Validity of the Multi-Directional Reach Test: A Practical Measure for Limits of Stability in Older Adults

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Background. Falls occur not only in the forward direction, but also to the side and backward. The purpose of this study was to develop a portable and valid tool to measure limits of stability in the anterior-posterior and medial-lateral directions.

Methods. Two hundred fifty-four community-dwelling older persons were administered the Berg Balance Test (BBT), the Timed Up & Go Test (TUG), and the Multi-Directional Reach Test (MDRT). For the MDRT, subjects performed maximal reaches with the outstretched arm forward (FR), to the right (RR), to the left (LR), and leaning backward (BR), with feet flat on the floor. Reach was measured by the subject’s total hand excursion along a yardstick affixed to a telescoping tripod.

Results. Mean scores on the MDRT were FR = 8.89 ± 3.4 in., BR = 4.64 ± 3.07 in., RR = 6.15 ± 2.99 in., and LR = 6.61 ± 2.88 in. Interclass Correlation (ICC2,1) for the reaches were greater than .92. Reliability analysis (Cronbach’s Alpha, .842) demonstrated that directional reaches measure similar but unique aspects of the MDRT. The MDRT demonstrated significant correlation with the BBT sum and significant inverse relationship with the scores on the TUG. Regression analysis revealed that activity level contributed to scores in the forward, right, and left direction and that fear of falling contributed to scores in the backward direction.

Conclusion. The Multi-Directional Reach Test is an inexpensive, reliable, and valid tool for measuring the limits of stability as derived by reach in four directions. Values obtained on relatively healthy community-dwelling older adults serve as norms for screening patient populations.

As the population of older adults increases, there is an acute awareness of the impact of falls and fall-related injuries because of morbidity, rising health care costs, and reduction in the quality of life for the elderly. Although research (1) and public health agendas (2) target the reduction of falls and fall-related-injuries among older adults, the number of hip fractures has increased as demonstrated in the mid-decade report of Healthy People 2000. Unintentional injuries are the sixth leading cause of death in individuals over age 65 and are the leading cause of death in people over age 85. The majority of these deaths are related to falls.

The fear of falling is common in older adults who have or have not sustained a fall. Estimates range as high as 73% of older adults have a fear of falling, which may lead to a decrease in activity levels and an increased risk of falls (3–5). Not only is fear of falling a recognized concern of older adults, but older adults also fear not being able to get up once a fall has occurred (6). Approximately half of the older adults who have fallen once or more than once required help to get up after one of the fall episodes (6,7). These facts are of concern particularly in light of the numbers of older adults who live alone.

The ability to confidently and safely perform routine daily activities requires the older adult to generate appropriate motor strategies to navigate in an environment containing both stationary and moving objects within varying contexts. Balance is also needed while the individual manipulates the environment and the feet are stationary. Activities such as bending or reaching up or to the side require shifting the center of gravity (COG) within the base of support (BOS). Once the COG moves outside the BOS, the limits of stability (LOS) for the currently executed balance strategy are exceeded. An automatic movement strategy is executed to maintain balance by either realigning the COG within the BOS or by evoking a step strategy and establishing a new BOS. If the appropriate movement strategy is not executed, the individual may stumble or fall in an attempt to regain balance.

The Functional Reach Test (FRT) is an inexpensive and easy to use tool to assess LOS in the forward direction (8). The FRT measures LOS only in the forward direction. Older adults with balance instability tend to overestimate their forward reach ability (9). An overestimation of forward reach coupled with reduced postural limits (10,11) may cause loss of balance in older adults performing activities associated with moving the COG toward the forward LOS.

Older adults also fall laterally and backward (12). Hip fractures are more likely to occur with a sideways fall (13–15), and among women wrist fractures are more likely to occur from falling on the outstretched hand in the backward direction (13). Induced sway in lateral direction during blindfolded conditions has been found to be an excellent predictor of fall risk (16,17). An assessment tool was developed to measure medio-lateral reach, but as with the For-
ward Reach Test it is limited in the direction of reach (18). Knowledge of reach in one direction has not been shown to predict reach in other directions.

