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Comparison of Elderly Non-Fallers and Fallers on Performance Measures of Functional Reach, Sensory Organizations, and Limits of Stability

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COMPARISON OF ELDERLY NON-FALLERS AND FALLERS ON PERFORMANCE MEASURES OF FUNCTIONAL REACH, SENSORY ORGANIZATION, AND LIMITS OF STABILITY

by

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Each person whose signature appears below certifies that this publishable paper in their opinion is adequate, in scope and quality, as a publishable paper in lieu of a thesis for the degree Doctor of Physical Therapy Science.

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ABSTRACT

OBJECTIVE: The purpose of this study was to compare elderly non-fallers and fallers for differences in the following: (1) mean functional reach (FR), (2) mean anterior limits of stability (LOS), (3) mean posterior LOS, and (4) mean sensory organization test (SOT) composite score. The following correlations were tested for significance separately in the sample of non-fallers and the sample of fallers: (1) FR and anterior LOS, (2) FR and posterior LOS, (3) FR and SOT composite score, (4) anterior LOS and the SOT composite score, and (5) posterior LOS and the SOT composite score.

DESIGN: Two group comparison design.

SETTING: A university physical therapy research laboratory.

PARTICIPANTS: The 25 participants recruited for this study included 15 elderly non-fallers and 10 idiopathic fallers.

MEASUREMENTS: Outcome measures included FR and forceplate measures from the LOS test and the SOT. The forceplate measures, obtained using the NeuroCom Smart® Balance Master system, included maximum end point excursion for anterior, posterior, right, and left movements for the LOS test and a composite score for the SOT. The composite score consisted of sway area using six different sensory conditions with eyes open and closed.

RESULTS: There was no significant difference in mean FR distance between elderly non-fallers and fallers. 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 non-fallers and fallers as well as a significant positive correlation between the composite score and anterior displacement on the LOS test for fallers. Age showed a significant negative correlation with the composite score for both non-fallers and fallers.

CONCLUSION: The results suggested that FR measures do not appear to differentiate non-fallers from fallers, as they both attained nearly the same mean FR distance. In contrast, this study demonstrated that using the SOT protocol can differentiate non-fallers from fallers for balance impairment. Caution should be used when interpreting information from the FR test in determining a balance-impaired population.

INTRODUCTION

Daily activity requires that people make postural adjustments to environmental distractions that may challenge their balance. The inability to make these compensations, secondary to disabilities or abnormal compensatory responses, would predispose them to falls. A fall may be defined as the result of inadequate functional balance that may result from interplay among intrinsic, situational, and environmental factors. [1,2] Falls in the elderly present a significant challenge to the health care industry due to the various risk factors that have been identified as potential contributors and the number of injuries that result. [3-6] Although many disabilities are prevalent in the elderly, not all may be predictive of falling. Other factors may come into play.

Age-related Factors

With increasing age, mechanisms for postural control begin to deteriorate resulting in a decline in postural stability and an increased susceptibility to falls. [5,6] Between one-third and one-half of the elderly over age 65 experience falls annually and 6% sustain fractures. [7,8] In fact, half of the elderly who fall, do so repeatedly. [9]

A study comparing frail elderly fallers and vigorous elderly fallers found that the frequency of falling was much higher among the frail, although the vigorous group had a greater chance of suffering a serious injury. [1] The fear of falling in the elderly can be so overwhelming that it frequently leads to subsequent self-imposed inactivity, thereby increasing the risk of future falls secondary to loss of strength, flexibility, and mobility. [10] These limitations may lead to musculoskeletal restrictions, which may then lead to limitations in the movement strategies used in balance.

Postural Control

Postural control is the ability to maintain equilibrium by keeping or returning the center of gravity (COG) over its base of support. An inability to correctly maintain this COG over the base of support results in impaired balance. Postural stability, on the other hand, has been defined as the ability to maintain the position of the body and the COG within specific limits of stability (LOS). The LOS are specific boundaries of space where the body can maintain its position without changing its base of support. [11] In adults, Nashner [12] found the LOS to be 12 degrees in the anterior-posterior (AP) direction and, with the feet four inches apart, 16 degrees in the medial-lateral (ML) direction.

Sensory input from the environment is also important when considering the COG alignment and can affect the visual, somatosensory, and vestibular systems. Sensory organization involves comparison among these three sensory systems and between the different body parts. [13,14]

An important indicator of balance function is postural sway [15] and the strategies involved in controlling forward or backward sway. [16] Researchers have shown that sway increases in the elderly [17-19] and that the frequency of falls increases as sway increases. [20,21] Research suggests that elderly fallers have more difficulty maintaining postural control, and sway more in quiet or perturbed stance, than those who are non-fallers. [2,22] Although not completely understood, investigators have also found that the LOS in the elderly are more confined than in younger individuals. [23]

Many researchers have studied the organization of movement strategies used in recovering stability after either a perturbation or a displacement of the supporting structure. These postural movement strategies have been described in the literature and are referred to as ankle, hip, and stepping strategies. [7,11,13,16,24] Whereas younger adults compensate using an ankle strategy when balance is threatened, older adults tend to use a hip strategy more frequently. [25]

Balance Assessment

It is important to screen individuals to identify potential balance problems, since a considerable amount of time is spent retraining individuals with posture and balance limitations. Prior studies have shown that balance impairment is a primary risk factor in the occurrence of falls. [3,7,26] Efforts to study the phenomenon of falling have led clinicians to develop gross standardized balance assessment tests to distinguish elderly non-fallers from fallers by describing and measuring balance impairment. Examples of these tests have been cited in the literature, [27-31] including the functional reach (FR) test used in this study, as clinically accessible dynamic balance measures for assessing control of center of gravity (COG). [6] Volitional postural control is measured by evaluating an individual's COG as that person moves within the available LOS. In order to quantify balance impairment in the elderly, a tool is required that has been tested for reliability, validity, and sensitivity to change. The FR test has previously established reliability, validity, and sensitivity. [4,6,31]

Quantitative measurements of balance and postural control through the use of computerized dynamic posturography (CDP) have provided clinicians with the ability to objectively measure the multiple dimensions of the postural components of balance. [15,32-36] CDP measures feet-in-place balance and assesses sway by measuring shifts in the COG. Unlike the gross clinical screening tests, CDP allows researchers to examine abnormalities of visual, somatosensory, and vestibular input, as well as motor input via postural perturbation.

Two types of tests used with CDP are the Sensory Organization Test (SOT) and the Limits of Stability test (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, providing information as to which cues the individual is unable to utilize when attempting to maintain postural control during a specific task. The LOS test measures volitional control of the COG, while simultaneously assessing speed, direction, and distance of COG movement. Several studies have been conducted establishing the test-retest reliability, sensitivity, and validity for both the SOT and the LOS test. [3,19,32,34-42]

Despite these previous studies, there remains a paucity of research establishing the relationship between FR and LOS or between the SOT and LOS. According to Duncan et al., [6] the measure of standing functional reach is a reliable measure of balance, showing a moderate association with anterior-posterior (AP) center of pressure excursion (COPE) and was designed as a measure of the margin of stability similar to the COPE. They state that reach tasks represent the same kind of controlled COPE within the base of support (BOS) as do leaning tasks. However, the FR assesses the dynamic stability only in an anterior direction and not in the posterior direction. Also, it does not address medial-lateral (ML) instability.

