Authors:
Sally A. Engler, DPT
Kristina A. Lilly, DPT
Jan Perkins, PhD
Ksenia I. Ustinova, PT, PhD

Affiliations:
From the Graduate Program in Physical Therapy, Herbert H. and Grace A. Dow College of Health Professions, Central Michigan University, Mt Pleasant.

Correspondence:
All correspondence and requests for reprints should be addressed to: Ksenia Ustinova, PT, PhD, Doctoral Program in Physical Therapy, Central Michigan University, Mt Pleasant, MI 48858.

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ORIGINAL RESEARCH ARTICLE

A Pointing Task to Improve Reaching Performance in Older Adults

ABSTRACT

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Objective: The objective of this study was to evaluate whether adding a pointing task would influence functional reach test performance in younger and older adults.

Design: While standing on a force plate, 20 older (73 ± 8 yrs) and 20 younger (23 ± 1 yrs) adults were randomly administered a modification of the functional reach test and the functional point test. Functional pointing involved reaching and pointing at the farthest possible target in a series of 1.27-cm colored craft pom-poms attached at 2.54-cm intervals on a yardstick.

Results: Both older adults ($P = 0.001$) and younger adults ($P = 0.043$) reached farther using the functional point test. Older adults also increased their anterior center of pressure displacement with this test ($P = 0.037$).

Conclusions: The addition of a pointing task can make the original clinical test more functional and increase reaching distance in both older and younger adults. Further research is needed to determine whether functional pointing challenges subjects' stability limits more than the traditional test does and offers greater sensitivity in the evaluation of functional balance and fall risk.

Key Words: Aging, Rehabilitation, Motor Control, Balance

Many daily activities require individuals to maintain postural stability while coordinating arm movements such as reaching to point, grasp, or manipulate objects. Examples include operating appliances such as microwaves or light switches, putting away groceries, and washing dishes. As individuals age, they develop difficulties with balance that can place them at an increased risk of falling during the performance of these or other functional activities.

The functional reach (FR) test was developed to evaluate stability of upright posture during arm movement and to establish fall risk.[1] It measures maximal excursion of the dominant arm as it reaches forward in a horizontal plane while the participant remains in a feet-fixed standing position. The FR test has been shown to be a clinically accessible measure of dynamic balance, sensitive to age-related functional changes.[1–10] Reliability has been tested in healthy adults,[2] community-dwelling elders with cognitive impairment,[10] individuals with multiple sclerosis,[11] and people in the early and middle stages of Parkinson disease.[12] Examining criterion validity, Weiner and colleagues[9] found that results of the FR test strongly correlated with the center of pressure (COP) excursion, although others have had different results.[5,13] The FR test is considered to be a valid and reliable tool and is a standard measure used in geriatric and neurologic practice.[2–6]

One limitation of the FR test is that the reaching used does not involve pointing, grasping, or manipulating an object as seen in the natural arm movements performed during daily activities. This decreases the ability of the FR test to mimic functional movement and to meet rehabilitation goals of testing under conditions that simulate real-life situations. The addition of a goal could alter individual reaching performance and encourage individuals to maximize their forward reaching distance.

The effect of goal-directed tasks on motor behavior has been recognized since the 1930s.[14,15] Illustrating the task dependency of arm movements, Bernstein[15] has described how an individual will raise an arm higher when asked to reach for an object than when asked just to raise the arm. Current research shows that a functional task or target increases reaching distance, improves movement kinematics, and alters parameters of postural stability in healthy adults and patients poststroke.[16–19] This implies that making the FR test goal directed may improve reaching performance, particularly in older individuals. Testing this possibility is important to optimize clinical measurement tools that assess functional ability, activity level, potential safety risk, and participation of an individual within their environment.

The purpose of this study was to investigate whether the use of a targeted pointing task during administration of the FR test would influence test performance in older adults and whether their results would differ from those of younger adults. To answer this question, we modified the FR test to include a targeted pointing task. We refer to this as the functional point (FP) test.