A primary aim of this study was to test the reliability and validity of the Multi-Directional Reach Test (MDRT) as an inexpensive screening tool to measure the limits of stability in four directions. That is, how far an individual can voluntarily reach, thereby shifting the COG to the limits of the BOS with the feet stationary. A secondary aim was to determine whether reach in one direction predicts reach in other directions. A preliminary introduction to this test is found elsewhere (19).

Methods
Subjects were 254 community-dwelling older adults (mean age = 74.1 ± 7.9 years) from senior centers or residential housing centers located in North Philadelphia, a federally designated medically underserved area. Older adults were excluded if they were wheelchair bound or could not lift both outstretched arms to 90° in the forward direction. Eighty-six percent of the population represented minority backgrounds. The majority of the participants were women who lived alone.

After signing an informed consent form, subjects completed a questionnaire that included demographics, health, activity status, and fall history. Translators were used for Spanish-speaking subjects. The questionnaire included items related to health status (excellent, good, fair, poor), the number of falls in the past six months, the frequency of performing social and physical activities, and a fear of falling index (6,20). The Berg Balance Test (BBT) (21), the Timed Up & Go Test (TUG) (22), and the MDRT were administered. The customary assistive device was permitted only during the performance of the TUG.

The BBT assesses performance on 14 routinely performed activities. Tasks include standing, turning 360°, picking up an object from the floor, and alternate foot placement (19). A zero to four point rating system is used for each task for a maximum score of 56. The TUG is a timed measure of an individual’s ability to stand, walk 10 ft, and return to the initial seated position. Subjects completed the TUG at their typical pace.

The following procedures were used for the MDRT (Figure 1). A yardstick affixed to a telescoping tripod was placed at the level of the subject’s acromion process. Prior to the reach, the yardstick was leveled so that it was horizontal to the floor. The older adult lifted an outstretched arm to shoulder height, paused for an initial reading, then reached as far forward (FR) as possible. Instructions given to older adults were “without moving your feet or taking a step, reach as far (direction given) as you can, and try to keep your hand along the yardstick.” For the backward direction the subject was asked to “lean as far back as you can.” Individuals used their typical strategy to accomplish the task. Participants used their arm of choice for the forward and backward tasks, and used the respective arm for the right and left reaches. The start and end positions of the index finger of the outstretched hand were recorded, and the difference represented the total reach for that direction. Feet were maintained flat on the floor; if the feet were moved, the trial was discarded.

Two trials were recorded for each direction. The procedure was repeated with the backward (BR), right (RR), and left (LR) directions.

Appropriate descriptive statistics were used to analyze data from the questionnaire. Test-retest reliability was obtained for the MDRT. Pearson correlation statistics were used to compare scores on the MDRT to scores on the BBT and TUG. Multiple regression analysis was used to determine how factors such as health status, activity status, fall history, and fear of falling as measured by a Fear of Falling Index contributed to scores on the MDRT. ANOVA with post-hoc Bonferroni analysis was used to examine the mean for each direction of the MDRT in relation to the use of assistive devices and health status (i.e., excellent, good, fair, poor).

Results
Table 1 gives the socio-demographic and health status data for the sample. The group, by self-report, considered their health status as good to excellent (67.1%), did not have a fear of falling (58.6%), and had not fallen in the past 6 months (78.6%). Approximately 19% of the older adults did not take medications, and 10% took more than four medications. The majority of older adults did not use an ambulatory device (69.6%), and those using a mobility aid used a cane.
Table 2. Scores on the Berg Balance Test, Timed Up & Go, and Multi-Directional Reach Test

<table>
<thead>
<tr>
<th>Test</th>
<th>Mean</th>
<th>SD</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>BBT (max. = 56)</td>
<td>48.6</td>
<td>6.0</td>
<td>23.0</td>
<td>56.0</td>
</tr>
<tr>
<td>TUG (s)</td>
<td>15.6</td>
<td>7.0</td>
<td>6.0</td>
<td>47.8</td>
</tr>
<tr>
<td>MDRT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FR (in)</td>
<td>8.89</td>
<td>3.4</td>
<td>0.5</td>
<td>16.8</td>
</tr>
<tr>
<td>BR (in)</td>
<td>4.64</td>
<td>3.1</td>
<td>0.4</td>
<td>14.0</td>
</tr>
<tr>
<td>RR (in)</td>
<td>6.86</td>
<td>3.0</td>
<td>0.7</td>
<td>18.2</td>
</tr>
<tr>
<td>LR (in)</td>
<td>6.61</td>
<td>2.9</td>
<td>0.0</td>
<td>14.4</td>
</tr>
</tbody>
</table>

**Note:** BBT = Berg Balance Test; TUG = Timed Up & Go Test; MDRT = Multi-Directional Reach Test; FR = arm stretched forward; BR = leaning backward; RR = arm stretched to the right; LR = arm stretched to the left.