Blaszczyk et al. [38] found significantly reduced maximum excursion distances in the elderly, most notably in the posterior direction. Wernick-Robinson et al. [43] concluded that the FR does not really measure dynamic balance. A study by Maki et al. [44] revealed that fallers exhibit greater amplitudes of center of pressure displacement in the ML rather than the AP direction compared with non-fallers, and that lateral amplitude was found to be the single best predictor of future falling risk. If this is the case, then one must question the relationship of FR to the LOS, since both purportedly quantify the ability to voluntarily displace the COG. A question also arises as to the relationship between LOS and the postural control components involved in balance. Using the SOT and LOS test protocols allow objective measurement of sway and the LOS. If the FR test is to be used as a clinical screening tool to predict falls, then the relationship between FR and LOS for non-fallers and fallers needs to be identified. Additionally, the relationship between LOS and the sensory components of balance needs to be investigated.

The purpose of this study was to compare elderly non-fallers and fallers for differences in the following: (1) mean FR, (2) mean anterior LOS, (3) mean posterior LOS, and (4) mean SOT composite score. The following correlations were tested for significance separately in the sample of non-fallers and the sample of fallers: (1) FR and anterior LOS, (2) FR and posterior LOS, (3) FR and SOT composite score, (4) anterior LOS and the SOT composite score, and (5) posterior LOS and the SOT composite score.

METHODS

Participants

Participants for this study were a convenience sample of volunteers recruited from senior centers in a major metropolitan area and were contacted via a recruitment advertisement through each center's Director. The principal investigator gave balance presentations to each group solicited. Those interested signed an informed consent to participate in the study.

A slightly modified definition of a fall was given to the participants as follows: a person had a fall if they ended up on the ground or floor when they didn't expect to during a routine activity. If a person ended up on the ground, either on their knees, their belly, their side, their bottom, or their back, they were considered as having had a fall. A fall was not counted if it occurred due to fainting, being ill, during unusual activities in which a fit active person may fall, or in an unusually hazardous environment [after Duncan [6]].

Participants needed to experience at least one unexplained fall within the last twelve months, which was verified via a questionnaire, to be considered as viable candidates for meeting the criteria for fallers. Table 1 contains more detailed criteria for inclusion into the study. The non-faller group was selected based on the same criteria except that they had no history of falls in the past twelve months.

Table 1
Criteria for Inclusion for Fallers

Criteria
1. No current or past medical diagnosis of injury affecting balance within the last three years
2. No medications affecting the CNS or known to affect balance or coordination
3. No current symptoms of dizziness or lightheadedness
4. No orthopaedic or neurologic diagnosis or symptoms suggestive of vestibular or neurologic disorders
5. A history of one or more unexplained falls related to loss of balance within the past twelve months
6. Able to stand for ten minutes without the use of an assistive device
7. Able to raise and keep arm parallel to the ground while leaning forward
8. No pain that would limit their ability to stand or reach
9. Was 60 years of age or older
10. Had normal corrected or uncorrected vision

Instrumentation

The SOT and LOS test protocols were administered using the NeuroCom Smart® Balance Master system (NeuroCom), which consisted of a movable dual forceplate, movable monitor, and an overhead bar with safety harness and straps. The forceplate moved in and out of the horizontal plane. This functioned to pitch the individual forward or backward. [45]

In addition to the computer-controlled moveable forceplate, a moveable visual surround was used to allow for sway referencing. Sway referencing is the act of moving the dual forceplate and/or the visual surround to exactly follow the person's sway. This is similar to the postural challenges posed by activities such as leaning and reaching. The forceplate and visual surround moved in response to the participant's forward and backward sway and created a disturbed proprioceptive and/or visual input to the brain so that the person had to rely more heavily on alternative senses to maintain equilibrium. A computer analyzed the center of force versus time responses. The dual forceplate consisted of two 9 x 18 inch footplates connected by a pin joint. Four transducers were mounted symmetrically under the footplates on a supporting center plate, and a fifth transducer was bracketed to the center plate directly beneath the pin joint. The corner transducers measured vertical forces, while the center transducer measured shear forces in the plane parallel to the floor. Three servomotors, each powered by its own linear direct amplifier, moved the forceplates and visual surround in response to commands from the computer.

SOT Measures

The SOT identified impairments in the three primary sensory systems that contributed to balance. In order to interpret the SOT results, the composite equilibrium score needed to first be examined. The composite equilibrium score consisted of an averaging of three equilibrium scores for each of the six trial conditions and was based on the assumption that a normal individual exhibited anterior to posterior sway over a total range of 12.5 degrees. [46] Equilibrium scores were expressed as a percentage between 0 and 100 with 0 indicating sway that exceeded the limits of stability (sway is large), resulting in a loss of balance, and 100 indicating perfect stability (sway is small). SOT results were considered abnormal when the composite score fell below the 5th percentile as compared to an age-matched population. [46] The composite equilibrium score reflected the overall performance on the SOT and was used in this study as a measure of balance. It was calculated by independently averaging the scores for conditions 1 and 2, adding these two scores to the equilibrium scores from each trial of the sensory conditions 3, 4, 5, and 6, and then dividing the sum by 14.

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 in percentage of the maximum end point reached during an eight-second trial.