We expected that older adults would challenge their anatomical stability limits to a greater degree by reaching further with the FP test and increasing their anterior COP displacement. It is possible that this effect could be associated with increased risk of an unexpected fall. However, the introduction of more challenging testing and training conditions in a safe environment may help in assessing and retraining postural control in vulnerable individuals.

METHODS

Participants

The project received approval from the university institutional review board, and all documents were prepared in compliance with the Helsinki Declaration. Participants were a convenience sample of 40 healthy community-dwelling volunteers in two distinct age groups.

Twenty older participants, 3 men and 17 women, with a mean age of 73 yrs (SD, 8 yrs; range, 56–88 yrs) were recruited from a community independent senior living facility and the local Commission on Aging. All participants lived independently and, based on self-report, functioned in multiple community environments without significant balance or mobility difficulties. All ambulated without an assistive device and were able to follow directions for simple tasks. Researchers observed no gait abnormalities interfering with the ability to perform experimental tasks. Participants were asked about unanticipated falls experienced over the past 12 mos and were then questioned regarding the possible causes of any fall. A fall was defined as any circumstance in which the participant came to rest unexpectedly on the ground or a lower surface, and falls were classified according to the method of Brauer et al.[21] Only six older participants reported falls in the previous year, with fall numbers ranging from one to five (Table 1).

TABLE 1 Demographics and fall history (number in previous 12 mos) of older participants

Subject	Sex	Age, yrs	Falls	BBS	TUG, sec
1	Female	72	0	50	11.7
2	Female	81	1[a]	53	8.8
3	Female	82	0	47	12.5
4	Female	69	0	56	7.9
5	Female	65	5[b]	53	8.8
6	Female	68	2[b]	49	9.1
7	Male	73	1[b]	52	6.9
8	Female	71	0	55	11.5
9	Male	76	0	48	10.5
10	Female	64	0	47	10.2
11	Female	73	0	52	10.4
12	Male	74	0	49	12.1
13	Female	76	0	49	11.0
14	Female	56	0	50	16.7
15	Female	88	0	50	14.9
16	Female	67	0	48	7.3
17	Female	85	2[a]	49	10.3
18	Female	78	0	47	13.2
19	Female	80	0	47	10.3
20	Female	66	1[a]	47	12.4
	Mean	73.2	0.6	49.9	10.8
	SD	8	1.2	2.8	2.4

[a]Fall(s) occurred because of tripping on an object.

[b]Fall(s) occurred because of slipping on surface.

BBS indicates Berg Balance Scale; TUG, timed up and go.

Twenty younger participants, 10 men and 10 women, with a mean age of 23 yrs (SD, 1 yr; range, 20–25 yrs) were recruited from the university community. All reported good health and no comorbidities or preexisting conditions that would affect their ability to participate.

All participants reported normal vision or used their usual corrective lenses or glasses during testing. They reported no known orthopedic, neurologic, cardiovascular, cognitive, or pulmonary impairments that could interfere with balance and no current pain condition that could affect their ability to perform the test. Arm dominance was determined based on participants' self-report. No volunteers were excluded; all who volunteered met inclusion criteria. Participants were not excluded for past participation in rehabilitative services or for current medication use.

Procedure

All participants performed three trials of the modified version of the FR test (mFR) with a standard yardstick and three trials of its goal-directed version, the FP test, with the targeted yardstick (Fig. 1) while standing on a NeuroCom long force plate. In the original FR test, participants are asked to stand beside a wall on which a yardstick was attached at the height of their acromion, then to

