The effects of short term balance training on the postural control of older adults

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Received 27 August 1996; received in revised form 21 February 1997; accepted 14 March 1997

Abstract

The purpose of this study was to determine and contrast the effect of five weeks of balance training on the postural stability of elderly adults with a history of falls (F) and those who have not previously fallen (NF). Twelve F subjects, 12 NF subjects, and 14 control subjects participated. Balance training consisted of exercises designed to stress balance and coordination performed three times per week for five weeks. Postural stability was evaluated with an ADL test resembling activities of daily living and force-platform-based postural sway measurements. In general F and NF reflected similar improvements in postural stability following training. F and NF demonstrated small improvements (5–10%) on the ADL tests with respect to the control group. The postural sway measures provided only moderate support for the effectiveness of training, with the control subjects exhibiting improvements similar to those of the training groups (approximately 15–30%). Overall the data provide moderate support for the effectiveness of short term balance training for functionally independent elderly adults. © 1997 Elsevier Science B.V.

Keywords: Age; Aging; Stability; Rehabilitation; Falls

1. Introduction

One of the most significant complications associated with aging is falling, which leads to a multitude of problems such as fractures, decreased mobility, debilitating fears of future falls, and even death. One third of those over the age of 75 fall yearly [1,2]. It is reasonable to speculate that if the elderly improved postural control, the risk of falling may be reduced. Effective balance training studies have employed the principal of overload to elicit improvements in stability [3–9]. In these studies, sensory organization was stressed by selectively inhibiting either vision, vestibular function, or proprioception. Blocking inputs from one system at a time placed increased demands on the other systems and forced subjects to rely more heavily on them. In addition, some of the studies used biofeedback training in which subjects learned to displace a cursor representing their center of pressure position to various targets on a monitor. Results indicate that balance training ranging in duration from five to 48 total contact hours spread out from one to 16 weeks can improve balance performance. Training subjects, both young and old, improved significantly on various descriptors of stability such as time standing on one foot [4,6,8,9], measures of postural sway [3,6,7], the ability to use visual feedback of center of pressure location to control stability [7], and the number of losses of balance occurring during sensory organization tests [4].

The FICSIT trials [8,9] have provided evidence from two experiments that long term training (approximately three months) improves the balancing abilities of older adults. In addition, they demonstrated that improvements decayed little over a long term retention period. The benefits and persistence of short term training (two to five weeks), however, are not as clearly defined, despite the fact that most of the research has focused on short-term responses. It is especially important to

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4. Conclusions

In summary, it is concluded that:
1. the effects of short term balance training are modest for functionally independent elderly adults,
2. F subjects do not improve substantially more than NF subjects when exposed to the same volume of training, and
3. when significant improvements due to training are obtained, performance does not immediately decline towards pre-training levels upon the removal of training.

Elderly adults with a history of falls show greater loss of improvements over a short term retention period than those without a history of falls.

Acknowledgements

This project was funded by the Graduate Research Development Program and the Office of the Vice President for Research at Arizona State University. The author thanks Scottsdale Senior Center and Brighton Gardens by Marriott for providing space for the training and testing and for assistance with subject recruitment. Drs G.E. Steinach and R.N. Hinrichs provided perceptive comments and suggestions.

References

3.2. Group differences

Both the F and the NF groups demonstrated comparable improvements with respect to the control group on the ADL tests and backward leaning distance. Only the NF group, however, demonstrated improvements in sway area during the forward leaning trials. This suggests that, in some aspects of balance, those with a history of falls may not benefit from training to the same extent as those without a history of falls.

Perhaps the most consistent observation in the present study was the poorer postural stability responses of subjects who had a history of falls in comparison with those who did not. This provides support for the faller classification scheme applied in this study and supports an association between quasi-static postural sway characteristics and the incidence of falls. Topp and colleagues [29] found that medial-lateral postural sway (with the eyes closed) was the best predictor of falling in a one year follow-up period. This study, however, provides evidence that both medial-lateral and anterior-posterior sway descriptors can be used to identify those with a previous history of falls, who may be more likely to experience future falls than their non falling counterparts.