FR Measures

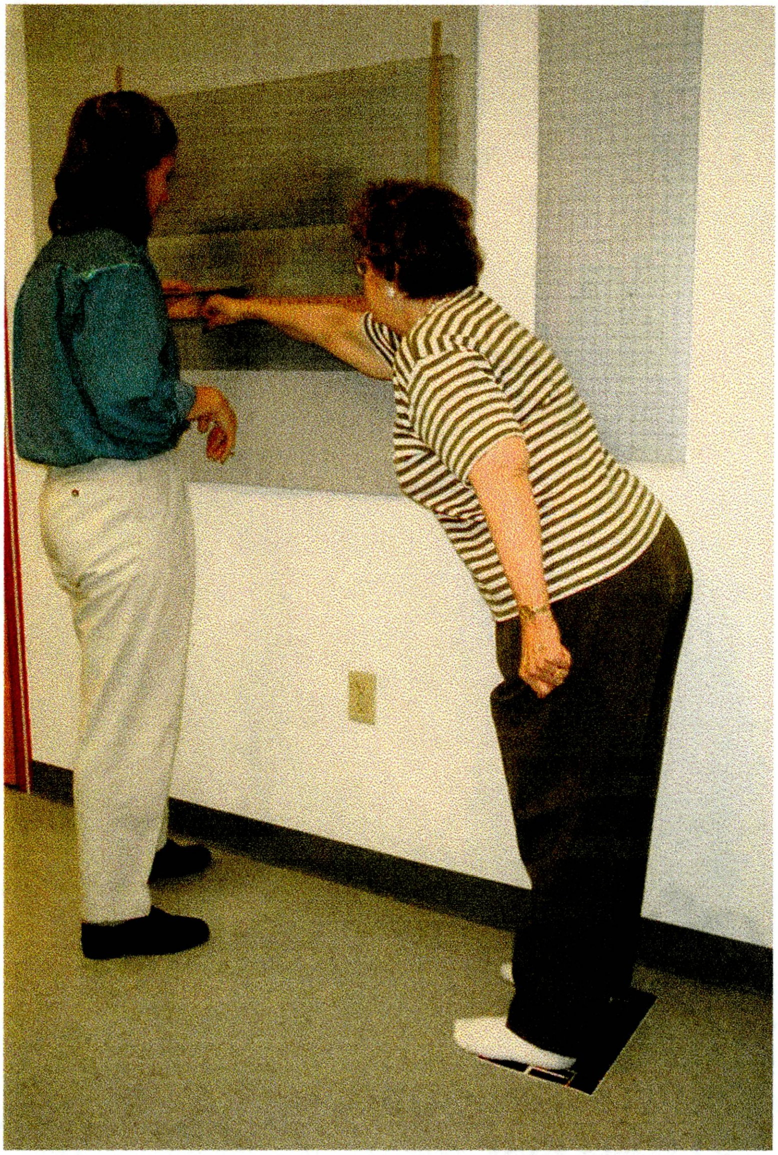
FR was performed using a leveled yardstick secured to the wall as a guide at the height of the acromion on the dominant arm (Figure 1). The actual distance was measured in centimeters using a metric tape measure. A plastic grid was affixed to the wall in order to mark starting and ending points. For consistency, foot placement was in accordance with the NeuroCom manufacturer's standard protocol for the SOT and LOS tests; a copy of the foot placement was made and used in the FR test. The starting position of the participant was similar to that used by Duncan et al. [6] The only difference was that the starting position was marked according to acromion height prior to each trial. The score was the mean of three trials.

Procedures

Individuals agreeing to participate and meeting the criteria were notified of the testing time and transported to the testing site where a member of the research team screened them. The research team consisted of two research assistants and the principal investigator. The screening included the following measures: (a) a questionnaire to determine the activity level of each participant; (b) a brief musculoskeletal and neurological examination to assess active elbow and shoulder range of motion as well as lower extremity reflexes to determine if the participant was able to attain appropriate shoulder flexion for the FR test; and (c) height, which was necessary to calculate the participant's LOS. Testing included (a) FR, (b) the SOT, and (c) the LOS test. Testing order was randomized.

Figure 1

The Functional Reach 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, while keeping their arm parallel to the yardstick, without losing balance or taking a step (position 2). Verbal directions without demonstration were “keeping your arm in front of you, reach forward as far as you can without taking a step. Begin reaching when I say 'go'.” 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 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 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. [34] The medial malleoli were placed over the placement strip imprinted on the forceplate. Participants were instructed to stand quietly with their hands on their hips or their arms at their sides for the SOT and LOS tests, respectively; and to keep their feet in the correct position at all times during each trial. During the SOT, participants were tested during three 20-second trials for each of six conditions

(Figure 2). The protocol for the SOT has been previously described [10,39] and is included in Table 2. The first trial of 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, a zero was scored.

During the LOS test, participants were instructed to move to four predetermined square targets in the periphery. A center target, which represented the centered COG, was the starting position. The targets were located on a video screen in front of the individual at eye level (Figure 3). 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 (diagonal targets were not used). Participants were instructed to stand as still as possible on the forceplate while keeping the cursor in the center target area. Next, the participants were asked to move the cursor from the center target to the designated LOS target so that the cursor coincided with the target displayed, hold that position for eight seconds, and then return to the center target. The targets were sequentially highlighted in a clockwise direction during testing. If participants were not able to reach the target, they were instructed to lean as far as possible in that direction without losing balance for the full eight seconds. Foot position was checked after each test and the feet were repositioned if necessary following loss of balance or foot shift during testing. One practice trial to each target in the cardinal planes (four trials) was allowed in order to familiarize the participant with the test.

Figure 2

The six conditions of the SOT (Figure courtesy of

NeuroCom International Inc., Clackamas, OR)

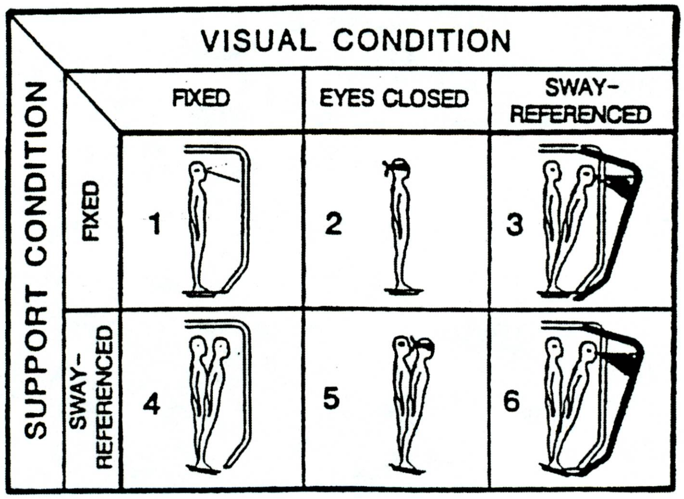


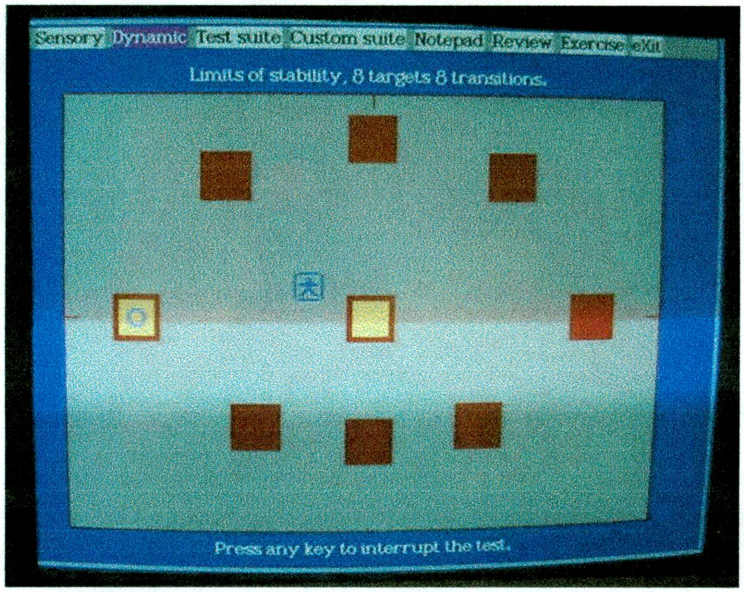
Table 2

The SOT Protocol

Protocol
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)

Figure 3

The LOS Test



Data Analysis

Data was analyzed using the SPSS statistical package for Windows®, release 10.0. Means and standard deviations were calculated for the outcome variables separately for non-fallers and fallers. Independent t-tests were used to compare differences in FR distance and physical performance measures on the SOT and LOS test between non-fallers and fallers. The association between FR scores, the LOS test, and the SOT were tested using the Pearson correlation coefficient separately for non-fallers and fallers. Alpha levels were set at 0.05.

