Comparison of Elderly Nonfallers and Fallers on Performance Measures of Functional Reach, Sensory Organization, and Limits of Stability

Harvey W. Wallmann

Department of Physical Therapy, College of Health Sciences, University of Nevada, Las Vegas.

Background. Previous literature indicates that balance impairment is a primary risk factor in the occurrence of falls, which has led clinicians to develop gross standardized balance assessment tests to distinguish elderly nonfallers from fallers. The purpose of this study was to compare functional reach (FR), limits of stability (LOS), and sensory organization among elderly nonfallers and fallers.

Methods. FR was examined in 15 elderly nonfallers and 10 idiopathic fallers who were at least 60 years of age. Force-plate measures from the NeuroCom Smart Balance Master system, which included the LOS test and the sensory organization test (SOT), were used to quantify limits of stability and balance. Associations among the three tests were examined.

Results. There was no significant difference in mean FR distance between elderly nonfallers and fallers using the functional reach test. FR distance did not correlate with anterior displacement on the LOS test. There was a significant difference in mean composite score on the SOT between nonfallers and fallers as well as a significant positive correlation between the SOT composite score and anterior displacement on the LOS test for fallers.

Conclusions. The results suggest that FR measures do not differentiate nonfallers from fallers. In contrast, this study demonstrates that using the SOT protocol could differentiate elderly nonfallers from fallers for balance impairment. Caution should be used when interpreting information from the FR test in determining a balance-impaired population.

Prior studies have indicated that balance impairment is a primary risk factor in the occurrence of falls (1–3), leading clinicians to develop gross standardized balance assessment tests to distinguish elderly nonfallers from fallers. The functional reach (FR) test has been used as a clinical balance measure for assessing control of the center of gravity (COG) (4).

The use of computerized dynamic posturography (CDP) has allowed clinicians to objectively measure the postural components of balance (5–10). CDP assesses sway by measuring shifts in the COG as a person moves within the available limits of stability (LOS). Two types of tests used with CDP are the Sensory Organization Test (SOT) and the LOS test. The SOT measures sway and is designed to quantify an individual’s ability to maintain balance in a variety of complex sensory conditions. The LOS test measures volitional control of the COG.

Despite previous studies establishing the test–retest reliability, sensitivity, and validity for these tests, there remains a paucity of research establishing the relationship between FR and LOS or between sensory organization and LOS (1,4,6,8–19). According to Duncan and colleagues (4), the measure of standing functional reach shows a moderate association with the anterior–posterior center of pressure excursion (COPE). They imply that, within the base of support, reaching tasks represent the same kind of controlled COPE as leaning tasks. If the FR test is to be used as a clinical screening tool to predict falls, then the relationship among FR, LOS, and the sensory components of balance for nonfallers and fallers needs to be identified.

The purpose of this study was to compare elderly nonfallers and fallers for differences in (i) mean FR, (ii) mean anterior LOS, and (iii) mean SOT composite score. The following correlations were tested for significance separately in the sample of nonfallers and the sample of fallers: (i) FR and anterior LOS, (ii) FR and SOT composite score, and (iii) anterior LOS and the SOT composite score.

METHODS

Participants
Participants for this study were a convenience sample of volunteers recruited from senior centers and were contacted via a recruitment advertisement through each center’s director. Those interested signed an informed consent to participate in the study.

The following criteria were used to select the participants: the control group had no current or past medical diagnosis of injury affecting balance within the last 3 years; was taking no medications affecting the central nervous system or known to affect balance or coordination; had no current symptoms of dizziness or lightheadedness; had no orthopedic or neurologic diagnosis or symptoms suggestive of vestibular or neurologic disorders; had no history of one or more unexplained falls related to loss of balance within the past 12 months; was able to stand for 10 minutes without...
the use of an assistive device; was able to raise and keep one arm parallel to the ground while leaning forward; had no pain that would limit their ability to stand or reach; was 60 years of age or older; and had normal corrected or uncorrected vision.

