Multifactorial Intervention with Balance Training as a Core Component Among Fall-Prone Older Adults

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ABSTRACT

Purpose: The purpose of this randomized controlled trial was to measure the effectiveness of *A Matter of Balance*, a small-group based balance program, on muscle strength, gait, balance, and fall risk among older community-dwelling adults at risk for falls. A secondary aim was to measure the effects of the program on actual fall rates over the 3-month study. **Methods:** Twenty-three older adults were randomly assigned to either an experimental group that participated in a 12-week small-group based balance program or a control group. Subjects were assessed at baseline and following an intervention using the following outcome measures: lower extremity manual muscle testing (MMT) and range of motion; gait analysis on the GAITRite® system; balance parameters on the SMART EquiTest®, the Timed Up and Go test, the Berg Balance Scale, and incidence of falls. **Results:** A repeated measures ANOVA revealed that there was a significant interaction between groups over time in the Berg Balance Scale scores, $P \leq .05$. The experimental group improved over time (48.1 to 52.9/56, respectively), whereas the control group decreased in performance (49.1 to 47.8/56, respectively), $P \leq .05$. The mean number of falls was significantly less in the experimental group during the intervention compared with the control group (0.09 and 0.50, respectively), $P \leq .05$. **Conclusions:** A community-based multifactorial intervention including individualized fall risk assessment, exercise, and home assessment appears to safely and effectively reduce the number of falls, resulting in significant improvements in functional balance ability and decreased fall risk.

Key Words: older adult; falls; fall risk; balance

INTRODUCTION

It is estimated that more than one third of older adults fall annually in the United States,[1] and the possibility of falling increases considerably with age.[2] Fall-related injuries cause significant loss of life, disability, dependence, and early admission to nursing-homes.[3] Twenty to 30% of people who fall sustain moderate to severe injuries that decrease mobility and independence and increase the chance of untimely death. Moreover, in the United States, 13% of the population is 65 years and older, yet this group accounts for 75% of the deaths from falls.[4] Falls can have emotional consequences in addition to physical injury.[5]

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A number of risk factors for falling have been identified. Risk factors include impairments in leg muscle stength,[6] gait[7] and balance,[8] vision,[9] and cognition.[10] For example, data suggest that people with leg weakness have a 4-to-5 fold increase in risk for falls, and people with impaired gait or balance have approximately a 3-fold increase.[11] In addition, postural hypotension,[6,12-14] cardiovascular abnormalities,[15] psychoactive and cardiac medications,[16,17] polypharmacy,[17] and environmental factors[18] are associated with falls.

Multifactorial interventions conducted by health professionals with skills in geriatric medicine have generally been consistent in showing an effect in preventing falls,[19] particularly if they target persons at risk,[20] and include several intervention strategies.[21] However, there is limited evidence that interventions which are specifically tailored to target risk factors and impairments are more effective than those administered as a standard intervention.

We conducted a randomized controlled trial to measure the effectiveness of *A Matter of Balance*, a small-group based balance program, on muscle strength, gait, balance, and fall risk among older adults at risk for falls. A secondary aim was to measure the effects of the program on actual fall rates over the three month study.

METHODS

Subjects

Twenty-three volunteers (12 men and 11 women) who were interested in participating in the study and met the inclusion criteria, received medical clearance from their physician and signed a written informed consent approved by the Standing Advisory Committee for the Protection of Human Subjects at California State University, Northridge were enrolled in the study. Volunteer participants were recruited through press releases and advertisements in newspapers, and a university webpage. Eligibility screening occurred in 2 steps. An initial telephone interview screened based on the following inclusion criteria: age 65 years or older, community-dwelling, English-speaking, minimal vision and hearing limitations, access to transportation, willingness to participate in group exercise class for at least 3 months, and physician approval to participate in study. Subjects were excluded if they reported a history of cardiac conditions, musculoskeletal, and/or neurologic limitations that could account for possible imbalance and falls such as cerebrovascular accident, spinal cord injury, Parkinson disease, transient ischemic attacks, lower-extremity joint replacements/fusions/amputations (could use a cane or walker), or fracture within past year. A follow-up-in-person enrollment interview required potential subjects to be able to pass the Mini Mental State exam[22] with a score of $\geq$ 24/30 points[23] and to complete a 3-meter Timed Up and Go Test[24] $\geq$ 13.5 seconds,[25] and/or to have 2 or more falls in the past year, and/or one fall with an injury in the past year. A fall was defined as any event which results in a person's coming to rest inadvertently on the ground or other lower level. Unintentional falls onto a chair or bed or falls against an object on which the subject did not come to rest on the ground, and sports-related falls were not considered falls for the purpose of this study.

