# Effects of a Short-term Dynamic Balance Training Program in Healthy Older Women

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## DISCLOSURE

All balance training equipment used in this study was provided by an equipment grant from Springboard Orthopedics, Mt Sterling, KY.

## ABSTRACT

**Purpose:** Aging is associated with deterioration of the physiologic systems controlling balance. Consequently, a multitude of intervention trials has appeared in the last 2 decades attempting to improve control of balance. Effective programs often require substantial and frequent time commitments, expensive and specialized equipment, professional assistance, and clinical settings. This investigation reports the effects of a simple, short-term balance training program on dynamic balance in healthy older women. **Methods:** Subjects included 11 healthy women (75.6 ± 6.4 years) who participated in biweekly, 15-minute balance training sessions for 5 weeks, and 10 age-matched women (71.2 ± 9.1 years) who served as controls. Balance training involved medial-lateral and anterior-posterior movements and bilateral partial squats while standing on semi-compressible foam roller-devices. Dynamic balance was quantified using functional reach in the forward, left, and right directions, and a lower extremity reach test. **Results:** Significant increases were observed in the balance trained group: 25% in functional reach right ($P = 0.014$) and left ($P < 0.001$) and 16% in lower extremity reach ($P = 0.001$). No change was noted in the control group. **Conclusions:** Improvements in dynamic balance can be realized following 5 weeks of dynamic balance training using this novel, simplistic, and short-term protocol.

*Key Words*: balance, functional reach, proprioception, training

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## INTRODUCTION

Balance control is the manifestation of concerted interaction between the neuromusculoskeletal, proprioceptive, vestibular, and visual systems.[1] As age increases, the influence of these systems deteriorates, resulting in an increased susceptibility to falling.[2] Efforts to reduce the risk and incidence of falls in older adults are plentiful, as evidenced by intervention studies which have appeared in the literature within the last 2 decades detailing various exercise interventions intended to reduce falls.[3-5] These interventions have emphasized a variety of exercise modes including resistance training,[5] Tai Chi,[6] yoga,[7] computerized biofeedback of sway,[8] and flexibility exercises.[6] More commonly, some combination of these and other similar activities are used.[3,9-11] This latter approach makes it difficult to determine which components of the intervention are responsible for the desired outcomes.

Evidence of improved balance and reduced falls following exercise interventions has been equivocal at best. However, a meta-analysis of data from the multi-site FICSIT study (Frailty and Injuries: Cooperative Studies of Intervention Techniques) has shown evidence of a 10% to 20% reduction in falls when exercise is used as a component of a more encompassing training intervention.[12] Of specific interest is the 25% reduction in risk of falling in those trials that more specifically focused on balance training as part of the training intervention. These findings are supported by other systematic reviews of intervention trials suggesting that exercise is effective in reducing fall-risk only when part of a multifactorial approach that specifically includes balance training.[13,14]

While the FICSIT study offers compelling evidence to support the specific inclusion of balance training activities for improved balance, many balance-oriented intervention programs are poorly defined, require substantial and frequent time commitments from participants, and often last several months.[3,15] Likewise, many balance training programs use expensive clinical equipment, professional staff, and a clinical environment.[4,9,16] Because of these traits, many balance programs may not be available to those who may benefit from such activities. The need for a simplistic, concise, short-term balance training program that addresses dynamic balance and can be performed independently without expensive clinical equipment is evident. Therefore, the intent of this investigation was to examine the effect of a novel, short-term balance training program on dynamic balance in healthy older women.

## METHODS

### Study Design

A pretest/post-test control group design was used to assess the 4 dependent measures of balance: functional reach forward (FRF), functional reach right (FRR), functional reach left (FRL), and lower extremity reach (LERT) before and after 5 weeks of balance training. All procedures were approved by the Institutional Review Board of the Louisiana State University Health Sciences Center-Shreveport. Data collection was completed during a single session for all subjects and the order of testing was randomized to minimize threats to internal validity. Prior to data collection, a group of 20 subjects not enrolled in this study was examined to determine agreement between examiners. The intraclass correlation coefficient ($ICC^{2,1}$) was selected as it reflects the variability of measurements taken by any examiner on any subject.[22]

### Subjects

Subjects were living independently, self-ambulatory, and healthy, having no known neuromuscular, musculoskeletal, cardiopulmonary, or any other chronic debilitating condition in which proprioceptive exercise would be contraindicated. Any subjects with a reported fall within the last 2 years or those who were unable to achieve bilateral overhead shoulder flexion or abduction were excluded. The experimental group consisted of 11 females (75.6 ± 6.4 years; 68.8 ± 5.4 kg; 165.1 ± 7.0 cm). A control group of 10 females (71.2 ± 9.1 years; 63.4 ± 9.8 kg; 164.1 ± 6.8 cm) participated in data collection but not in proprioceptive training. All subjects were recruited from local church senior groups.