Figure 2. Distribution of reach scores for the Multi-Directional Reach Test (average of two trials). A, Histogram of forward reach scores. B, Histogram of backward reach scores. C, Histogram of right reach scores. D, Histogram of left reach scores.
cause of the biomechanical arrangement of the ankle and were not influenced by either arm or foot dominance. Be-
reaches to the right and left were symmetrical and therefore expected in the forward compared with the backward direction, subjects were subdivided relative to health status, use of an assistive device, and history of falls. Mean scores on the MDRT for each subcategory were obtained (Table 4). No significance associations (p > .5) were noted between mean scores on the MDRT and these categories of health status.

**DISCUSSION**

Limitations in the ability to shift the center of gravity toward the limits of stability may result in reductions in the activity level of older adults. The use of force plates to examine postural responses to unexpected perturbing conditions or to measure forward reach may not be practical for screening, particularly in community settings (23–25). In addition, force-plate studies using destabilizing forces evoke a compensatory motor response compared with an anticipatory balance strategy evoked during voluntary movement of the COG when the person performs activities of daily living.

This study examined the reliability, validity, and practicality of the MDRT to measure limits of stability in settings where computerized force-plate systems are too expensive or where a more mobile clinical assessment is required. When voluntarily moving the center of gravity toward the limits of stability (with feet not moving), a greater excursion is expected in the forward compared with the backward direction, and medio-lateral excursions should be symmetrical. This excursion pattern was observed with the MDRT (Figure 2). Reaches to the right and left were symmetrical and therefore were not influenced by either arm or foot dominance. Because of the biomechanical arrangement of the ankle and foot, there is a greater capability for forward excursion of the body over the foot than for backward excursion. In addition, fear may be contributing to this decreased amount of BR as noted by a significant affect of fear, as measured by the Fear of Falling Index, on the BR scores. Although not tested, muscle strength of the anterior tibialis and hip abductor muscles may contribute to reach scores in the respective directions.

In this group of community-dwelling older adults, no association was noted between assistive device use, health status, or self-report of falls. However, the results indicate a tendency for lower mean reaches for each of these categories. To determine if the MDRT predicts falls, a sample of community-dwelling older adults with medically documented falls is currently under study. The group of older adults represents primarily a culturally diverse sample (86.1% African American and Hispanic) from a relatively low socio-economic region (North Philadelphia). The predictability of the MDRT for assistive device usage and falls needs to be examined in other socio-economic and ethnic groups, in homebound community-dwelling older adults, and in those residing in long term care facilities.

In this study, older adults voluntarily performed the MDRT in a freestanding environment and not close to a wall as noted in the FRT. Therefore, the MDRT may be more challenging because there is no wall to provide perceived security. This factor may account for the lower mean FR observed in the MDRT (8.89 in) as compared with published mean values of the FRT (10.9 in.) (26). A lower reach score also occurred because the subjects were instructed to maintain the feet flat on the floor and not to take a step. Such instructions provide a more accurate assessment of the limits of stability. Overbalancing and taking a step indicates that the postural strategy used to maintain COG over the BOS was exceeded and that a new movement strategy was evoked to maintain balance.

When administering the MDRT, it is recommended that two trials be given for each direction. Although there was a notable difference between the first and second trials in the backward, right, and left directions, the effect size was small. That is, the relative magnitude of the differences between the two trials for a particular reach direction was small. Variation in the movements used to perform the reach may account for the differences noted between the two trials per task. A current study will examine the method of reach in each direction through component analysis of movement patterns used in the upper extremities, trunk, and lower extremities.