Eligibility Screening

The Mini Mental State Examination (MMSE*)*

The Mini Mental State Examination (MMSE) is a pencil and paper test that takes approximately 5 to 10 minutes to complete and measures cognition.[22] To be included in the study, subjects had to have a minimum MMSE score of 24 to read and execute simple written and verbal commands.[22] The MMSE has established construct validity, concurrent validity, and inter-rater reliability.[22]

The Timed Up and Go Test (TUG)

Since its introduction in 1991,[24] the Timed Up and Go (TUG) test has been used extensively to characterize the functional/balance status of older adults. Construct, convergent, discriminant, and predictive validity have been supported for the TUG test.[26,27] Numerous researchers have demonstrated that the TUG test is reliable for community-dwelling older adults.[26-29] For identifying older adults who fall, the TUG test was found to have a sensitivity and specificity of 87% and a cut-off level of 13.5 seconds.[25] Subjects in both groups who were enrolled in the study performed the TUG a second time at the conclusion of the study.

Procedures

Health status questionnaire

After informed consent was obtained, subjects completed a health status questionnaire providing information on age, residential status, medical history, current coexisting medical conditions, type of assistive device used for ambulation, exercise history, use of alcohol, medication history, and circumstances of each fall in the past 12 months. This information was used to characterize the demographics and health status of subjects participating in the study. The number of falls that occurred in both groups during the 12-week intervention was also collected at the end of the intervention

Medication review

Subjects taking more than 4 prescription medications[30] and/or drugs that may increase the risk of falling[17,31] (benzodiazepines, antidepressants, sedatives/hypnotics, antihypertensives, Class Ia antiarrhythmics, digoxin, and diuretics) were referred to his/her primary physician for medication review (n=14). These 14 subjects remained in the study and their medications were not changed.

Assessment for postural hypotension and cardiac arrhythmias

Heart rate and blood pressure were taken manually and with a sphygmomanometer, respectively. The subject was asked to stand and blood pressure was taken again. If systolic blood pressure dropped more than 20 mm Hg, was less than 90 mm Hg, and/or an irregular heartbeat was detected (n=4), subjects were referred to their primary physician. All 4 subjects were examined by their physicians and remained in the study.

Visual screening

Subjects were asked to wear their corrective lenses for the purpose of visual screening. Screening was conducted if the subject reported visual problems using a Snellen eye chart for visual acuity (n=5). For peripheral fields, the examiner brought her fingers behind the subject's head at eye level while the subject stared straight ahead. The subject identified when s/he first noticed the examiner's finger in the side view. For depth perception, the examiner held her index fingers parallel and pointed upward in front of the subject's eye level. As the examiner moved her fingers apart (one forward, one back), the subject was asked to identify when the fingers were back together and parallel. A referral for formal visual assessment was given to subjects if: (1) a score of 20/200 or below was present from the Snellen exam, (2) if a significant unilateral or bilateral field cut was noticed on the peripheral field test, and (3) if the subject was off by 3 or more inches during the depth perception test. No subject required a referral for visual assessment.

Manual Muscle Testing and Range of Motion Measurement

Kendall's method of manual muscle testing[32] was used to determine the strength of the knee extensors and ankle dorsiflexors. Bilateral lower extremities were tested in both groups. Intra-rater and inter-rater reliability was not determined for strength testing among the 3 testers.

Ankle dorsiflexion range of motion (ROM) was measured on bilateral lower extremities using standard goniometry.[33] Intra-rater and inter-rater reliability was not determined for ROM testing among the 3 testers.

Gait Analysis

The GAITRite® system (CIR Systems, Havertown, PA) was used to analyze the following gait parameters: cadence, stride length, step length, velocity, base width, double support, swing, and stance. Three trials were recorded for each subject and the average gait parameter was used for subsequent analysis. The GAITRite® system has strong concurrent validity and test retest reliability, in addition to being a portable, simple clinical tool for the objective assessment of gait.[34]

Balance Measurements

Balance testing was done using dynamic posturography with the Smart EquiTest® (NeuroCom® International, Inc, Clackamas, OR) and included the Sensory Organization Test, the Motor Control Test, and the Adaptation Test. The SMART EquiTest® provides objective assessment of balance control and postural stability under dynamic test conditions to reflect functional activity.

Sensory organization test

Sensory impairments were measured during the Sensory Organization Test (SOT). The SOT can identify problems with postural control by assessing the participant's ability to make effective use of visual, vestibular, or proprioceptive information. During the SOT, the subject was asked to stand steady during 3 trials of 6 sensory conditions: (1) eyes open, fixed surface and visual surround; (2) eyes closed, fixed surface; (3) eyes open, fixed surface, sway referenced visual surround; (4) eyes open, sway referenced surface, fixed visual surround; (5) eyes closed, sway referenced surface; and (6) eyes open, sway referenced surface and visual surround.