### Measurement Procedures: Functional Reach

Functional reach forward (FRF), functional reach right (FRR), and functional reach left (FRL) were measured using previously reported procedures.[2,17-19] Functional reach has been defined as the maximal distance an individual can reach while maintaining a fixed base of support in standing.[2] To quantify functional reach, a yardstick, attached to a telescoping tripod, was positioned at the level of the subject's acromion process. Before testing, the yardstick was leveled so that it was horizontal to the floor. To assume the starting position, subjects were instructed to stand with their feet flat on the ground shoulder width apart, raise their dominant arm to shoulder height, and finally, to open their hands with fingers extended as far as possible. To eliminate the effect of scapular protraction on functional reach, subjects were asked to "push their arm and hand out as far as possible" in the direction of the yardstick. To perform the functional reach task, subjects were then instructed to reach as far as possible forward, to the right, or to the left while keeping their finger tips along the yardstick. A trial was repeated if the subject lost balance, took a step, or raised the heels. For functional reach left and right, subjects were not permitted to rotate the trunk or hips. Using the tip of the middle finger, the difference between the starting position and the extended 'reach' position was recorded to the nearest quarter inch. Each subject performed 3 consecutive trials in each direction and the average score for each direction was used for data analysis. The ICC values were all acceptable: 0.896 for FRF, 0.878 for FRR, and 0.756 for FRL.

### Measurement Procedures: Lower Extremity Reach

The lower extremity reach test (LERT), an analog of the upper extremity functional reach test, is an assessment tool that incorporates dynamic control of single limb balance with lower extremity neuromuscular control. The LERT requires a subject to remain standing on one limb while reaching as far as possible with the opposite limb in the direction away from the stance limb. The distance reached with the extended extremity is interpreted to reflect dynamic balance.[20,21]

To quantify lower extremity reach, 2 wooden yardsticks were fixed to the floor in a perpendicular orientation. Subjects stood at the point where the yardsticks joined so that each yardstick was oriented forward and away from the subject at 45° to the sagittal and frontal planes (Figure 1). Subjects stood without shoes and placed the first toe of their self-reported dominant lower extremity at the intersection of the yardsticks. Dominance was determined by asking the subject "Which leg would you choose to kick a ball as far as you could?" Lower extremity reach was measured in only one direction—away from the stance limb thus assessing stability and control of balance using the dominant limb. While balancing on the dominant limb, subjects lifted the nondominant limb and extended the limb along the yardstick as far as possible in the forward and lateral direction. Subjects were permitted to hold their foot above the yardstick at a height that allowed them to perform the test. Each subject was required to hold the limb in the 'reach' position for at least 2 seconds while the examiner recorded the reach distance.

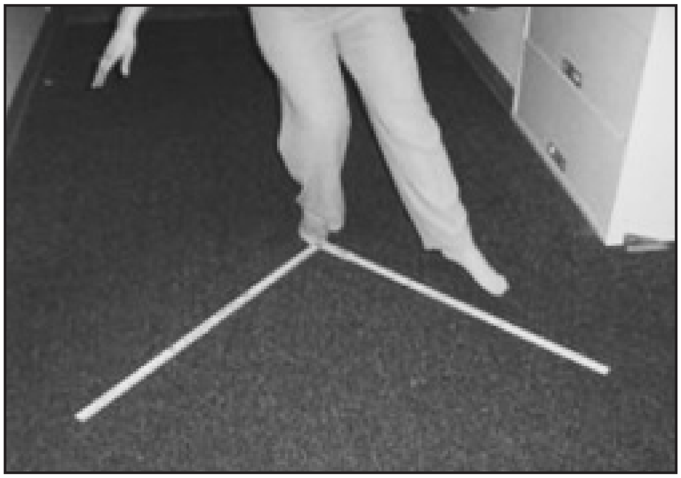

**Figure 1. Lower extremity reach test.**

The maximal distance reached was visually measured by an examiner standing over the yardstick. Three consecutive trials in one direction were recorded to the nearest one-half inch. Prior to each trial, subjects were given up to 90 seconds to return to the original starting position, but were permitted to perform another trial if ready in less than 90 seconds. The average of the 3 trials was used for data analysis. No restrictions were placed on how the subjects manipulated their arms or trunk during the test, however, a trial was considered a failure and repeated if subjects lost balance from the stance limb, touched the floor with the extended foot, moved the stance foot, or were unable to hold the reach position long enough for the examiner to record the distance. Prior to data collection, the ICC calculated for this measurement was 0.943.