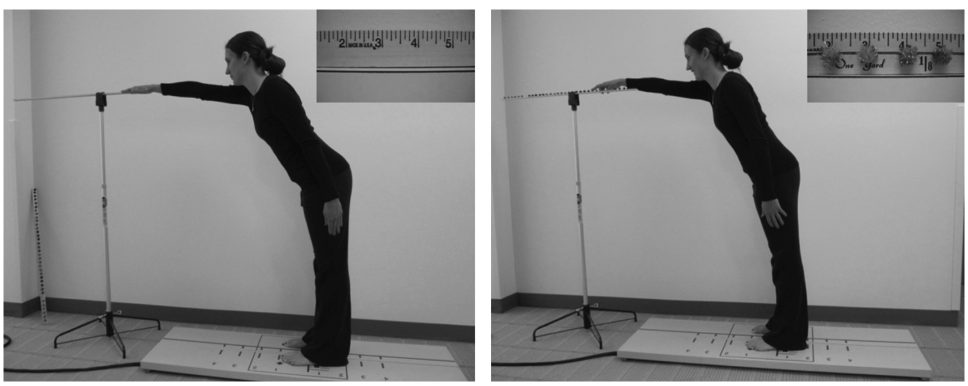

FIGURE 1 *Testing conditions for performance on the modified version of the functional reach test (left panel) and the functional point test (right panel).*

raise their dominant arm with the elbow extended and hand closed in a fist so that their shoulder was at 90 degrees flexion, and to reach as far forward as possible without taking a step or losing their balance.[1] The reaching distance was measured from the distal end of the third metacarpal along the yardstick.

For this study, the original protocol[1] was modified in the following manner. The yardstick was fastened to an adjustable tripod using a clamp instead of being attached to the wall as in the original version. This apparatus was placed adjacent to a wall to ensure that, in other respects, it simulated the standard test. The tripod allowed easy height adjustment to the acromion level for each participant. The yardstick was placed so that before performing the reach, the end of the participants' second digit was aligned with 0 cm when their dominant arm was flexed to 90 degrees at the shoulder, their elbow fully extended, and their hand flat. Participants then reached forward, and reach distance was recorded with reference to the end of the participants' second digit. The mFR test distance was measured in inches. Participants were instructed to reach as far as possible without taking a step, losing their balance, or leaning on the testing device. All measurements were converted from inches to centimeters for analysis.

The FP test was performed using the same positioning and testing device, except the yardstick used had 1.27-cm diameter pom-pom balls glued at 2.54-cm increments to provide participants with a target for their reach. Participants raised their dominant arm to 90 degrees of shoulder flexion with their elbow extended and their index finger pointed forward. Instructions were to point with their index finger to touch the farthest pom-pom ball possible without taking a step, losing their balance, or leaning on the testing device. Most participants reached directly to touch the farthest pom-pom possible; however, in the few cases where participants reached to a point between two pom-poms, the lower distance was recorded.

Participants were instructed to reach at a comfortable speed during trials for both the mFR and FP tests as if they were performing a task in a natural environment. For both testing conditions, participants performed two practice trials followed by three test trials. The final test score was the mean of the three test trials. Half the participants performed the mFR test first, followed by the FP test, and the other half reversed the procedure. Two researchers performed data collection. One researcher obtained informed consent, gathered self-report data, and assessed participants with the clinical scales). The other researcher adjusted equipment, gave directions for the mFR and FP tests, gathered force plate data, and recorded reach measurements.

In the older participants, balance and dynamic movements were measured using the Berg Balance Scale (BBS)[22] and the timed up and go (TUG) test.[23] The BBS was developed to measure functional balance impairments by assessing specific functional tasks. Scores range from 0 to 56, with scores less than 45 indicating increased fall risk among community-dwelling older adults.[24] In the TUG test, participants sit in a chair with armrests and are timed from being told "go" as they rise, walk a distance of 3 m, turn, and return to the chair.[23] This study used the TUG test instructions of Shumway-Cook et al.,[25] where the participant is encouraged to walk "as quickly and as safely as possible." The TUG test classifies a score of less than or equal to 10 secs as independent, less than 20 secs as independent for basic tub or shower transfers and able to climb stairs or go outside alone, and more than 30 secs as dependent in most activities.[23] A TUG test score of greater than or equal to 14 secs is considered indicative of high fall risk.[25] Previous research found mean TUG test times of 8.4 secs for participants without a fall history and 22.2 secs for participants with a history of falls.[25] Younger participants in this study were not assessed with the BBS or TUG test, as all would have been classified as no or low fall risk.