Motor control test

Automatic motor responses were measured with the Motor Control Test (MCT). The MCT assesses the participant's ability to respond to and quickly recover from unexpected surface perturbations. Potential subjects who demonstrated prolonged latencies of motor responses were excluded from the study (n=1). Results of the MCT were not used in the final data analysis.

Adaptation test

The Adaptation Test (ADT) assesses the participant's balance during toes-up and toes-down surface changes and their ability to minimize sway or modify motor reactions when the support moves unpredictably. For the purpose of data analysis, performance on the ADT was classified as follows: Adaptive to surface rotations = no falls and $\leq$ 2/5 trials in abnormal range; Maladaptive = no falls and > 2/5 trials in abnormal range; and Unable to Adapt = any fall during the trials.

Berg Balance Scale

The Berg Balance Scale was used to assess functional balance.[35] The Berg Balance Scale has previously been shown to have concurrent, discriminant, and predictive validity and high interrater and intrarater reliability in older adults.[35-37]

Intervention

Twelve subjects were randomly assigned to the experimental group and 11 subjects were randomly assigned to the control group. The experimental group received balance interventions for 12 weeks while attending *A Matter of Balance*, a small-group based balance program. Subjects in the control group were instructed to maintain their current level of activity during the study and were invited to complete a 12-week balance intervention at the conclusion of the post-test measurements. Both groups were retested at the end of the balance intervention.

The *Matter of Balance* class met 3 times a week for 12 weeks and subjects were required to attend a minimum of 30 sessions. The class content of *A Matter of Balance* was designed by a physical therapist to specifically address physical fall risk factors identified during pretesting. This intervention included center of gravity exercises (closed chain); balance strategies such as ankle, hip and stepping strategies; treatment of sensory impairments such as stimulation to use visual inputs and use of somatosensory inputs; and exercises to increase range of motion and strength. Participants were encouraged to attend all exercise classes (at least 30 sessions) with make-up classes arranged as needed for those who missed classes. The *Matter of Balance* program was held at the Department of Physical Therapy at California State University, Northridge.

A Matter of Balance class activities were designed to match the impairments and functional limitations determined by objective tests of balance, mobility, sensory organization, strength, range of motion, and difficulty adapting to a moving floor surface. All subjects were trained in a group class format, with like activities performed with each individual. The first 20 to 30 minutes of the 1-hour class consisted of standing balance activities with progressively decreased base of support including wide base, normal stance width, feet together, stride, tandem, and single limb stance positions with and without head movements left to right, up and down, and with altered visual conditions including slow blinks or eyes closed. Weight shifting activities were then performed with emphasis on shifting to the maximum safe distance in lateral, anterior, and posterior directions. Subjects performed forward reaching activities with target objects placed on tables in front of each subject. Vestibular ocular reflex activities (VOR) were performed using gaze stabilization training (VORx1 paradigm) with visual targets (the letter "B" or other symbols) drawn on a white board in large font size approximately 20 feet in front of the subjects. Dynamic visual acuity activities were done in vertical and horizontal planes of head movement with an emphasis on keeping the image clear while increasing the speed of head movement, and maintaining a continuous movement without pausing unless a loss of balance was experienced. More dynamic activities of marching in place with eyes open and closed, and "look arounds" with emphasis on trunk and neck rotations were then performed.

Following the group balance exercises listed above, subjects were divided into smaller groups of 2 to 3 persons and continued the training at stations that were positioned around a large physical therapy laboratory classroom. Each subject spent approximately 5 to 6 minutes at each of 5 stations: (1) Ankle stretching with prolonged holds into dorsiflexion range of motion on practice stairs with upper extremity support for balance. (2) Standing on foam with feet apart, together, and stride, manipulating visual conditions of eyes open, slow blinks, and eyes closed. Marching was added with eyes open and closed by week 6 of training. Three subjects were trained at the same time by placing 3 AirEx® Balance Pads (Alcan AirEx AG, Sins, Switzerland) between parallel bars that were raised approximately to hip level to prevent falls. (3) Rocker board training for ankle strengthening, balance reactions on a moving platform with and without perturbations to the board, and weight shifting with eyes open and closed. (4) An obstacle course that included walking through 3 cones spaced approximately 3 feet apart, then stepping up and over a 6-inch curb step and an 8-inch curb step, picking up a ping pong paddle from a third 6-inch box, hitting a plastic ball suspended overhead from the ceiling by a strap, replacing the paddle onto the box, and returning through the obstacle course in the reverse order. Each subject performed this sequence 3 times in a row and with close contact guard or supervision. (5) Walking station. This station began with subjects walking on flat plastic disks placed far enough apart to force larger-than-normal step length. Subjects mastered this activity quickly and the station was progressed to walking with head turns with vision fixed on a far target.