### Balance Training Program

The balance training program was performed as a group session on Mondays and Thursdays for 5 consecutive weeks under the supervision of the study staff. To provide a postural challenge, we used the Ankle Arc™ proprioceptive device (North Coast Medical, Morgan Hill, Calif). The Ankle Arc™ is a semi-compressible foam roller device approximately 13 inches long by 6 inches wide that resembles a football cut lengthwise (Figure 2). When standing on the Ankle Arc™ with the long axis pointed in the anterior-posterior direction, the device imparts a predominant medial-lateral (frontal plane, pronation/supination) and secondary anterior-posterior (sagittal plane plantar- and dorsiflexion) perturbation; whereas, when turned with the long axis pointed left-to-right, the device imparts a predominant anterior-posterior and secondary medial-lateral perturbation (Figure 3). For our population, we selected the 'light' version recommended for up to 175 lb.

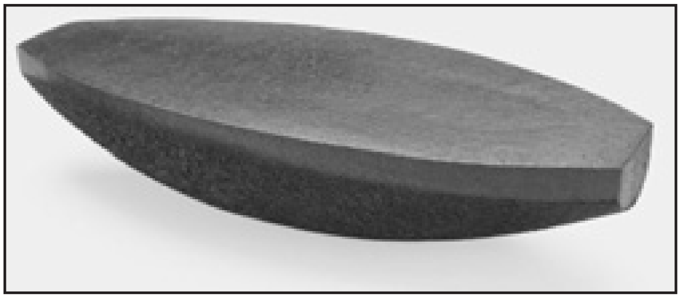

**Figure 2. The Ankle Arc™ proprioceptive training device.** (Image provided by North Coast Medical.)

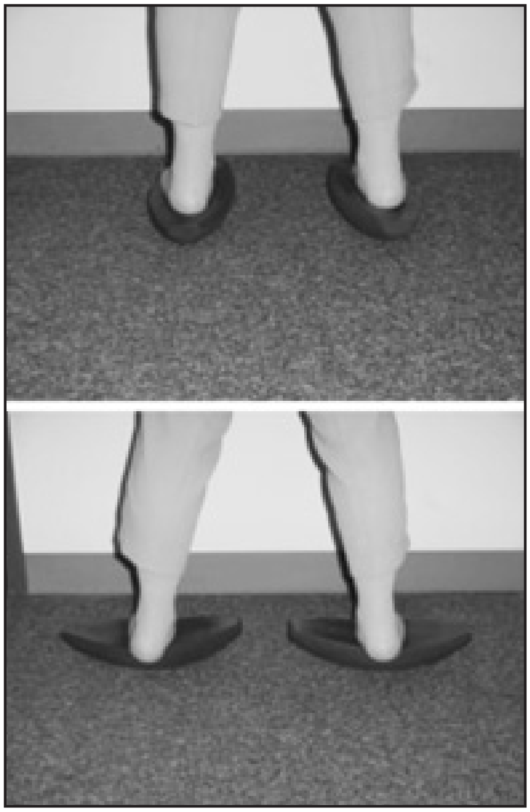

**Figure 3. Ankle-Arc in anterior-posterior and medial-lateral orientation.**

The entire training protocol, including warm-up, was designed to last approximately 15 minutes (Table 1). To warm-up, subjects placed 1 foot on a single Ankle Arc™ aligned with the long axis pointed in the anterior-posterior direction and the other foot flat on the floor beside the Ankle-Arc™. Keeping the majority of their body weight on the foot in contact with the floor, subjects were instructed to firmly press the other foot onto the Ankle Arc™ while moving that ankle through a pronation/supination range of motion for one minute. Following this activity, the device was rotated 90° to align the long axis in the medial-lateral direction while the subjects performed a plantarflexion/dorsiflexion range of motion for one minute. These procedures were repeated for the opposite ankle.