The baseline group difference in postural sway between the F and the NF groups in this study is similar to other studies demonstrating that those with a history of falls have poorer motor skills than their age-matched peers [14,30–32]. Across the various tests performed in the current study, it appears that the F group had approximately 25% poorer sway scores at the pre-test occasion than the NF and control groups. They were also slower in leaning and did not lean as far as their non falling counterparts, and were less stable when maintaining a leaning position. This may be due to a lack of confidence in balancing abilities when the center of mass is displaced towards the edge of the base of support. These results may also be due to muscular weakness or inflexibility surrounding the ankle joint. Indeed, Whipple and colleagues [33] have demonstrated that fallers have up to 7.5 times less capacity to generate ankle torque than non fallers. However, Schultz [34] has pointed out that, despite significant declines in strength that occur with advancing age, the majority of elderly adults have more than adequate strength to maintain balance and to rise out of a chair. An alternative explanation for higher sway scores is the higher sensory threshold for the elderly, causing them to require larger CP displacements in order to detect movements [35,36].

3.3. Retention of training effects

ADL test performance declined across the five week retention period for both the F and the NF group. This is in contrast to the results of the FICSIT trials [8,9] in which little decline in postural stability was seen over a six-month retention period. Thus it may be that long-term training is required not only for substantial improvements in postural control but also for persistence of training effects upon the completion of training. In our project, in contrast to the NF group, the F group demonstrated significant declines in performance over the retention period on several measures, including two foot stance resultant migration and sway area and backward leaning velocity. These results suggest that elderly with a history of falls not only have impaired balancing abilities but that they also may be impaired in the acquisition of long-lived improvements in balance. Thus, rehabilitation programs may need to be specially tailored to this population.

3.4. Postural assessments

One possible explanation for the lack of support for the hypotheses is that the tests were insufficiently sensitive to changes in balancing abilities that resulted from training. This is not likely, however, as both ADL and laboratory tests were able to effectively discriminate between the F and the NF groups, providing support for the faller classification scheme. Although the \( \omega^2 \) value of 0.16 suggests a large training effect on the ADL tests, the training groups only improved on average by three out of 70 points. This may be related to the fact that all three groups performed at the high end of the scale from the outset; the poorest performance on the ADL tests was reflected by the F group who scored an average of 57 out of 70 possible points during the pretest. In other words, subject selection criteria may have been sufficiently strict to eliminate more frail and less functionally independent individuals who would have been challenged more substantially by the ADL tests. The high performance variability on the laboratory tests may also have contributed to the lack of significant training effects obtained. This is unlikely, however, as the relative treatment magnitudes were quite small on many of the measures (\( \omega^2 < 0.02 \)).

It is unclear why the training subjects did not show improvements over the control group on all of the laboratory tests while they did on the ADL tests. It may be that the ADL tests better reflect balancing abilities during typical movement situations. Performance on the laboratory tests, however, has been shown to predict approximately 65% of future falls [29] and therefore should be reflective of balance performance. Recent work by Thapa and colleagues [37] demonstrates separate correlations between age-related musculoskeletal declines and clinical and laboratory tests of balance, but not between the clinical and laboratory tests themselves. This implies that the two types of tests reflect different aspects of balance performance that may be differentially affected by training.
group responses across test occasions were similar to those of the F and NF groups despite not having participated in balance training sessions. The lack of a control group in the study by Woollacott and colleagues [4] may have contributed to an overly optimistic interpretation of the benefits of balance training. Indeed, 50% of their subjects demonstrated improved performance during the retention testing period, even though training had already been withdrawn. In addition, while the 15–20% improvement in postural stability observed by Woollacott and colleagues [4] was similar to that observed in the present study, it is important to remember that our control group exhibited a consistent testing effect on the postural sway measures. In other words, the control group improved postural stability from the first test to the second test by an amount similar to that seen in the NF training group and in some instances the F training group, suggesting the presence of a learning effect. Large improvements were also displayed by control group subjects in research by Hu and Woollacott [12,13]. It was not expected that subjects would need substantial accommodation to the balance tasks prior to data collection, especially for the two-foot stance trials. However, it may be that the subjects had some anxiety due to the novel situation. Research by Hunter and Kearney [26] has shown that increased heart and respiration rates affect postural sway as reflected by heightened center of pressure migration. Efforts were made to put the subjects at ease by having them perform the easier ADL test portion of the balance assessment first and by providing a brief explanation of the force plate and the method by which balance scores would be computed. In addition, the test protocol was demonstrated for each subject, and they were allowed to practice before recordings were made. In spite of these precautions, it appears that a more substantial accommodation effort was needed. Future studies should allow for such accommodation efforts to ensure that performance levels are stable prior to data collection and the initiation of training.