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 females and 7 males with a mean age of 74.9 $\pm$ 8.6 years for non-fallers and 72.7 $\pm$ 9.2 years for fallers. Fifteen participants met the eligibility criteria for non-fallers, while 10 participants met the eligibility criteria for fallers. Performance on physical performance measures is summarized for non-fallers and fallers in Tables 3-6.

Comparison on the physical performance measures

Comparisons of non-fallers and fallers for the FR test are reported in Table 3. There was no significant difference in mean FR measures between groups. Tables 4 and 5 compare non-fallers and fallers for the anterior and posterior LOS tests. No significant differences were found between groups for either test. Table 6 compares non-fallers and fallers for the mean SOT composite score. A significant difference was found between groups ($p = 0.03$).

Fallers demonstrated decreased mean scores for conditions 3-6 on the SOT, but exhibited significantly greater sway compared with non-fallers on condition 4 only. These results are summarized in Table 7.

TABLE 3

Functional Reach

Group	Min	Max	Mean	S.D.	p-value
NF (n=15)	16.6	35.2	27.21	5.75	
F (n=10)	6.1	44.1	26.43	11.49	0.82*

NF - non-faller
F - faller
* Faller not significantly different from NF using independent t-test

TABLE 4

LOS Anterior

Group	Min	Max	Mean	S.D.	p-value
NF (n=15)	48	109	79.5	19.0	
F (n=10)	29	91	63.9	19.9	0.06*

NF - non-faller
F - faller
* Faller not significantly different from NF using independent t-test

TABLE 5

LOS Posterior

Group	Min	Max	Mean	S.D.	p-value
NF (n=15)	26	95	65.40	23.5	
F (n=10)	0	86	55.00	24.9	0.30*

NF - non-faller
F - faller
* Faller not significantly different from NF using independent t-test

TABLE 6

SOT Composite

Group	Min	Max	Mean	S.D.	p-value
NF (n=15)	48.00	80.00	63.73	9.48	
F (n=10)	34.00	72.00	53.40	13.08	0.03*

NF - non-faller
F - faller
* Faller significantly different from NF using independent t-test

Table 7

Comparisons of characteristics of participants for Trials 3-6 on the SOT for Non-fallers and Fallers (Refer to Figure 2)

Condition	Min	Max	Mean	S.D.	p-value
Condition 3					
NF (n=15)	51.00	94.00	82.66	10.50	
F (n=10)	49.70	87.30	77.24	11.61	0.24
Condition 4					
NF (n=15)	54.00	89.00	76.95	9.45	
F (n=10)	41.00	85.00	64.80	15.36	0.02*
Condition 5					
NF (n=15)	.00	70.30	43.31	19.12	
F (n=10)	.00	66.67	30.18	25.32	0.15
Condition 6					
NF (n=15)	.00	73.00	33.30	26.39	
F (n=10)	.00	59.00	19.43	24.28	0.20

NF - non-faller
F - faller
* Faller significantly different from NF using independent t-test

Correlations between the physical performance measures

Assessment of the relationship between the performance on the FR and anterior displacement on the LOS test did not reveal a significant correlation for non-fallers (r=-0.009, p=0.98) or fallers (r=0.17, p=0.65). However, there was a significant positive correlation between anterior displacement on the LOS test with the SOT composite score for fallers (r=0.79, p=0.006), but not for non-fallers (r=0.43, p=0.11). There was a significant negative correlation between age and the composite score for fallers (r=-0.78, p=0.008), but only a moderate significant negative correlation with non-fallers (r=-0.53, p=0.05). As age increased, the composite score decreased. Correlations for non-fallers and fallers for the different performance standards are shown in Tables 8 and 9.

Table 8

Correlations for Non-fallers

	Comp	FR	Ant	Post
Age	-0.53* (0.05)†	-0.23 (0.41)	-0.30 (0.28)	-0.47 (0.08)
Comp		0.35 (0.20)	0.43 (0.11)	0.31 (0.27)
FR			-0.009 (0.98)	0.41 (0.13)
Ant				0.26 (0.36)

* Pearson correlation coefficient
† p-value
Comp - SOT, composite score
FR - functional reach
Ant - LOS test, anterior displacement

Table 9

Correlations for Fallers

	Comp	**FR**	**Ant**	**Post**
Age	-0.78* (0.008)†	-0.27 (0.45)	-0.55 (0.10)	-0.41 (0.24)
Comp		0.18 (0.63)	0.79 (0.006)	0.38 (0.28)
FR			0.17 (0.65)	0.59 (0.07)
Ant				0.05 (0.90)

* Pearson correlation coefficient
† p-value
Comp - SOT, composite score
FR - functional reach
Ant - LOS test, anterior displacement

DISCUSSION

Functional Reach and LOS Measures

Analysis of the 25 participants in this study revealed that FR measures do not differentiate elderly non-fallers from fallers, as no significant difference was found between groups for mean FR distances. These results are in agreement with other authors, who found that measurement of FR distance did not differentiate healthy elderly non-fallers from fallers and other individuals with known balance impairments.[43,47] This is in stark contrast to results found by Duncan et al.,[31] who found significant differences between non-fallers and fallers with the FR test. In the current study, the mean FR distance of non-fallers was lower than the mean FR distance among age-matched elderly found by Duncan et al.[6] and was only slightly higher than the mean FR distance of the fallers. It was expected that fallers would have a shorter reaching distance than non-fallers; but, in the current study, both groups had approximately the same mean value. This may be because people with balance deficits use different movement strategies while reaching forward, thereby compensating for decreases in LOS.

In fact, the manner in which individuals perform the FR test has been a matter of controversy, regarding how far the COG is displaced, and may be largely dependent on the strategy employed. Wernick-Robinson et al.[43] showed that different types of movement strategies may be used with the FR test to reach forward. This may potentially differentiate it from a leaning task, since the use of compensatory movement strategies may not have the effect of maximally anteriorly displacing the COG. The authors suggested that it may be possible to reach forward without increasing the moment arm, thereby differentiating a reaching task from a leaning task. Utilizing the LOS test, however, allows testing and quantification of anterior stability. No significant relationship was found for FR measures with anterior displacement on the LOS test. The data from this research suggested that a simple reaching task, as simulated by the FR test, is not correlated to a simple forward leaning task, as simulated by the LOS test. Clinically, determining the type of strategy employed may assist the clinician in assessing underlying impairments contributing to functional limitations.

SOT Measures

In this study, balance scores were significantly lower in fallers compared to non-fallers, as presented by the six different conditions on the SOT, indicating that fallers were unable to compensate for overall challenges to balance as well as non-fallers could. This is in agreement with other investigators who have suggested that balance function is a predictor of falls. [6,20] These results could potentially impact physical therapy practice by placing more emphasis on quantitative assessment of balance, compared to subjective clinical assessment tests, to more accurately assess the types of balance impairments. This could lead to more definitive intervention based upon the type of impairment noted.