**Table 1. Dynamic Balance Training Protocol**

| | | |
|---|---|---|
| **Warm Up** | | |
| | **Duration** | **Activity** |
| | 1min | unilateral pronation/supination R ankle |
| | 1min | unilateral plantar-/dorsiflexion R ankle |
| | 1min | unilateral pronation/supination L ankle |
| | 1min | unilateral plantar-/dorsiflexion L ankle |
| **Training** | | |
| | **Duration** | **Activity** |
| | 2 min | bilateral pronation/supination |
| | 1set x 10 repetitions | bilateral partial squats |
| | 2 min | bilateral plantar-/dorsiflexion |
| | 1set x 10 repetitions | bilateral partial squats |
| | 2 min | bilateral pronation/supination |
| | 1set x 10 repetitions | bilateral partial squats |
| | 2 min | bilateral plantar-/dorsiflexion |
| | 1set x 10 repetitions | bilateral partial squats |

Following warm-up, subjects placed 2 Ankle Arc™ devices on the floor in front of them, first pointing in the anterior-posterior direction. After assuming bilateral stance upon the 2 foam rollers, subjects were instructed to perform bilateral pronation/supination of the ankles through "a range of motion as much as you can control." This was performed for 2 minutes and was followed by a set of 10 bilateral squats with subjects instructed to squat "as deep as you can control" while remaining on the foam devices. Following the squats, the alignment of the Ankle Arc™ devices was changed to the medial-lateral direction where the subjects performed 2 minutes of plantarflexion/dorsiflexion followed by 10 squats. Up to 30 seconds was allowed between the range of motion and squat activities to rest and change the alignment of the Ankle Arc™. This sequence was then repeated once more for a total of 4 minutes of range of motion in each direction and 40 squats. All subjects wore athletic style shoes for the exercise session. The subjects performed these activities adjacent to a wall and were permitted to use hand support against the wall as they needed but were encouraged to discontinue hand support as they felt comfortable. By the fourth week, none of the subjects was using hand support and there were no instances of falling.

### Statistical Analyses

All calculations were completed using SPSS statistical software (v.12.0 for Windows). The effect of this novel balance training protocol was assessed using a positive control procedure to evaluate the possibility that change over time occurred by chance. Paired-samples t-tests were used to assess change in the trained and untrained group after 5 weeks. To protect against multiple testing error when assessing change in the 3 repeated measures of functional reach, a Bonferroni correction was used to adjust the alpha level of significance for the 3 tests.[23] Therefore, the criteria level for significance for each test of functional reach was set at $P < 0.017$ (ie, alpha level of 0.05 ÷ 3 tests). The alpha level of significance for the lower extremity reach test was maintained at $P < 0.05$.

## RESULTS

Anthropometric characteristics of each group are shown in Table 2. Balance performance data are shown in Table 3. There were no significant differences between groups for the anthropometric and pretraining balance data. There was no significant change in any of the 4 dependent measures of balance for the control group. Following the 5-week training period, there was no significant change noted in FRF in the exercise group. There, however, was a significant ($P = 0.014$) improvement in FRR, as the exercise group was able to reach an average 2.1 inches (29%) farther. The exercise group demonstrated a significant ($P < 0.001$) improvement of 1.6 inches (22%) in FRL. Likewise, there was a significant improvement ($P = 0.001$) in the LERT, as the exercise group was able to reach 4.3 inches (16%) farther.

## DISCUSSION

The findings of this study show that significant improvements in balance control can be realized following this short-term balance training program that specifically emphasizes dynamic balance activities. That lateral functional reach improved by a combined average of 25% and lower extremity reach by 16% is evidence of this assertion. With these findings, this investigation offers new information to the literature on training-related adaptations in control of balance and more specifically, offers a novel training program for balance.

The mean FRF distance of our subjects before training was similar to that of age-matched subjects examined by other investigators using similar testing procedures.[1,2] The mean FRR and FRL distances of our subjects were only slightly greater than those reported by DeWaard et al; however, the mean age of their subjects was 5 years greater than ours.[17] In this regard, the baseline measures of reach in our subjects were similar to those from previous studies. A comparison of our subjects' performance on the LERT is difficult as we found no data obtained using similar procedures and age-relevant subjects.

**Table 2. Demographics (mean ± standard deviation) for Subjects**

| Group | Age (yrs) | Weight (kg) | Height (cm) | Body Mass Index (kg/m$^2$) |
|---|---|---|---|---|
| Exercise | 75.6 ± 6.4 | 68.8 ± 5.4 | 165 ± 7.0 | 25.4 ± 2.6 |
| Control | 75.6 ± 6.4 | 68.8 ± 5.4 | 165 ± 7.0 | 25.4 ± 2.6 |

Because our training protocol specifically incorporated balance training activities in the medial-lateral direction, not solely anterior-posterior, it is not surprising that significant gains were made in FRR, FRL, and the LERT, the measures of lateral balance. This is consistent with the concept of 'specificity of training' which indicates that neuromuscular adaptations occur according to the specific manner in which the exercise or activity stress the system.[24] For example, the present training protocol included multiple and repetitive sets of partial squats while subjects stood on the foam devices. Following training, significant improvement in lower extremity reach was noted in the exercise group. During the LERT, while attempting to reach with one limb, most subjects used some amount of knee flexion to stabilize their body and increase their reach. That is, they squatted to some degree to increase their reach. It is reasonable to suggest therefore, that because our training protocol incorporated squatting activities, improvements in the LERT are related to the specific training task. While it is beyond the scope of this investigation to discuss adaptations in the physiologic systems underlying balance, the improvements in dynamic balance following this protocol are evinced by positive changes in only the exercise group who performed the balance training.