An additional consideration related to the absence of a substantial balance training effect may be related to the intensity and/or the frequency of training. Perhaps intensity and frequency of training were not sufficiently high to elicit significant improvements in the training groups. The volume of training performed (15, one-hour sessions over a five week period) was similar in scope to that used in other balance training studies with elderly subjects [4–6]. When balance training is performed for vestibular rehabilitation, patients often train twice a day for about 30 min each session [27,28]. After six weeks, these patients reflected substantial improvements in dizziness ratings, could stand on one foot 20% longer than prior to training, and exhibited 20–30% better performance on the more difficult sensory organization tests. Presumably these patients relearn sensory integration and compensation as a result of performing movements that stress balance and tax the sensory systems. Teasdale and colleagues [29] have demonstrated that older adults are impaired in visual sensory integration, thus it may be that this high frequency of training is required to elicit substantial short term balance improvements for the elderly as well.

The FICSIT studies [8,9] have demonstrated clear benefits of long term balance training. It appears, however, that a substantial training period is required to produce significant benefits. Future studies should continue to investigate the effectiveness of various types of strength and balance training routines applied at different intensities in order to further uncover the issue of whether or not those with a history of falls are presenting a limitation in capacity or if they can be rehabilitated to performance levels of their age-matched peers.
3. Discussion

3.1. Training effects

In general, the results from this investigation provided mixed support for our hypotheses. Significant training effects, as evidenced by a significant contrast between the two training groups and the control group at the first post test occasion, were observed only for the ADL tests and for the laboratory test dependent variable of backward leaning distance. The effect size for the ADL tests was large, while that for backward leaning distance was small. It is unclear why the training subjects did not show improvements over the control group on all of the measures when prior balance training investigations have supported the effectiveness of training leading to improvements in stability [3–9]. Despite the small number of training effects obtained in the current investigation, improvements seen in the two training groups were similar in magnitude to those obtained in previous studies. One of the sensory organization conditions examined in previous studies was essentially postural sway measured during two-foot stance, which was incorporated into the present study. Ledin and colleagues [6] and Lichtenstein and colleagues [5] found no significant reduction in sway due to training under this condition, although values decreased by approximately 15–30%. Woollacott’s [4] F and NF groups reduced RMS of sway by approximately 15 and 20%, respectively, during two-foot stance. Similarly, both the F and NF groups in the current study reduced sway approximately 15–30% under two-foot as well as one-foot stance conditions.

The two training groups in this investigation increased backward leaning distance by about 5% of foot length, which is a 38% increase over the pre test value for the F group. King and colleagues [17] have reported that functional base of support, analogous to total leaning distance in the current investigation, decreases by 16% with each decade beyond the age of 60 years. Extrapolating from these results, it appears that five weeks of balance training can increase the functional base of support for those with a previous history of falls to a size comparable to that of individuals substantially younger, perhaps as much as two decades younger.

Despite the fact that improvements obtained in the current investigation are similar in magnitude to previous studies, very few statistically significant training effects were obtained. This reflects that the control...
Both F and NF groups showed improved backward leaning distance immediately following training relative to the control group (Fig. 6, $F_{1,34} = 3.07, P = 0.09$). The $\omega^2$ value of 0.04 reflects a small effect size. There were no training effects for forward leaning distance or total leaning distance; there were no changes in leaning distance during the retention period.

None of the groups significantly increased average leaning velocity as a function of training (Fig. 7). One notable anomaly is the fact that the F group presented a positive (forward) average backward leaning velocity at the pretest occasion. This reflects the difficulty that a few of the F subjects had in performing this task. When instructed to lean backward, they rocked in such a manner that their average post-lean position was anterior to their pre-lean position. There were no changes in forward leaning velocity during the retention period; backward leaning velocity for the F group deteriorated in a linear fashion ($F_{1,37} = 4.33, P = 0.05$), indicating that they were leaning backwards more slowly over the retention period.
response between the control group and the two training groups (i.e., all three groups showed similar improvements). This suggests that the improvements were not attributable to the training per se. There were no statistically significant effects describing retention performance, indicating that one foot sway performance did not return toward pre training levels.