In addition to clinical testing, the stability of upright posture was evaluated with a bilateral force plate (NeuroCom, Inc). Kinetic data, including the ground reaction forces, were recorded at 100 Hz for 10-sec intervals during three trials each, beginning with static standing with arms by their sides and followed by the randomly administered set of mFR and FP trials. Participant foot placement was determined using the standard protocol from NeuroCom based on individual participant height. These recommendations ensured that each participant's foot placement allowed the medial-lateral axis passing through the lateral malleoli to be located at the center of the force plate.

Data Analysis

Distance recorded in the mFR and FP tests was expressed in centimeters and was not normalized to participant height to follow the original protocol for clinical testing. From filtered kinetic data, the COP anterior-posterior (AP) displacement was calculated as peak-to-peak deviation of averaged ground reaction force recorded by four transducers with accuracy of 0.05 N.

Statistical analysis was done with Statistica 7 software (StatSoft, Inc). Parametric statistics were used following testing for distribution normality. From individual data, the means, standard deviations, and 95% confidence intervals (CIs) were computed. The mean values of the reaching distance and the COP displacement were compared using two-way mixed analysis of variance with factors of group (older *vs.* younger) and test (mFR *vs.* FP test). Within- and between-group comparisons were done with dependent and independent t tests. Effect size considerations were from Cohen,[26] where an r of 0.1 is considered a small effect; 0.3, a medium effect; and 0.6, a large effect. Pearson correlation analysis was used to determine the influence of demographic data and clinical scales scores on reaching distance in older participants. An alpha level of 0.05 was used for all statistical tests.

A one-way random effect analysis of variance was used for within-session reliability measurements, as described by Shrout and Fleiss.[27] Intraclass correlation coefficients were computed across three trials for each test separately.

RESULTS

Reaching Distance

Figure 2 shows mean reaching distance for both tests by older participants (left panel) and younger participants (right panel). Mean reaching distance was further during the FP test (gray bars) than during the mFR test (white bars). A mixed analysis of variance showed a significant effect of group age ($F_{1,38}$ = 179.83, P < 0.001) and test ($F_{1,38}$ = 18.52, P < 0.001) on reaching distance. Older participants increased their reaching distance (P = 0.001, effect size = 0.745) from a mean (SD) of 24.25 (3.78) cm on the mFR test (95% CI, 22.48–26.02) to a mean (SD) of 27.51 (4.10) cm on the FP test (95% CI, 25.59–29.43). Younger participants increased their reaching distance (P = 0.043, effect size = 0.445) from a mean (SD) of 40.16 (3.46) cm on the mFR test (95% CI, 38.54–41.78) to a mean (SD) of 42.10 (4.81) cm on the FP test (95% CI, 39.85 44.35). Younger participants reached farther than older participants did on both the mFR and FP tests (P < 0.001). Pointing at a target increased reaching distance by more than 3 cm in older participants and approximately 2 cm in younger participants.

COP Displacement

Figure 3 shows the mean (SD) COP displacement achieved by older participants (left panel) and younger participants (right panel). Greater reaching distance was accompanied by increased COP displacement in the anterior direction in older participants. A mixed analysis of variance showed an effect of group age ($F_{1,38}$ = 37.90, P < 0.001) and test ($F_{2,76}$ = 702.31, P < 0.001) on COP displacement relative to the measure used to test functional