Results from the SOT allow researchers to determine the amplitude of postural sway oscillations as each trial progresses. Postural sway measurement has been reliable in detecting individuals who are at risk of falling. [20] If the sway breaches the LOS, a fall may result, unless other strategies, such as hip, ankle, or stepping are used to compensate. Some researchers have shown that postural sway increases with age, [2,18,28,37,44,48] suggesting less postural stability and decreased balance. Results of the current study revealed that fallers had decreased anterior displacement on the LOS test when compared with non-fallers. Although no significant difference was found between non-fallers and fallers, clinically, this suggests a constriction of fallers' anterior LOS, thus predisposing them to falling.

The strong positive relationship between anterior displacement on the LOS test and the composite score on the SOT for fallers demonstrates that decreased LOS results in decreased composite scores and decreased balance, especially when visual and tactile-proprioceptive inputs are distorted, such as in conditions 3-6 of the SOT. If an individual has severely limited LOS, it will impact the SOT score, because the person is unable to attain full sway.

It should be noted that SOT scores may not adequately differentiate participants who show a high sway amplitude from participants who are able to maintain their LOS for the majority of the trial. Ford-Smith et al. [49] noted this in their study of the test-retest reliability of the SOT. If a participant has a loss of balance (LOB) episode at anytime during the trial, then a zero is scored. This could occur at the last second of the trial; whereas, the participant who sways constantly during the trial, but does not fall, may receive a score greater than zero. This would seem to decrease the sensitivity of the composite score, since it does not take into account how long the participant remained standing on any given trial. The data presented here, however, suggests that the SOT is able to detect instability in older adults, since the protocol was able to differentiate known elderly non-fallers from fallers.

LOB episodes occurred frequently in several of the non-fallers and fallers for conditions 4, 5, and 6 on the SOT. Several of the participants fell less frequently in their second or third trial than in the first. This could point to decreased test anxiety, resulting in increased comfort with the equipment and testing procedures. Since the trials were randomized, a learning curve would probably not account for this. A LOB on a single trial equals a score of zero, which may have accounted for the lower composite scores for many of the non-fallers and fallers. It appears the composite score as well as assessment of an individual's anterior LOS, may prove to be the most useful measures in assessing balance performance.

The significant difference in composite scores for non-fallers and fallers under different sensory conditions suggests that balance needs to be tested dynamically, as this more appropriately represents the domains of postural control required in daily activities. This is particularly true for conditions 3-6 on the SOT. As the surrounding and support surface characteristics are altered, postural responses change as well. Unless the LOS are breached, as happens with leaning tasks or perturbations to sway, no substantial differences in postural responses will result. Any increase in the severity of these perturbations may bring out balance abnormalities that might be predictive of a tendency to fall.

Another factor that may serve to differentiate non-fallers from fallers is the number of times a person falls. In the current study, there were five recurrent fallers and five one-time fallers. The data suggested there are differences between groups of fallers and recurrent fallers for the anterior LOS test and the composite score. It may be that falling more than once is more likely to be associated with balance impairments, since single falls may be potentially classified as random events.

The results of this study have significant implications for practitioners. Educating elderly fallers concerning the difference between leaning and reaching is crucial for practitioners working with this population. Although it may depend on the underlying impairment, this research suggests that practitioners should work on leaning tasks as opposed to reaching tasks for two reasons: 1) reaching tasks do not correlate with leaning tasks, and 2) 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. Due to a lack of an agreed upon definition of falling, only those reporting an unexplained fall within the last year prior to the onset of the study were recruited into the faller group. Anyone experiencing falls beyond that time period was not recruited. 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 participant's motivation and ability to follow the instructions may also have influenced the results. Additionally, despite the strict adherence to the inclusionary criteria, some participants may have had undiagnosed pathological conditions that may have affected their ability to control posture.

CONCLUSION

Based on the results of this study, FR is not an appropriate indicator for differentiating elderly non-fallers from fallers. In contrast, this study demonstrated that CDP can differentiate non-fallers from fallers for balance impairment.

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APPENDIX A

COMPLETE LITERATURE REVIEW

Posture and balance are essential for many of the tasks involved in our daily activities and are neither identical nor completely separate. Although there is no universal agreement as to the definition of posture and balance or on the underlying neural mechanisms, many clinicians would be quick to acknowledge their importance. Posture usually refers to the alignment of the body in relation to a reference point, whereas balance is a highly integrative process involving multiple afferent and efferent pathways that work together to control posture. [1] Balance may be specifically defined as the stability produced on each side of a vertical axis. [2]

Age Related Factors

Normal postural control involves the control of relative positions of body parts by skeletal muscles, with respect to gravity and to each other. [2] With increasing age, mechanisms for postural control begin to deteriorate, resulting in a decline in postural stability and an increased susceptibility to falls. [3,4] Although it is difficult to predict fallers with certainty, several individual risk factors are usually present that contribute to producing falls. These risk factors may include motor, sensory, and cognitive processes. Examples of risk factors predisposing one to falling include multiple chronic diseases and disabilities such as diabetes or Parkinson's disease, cognitive impairment, lower and upper extremity disabilities, arthritis, visual or vestibular impairments, and gait disorders. Nearly one-third of the elderly over age 75 fall at least once and 6% sustain fractures over a one year period, [5] while every year one-third to one-half of the population aged 65 and over experience falls. [6] In fact, half of the elderly who fall, do so repeatedly. [7] Falls are responsible for more than 200,000 hip fractures annually with one in four survivors never regaining their previous mobility. [8,9]

A study comparing frail elderly fallers and vigorous elderly fallers found that the frequency of falling was much higher among the frail, although the vigorous group had a greater chance of suffering a serious injury. [10] The fear of falling in the elderly can be so overwhelming that it frequently leads to subsequent self-imposed inactivity, thereby increasing the risk of future falls secondary to loss of strength, flexibility, and mobility. [9] These limitations may lead to musculoskeletal restrictions, which may then lead to limitations in the movement strategies used in balance.

Postural Control

To understand postural behavior in an individual, it is necessary to understand the task of postural control. The postural control system acts as a feedback control circuit between the brain and the musculoskeletal system. [11] Postural control relates to how the body's position in space controls for stability and orientation and is the ability to maintain equilibrium by keeping or returning the center of gravity (COG) over its base of support. The COG is a point where all the mass of an object may be concentrated with respect to the pull of gravity. [1] Postural requirements have components integral to all tasks, with each task having an orientation component and a stability component. Postural orientation is the ability to maintain an appropriate relationship between the body segments. Postural stability, on the other hand, has been defined as the ability to maintain the position of the body and the COG within specific limits of stability (LOS) and is affected by factors such as nervous disorders, optic nerve dysfunction, and vestibular mechanisms.[1,11,12] The LOS are specific boundaries of space where the body can maintain its position without changing its base of support.[12] In adults, Nashner[13] found the LOS to be 12.5 degrees in the anterior-posterior (AP) direction and, with the feet four inches apart, 16 degrees in the medial-lateral (ML) direction.