Results for resultant migration speed during leaning (Fig. 5) did not support the existence of a beneficial training effect. Sway area decreased during forward leaning following training ($F_{1,34} = 2.73, \ p = 0.08$), but follow up contrasts revealed that the control group responses were similar to those of the two training groups combined. When the F and NF groups were contrasted, the NF group reflected greater improvement in sway area than the F group ($F_{1,34} = 4.89, \ p = 0.03$ for forward leaning). The $\omega^2$ value of 0.07 indicates a medium effect size. There were no significant retention effects for these leaning descriptors, indicating that there were no changes in stability during leaning over the retention period.

Fig. 3. Two-foot stance CP descriptors. Balance training did not produce improvements in postural sway characteristics during two foot stance when comparing pre and post training performance. During the retention period, the F group increased resultant migration speed and sway area while the NF and control groups showed no change (* significant group by time interaction for sway area) ($F_{1,34} = 1.13, \ p > 0.10$). There was a significant group main effect for the ANCOVA on the resultant migration speed retention tests ($F_{1,34} = 9.20, \ p = 0.001$) and a trend for a group by time interaction ($F_{1,34} = 2.14, \ p = 0.09$). Follow up contrasts revealed that the F group showed an increase in the speed of swaying across the retention period (significant linear trend, $F_{1,31} = 5.99, \ p = 0.02$) while the NF and control groups did not change. A similar group by time interaction was obtained for the two foot stance sway area retention scores ($F_{1,30} = 4.37, \ p = 0.03$). In other words, the F group increased sway area across the retention period ($F_{1,31} = 15.14, \ p < 0.001$) whereas NF and control groups showed no change in sway area.

Results for the one foot stance test (Fig. 4) also did not support our hypothesis that training would decrease postural sway. While the resultant CP migration speed decreased significantly from pre to post training ($F_{1,31} = 4.33, \ p = 0.04$), there was no difference in this

Fig. 4. One-foot stance CP descriptors. All three groups showed a significant decrease in resultant migration speed from the pretest to the initial posttest (* significant time effect). There were no significant effects for the retention period or for sway area.
2.6. ADL Tests

Results of the ADL tests were consistent with the hypothesis that balance training improves postural stability. There was a group main effect at the initial post test following adjustment for pre test scores, indicating a treatment effect ($F_{2,24} = 5.32$, $P = 0.01$). Follow up tests revealed that the F and NF groups differed from the control group ($F_{1,13} = 10.52$, $P = 0.003$), improving ADL test performance significantly (approximately 5–10%) from the pre- to the initial post-test while the control group exhibited no change (Fig. 2). The $\omega^2$ value of 0.16 represents a large treatment effect. There was no difference in the training effect between the F and NF groups ($F_{1,13} < 1$, $P > 0.10$). There was a trend for a time effect across the post-test occasions ($F_{2,13} = 2.67$, $P = 0.08$). Follow up contrasts revealed that the control group did not change ADL test performance during the post-training retention period, whereas both F and NF groups showed a linear decline in performance during this period (F group: $F_{1,13} = 3.76$, $P = 0.06$, NF group: $F_{1,13} = 2.80$, $P = 0.07$).

2.7. Laboratory tests

In general, the laboratory tests provided only limited support for the effectiveness of balance training (Figs. 3–7). Although the balance performance of F and NF groups improved between pre and post testing, control group performance reflected a similar trend suggesting the presence of a testing accommodation effect rather than a true training effect. As expected, the F group consistently displayed poorer performance than the NF and control groups. In addition, stability performance for the F group tended to deteriorate upon the removal of training.