All subjects returned to a large group and performed repeated sit-to-stand exercises while holding onto a therapy ball. The size and/or weight of the therapy ball increased as subjects' performance improved. Over the 30 training sessions the number of sit-to-stand repetitions was progressed from 10 to 20, and subjects were expected to perform at least 10 repetitions in a row by the end of training, plus have the control to stop and "freeze" at any position during each transfer on the command of the class instructor. The class concluded with subjects standing behind their chairs performing heel raises and toe raises. These began with 10 repetitions and progressed to 30 repetitions over time. Deep, slow breathing with arms overhead was performed at the end of class and the instructor gave positive reinforcement for individual and group performances.

Each subject in the experimental group received a falls risk home assessment using a standardized home assessment form[38] by teams of physical therapist students enrolled in the last semester of their curriculum. Written recommendations were given to each subject and discussed. Funds were made available to make minor home modifications as recommended. Each subject in the experimental group was measured for and received hip protectors.

Data Analysis

All data analyses were performed using SPSS 16.0 for Windows (SPSS Inc. Chicago, Il). Simple descriptive statistics were calculated on all subjects (Table 1). Means and standard deviations were also determined. Chi-square tests for cross-tabulation tables and t-tests for independent samples were used to compare the prevalence of gender distribution, medication and alcohol use, and activity level and the means of age, height, weight, and scores on the Mini Mental State Exam of the experimental and control groups at initial assessment. The number of falls and the SOT composite scores in the 2 groups were compared with an Analysis of Variance (ANOVA) with 2 repeated measures (baseline and postintervention). A repeated measures multivariate analysis of variance (MANOVA, Wilk's criterion) was performed on the combined gait measures and the range of motion measurements. In cases where the MANOVA demonstrated a significant difference, a *post* hoc within-subject analysis was performed. The Wilcoxan signed rank test was used to make comparisons within each of the groups and the Mann-Whitney U-test was used to analyze the difference between the groups for manual muscle testing, SOT bar color, and performance on the Adaptation test. All statistical tests were conducted at the $P \leq .05$ level.

RESULTS

Descriptive Characteristics

Twenty-three subjects enrolled in the study. One of the 12 subjects randomized to the experimental group did not complete the post-test measurements because of an unrelated hospitalization and deteriorating health. Three of the 11 subjects randomized to the control group were excluded from further analysis: one demonstrated prolonged latencies of motor responses during the Motor Control Test, one refused further participation because of unrelated health problems, and one enrolled in a Tai Chi course during the study to improve balance. The mean age of the 19 subjects who completed the study was 80 years, and 58% were men (78.9% white, 15.8% Hispanic, 5.3% Asian). Experimental and control groups did not differ in baseline for age, gender, height, weight, cognitive state, alcohol use, exercise habits, polypharmacy, or number of falls during the past year (Table 1).

Manual Muscle Testing and Range of Motion

The experimental group showed significant increases in pre-post MMT values in bilateral dorsiflexion, whereas the control group did not. There was no improvement in knee extension MMT values within either group over time. However, the experimental group had greater knee extension MMT values than the control group after the intervention (Table 2). There were no significant within or between group differences in ankle dorsiflexion range of motion.

Gait Analysis

A repeated measures multivariate analysis of variance (MANOVA) was conducted to determine group differences in gait parameters. There were no significant within group, between group, or interaction effects (Table 3).

Posturagraphy

A repeated measures ANOVA revealed no significant within, between, or interaction group effects on the SOT composite scores. A Wilcoxan signed ranks test revealed that the experi-

Table 1. Baseline Characteristics of Subjects, According to Treatment Group

Characteristics		Experimental (n=11)	Control (n=8)	Total (n=19)
Age (y)	mean (SD)	79 (6.5)	81 (5.0)	80 (5.8)
Gender	n (% women)	4 (36.4)	4 (50)	8 (42.1)
BMI (kg/m^2)	mean (SD)	26.3 (4.8)	26.8 (5.8)	26.5 (5.1)
MMSE (0-30)	mean (SD)	27.1 (1.7)	26.9 (1.1)	27.0 (1.5)
Alcohol consumption (>2 drinks qd)	n (%)	1 (9.1)	1 (12.5)	2 (10.5)
Regular Exercise	n (%)	4 (36.4)	6 (75)	10 (52.6)
Medications (>4)	n (%)	9 (81.8)	5 (62.5)	14 (73.7)
Falls in previous 12 months	Mean (SD) n (%)	1.0 (1.1) 11 (35.5)	2.5 (2.4) 20 (64.5)	1.6 (1.9 31 (100)
Falls during study period	Mean (SD) n (%)	0.09 (0.3)* 1 (20)	0.50 (.5) 4 (80)	0.26 (0.4) 5 (100)
*Significantly less than control group, P≤.05				

