The Dose-Response Relationship of Balance Training in Physically Active Older Adults

Kristen K. Maughan, Kristin A. Lowry, Warren D. Franke, and Ann L. Smiley-Oyen

A 6-wk group balance-training program was conducted with physically active older adults (based on American College of Sports Medicine requirements) to investigate the effect of dose-related static and dynamic balance-specific training. All participants, age 60–87 yr, continued their regular exercise program while adding balance training in 1 of 3 doses: three 20-min sessions/wk (n = 20), one 20-min session/wk (n = 21), or no balance training (n = 19). Static balance (single-leg-stance, tandem), dynamic balance (alternate stepping, limits of stability), and balance confidence (ABC) were assessed pre- and posttraining. Significant interactions were observed for time in single-leg stance, excursion in limits of stability, and balance confidence, with the greatest increase observed in the group that completed 3 training sessions/wk. The results demonstrate a dose-response relationship indicating that those who are already physically active can improve balance performance with the addition of balance-specific training.

Keywords: elderly, exercise prescription, one-leg standing, limits of stability

In 2007, the American College of Sports Medicine (ACSM) and the American Heart Association (AHA) issued a statement on physical activity and public health in older adults (Nelson et al., 2007). Along with specific recommendations for older adults to engage in regular aerobic activity and strength training, balance training was recommended for community-dwelling older adults at substantial risk of falls.

One question that emerges from these guidelines is whether balance training is beneficial for older adults who are already participating in a regular program of physical activity and are not at substantial risk for falls. Considerable evidence suggests that regular physical activity in older adults has a positive impact on balance, mobility, and the reduction of falls (Barnett, Smith, Lord, Williams, & Baumand, 2003; Bird, Hill, Ball, & Williams, 2009; Federici, Bellagamba, & Rocchi, 2005; Gillespie et al., 2009; Lord et al., 2003; Perrin, Gauchard, Perrot, & Jeandel, 1999; Province et al., 1995). Specific types of physical activity may further enhance bal-
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These include proprioceptive activities such as Tai Chi and yoga (Cromwell, Meyers, Meyers, & Newton, 2007; Federici et al., 2005; Gatts & Woollacott, 2006; Gauchard, Gangloff, Jeandel, & Perrin, 2003; Gauchard, Jeandel, Tessier, & Perrin, 1999; Gillespie et al., 2009; Li et al., 2005; Province et al., 1995; Schmid, Van Puymbroeck, & Koceja, 2010; Wolf et al., 1996) and balance-specific programs that include such activities as standing on one leg, standing with eyes closed, and standing or moving on unstable surfaces (Islam et al., 2004; Province et al., 1995; Sakamoto et al., 2006; Toulouette, Thevenon, & Fabre, 2006).

Clinical balance trials in adults have been conducted over a wide range of physical-performance capacities from frail, institutionalized adults (Sakamoto et al., 2006) to independent, community-dwelling adults (Cromwell et al., 2007; Fu, Choy, & Nitz, 2009; Islam et al., 2004; Li et al., 2005; Robitaille et al., 2005; Toulouette et al., 2006). Although independent, community-dwelling adults are one subgroup of the older adult population, there is a wide range of physical activity levels in this group. This is reflected by the variability of pretrial physical activity levels among subjects in different studies, from sedentary (Li et al., 2005), to variable (Robitaille et al., 2005; Toulouette et al., 2006), to unknown or at least not reported (Cromwell et al., 2007; Islam et al., 2004). Therefore, it is unclear whether older adults who are already meeting current ACSM/AHA physical activity guidelines would derive additional benefits from balance training.

A second question arising from the ACSM/AHA guidelines relates to exercise prescription and addresses how often and how much balance training is needed to observe a change in balance. The guidelines suggest frequency and duration for both cardiovascular and resistance training, but there are no guidelines for either the frequency or the duration of balance training. Previous investigations have used varying frequency and duration of training, with extremes being 6 min of one-leg standing per day for high-risk older adults (Sakamoto et al., 2006) to 90 min/day, 5 days/week (Gatts & Woollacott, 2006), both resulting in positive outcomes, but none have compared varying doses in the same study.