Sensory input from the environment is also important when considering the COG alignment. Changes in the environment, whether they are stable or unstable, can affect the visual, somatosensory, and vestibular systems. Sensory organization involves comparison among these three sensory systems and between the different body parts.[1,11] The ability to control our body's spatial orientation is fundamental to everything we do. Subsequently, understanding balance is essential to clinical practice, since a considerable amount of time is spent retraining individuals with posture and balance limitations.

Conceptual theories describing neural control of posture and balance exist. However, within the past several years, research into posture and balance control has broadened. Many clinicians today relate to a systems approach model, suggesting that postural actions emerge from an interaction between the individual, the task, and the environment.[12,14] Since postural control requires a complex interaction between musculoskeletal and neural systems, it depends on the demands of the task, the stability and orientation components of the task, and the environment. Such is the case with stance postural control. Although the orientation component, which is usually vertical, may vary, the stability component of this task requires that the COG be kept within stringent limits. If this does not happen, a fall will occur.

Components of Postural Control

Balance depends on the interplay of the different functional components of the postural control system. These include *sensory organization*, which consists of somatosensory, visual, and vestibular inputs; *central motor planning and control*, which consists of the brain for the integration and the formation of a motor plan; and *peripheral motor execution*, which consists of the musculoskeletal system for the production of appropriate movement strategies to execute the plan. [1]

Feedback obtained from the sensory system relays commands to the extremity muscles, thereby generating appropriate contractions to maintain postural stability. [11,15] Visual input measures the orientation of the eyes relative to the environment, whereas the somatosensory input provides information concerning support surfaces. Vestibular input, however, is an internal reference that measures orientation of the head in space and is not referenced to external objects. [13] It has been shown that, under normal conditions, visual and somatosensory inputs are used primarily to maintain balance, [2,11,13,16] since it is speculated that both are more sensitive to subtle movements in COG position than is the vestibular system. However, both may be more prone to providing erroneous orientation information, depending on whether the surface is compliant or if the surrounding field is moving, thereby shifting responsibility to the vestibular system to account for discrepancies in the other two systems. This redundancy of sensory input ensures stability in situations where one or more of the inputs is lost. [2,17]

Problems that result in balance disorders or deficits may result in inadequate control of posture and balance and can lead to a fall, especially in the elderly population. Therefore, it is important to screen individuals to identify potential balance problems. The difficulty lies in identifying the systems that need to be examined for the possible impairments involved. One way of doing this is to identify impairments in the three primary sensory systems contributing to balance. Multiple risk factors might help explain why the problems within a single system would produce instability. [18] However, many individuals have no discernible diagnoses or risk factors that would explain their propensity for falls. Instead, they may have several smaller scale problems across systems that, in combination, interact to produce falls.

Postural Sway

An important indicator of balance function is postural sway (changes in the center of the patient's applied force). [19] Researchers studying postural control mechanisms have examined the strategies involved in controlling forward or backward sway. [20] Although body sway is a normal phenomenon, many researchers have shown that sway increases in older people [21-23] and that the frequency of falls increases as sway increases. [24,25] Research suggests that elderly fallers have more difficulty maintaining postural control, and sway more in quiet or perturbed stance, than those who are non-fallers. [26,27] Since postural control encompasses many systems, it is important for postural control measurement to identify not only maintenance of equilibrium, but also movement strategies used to reach that position. [20] Many researchers have studied the organization of movement strategies used in recovering stability resulting from either a perturbation or a displacement of the supporting structure. These postural movement strategies have been described in the literature and are referred to as ankle, hip, and stepping strategies. [1,5,12,20,28]

Movement Strategies

One of the first patterns to be identified was the ankle strategy. This strategy allows the COG to be restored through the use of body movement centered primarily about the ankle joints. However, synergistic activation of other muscle groups is necessary in order to correct for forward and backward sway. These muscle activation patterns occur in a distal to proximal sequence. [2] This strategy is most commonly used during situations where the perturbation is minimal and the support surface is firm, requiring intact ROM and strength. [12,20] The ankle strategy is most effective when the COG moves slowly and between positions located well within the LOS boundary. [29]

Another strategy that has been identified for controlling sway is the hip strategy. With this strategy, the COG is controlled by producing large amplitude movements about the hip joints in association with synergistic muscle activity in a proximal to distal pattern to assist in controlling sway. Researchers suggest that this strategy is used in response to larger perturbations, with a compliant support, or when the support surface is smaller than the feet (such as standing on a beam). [20,28] The hip strategy is most effective for rapid movements and movements near or on the LOS boundary. [29] Whereas younger adults compensate using an ankle strategy for balance, older adults tend to use a hip strategy more frequently. [30]

If the stability limitations are breached and the COG lies outside the support base of the feet, a fall will occur. Quite often, this happens when very large or fast perturbations occur for which the ankle or hip strategies are insufficient. In this case, it is necessary to change the base of support; this is accomplished by employing a stepping strategy to realign the base of support under the COG. [2,20,28]

Balance Assessment

Prior studies have shown that balance impairment is a primary risk factor in the occurrence of falls. [5,21,32] Efforts to study the phenomenon of falling have led clinicians to develop gross standardized subjective balance assessment tests to distinguish elderly non-fallers from fallers by describing and measuring balance impairment. Examples of these tests include the Tinetti Balance and Gait Scale; [33] the Berg Balance Test; [34] the Timed Up-and-Go-Test [35] for mobility and functional assessment; the Romberg sign for static balance assessment; [36] and the test used in this study, the Functional Reach (FR) test, as a measure of dynamic balance for assessing control of COG. [4]

Volitional postural control is measured by evaluating an individual's COG as that person moves within the available margins of stability. In order to quantify this balance impairment in the elderly, a tool is required that has been tested for reliability, validity, and sensitivity to change. It has been demonstrated that the FR test test-retest reliability, interobserver reliability, criterion validity, and predictive validity in identifying recurrent falls. [4,37] The FR was designed as a measure of the margin of stability, being used as a tool to measure anterior and posterior dynamic stability. The FR combines current dynamic postural control theory with a practical measurement system (a yardstick), thus allowing its application in a wide variety of settings. [38] It is defined as the maximal distance one can reach forward beyond arm's length, while maintaining a fixed base of support in the standing position.

Although not completely understood, investigators have found that the LOS in elderly individuals lies within a limited area. This may be in response to an impaired postural control mechanism. [39] Inasmuch as the gross screening tests are determined to be valid and reliable for identifying functional motor limitations, they do not discriminate between the somatosensory, visual, or vestibular systems, thereby making it difficult to judge the sensitivity or specificity of the tests.