mental group improved significantly over time in the SOT composite score values from an abnormal range to a normal range (Figure 1) and on the Adaptation Test in both the toes up (Figure 2) and toes down (Figure 3) conditions, respectively. A Mann-Whitney test revealed no significant between group differences in SOT composite score ranges or performance on the Adaptation test (Table 4).

Timed Up and Go and the Berg Balance Scale

A repeated measures ANOVA revealed that there was a significant interaction between groups over time in the Berg Balance Scale scores (Table 4). The experimental group improved over time (48.1 to 52.9/56, respectively), whereas the control group decreased in performance (49.1 to 47.8/56, respectively) (Figure 4). There were no other significant within or between group main effects on either the TUG or the Berg Balance Scale.

Falls

The mean number of falls was significantly less in the experimental group during the intervention compared with the control group (0.09±.30 and 0.50±.54, respectively) (Table 1).

DISCUSSION

The training program implemented in this study was effective at improving several aspects of balance and mobility that have been shown in the literature to be important determinants of fall risk and mobility status in older adults.[6,8,11,19,20,39] The balance class that was designed to address impairments that were determined through baseline objective measures of balance and mobility was beneficial for the subjects in this study who had a history of falls prior to training. The group balance activity class consisted of: (1) activities that forced the use of vision, vestibular, and somatosensory systems for standing balance control; (2) standing limits of stability and functional reaching; (3) standing on one leg and in various small base of support stance configurations; (4) walking with head movements; (5) gait training with visual targets to increase stride length and improve gaze stabilization during walking; (6) strengthening exercises for lower extremity muscle

Table 2. Means and Standard Deviations of Strength and Range of Motion Measurements

	Baseline		Retest	
Outcome Measure	**Experimental**	**Control**	**Experimental**	**Control**
MMT				
Right knee extension	4.7±0.5	4.4±0.5	4.9±0.4*	4.3±0.5
Left knee extension	4.7±0.5	4.5±0.5	4.9±0.4*	4.3±0.5
Right dorsiflexion	4.1±0.7	4.1±0.4	4.6±0.7†	4.3±0.5
Left dorsiflexion	4.0±0.6	3.8±0.4	4.3±0.8†	3.7±0.9
ROM (degrees)				
Right dorsiflexion	2.6±5.6	3.1± 2.4	5.0±4.8	4.0±2.2
Left dorsiflexion	1.9±5.8	1.9±3.8	3.8±6.0	1.4±5.3

*Experimental group significantly greater than control group in retest, P<.05.
†Significantly greater than baseline, P<.05.

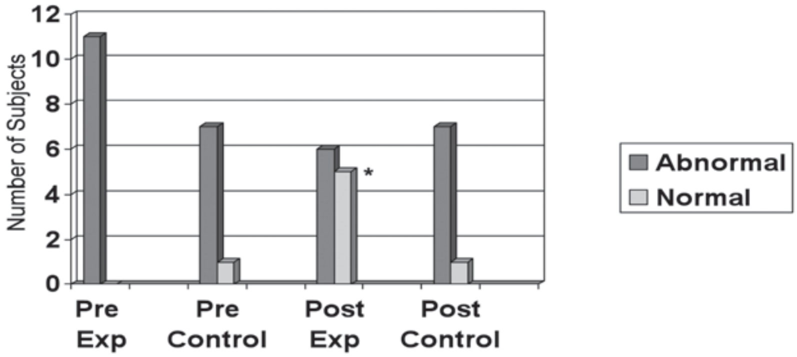
Table 3. Means and Standard Deviations of Gait Parameters