While improvements in medial-lateral balance and lower extremity reach were noted, no improvement was observed in forward reach despite the inclusion of anterior-posterior activities in the balance program. It is our contention that because most daily tasks are performed in front of the body and these activities are familiar, there was a greater likelihood for improvement in the lateral direction than forward. This is also based on the subjective reports of study participants and clinical observations of older adults in whom we have used these tests. There exists a collective opinion among participants and patients that the forward reach test is much easier than the lateral and lower extremity reach tests. While this has not been formally investigated, the level of familiarity and more frequent exposure to daily tasks requiring forward reach remains a plausible underlying mechanism explaining the lack of the improvement in forward reach.

That the subjects used in this study were healthy and without a history of falling lends support to this notion of

**Table 3. Summary (mean ± standard deviation) of Balance Measures (inches) Obtained Pre- and Post-training**

| Group | Time | Functional Reach Forward | Functional Reach Right | Functional Reach Left | Lower Extremity Functional Reach |
|---|---|---|---|---|---|
| Exercise | Pre | 12.9 ± 3.8 | 7.3 ± 1.1 | 7.2 ± 1.2 | 28.0 ± 4.5 |
|  | Post | 12.7 ± 3.0 | 9.5 ± 2.5* | 8.7 ± 1.5** | 32.4 ± 4.0** |
| Control | Pre | 12.2 ± 2.3 | 7.3 ± 1.3 | 7.4 ± 0.9 | 28.5 ± 3.2 |
|  | Post | 12.7 ± 2.6 | 8.4 ± 2.3 | 7.6 ± 0.9 | 26.1 ± 3.2 |

* = $P < 0.017$
** = $P \leq 0.001$

familiarity. Their exposure to routine daily tasks which require forward reach is likely greater than that of more frail, institutionalized, less mobile older adults. Thus, our subjects may have been inherently more capable of such tasks and therefore less likely to show training-related improvements in forward reach. In contrast, daily tasks requiring medial-lateral reach as measured in this study are less common and may be more difficult to perform. That exposure to specific activities using medial-lateral motion can potentiate improvement of balance control in the medial-lateral direction is supported by this study's use of such activities. Because our subjects were healthy and without history of falling, the question arises regarding the generalizability of these results to individuals who may be more frail or in need of balance training. We suggest that if significant improvements were noted in a group as healthy and robust as those used presently, then perhaps those less able or with a greater need for balance improvement would show a greater improvement. Certainly this training program is not appropriate for all populations needing balance training as this protocol requires a requisite amount of balance control to even stand upon the foam devices. But for those with the physical ability to perform this program, the evidence provided herein offers new information to assist clinical and home-based balance training.

Based on the findings of the FICSIT study and others, the specific inclusion of balance activities is warranted in exercise interventions with goals of improving balance.[12-14,25] However, many programs reported in the literature are of significantly greater duration and frequency, and require more specialized equipment, staff, and facilities than the program reported in this study.[4,9,16] As clinicians, we are challenged to identify and offer therapeutic programs that provide improvement in control of balance. It has been our goal to identify an efficacious training protocol that would improve dynamic balance in older adults while at the same time minimizing frequency, duration, and expense. The present balance training intervention is appealing in that it required only two 15-minute sessions per week, could be performed independently, and requires no expensive equipment (at the time of this writing, the retail price of the Ankle-Arc™ is $19.95). Further establishment of the efficacy of this program in a larger population is warranted, but these findings provide a fundamental framework from which to expand and develop this and other balance training programs.

## CONCLUSION

The recent literature contains many investigative reports of intervention trials designed to reduce the incidence and risk of falling in older adults. Several of these studies support the specific inclusion of balance training activities. Unfortunately, however, many of these training interventions require frequent training sessions, long durations, expensive equipment, clinical settings, or professional assistance. There exists a need, therefore, for balance training programs that are uncomplicated, short-term, inexpensive, but foremost, efficacious. The findings of this study support a training program that meets this need by providing a training protocol based on ten 15- minute bi-weekly sessions over 5 weeks.

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