The test group was selected on the basis of the same criteria except that they had a history of at least one unexplained fall in the past 12 months. A fall was not counted if it occurred due to fainting, illness, during unusual activities in which a fit active person may fall, or in an unusually hazardous environment. A person had a fall if they ended up on the ground or floor when they did not expect to during a routine activity.

**Instrumentation**

The SOT and LOS test protocols were administered using the NeuroCom Smart Balance Master system (NeuroCom, Clackamas, OR). The equipment has been described in previous literature (9,20).

**SOT Measures**

The composite equilibrium score reflected the overall performance on the SOT and was used in this study as a measure of balance. This score consisted of averaging the three equilibrium scores for each of the six trial conditions. Equilibrium scores were expressed as a percentage between 0 and 100, with 0 indicating sway that exceeded the limits of stability (large sway), resulting in a loss of balance, and 100 indicating perfect stability (small sway).

**LOS Measures**

The LOS test measured control of the COG. Test measures included maximum end-point excursion for anterior, posterior, right, and left movements and were measured as a percentage of the maximum end point reached during an 8-second trial.

**FR Measures**

FR was performed using a leveled yardstick secured to the wall as a guide at the height of the acromion on the dominant arm with the actual distance measured in centimeters. A plastic grid was affixed to the wall to mark starting and ending points. For consistency, foot placement was in accordance with the NeuroCom manufacturer’s standard protocol for the SOT and LOS tests. The starting position of the participant was similar to that used by Duncan and colleagues (4). Additionally, acromion height was marked prior to each trial. The score was the mean of three trials.

**Procedures**

The screening included (i) a brief musculoskeletal and neurological examination to assess active elbow and shoulder range of motion as well as lower extremity reflexes and (ii) height, which was necessary to calculate the participant’s LOS. Testing order was randomized and included the FR test, the SOT test, and the LOS test.

For the FR test procedure, participants stood in their stocking feet and were asked to make a fist and raise their arm out in front of them parallel to the yardstick (Position 1). A measurement was recorded at the distal end of the third metacarpal along the yardstick on the grid. Participants were then asked to reach forward as far as possible, keeping their arm parallel to the yardstick, without taking a step (Position 2). The position at the distal end of the third metacarpal was then recorded. No attempt was made to control the participant’s method of reach. However, the trial was considered invalid and was repeated if the participant touched the wall or stepped to maintain balance. Each participant was given two practice trials and three test trials, with the FR score defined as the mean difference between Positions 1 and 2 over the last three trials. During testing for all procedures, an additional researcher was always present to protect against falling in case of a loss of balance.

For the SOT and the LOS tests, participants stood in their stocking feet, were placed in a safety harness, and were positioned on the NeuroCom forceplate facing the monitor at eye level according to the manufacturer’s standard protocol for both tests (21). During the SOT, participants were tested during three 20-second trials for each of the following six conditions:

1. Eyes open, fixed support surface and surround (visual, vestibular, and somatosensory modalities available)
2. Eyes closed, fixed support surface and surround (absent visual input)
3. Eyes open, sway-referenced surround, and fixed support surface (visual input inaccurate)
4. Eyes open, sway-referenced support surface, and fixed surround (somatosensory inputs inaccurate)
5. Eyes closed, sway-referenced support surface, and fixed surround (absent visual input and somatosensory input inaccurate)
6. Eyes open, sway-referenced surround and support surface (inaccurate visual and somatosensory inputs)

In the first trial, each of the six conditions was performed consecutively with instructions to familiarize the participant with the equipment. However, the order of the next 12 trials was randomized. If the participant fell or stepped to maintain balance, a zero was scored.

During the LOS test, participants were instructed to move to four predetermined square targets, with the center target representing the starting position. The targets were located on a video screen at eye level. Targets were spaced at 90-degree intervals around an oval representing 100% of the distance from the center position to the participant’s theoretical LOS. Participants were asked to move the cursor from the center target to the designated target so that the cursor coincided with the target displayed, hold that position for 8 seconds, and then return to the center target. The targets were sequentially highlighted in a clockwise direction during testing. Feet were repositioned if necessary following loss of balance or foot shift during testing. One practice trial to each target in the cardinal planes was allowed to familiarize the participant with the test.