	Baseline		Retest	
Outcome Measure	**Experimental**	**Control**	**Experimental**	**Control**
Cadence (steps/min)	103.5±10.4	107.2±11.7	107.9±10.1	106.8±9.8
Stride Length (cm)				
Right	102.2±19.2	102.3±25.4	105.8±17.3	102.8±23.7
Left	102.0±19.2	102.6±25.8	105.5±17.4	102.3±23.7
Step Length (cm)				
Right	50.9±9.9	52.1±12.9	52.2±8.7	52.1±12.1
Left	50.9±10.1	49.6±12.8	53.2±9.2	50.1±12.3
Velocity (cm/s)	87.9±20.0	90.3±22.2	95.1±21.7	90.8±21.4
Base Width (cm)				
Right	12.3±4.9	12.6±12.6	11.4±5.2	13.6±5.6
Left	11.8±5.6	12.5±5.4	11.9±5.4	13.6±5.3
Double Support (% of gait cycle)				
Right	28.2±5.8	32.7±3.6	28.9±3.9	32.8±(4.0
Left	27.9±5.5	32.8±3.7	29.3±4.4	32.6±4.1
Swing (% of gait cycle)				
Right	36.3±3.0	33.7±2.6	5.6±2.7	34.0±2.6
Left	36.1±2.1	34.1±2.0	35.3±2.2	33.4±2.4
Stance (% of gait cycle)				
Right	63.7±3.0	66.2±2.5	64.4±2.7	66.0±2.6
Left	63.9±2.1	65.9±2.0	64.7±2.2	66.6±2.4

Table 4. Balance Parameters

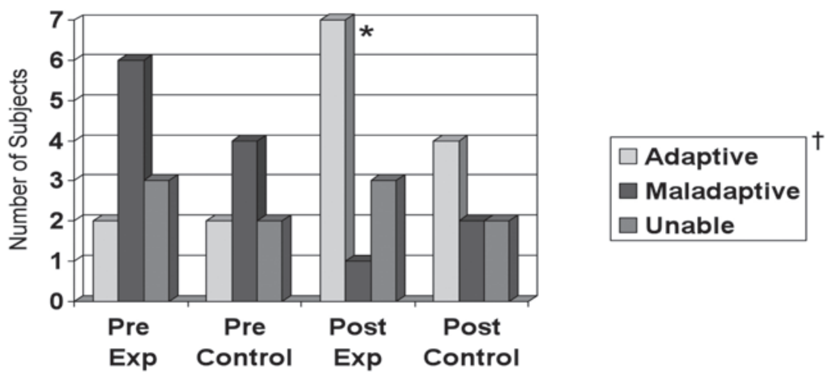
	Baseline		Retest	
Outcome Measure	**Experimental**	**Control**	**Experimental**	**Control**
Equitest*				
SOT Composite Score	47.7±10.1	50.1±9.5	57.4±9.4	51.1±13.0
Normal Range SOT				
Composite Scores	0 (0)	1 (12.5)	5 (45.5)*	1 (12.5)
Adaptation Test (Able to Adapt)†				
Toes Up	2 (18.2)	2 (25)	7 (63.6)*	4 (50)
Toes Down	4 (36.4)	4 (50)	7 (63.6)*	4 (50)
TUG	14.0±3.8	15.6±4.9	12.7±2.4	14.9±4.7
Berg Balance Scale‡	48.1±7.7	49.1±5.6	52.9±2.5	47.8±3.1

NOTE. Values are mean ± (standard deviation or n (%). Normal SOT Composite Score Range=Green color and Abnormal SOT Composite Score Range=Red color (as compared to older adults by normative values by height and age up to 79 years old - NeuroCom* International, Inc, Clackamas, OR).
*Significant improvement compared to baseline, P<.05.
†Adaptive = < 2 trials are abnormal; Maladaptive = >3 trials are abnormal; Unable to Adapt = any fall during the trials
‡Significant interaction of balance intervention by time, P<.05



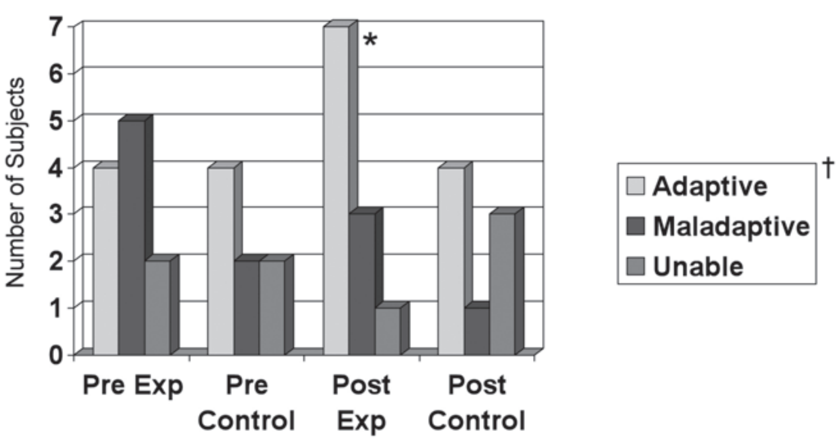
*Significant improvement after intervention within experimental group, P<.05.