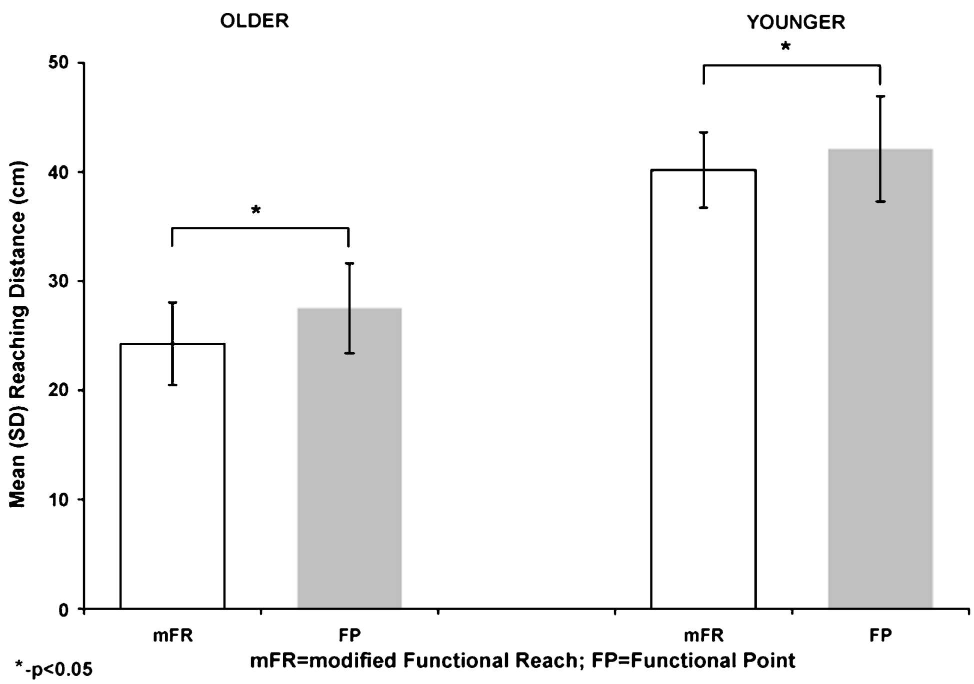

FIGURE 2 *Mean (SD) reaching distance using the mFR and FP tests for older participants (left panel) and younger participants (right panel).*

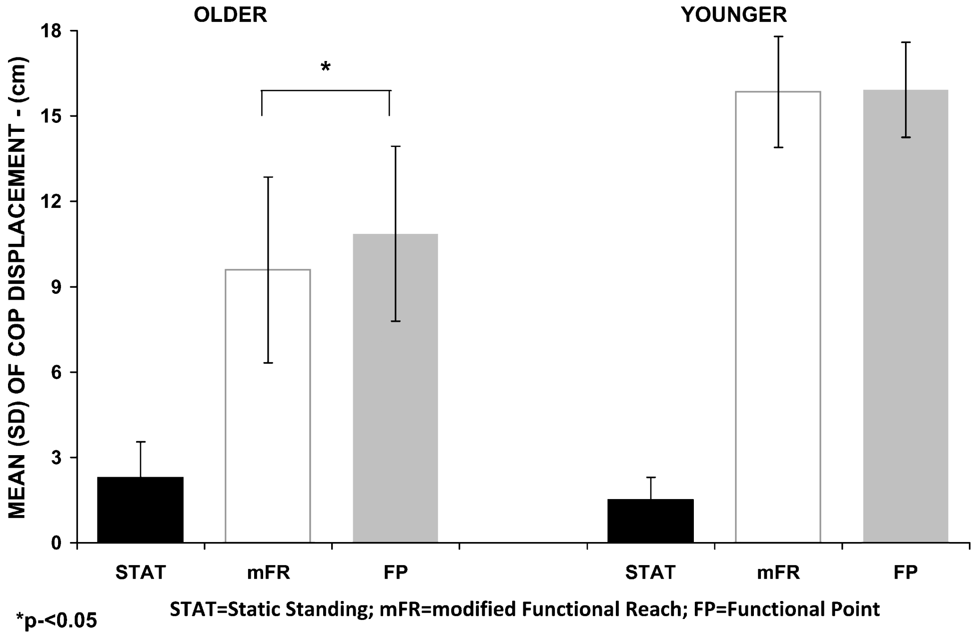

FIGURE 3 *Mean (SD) COP displacement for static standing, mFR test, and FP test of older participants (left panel) and younger participants (right panel). COP indicates center of pressure.*

activity. AP COP excursion in older participants was greater than in younger participants during static standing ($P < 0.01$); however, the older participants actually leaned forward much less than younger individuals did during measurement in the mFR and FP tests. Older participants also showed greater COP displacement ($P = 0.037$, effect size = 0.400) when performing the FP test, with an AP excursion mean (SD) amplitude of 10.86 (3.07) cm (95% CI, 9.42–12.30), and less COP displacement during the mFR test, with an AP excursion mean (SD) amplitude of 9.59 (3.27) cm (95% CI, 8.06–11.12). Younger participants had no significant difference in the COP displacement ($P = 0.067$) during the FP test, with an AP excursion mean (SD) amplitude of 15.92 (1.68) cm (95% CI, 15.13–16.70) as compared with 15.85 (1.96) cm (95% CI, 14.93–16.76) during the mFR test.