After adjustment for pre test differences, scores on the initial post tests for the two foot stance descriptors (Fig. 3) did not support a beneficial training effect.
Table 3
Balance training exercises

<table>
<thead>
<tr>
<th>Exercise</th>
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<tbody>
<tr>
<td>1. One leg standing: Stand on one leg with the other placed mid way up the calf. Hold for 30 s, if possible. Repeat three times on each leg, once through with eyes open and again with eyes closed. Repeat on foam cushion, if able.</td>
</tr>
<tr>
<td>2. Neck hyper extension: Stand while slowly hyper extending the neck and then tipping it down forward. Repeat five times with eyes open, five times with eyes closed. Repeat on foam cushion, if able.</td>
</tr>
<tr>
<td>3. Fre leg swinging: Stand on one leg while moving the other slowly forward, side and back. Switch legs and repeat three times, then again with eyes closed. Subjects may slide over the floor at first, later in the class progress to lifting the leg completely off the floor.</td>
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<tr>
<td>4. Head and toe raises: Rock slowly up onto toes and hold, back onto heels and hold. Repeat three times with eyes open, 3 with eyes closed.</td>
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<tr>
<td>5. Point fixation: 'glue' eyes to a point on the wall at eye level while slowly twisting the neck side to side, nodding the head, bending side to side and twisting at the waist. Perform 3 times standing on foam cushion.</td>
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<tr>
<td>6. Moving objects: Reach up high, extending head back as if to remove something from a high shelf. Bend down as if placing object on the floor. Repeat twice on the floor, twice on the foam cushion.</td>
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<tr>
<td>7. Walking in place: Step in place on the foam cushion, progress to nodding the head at the same time, then close the eyes as well. Perform four times, approximately 1 min each.</td>
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<tr>
<td>8. Sideways walking: Walk sideways, bringing trail foot just up to the lead one.</td>
</tr>
<tr>
<td>10. Backward walking: Walk backward along a line, do not look at the ground.</td>
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</table>

Before further analysis, data were plotted and inspected. For one-foot trials in which a subject lost his or her balance or moved a foot, only the portion of the trial before the loss of balance occurred was analyzed. If balance during one-foot trials was not maintained for at least 3 s, the trial was repeated.

Average resultant speed of CP migration (RMIG) was calculated from medial-lateral (ml) and anterior-posterior (ap) CP position data by dividing the total distance the CP traveled by the time over which CP motion was assessed:

\[
RMIG = \frac{\sum (CP_{ml_t} - CP_{ml_t-1})^2 + (CP_{ap_t} - CP_{ap_{t-1}})^2)^{1/2}}{t}
\]

where \(i\) and \(i-1\) represent adjacent instants of sampling and \(t\) represents total time over which CP motion was quantified. Sway ranges were computed in the medial-lateral and anterior-posterior directions, and then multiplied together to obtain an estimate of sway area [19–23].

For the forward and backward leaning trials, the anterior-posterior difference between the average position before leaning was initiated and the average CP position of the new position being maintained during leaning was calculated. Total leaning distance was determined by computing the sum of the average forward leaning distance and the average backward leaning distance, expressed as a percentage of foot length.

Average leaning velocities in the anterior and posterior directions were also calculated. Average CP migration speed and sway area were determined for the portion of the trial when the lean was being maintained. Fig. 1 provides a sample anterior-posterior record for a forward leaning trial.

As the groups differed in pre test scores, an ANCOVA was performed with the pre test score as the covariate. This analysis was first performed on the initial post test data, and secondly using the three post tests to examine the retention issue. All data were collapsed across gender since results did not differ for males and females in the two training groups. The alpha level was set at 0.05.

Keppel’s equation for analysis of covariance designs was used to compute \(\omega^2\), an estimate of the total population variance that is explained by the variation due to the treatment [24]. Its value does not depend on sample size or power of the experiment. Cohen [25] suggests that a small effect is comparable to an \(\omega^2\) of 0.01, a medium effect is 0.06, and a large effect is 0.15 or greater. These standards were employed in our assessment of treatment effect sizes.