Figure 1. SOT Results: Composite Score Ranges



*Significant improvement after intervention within experimental group, P<.05.
†Adaptive = <2 trials are abnormal; Maladaptive = >3 trials are abnormal; Unable to Adapt = any fall during the trials

Figure 2. Adaptation Test: Toes Up Condition



*Significant improvement after intervention within experimental group, P<.05.
†Adaptive = <2 trials are abnormal; Maladaptive = >3 trials are abnormal; Unable to Adapt = any fall during the trials

Figure 3. Adaptation Test: Toes Down Condition

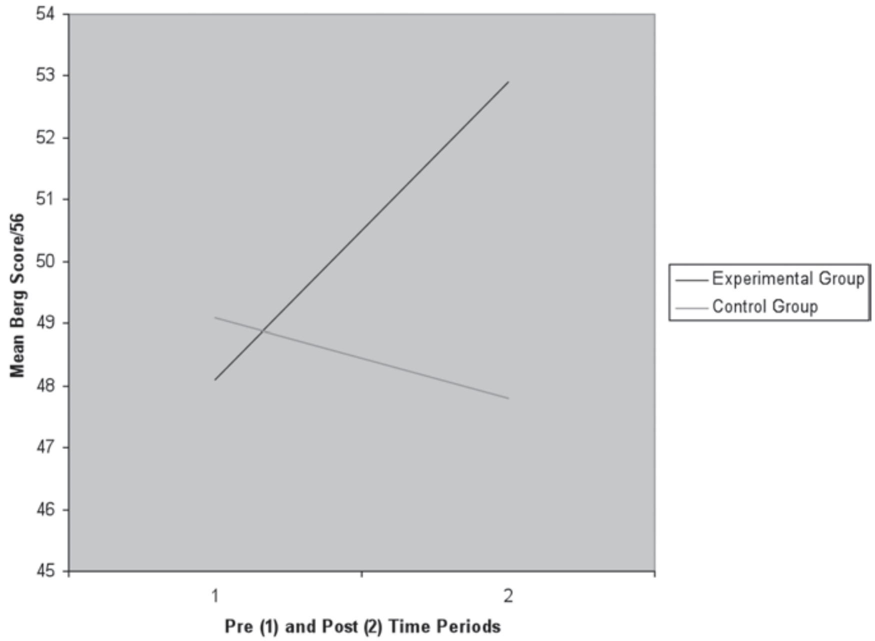
groups; (7) balancing during surface perturbations and on unstable platforms; (8) prolonged ankle stretching in standing; (9) gait with obstacle avoidance, curb stepping, bending, picking up objects from the floor, and turning.

All baseline characteristics (Table 1) and objective measures were the same between the experimental and control groups during screening and pretesting. The control group did not demonstrate any significant change on any outcome measure during the intervention period, scoring similar to pretest measures at the end of the 12-week period. Significant improvement in balance and mobility in the experimental group after training was demonstrated for the following measures:

Manual Muscle Test (MMT) scores for lower extremity strength improved for mean knee extension scores (0.6) between groups and within the experimental group for mean bilateral ankle dorsiflexion (0.3-0.5). However, these results did not reach clinical significance, and it is difficult to relate the MMT scores to other gains in function. Although MMT is an important clinical tool that is commonly used by physical therapists, the ability to make accurate, reliable clinical assessments of patient strength using this method is of questionable value.[40]

Although the repeated measures MANOVA performed on range of motion data showed no statistically significant change within or between groups, there was a trend for improvement in range of motion (ROM) scores for ankle dorsiflexion between pre- and posttesting for the experimental group, with essentially no change in ROM in the control group. This trend may have been due to ankle stretching, dorsiflexion exercises, and balance activities performed on moving platforms that allowed dorsiflexion range of motion to occur. An increase in ankle dorsiflexion range of motion may have contributed to the improvement seen on the Adaptation Test, which requires that subjects respond quickly to an 8° platform rotation during toes-up testing. Calf muscle stretching using prolonged stretching methods can provide small and statistically significant increases in ankle dorsiflexion ROM, but if itdifficult to determine if these small changes are clinically important.[41]

Gait characteristics, including gait velocity, stride and step length, step symmetry, cadence, double and single limb support, and step width measured using the GAITRite®



*Significant interaction of balance intervention by time, P≤.05

Figure 4. Berg Balance Scale*

Although times on the TUG were not determined to be significant within or between the 2 groups, post test TUG scores for the experimental group improved to below the 13.5 second cutoff determined for older adults by Shumway-Cook et al to 12.7 seconds.[45] Subjects did not, however, exceed the more sensitive cutoff score of ≤ 11.1 seconds determined for subjects with vestibular dysfunction who were at risk for falls.[46] Although the subjects in this study did not have known vestibular system dysfunction they all did poorly on conditions 5 and 6 of the NeuroCom® SOT test, indicating poor ability to use vestibular cues for balance.