Reliability of Measurements

The mFR and FP tests were reliable in both groups of participants. Within-trial intraclass correlation coefficients for the mFR test were $r = 0.95$ in younger participants and 0.91 in older participants, whereas for the FP test, intraclass correlation coefficients were 0.96 for the younger group and 0.94 for the older group.

Clinical Characteristics and Test Performance

Older participants (Table 1) presented with a range of ages (55–88 yrs), BBS scores (47–56), TUG test scores (6.9–16.7 secs), and self-reported falls (none to five). All of the older participants had BBS scores of 47 or higher, indicating that, consistent with their self-report of falls, the BBS classified them as at low risk of falling. TUG test scores for our participants ranged from 6.9 to 16.7 secs, with a mean of 10.8 secs. The one participant with a high TUG test score did not report a history of falls. No significant correlation between these clinical parameters and performance on the mFR or FP test was found with respect to reaching distance or force plate data ($-0.11< r <0.17$; $P = 0.147$ and $P = 0.114$, respectively). The BBS and TUG tests had low cor relations with each other ($P = 0.055$; $r = 0.31$). No relationship between reaching distance and COP displacement was found for the mFR (older: $P = 0.062$; $r = 0.41$; younger: $P = 0.137$, $r = 0.13$) and FP (older: $P = 0.102$, $r = 0.20$; younger: $P = 0.083$, $r = 0.28$) tests.

DISCUSSION

This study shows that addition of a pointing task to the original FR test enabled older and younger participants to increase their reach distance by approximately 2 and 3 cm, respectively. The influence of pointing on reach distance was greater in older individuals, as shown by the large effect size. Older participants also achieved significantly greater anterior COP displacement with the FP test than with the mFR test.

Motor performance is largely dependent on the movement task and contextual setting.[14,15] It has been shown that when individuals were asked to retrieve an object from a high shelf, they would generate greater angular displacement in the shoulder than when asked to simply raise an arm as high as possible.[15] This effect was explained by the increased involvement of higher cortical structures necessary to create the accuracy, amplitude, and precision required for goal-directed movements. More recent studies have confirmed these observations and shown the beneficial effects of a functional task or target on reaching and postural balance in healthy participants and individuals with stroke.[17–19,28] Participants with post-stroke hemiparesis exhibited significantly smoother, faster, and more forceful preplanned movements when reaching for a preferred food item than to an abstract spatial location.[29] Older adults who are considered at high risk for falls reached farther when asked to reach for a soup can than when doing the FR test using the standard approach.[19] Consistent with these findings, our study showed that when given a functional task both younger and older participants were able to achieve greater reaching distances.

Current theories of perception and action integration state that movements are planned and executed according to a specific set of spatial and temporal movement variables, often referred to as a frame of reference.[30–32] Depending on the task, the movement may be centered around the body or relative to contextual features of the object.[33,34] It seems likely that participants in our study used a gravitational vector as a reference to organize upright trunk positioning when performing the mFR test. These reaches were characterized by smaller COP displacement and, therefore, greater stability. In contrast, reaches performed using the FP test were task-centered on the pom-pom with consequent adjustment of all movement parameters to increase reaching distance. These reaches were characterized by greater endpoint displacement.