2.5. Results

The pattern of results did not differ between the medial-lateral and anterior-posterior sway range descriptors, thus only the combined measure of sway area is reported. In order to demonstrate support for the effectiveness of balance training, there needed to be a group difference at the initial post test, after adjustment for the covariate. Follow-up contrasts were used to determine whether the two training groups differed from the control group, and whether training responses differed between the F and NF groups. A lack of retention following the completion of training would be supported by a significant decreasing linear or quadratic trend over the three post test occasions. The reader is reminded that test occasion one reflected pre-training status, test occasion two was immediately post-training, and occasions three and four were three and five weeks post-training, respectively.
training, when a substantial number of screened individuals decided not to commit to the project. Subjects who dropped out after the program had begun cited reasons such as needing to care for a spouse, extended vacation, or difficulty with transportation. Eight subjects in the F group, eight in the NF group, and 13 in the C group already participated in some form of regular exercise. Baseline health impairments in the F group included one subject who had a history of stroke, one who had had a heart attack, two with mild arthritis, one with asthma, and one with a pacemaker. Two NF subjects had arthritis and one had asthma. The C subjects included three with arthritis, three with asthma, and two with medically controlled high blood pressure.

Subjects were classified as 'fallers' if they had experienced two or more falls within the past five years. Eight of the 12 fallers had experienced three to five falls, while the remaining four had experienced seven or more falls during the past five years. Each of these four walked with a cane to aid balance but were ambulatory without it and did not use it during training or testing. All subjects provided written informed consent in accordance with human subjects policies.

2.2. Stability assessments

Postural stability assessments of training subjects were performed during a single test session in the week prior to the beginning of training, and again one, three, and five weeks after the five-week training program was completed. Control subjects were evaluated on the same time schedule. A single evaluator tested all subjects in order to ensure consistency.

Two types of stability assessments were performed:

1. Functional balance tests representing a portion of the Tinetti [15] gait and balance tests (Table 2) designed to evaluate abilities to perform activities of daily living (ADL) tests, and

2. Laboratory tests measuring center of pressure (CP) migration using a force platform.

The ADL tests had the advantage of being similar to daily activities, but the rating scale used a 3-level Likert scale that tends to be somewhat subjective and provided limited sensitivity. The laboratory tests were similar to those used in numerous other postural control research efforts which allowed for comparison of results to previous studies. Subjects completed force platform tests while barefoot. To allow foot position to be replicated from trial to trial, subjects were aligned with reference lines on the force platform with their feet together. Subjects stood with the head upright, gazing straight ahead at a wall. Force platform output was sampled at 100 Hz for 10 s per trial. Five trials each of quasi-static one-foot and two-foot stance were recorded. In addition, a leaning task similar to that used by Schieppati and colleagues [16] and King and colleagues [17] was used to provide a greater challenge to postural control. Upon initiation of force platform sampling for the leaning trials, subjects stood for \( \approx 2 \) s before being signaled to lean backward or forward (separate trials for each) as far and as rapidly as possible, pivoting about the ankle joint only, while maintaining balance and without taking a step. Subjects were required to maintain the leaning position for the remainder of the trial (\( \approx 5-6 \) s). The initial 2 s period was used as an indicator of baseline center of pressure position prior to backward or forward leaning. Five trials were performed for each leaning direction.

2.3. Training classes

The training and testing were performed on three separate cohorts in order to minimize the number of subjects participating at any one time. F and NF subjects participated in classes together. A single trainer worked with all training subjects in classes of 12 or smaller. Each training group met for 1 h classes held three days per week for five weeks. Subjects served as each others' spotters during training; thus, each participant practiced the balance exercises for approximately 30 min per class. The exercises (Table 3) were a compilation from previously successful balance training studies [3-7]. The majority of the exercises used were continuous rather than discrete tasks; therefore the magnitude of training was measured as contact time rather than as the number of trials performed. The minimum compliance was 14 out of 15 sessions, with the majority of the subjects attending 15 sessions, resulting in approximately 7.5 training hours per subject. The control subjects were instructed to continue their normal pattern of activity and not to begin any new physical activity programs during the course of the study.