Cronbach’s alpha was not improved with the deletion of any one of the reach directions, indicating that each direction measures similar but unique aspects. This finding indi-

### Table 3. Reliability Analysis (Cronbach’s Alpha) for the Multi-Directional Reach Test Correlation Matrix

<table>
<thead>
<tr>
<th>Direction</th>
<th>FR</th>
<th>BR</th>
<th>RR</th>
<th>LR</th>
</tr>
</thead>
<tbody>
<tr>
<td>FR</td>
<td>1.0000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BR</td>
<td>0.4979</td>
<td>1.0000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RR</td>
<td>0.6176</td>
<td>0.4957</td>
<td>1.0000</td>
<td></td>
</tr>
<tr>
<td>LR</td>
<td>0.6104</td>
<td>0.4926</td>
<td>0.7493</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

Alpha = 0.842

Note: Abbreviations as in Table 2.

Table 4 shows the mean scores for each direction of reach in relation to various health factors. Multiple regression analysis examining activity level, fear of falling, health status, and fall history revealed that the activity level contributed significantly (p < .0004) to the scores in the forward, right, and left directions. Fear of falling, as measured by the Fear of Falling Index, contributed significantly to scores in the backward direction. Subjects were subdivided relative to health status, use of an assistive device, and history of falls.

Mean scores on the MDRT for each subcategory were obtained (Table 4). No significance associations (p > .5) were noted between mean scores on the MDRT and these categories of health status.

<table>
<thead>
<tr>
<th>Direction</th>
<th>No Assistive Device</th>
<th>Yes Assistive Device</th>
<th>Health Status</th>
<th>No Falls</th>
<th>Yes Falls</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Excellent</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Forward (in)</td>
<td>9.72 (3.19)</td>
<td>7.10 (3.11)</td>
<td>9.29 (3.37)</td>
<td>9.07 (3.46)</td>
<td>8.81 (3.33)</td>
</tr>
<tr>
<td>Backward (in)</td>
<td>5.39 (3.19)</td>
<td>3.25 (2.20)</td>
<td>5.16 (3.18)</td>
<td>5.09 (3.19)</td>
<td>3.86 (2.69)</td>
</tr>
<tr>
<td>Right (in)</td>
<td>7.57 (2.96)</td>
<td>5.62 (2.55)</td>
<td>7.54 (4.10)</td>
<td>7.0 (2.89)</td>
<td>6.53 (2.57)</td>
</tr>
<tr>
<td>Left (in)</td>
<td>7.33 (2.80)</td>
<td>5.33 (2.45)</td>
<td>6.94 (3.03)</td>
<td>6.56 (2.83)</td>
<td>6.60 (2.99)</td>
</tr>
</tbody>
</table>

Table 4. Mean Multi-Directional Reach Test Scores in Relation to Selected Measures of Falls Status
icates that measurement in a single direction (e.g., forward reach) does not necessarily predict reach values in the other directions. Because falls occur in all directions, reach as a measure of the limits of stability needs to be assessed in all directions.

Although the effect of test order was not examined, it is recommended that a standard order of forward, backward, right, and left directions be used to compare the scores with published values. Because the backward direction is associated with the Fear of Falling Index, this direction should not be the first direction tested.

Scores on the MDRT demonstrated an appropriate positive relationship with scores on the BBT; that is, the higher the scores on the BBT (max = 56), the greater the distance reached in all directions on the MDRT. Conversely, scores on the MDRT demonstrated an appropriate inverse relationship with scores on the TUG; that is, the faster the individual performed the TUG (lower timed scores), the greater the distance reached in all directions on the MDRT. The significant but low correlation between scores in the MDRT and scores on the BBT and TUG indicate that these screening tests measure similar but unique aspects of balance abilities. Therefore, it may be justified to perform these tests in conjunction with one another to obtain a more comprehensive assessment of balance abilities. The MDRT measures the limits of stability with the feet stationary; the TUG measures balance abilities during various phases of standing, walking and turning, and the BBT measures balance abilities while the individual performs tasks that mimic tasks routinely performed in every day life.

In summary, the MDRT is a valid and reliable clinical measure for limits of stability. The screening tool can be used with other tools such as the BBT and TUG to obtain a comprehensive clinical measure of balance abilities in older adults. On the basis of such assessments, effective preventative and rehabilitative measures can be developed.

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