Greater reaching distance in younger than older participants was anticipated and is consistent with previous research.[2,3] Limits may be caused by an age-related decrease in range of motion in joints involved in whole body movement.[35] Another factor affecting reaching performance may be the slowing of movements with age. It is known that increasing speed results in larger amplitude movements,[36] and this general relationship applies to most human physical activities.[37,38] The shorter reaching distance in our older participants may reflect their generally slower movements. Finally, age-related postural changes, such as a flexed posture with anterior displacement of the center of gravity, slowness of reactive postural reactions, altered postural strategies, and fear of falling,[35] could affect reaching ability.

A result of the greater reaching distance seen in younger individuals was increased COP displacement. Although the relationship between reaching distance and COP displacement during the original FR test was not strictly linear,[5,13] COP is considered to be a key parameter reflecting displacement of partial or whole body mass. In our case, this displacement of mass was the upper trunk and arm moving forward, while the hip and pelvis were probably moving backwards.

In our study, older individuals showed a greater performance change than younger participants did between the mFR and FP tests. It is most probable that younger participants were already approaching their anatomical stability limit when assessed using the mFR test and had little room for improvement with the FP test. They shifted their COP 15–16 cm (mainly anteriorly) for both measures, already taking them close to their anterior anatomical stability limit. During standing, this is usually identified by the anterior base of support, which is formed by the length of the foot from the malleoli to the tip of the toes. In our participants, this ranged from 15 to 24 cm. In contrast, older participants' mean COP deviation was only 9.61 cm using the mFR test and 11.06 cm using the FP test. This suggests that older participants may have had more potential for improvement because their initial COP excursion was not approaching their anatomical limit. A factor limiting their reaches may have been their subjective perception of personal stability limits or a fear of falling. Having a target may have helped them override these concerns. Further studies are needed to support or refute this hypothesis.

Clinicians use the FR test to measure dynamic postural control, which is compulsory for functional movements.[1] We suggest that using the FP test instead of the original FR test could increase reaching distance in older adults and make it a test more reflective of the real-life functional activities that lead to falls. To further improve the sensitivity of the FP test, a measurement apparatus with targets spaced closer than 2.54 cm apart or a sliding target could be used. More studies are needed to clarify these questions and determine whether larger changes occur in clinical populations.

Reaching performance in older participants did not correlate with any of the data from self-reported falls, the BBS, or the TUG test. Our group was recruited from community-dwelling older adults; all of these individuals were classified by the BBS to be at low risk of falls and, consequently, would be expected to have fewer reaching limitations than would individuals in clinical populations. Previous research has shown variability in findings when clinical measures of balance and fall risk are compared.[4,7,10,21,39] Further research is indicated to determine which measures are best suited for different populations and whether functional refinements can improve test performance.

Limitations of This Study

This study was limited to a small sample of community residents 56 yrs or older and a young adult group. All were a volunteer sample of convenience and may not be truly reflective of the larger population from which they were drawn. Fall history was based on self-report, and it is possible that participants did not report this accurately. However, this low incidence of falls in our older participants is compatible with their TUG test and BBS scores. It is possible that the different distribution of men and women in the participant groups may have affected the results, particularly the absolute means of reaches and COP excursion. We acknowledge that positioning the pom-poms at 2.54-cm intervals on the FP assessment tool resulted in decreased instrument sensitivity, and further instrument refinement may be beneficial.

It is important to mention that the different reaching performances in the two groups may be related to the differences in the velocity and range of arm motion used by older *vs.* younger participants. One possible strategy to extend reach without loss of balance would be to increase speed of arm motion, thereby reducing the perturbation effect on postural stability.[40] Assuming that the younger individuals moved more quickly, they would be able to reach farther without loss of stability. This explanation is speculative, however, because neither the velocity nor the range of arm motion has been recorded, imposing a serious limitation on the interpretation of the study results.

CONCLUSION

The results suggest that the addition of a functional goal, such as pointing, on a standardized reach test can increase reaching distance. This effect is greater in older adults than in younger adults. This technique introduces a more natural measure to challenge postural control and may have particular relevance for clinical populations. Further research with larger sample sizes and other groups of vulnerable individuals is needed to confirm whether modifications for tests of reaching performance to include functional or targeted tasks can improve their ability to evaluate functional balance and predict fall risk.

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