**Data Analysis**

Data were analyzed using the SPSS statistical package for Windows, release 10.0. Means and standard deviations were calculated for the outcome variables separately for nonfallers and fallers. Independent t-tests were used to com-
pare differences in FR distance and physical performance measures on the SOT and LOS test between nonfallers and fallers. The association between FR scores, the LOS test, and the SOT was tested using the Pearson correlation coefficient separately for nonfallers and fallers. Alpha levels were set at .05.

RESULTS

Demographics and Number of Falls

Of the 27 participants enrolled in the study, two were excluded from the data analysis due to incomplete data. Participants with complete data included 18 women and 7 men with a mean age of 74.9 ± 8.6 years for nonfallers and 72.7 ± 9.2 years for fallers. Fifteen participants met the eligibility criteria for nonfallers, and 10 participants met the eligibility criteria for fallers.

Comparison on the Physical Performance Measures

There was no significant difference in mean FR measures between nonfallers and fallers (p = .82). No significant differences were found between nonfallers and fallers for the anterior LOS test (p = .06). A significant difference was found between nonfallers and fallers for the mean SOT composite score (p = .03). Fallers demonstrated decreased mean scores for Conditions 3 through 6 on the SOT but exhibited significantly greater sway compared with nonfallers on Condition 4 only (p = .02).

Correlations Between the Physical Performance Measures

Assessment of the relationship between the performance on the FR test and anterior displacement on the LOS test did not reveal a significant correlation for either nonfallers (r = −.009, p = .98) or fallers (r = .17, p = .65). However, there was a significant positive correlation between anterior displacement on the LOS test with the SOT composite score for fallers (r = .79, p = .006) but not for nonfallers (r = .43, p = .11) (Table 1).

DISCUSSION

Functional Reach and LOS Measures

Analysis of the 25 participants in this study revealed that FR measures do not differentiate elderly nonfallers from fallers, which is in agreement with other studies (22,23). However, this is in contrast to results found by Duncan and colleagues (13).

Wernick-Robinson and colleagues (22) showed that different types of movement strategies may be used with the FR test. This may potentially differentiate it from a leaning task, because the use of compensatory movement strategies may not have the effect of maximally anteriorly displacing the COG. No significant relationship was found for FR measures with anterior displacement on the LOS test, which suggested that a reaching task is not the same as a forward leaning task.

SOT Measures

Balance scores were significantly lower in fallers compared with nonfallers, indicating that fallers were unable to compensate for overall challenges to balance as well as nonfallers could. This is in agreement with other studies that have suggested that balance function is a predictor of falls (4,24).

The strong positive relationship between anterior displacement on the LOS test and the composite score on the SOT for fallers demonstrates that decreased LOS may have resulted in decreased composite scores and decreased balance, especially when visual and tactile-proprioceptive inputs were distorted, such as in Conditions 3 through 6 of the SOT. A limited LOS may impact the SOT score because the person may be unable to attain full sway.

Although this research may depend on the underlying impairment, it suggests that practitioners should work on leaning tasks as opposed to reaching tasks for two reasons: (i) reaching tasks do not correlate with leaning tasks and (ii) a lack of being able to lean forward as opposed to reaching forward significantly correlates to decreased balance.

A potential limitation of this study was the method of recruitment. Only those reporting an unexplained fall within the last year prior to the onset of the study were recruited into the faller group. It is also realized that a small sample was used for the study and that larger groups may be necessary to achieve or verify statistical significance. The participants’ motivation and ability to follow the instructions may also have influenced the results. Additionally, some participants may have had undiagnosed pathological conditions that may have affected their ability to control posture.

Conclusions

On the basis of the results of this study, FR is not an appropriate indicator for differentiating elderly nonfallers from fallers. In contrast, this study demonstrates that using the SOT protocol can differentiate nonfallers from fallers for balance impairment.

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Address correspondence to Harvey W. Wallmann, DPTSc, PT, SCS, ATC, CSCS, Department of Physical Therapy, College of Health Sciences, 4505 Maryland Parkway, Box 453029, Las Vegas, NV 89154-3029. E-mail: hwallmann@ccmail.nevada.edu

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