Since balance control depends upon the ability to adaptively modify the relative weighting of each sensory and motor modality according to the environment, it is necessary to go beyond the use of subjective assessment. Quantitative measurements of balance and postural control have been made possible through the advent of forceplate technology. Forceplates can be either static or dynamic and are equipped with strain gauges to measure and record postural sway that is unable to be seen by the unaided observer. [19] Improvements in technology have allowed linkage of these forceplates to electronic digital computers, resulting in what is known as computerized dynamic posturography (CDP). Since its inception, the concept of CDP has gained increasing popularity in the areas of balance assessment, rehabilitation, and research. [8,19,40] Nashner originally developed the concept of dynamic posturography in 1970. [41] However, CDP was not clinically available until 1986 with the advent of the EquiTest (NeuroCom International, Inc. Clackamas, Ore.). As a result of using CDP, clinicians are now able to objectively measure the multiple dimensions of the postural components of balance, enhancing their ability to identify and provide treatment for balance disorders. This is particularly important when describing balance impairment in the elderly.

Using a computerized forceplate, CDP is used to quantitatively measure feet-in-place balance and can assess sway by measuring shifts in the COG. This requires that the COG remain within the base of support. [40] An inability to correctly maintain this COG over the base of support results in impaired balance. Analysis in measuring postural sway usually includes a computation of the projection of the center of applied force upon the horizontal plate as a function of time. [19] The results are compared with the performance of normal individuals.

In addition to the dynamic forceplate, a moveable visual surround may be used. Such is the case with the NeuroCom Smart® Balance Master system marketed by NeuroCom International Incorporated. The forceplate or visual surround, or both, move in response to the patient's forward and backward sway, disrupting the proprioceptive and/or visual input to the brain. A computer analyzes the center of force versus time responses. Unlike the gross clinical screening tests, CDP allows researchers to examine abnormalities for visual, somatosensory, and vestibular input, as well as motor input via postural perturbation. [31]

Dynamic posturography test protocols are designed to isolate the principal sensory and motor components of balance. [6] The two protocols used to measure dynamic posturography are the Sensory Organization Test (SOT) and the Movement Coordination Test (MCT). The SOT provides information as to which cues the individual is unable to utilize when attempting to maintain postural control while performing a specific task. The conditions of the SOT include all combinations of eyes open, eyes closed, fixed support, sway-referenced support, and sway-referenced visual conditions. Sway referencing involves tilting the support surface and/or the visual surround to follow the person's COG sway in an anterior-posterior direction and is similar to the postural challenges posed by activities such as leaning and reaching. [11,40,42] The purpose of the test is to expose the individual to six conditions of increasing difficulty and to identify somatosensory, visual, and vestibular deficits of balance as well as to quantify the patient's ability to balance under all combinations of support surface and visual surround stability conditions. It evaluates the balance system and its ability to maintain postural control via an examination of the integration of these three sensory inputs and their ability to handle sensory conflict in isolation as well as during interactions. [1] If the support surface becomes disturbed, vision becomes the dominant input. If both the support surface and vision are disturbed, vestibular inputs, which are referenced to gravity, become dominant and resolve the sensory conflict. [2] When exposed to a sway–referenced input, the healthy individual should perceive that orientation in space is not changing when in fact it is. [19] Individuals with normal balance suppress sway-referenced inputs and rely on the alternative sense(s) to maintain balance. [1,11] However, if more than one sensory system is deficient, lack of balance control is evident. [30] The SOT was found to clearly distinguish fallers from non-fallers and is the most objective and reliable test available to quantify the relative use of each of the senses for postural control and quantifies the relative use of ankle versus hip strategy. [3,43]

The ability to control the movement of the COG over the base of support is crucial for normal balance to occur. Since many of the gross screening tests, such as the FR, also involve motor skills, use of another test to allow discrimination of the sensitivity of the motor component involved in these tests, as well as identify the LOS, is necessary. In addition to the SOT, the Movement Coordination Test (MCT), the second dynamic posturography protocol, exposes the individual to unexpected and abrupt horizontal translations. However, the MCT only measures one's automatic postural reactions in response to increasing magnitudes of perturbation; it does not identify one's LOS boundaries. This knowledge is necessary, because one must be able to control the speed, direction, and distance of COG movement through the LOS to permit function without exceeding the boundary, or else a fall will occur. A test that is available to measure these three parameters and is used specifically in this research is called the Limits-of-Stability Test (LOS test).

The LOS test is a dynamic standing balance test that measures volitional control of the COG. Dynamic standing balance refers to how well an individual can lean/weight shift over a stable base of support in a controlled manner. This test quantifies the patient's ability to quickly and accurately move the COG from a centered position to eight peripheral positions in forward, backward, left, right, and diagonal directions toward the LOS boundary and briefly maintain stability at those positions. For each movement direction, measurements include reaction time, average velocity including on-axis and off-axis sway components, path sway, end point excursion, and maximum excursion.

Reliability, Validity, and Sensitivity

Several studies have been conducted establishing the test-retest reliability, sensitivity, and validity for both the SOT and the LOS test. Wigglesworth et al. [8] computed intraclass coefficients (ICC's) to evaluate the reliability of scores obtained from the SOT in the elderly. These scores ranged from 0.73 to 0.94 over three trials, indicating moderate to high reliability. In long-term studies involving NASA astronauts, Paloski et al. [44] found a consistent pattern of abnormal performance using the SOT immediately after post-flight tests, demonstrating that the test does not allow subjects to modify their abnormal results. To determine test-retest reliability for the LOS test, Hageman et al. [45] assessed 12 participants during two sessions spaced one week apart. ICC's revealed high test-retest reliability for measures of sway (ICC's > 0.90). LOS measures of movement time and path sway were moderately reliable with ICC = 0.83 and 0.78, respectively. Clark et al. [46] determined sources of variability in the LOS test scores collected from 32 adults over four consecutive days. Retest reliability of movement velocity, end point distance, maximum distance, and directional control resulted in generalizability coefficients of 0.69 to 0.91.

The SOT and LOS test also showed sensitivity to functional decrements associated with normal aging. Camicioli et al. [10] compared the SOT results from 15 subjects less than 80 years old and 33 subjects over 80 years of age. Conditions 4 and 5 showed significant decreases with age. Blaszczyk et al. [47] studied nine healthy young controls (mean age = 26 years) and nine healthy elderly (mean age = 72 years). They found that the LOS in AP and ML directions were significantly reduced in the elderly individuals. Maximum excursion distances of the elderly were significantly reduced in all directions. In addition, movement times and sway oscillations were increased in the elderly. Other studies have shown that declines in the SOT and LOS were evident beginning at 60 years of age. Whipple et al. [48] and Wolfson et al. [23] reported similar LOS distances in subjects below 60 years of age. Differences in sway were not significant under conditions 1 through 4. The SOT was shown to be a highly sensitive measure for distinguishing among normal, abnormal, and exaggerated symptoms of balance disorder in a study conducted by Goebel et al. [49] They studied normals, patients with a wide variety of known balance pathologies, and normals instructed to deliberately exaggerate and were able to separate the symptom exaggerators with greater than 90% reliability.

SOT scores were significantly correlated with four daily living tasks in a sample of 200 patients with a variety of balance disorders. These tasks included rising from a chair, rising from bed, and walking with and without horizontal head movements. [50] In a study including 48 healthy elderly subjects between 65 and 90 years of age, [31] SOT scores were significantly correlated with the Tinetti Balance scale and functional measures of gait (r=0.46-0.58; and r=0.39, respectively). Topp et al. [51] tested 28 subjects over 65 years of age on their ability to perform standardized stair climb, car exit, street crossing, and out of bed tests. LOS movement velocities correlated with stair climbing (r=0.46), car exit (r=0.50), and street crossing (r=0.63). Measures of sway were not correlated with the tasks.