2.4. Data analysis

Data from the force platform were filtered by a low pass Butterworth fourth order digital filter with a cut-off frequency of 4 Hz. The cut-off frequency was chosen based on residual and frequency analyses of the data [18]. Anterior-posterior and medial-lateral coordinates of the CP position, which is a reflection of the projected center of gravity position and plantar pressure fluctuations related to activity of the muscles surrounding the ankle joint, were then calculated with respect to the force platform origin at each sampled instant in time. The origin of the force plate coordinate system was translated along the anterior-posterior axis such that it was aligned with the most posterior position of the heels. This allowed CP position to be expressed relative to the anterior and posterior boundaries of the foot.
Table 1

Subject group characteristics: means and standard deviations

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Height (cm)</th>
<th>Body mass (kg)</th>
<th>Gender (males/females)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fallers</td>
<td>76.4 (7.1)</td>
<td>166.3 (8.9)</td>
<td>64.9 (12.1)</td>
<td>5:7</td>
</tr>
<tr>
<td>Non Fallers</td>
<td>73.9 (6.5)</td>
<td>160.3 (7.0)</td>
<td>72.0 (15.0)</td>
<td>5:7</td>
</tr>
<tr>
<td>Controls</td>
<td>74.3 (4.7)</td>
<td>138.2 (6.2)</td>
<td>62.6 (12.2)</td>
<td>1:13</td>
</tr>
</tbody>
</table>

determine the effectiveness of short-term training for those with a history of falls, as Williams and Lord [10] have demonstrated that exercise adherence is relatively poor for elderly adults with impaired motor skills. In addition, attitudes towards exercise programs are negative for many elderly adults [11], which could substantially impact compliance with any physical activity program. It also remains unclear whether elderly adults with a history of falls respond to training in the same manner as their non-falling counterparts.

Research by Woollacott and colleagues [4] represents the only effort to examine the training response of elderly subjects who had a previous history of falls. These subjects reduced the number of losses of balance occurring during sensory organization tests from an average of 3.1 per subject to 3.1 per subject following eight weeks of training. The subjects continued to improve, however, from the one-week posttest to the three-week posttest (3.1 to 1.3 losses of balance per subject), suggesting that balance improvements may have been partially attributable to a learning effect from the tests themselves, rather than a training-related response. Unfortunately, Woollacott et al. [4] did not use a control group to differentiate improvements caused by training and learning or accommodation effects. As a result, the potential benefits of balance training are not well-defined, particularly for those with a history of falls. In addition, Woollacott and colleagues did not expose fallers and non-fallers to equal training hours, confounding comparisons between the groups. It is important to know if the two groups respond differently to training, because this information is essential for the design and planning of balance training classes. Follow-up work by Hu and Woollacott [12,13] provided non-falling elderly adults with 10 h of sensory organization training. Although the training group improved from the pre-test to the post-test, their performance continued to improve during the retention phase after training had been withdrawn. In addition, the control subjects improved their performance markedly during tests corresponding to the retention phase of the training group. This implies that improvements may have actually been due to practice of the difficult sensory organization tests rather than to the short-term training.

The purpose of this study was to test the hypotheses that:

1. Five weeks of balance training causes improvements in the postural stability of elderly adults,
2. Improvements in postural stability due to balance training are greater for those with a history of falls than those who have not fallen,
3. Removal of balance training causes postural stability to decline toward pre-training states for both fallers and non-fallers.

2. Methods

2.1. Subjects

A total of 74 individuals were recruited from the Phoenix metropolitan area as potential subjects through the use of advertisement in a senior newspaper and brief presentations at area senior centers. All were living independently. All were administered a questionnaire about health status and history of falls. Individuals who reported any neurological disease, vestibular disorder, extreme high or low blood pressure, or recent heart infarction were excluded as these conditions placed them at high risk of falling during the training and confounded their balance scores. However, because completely healthy subjects may not be representative of "normal" elderly [14], people who reported mild dementia or arthritis were not excluded. In addition, one subject who had a mild stroke a number of years ago with no present symptoms was included. As a result of the questionnaire, two individuals with Parkinson's disease and two with diabetic peripheral neuropathy were excluded. The remaining 70 were classified into three groups: control subjects (C, initially one with a history of falls, 20 without a history of falls), training subjects with a history of falls (F, initial n = 22), and training subjects without a history of falls (NF, initial n = 27). Every effort was made to randomize assignment to each of the groups. Some individuals, however, requested assignment to the control group due to time constraints and others requested assignment to the training group, causing assignment to be partially non-randomized. Subject dropout rate was 45% for the F training group, 56% for the NF training group, and 33% for the control group so that final sample sizes were 12 F, 12 NF, and 14 C (all NF) (Table 1). The majority of dropouts occurred prior to the initiation of