It is evident from the GAITRite® measurements of gait characteristics that subjects did not make significant improvements in gait velocity; however, many subjects were able to perform the sit to stand component of the TUG with greater ease after the repeated sit-to-stand training performed in the balance class. Subjects also practiced turning around while walking through the obstacle course and during gait training activities in the balance class. This training may have accounted for the small improvement documented on this test in the experimental group. The control group had a mean score of 14.9 seconds on the TUG at post-test, which remained in the fall-risk range.

system at pre- and posttesting demonstrated no statistically significant change for either group. Steps were found to be symmetrical in our population of older fallers; however, gait velocity was below normal at both pre- and posttesting for both the experimental (87.90 to 95.1 cm/sec pre to post testing) and control groups (90.3 to 90.8 cm/sec pre to post testing). Normal values for gait velocity for adults age 70-79 were determined to be 133 cm/sec for women and 127 cm/sec for men.[42]

A significant number of subjects in the experimental group improved from the abnormal to the normal range on the Sensory Organization Test (SOT) Composite Score value. Subjects were compared to the normative values that exist in the NeuroCom® system for height and age up to 79 years. The mean improvement on the SOT composite score in the experimental group was 9.7/100 points. An 8-point change is considered to be a clinically significant change in this score.[43] Activities that may have contributed to SOT performance improvements seen in subjects in the experimental group include practicing standing with eyes open and closed on firm and foam surfaces, with and without head shake and gaze stabilization activities (VORx1 paradigm).

Performance on the Adaptation Test (ADT) improved from pre- to posttesting for the experimental group with a greater number of subjects demonstrating improved ability to adapt to surface perturbations from unable to adapt to maladaptive, or maladaptive to adaptive status by the end of the training period. It is believed that exposure to unstable surface conditions (rocker board, foam balance pad, perturbations, and self initiated anterior-posterior and lateral rocking movements) helped subjects adapt to abrupt changes in surface conditions as experienced on the Adaptation Test and in community environments. There were no clinically significant changes in ankle dorsiflexion, range of motion or strength. Therefore, improvements were assumed to be adaptive in nature and not biomechanical.[44]

A significant interaction occurred with scores on the Berg Balance Scale (BBS) as the experimental group improved and the control group declined over time. Scores improved by 4.8 points overall in the experimental group from 48.1/56 on pretesting to 52.9 on post testing, bringing the final score much closer to the maximum score of 56 points on this test. This improvement indicates improved balance ability during functional tasks and static balance conditions. A change is BBS score by 5 points has been shown to be clinically significant in the literature.[47] Results in the experimental group in this study came very close to this level of improvement. Continuation of balance training may have resulted in a continued ability to perform component balance activities that would increase this score further. The control group, on the other hand, declined 1.3 points. In those scoring between 43 and 52 on the BBS, each one-point decrease in score has been equated with a 2% to 7% increase in fall risk.[48]

Findings from this preliminary study suggest that this intervention may lead to significantly fewer falls. The experimental group experienced significantly less falls (n=1) overall than the control group (n=4) during the 3-month intervention period.

Limitations of the Study

Although our findings appear to have clinical relevance, they should be interpreted cautiously. From a research design standpoint, our sample was relatively small and was derived from only community-dwelling older adults. Further limitations to our study exist and include: (1) no interrater reliability for MMT and goniometric measurements; (2) no objective measure of strength.

Recommendations for Future Research

A reduction in fall occurrence and fall risk is important. A prospective study such as ours with a larger sample size and a broader cohort documenting improved postural stability, reduced fall occurrence, and reduced fall risk as a result of multifactorial physical therapy intervention is needed. Although our research plan and data gathering were prospective, we relied on each participant's self-reported fall history over time. A similar method should be applied to a sample of people at risk for falls, with a daily telephone follow-up of fall history as the gold standard.

CONCLUSIONS

A community-based multifactorial intervention including individualized fall risk assessment, exercise, and home assessment appears to safely and effectively reduce the number of falls, resulting in significant improvements in functional balance ability and decreased fall risk. The decreased fall risk and improved functional balance ability may have resulted in significant improvements in the number of falls, improved stance ability during sensory challenges on the SOT, improved ability to adapt to surface perturbations as reflected on the components of the Adaptation Test, and improved scores on the Berg Balance Scale while at the same time declining in subjects without intervention. A multifactorial intervention may provide clinicians with a viable option for improving functional balance control that will help their patients remain independent, active, and healthy.

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