LOS measures were also moderately correlated with Berg Balance scale in a mixed population of patients. Alonte et al. [52] compared the Berg Balance scale and

LOS scores in 30 patients with a variety of diagnoses resulting in a Pearson correlation coefficient between Berg and LOS distances of r=0.60.

Despite the literature to date concerning the reliability, sensitivity, and validity of FR, [4,37,53,54] there remains a paucity of research establishing the relationship between FR and LOS associated with dynamic balance. According to Duncan et al, [4] the measure of standing functional reach is a reliable measure of balance, showing a moderate association with anterior-posterior (AP) center of pressure excursion (COPE) and was designed as a measure of the margin of stability similar to the COPE. They state that reach tasks represent the same kind of controlled COPE within the base of support (BOS) as do leaning tasks. However, the FR assesses the dynamic stability in an only anterior direction and not in the posterior direction. It also does not address ML instability. Wernick-Robinson et al. [54] studied 13 healthy elderly people and 15 people with vestibular hypofunction. Using a full body data acquisition system, they found that FR distance was not correlated to lateral stability measures, but was related to AP postural control measures of FR (r=0.69 to 0.84). They therefore concluded that the FR does not really measure dynamic balance. No correlation was found during backward displacement. A study by Maki et al. [55] revealed that fallers exhibit greater amplitudes of COPE in the ML rather than the AP direction compared with non-fallers, and that lateral amplitude was found to be the single best predictor of future falling risk. If this is the case, then one must question the relationship of FR to the LOS in dynamic balance. A question also arises as to what is the relationship between limits of stability and the postural control components involved in balance (sensory organization). Using the SOT and LOS test protocols will allow objective measurement of sway and the LOS. If the FR test is to be used as a clinical screening tool to predict falls, then the relationship between FR and LOS needs to be identified as well as the relationship between LOS and the sensory components of balance associated with fallers and non-fallers.

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APPENDIX B

ADDITIONAL FORMS

Screening Questionnaire
Exclusionary Criteria

Please answer the following questions to determine your eligibility for this research project:

1. Are you 60 years of age or older?

2. Do you have a current or past medical diagnosis of any injury that would affect your balance within the last three years? If so, what?

3. Are you taking any medications that would affect or that you know would affect your balance/coordination? If unsure, please attach a list of medications used.

4. Do you have any symptoms of dizziness or lightheadedness?

5. Have you ever been diagnosed with any of the following:

   Neurological problems?

   Vestibular disorders?

   Circulatory problems?

6. Have you had any unexplained falls within the past twelve months? (See attached sheet for definition of a fall)

7. Are you able to stand for ten minutes without the use of an assistive device (cane, walker, etc.)?

8. Do you have pain that would limit your ability to stand or reach?

9. Do you have normal vision with or without glasses?

Definition of A Fall

A person has a fall if they end up on the ground or floor when they did not expect to during a routine activity. Most often a fall starts while a person is on their feet, but a fall could also start from a chair or bed. If a person ends up on the ground, either on their knees, their belly, their side, their bottom, or their back, they have had a fall.

A fall is not counted if it occurs due to fainting, being ill, during unusual activities in which a fit active person may fall, or in an unusually hazardous environment (i.e. slipping on ice).

APPENDIX C

ADDITIONAL TABLES

Physical Performance Measures with Recurrent Faller Data

TABLE 10

Functional Reach

Group	Min	Max	Mean	S.D.	p-value
NF (n=15)	16.6	35.2	27.21	5.75	
F (n=10)	6.1	44.1	26.43	11.49	0.82*
One Fall (n=5)	6.1	37.7	26.82	12.17	0.92*
Two Falls (n=3)	10.6	44.1	25.20	17.16	0.70*
> Two Falls (n=2)	26.6	28.0	27.30	0.99	0.98*

NF - non-faller
F - faller
* Faller not significantly different from NF using independent t-test

TABLE 11

LOS Anterior

Group	Min	Max	Mean	S.D.	p-value
NF (n=15)	48	109	79.53	19.02	
F (n=10)	29	91	63.90	19.93	0.06*
One Fall (n=5)	43	91	62.80	18.82	0.11*
Two Falls (n=3)	75	84	80.33	4.73	0.94*
> Two Falls (n=2)	29	55	42.00	18.38	0.02†

NF - non-faller
F - faller
* Faller not significantly different from NF using independent t-test
† Faller significantly different from NF using independent t-test

TABLE 12

LOS Posterior

Group	Min	Max	Mean	S.D.	p-value
NF (n=15)	26	95	65.40	23.53	
F (n=10)	0	86	55.00	24.90	0.30*
One Fall (n=5)	0	84	47.60	31.29	0.19*
Two Falls (n=3)	50	86	69.33	18.15	0.79*
> Two Falls (n=2)	45	59	52.00	9.90	0.45*

NF - non-faller
F - faller
* Faller not significantly different from NF using independent t-test

TABLE 13

SOT Composite

Group	Min	Max	Mean	S.D.	p-value
NF (n=15)	48.00	80.00	63.73	9.48	
F (n=10)	34.00	72.00	53.40	13.08	0.03†
One Fall (n=5)	34.00	60.00	50.40	12.06	0.02†
Two Falls (n=3)	61.00	72.00	66.67	5.51	0.62*
> Two Falls (n=2)	38.00	44.00	41.00	4.24	0.005†

NF - non-faller
F - faller
* Faller not significantly different from NF using independent t-test
† Faller significantly different from NF using independent t-test

Table 14

Comparisons of characteristics of participants for Trials 1-6

on the SOT for Non-fallers and Fallers

Group	Min	Max	Mean	S.D.	p-value
Trial 1					
NF (n=15)	86.30	95.00	92.08	2.78	
F (n=10)	89.00	96.50	91.91	2.20	0.87*
Trial 2					
NF (n=15)	76.70	92.30	86.17	4.52	
F (n=10)	84.00	89.30	86.29	2.01	0.94*
Trial 3					
NF (n=15)	51.00	94.00	82.66	10.50	
F (n=10)	49.70	87.30	77.24	11.61	0.24*
Trial 4					
NF (n=15)	54.00	89.00	76.95	9.45	
F (n=10)	41.00	85.00	64.80	15.36	0.02†
> Two Falls (n=2)	45.00	63.30	54.15	12.94	0.007†
Trial 5					
NF (n=15)	.00	70.30	43.31	19.12	
F (n=10)	.00	66.67	30.18	25.32	0.15*
> Two Falls (n=2)	0.00	0.00	0.00	0.00	0.007†
Trial 6					
NF (n=15)	.00	73.00	33.30	26.39	
F (n=10)	.00	59.00	19.43	24.28	0.20*

NF - non-faller, F - faller
* Faller not significantly different from NF using independent t-test
† Faller significantly different from NF using independent t-test