized that repetitive barefoot landings on a hard support surface by individuals not accustomed to such an activity could potentially cause increased apprehension toward the end of the test. In addition, a large focus of the test resides in landing in a controlled manner while maintaining postural control. The desire to challenge participants to jump close to their maximal abilities, coupled with the goal to ultimately apply the test to injured populations, spurred us to use a distance that we felt would be challenging yet attainable by clinical populations. Our results demonstrated small nonsignificant correlations between test performance and height, supporting the idea that height bias in test performance can be reduced by adjusting floor pattern dimensions. Further research should consider the appropriateness of the floor dimensions used in this study for use with injured populations.

An important aspect of clinical evaluation techniques is knowing whether improvement on test performance over repeated exposures is the result of underlying pathology resolution or increased test familiarity. We chose to use three repeated sessions with a 1-day intertest interval to represent the shorter extreme of what is typically used in clinical situations. It is interesting to note that significant improvement was revealed only in the more static component of the test. Because our study is unique in considering static postural control for a period of time between dynamic movements, we cannot compare our results with any previously published literature. We could only find one other study considering the measurement of static single-leg stance at identical intertest intervals using a similar error-scoring system (26). In that study, the authors failed to reveal significant improvement under an eyes-closed condition across three testing sessions. With respect to the current study, we speculate that the improvement demonstrated during the static interval might have been a result of the participants becoming more accustomed to controlling their posture while preparing to make another dynamic movement. Further research should consider whether similar improvements occur with more clinically applicable intertest intervals, such as weekly or biweekly.

Conclusion

The results obtained in this investigation suggest that the multiple single-leg hop-stabilization test could provide an adjunct clinical procedure for evaluating functional postural control during a functional performance test. Because the test involves forward and/or lateral movements interspersed with quiet, single-leg standing, the demands for successful completion of the test exceed those required for single-leg hop tests. Thus, the single-leg hop-stabilization test might be better suited for later stages of postinjury evaluations. Further research is required to investigate the use and sensitivity of the test with pathological populations.

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