In light of these questions, the purpose of this study was to examine improvement in static and dynamic balance in physically active older adults given dose-related practice. We hypothesized that physically active older adults would improve in balance after a 6-week balance-training program and there would be a dose-response relationship between the frequency of balance training and the level of improvement in balance control.

Methods

Overall Design

This was a quasi-randomized control intervention, with the intervention being 6 weeks of group balance training that progressively increased in difficulty. There were three groups: one that received 20 min of balance training three times per week, one that received 20 min of balance training one time per week (same training, just less frequently), and a control group that did not receive any balance training. All participants were physically active and continued their regular physical activity regimen throughout the study.
Participants

Healthy, physically active, community-dwelling adults were recruited from two local exercise facilities. To qualify for inclusion in the study, volunteers had to be 60 years of age or older and be physically active based on self-report, that is, participating in aerobic physical activity 3 days/week for at least 30 min and strength-training exercises at least 2 days/week (based on ACSM exercise guidelines). Exclusion criteria included known neurological problems, unstable cardiopulmonary conditions, uncontrolled high or low blood pressure, use of lower limb orthotics or walking aids, significant problems with joints or muscles that affected mobility, or recent (within 6 months) lower body bone fracture or total knee or hip replacement.

Sixty-three people volunteered to participate in the study. Of those, 2 did not meet the inclusion criteria; therefore, 61 people completed preintervention balance testing. They were grouped by age (60–69, 70–79, and 80–89) and then randomly numbered by 3s so that we had similar age variation between groups. Husbands and wives were assigned as one so that they could participate as a couple. After initial randomization, some adjustment was made so that groups were not statistically different in baseline values. One-way ANOVAs were conducted to determine if there were group differences \( p < .05 \) in age, body-mass index, and pretest scores on left-leg single-leg-stance and alternate stepping (see Table 1 for means and standard deviations). One person in the 3-day intervention group discontinued participation in the study during Week 2 for health reasons.

Twelve or thirteen participants in each of the three groups reported having been physically active for 5 or more years. One participant in the control group and 2 in the 3-day intervention group had been active for only 2 years. Two participants in the 1-day intervention group had been active for 6 months, 1 for 1 year, and 3 for 2 years. Most of our participants had not experienced falls in the previous year. The following are those who did: In the 3-day group 6 reported one fall, 2 reported two falls, and 1 reported four falls; in the 1-day group 5 reported one fall; in the control group 2 reported one fall, 1 reported two falls, and 1 reported four falls. The participants were interviewed during the posttest session to determine if their exercise activity had changed since pretest. One person in the control group reported adding yoga to the exercise protocol; some participants reported increased physical activity, and some decreased, but there was no systematic pattern across groups, and all participants continued to meet the ACSM minimum physical activity inclusion criteria.

Table 1 Baseline Characteristics for Each Group

<table>
<thead>
<tr>
<th></th>
<th>Control, ( n = 19 )</th>
<th>1-day, ( n = 21 )</th>
<th>3-day, ( n = 20 )</th>
<th>( p^{a} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years, ( M ) (SD)</td>
<td>71.7 (7.7)</td>
<td>72.3 (7.7)</td>
<td>74.4 (6.8)</td>
<td>.51</td>
</tr>
<tr>
<td>Men, ( n ) (%)</td>
<td>7 (37%)</td>
<td>8 (38%)</td>
<td>9 (45%)</td>
<td></td>
</tr>
<tr>
<td>Women, ( n )</td>
<td>12</td>
<td>13</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Body-mass index, ( M ) ( (SD) )</td>
<td>25.9 (3.9)</td>
<td>27.2 (3.9)</td>
<td>25.5 (2.7)</td>
<td>.31</td>
</tr>
<tr>
<td>Single-leg stance, s, ( M ) ( (SD) )</td>
<td>24.9 (18)</td>
<td>20.9 (15)</td>
<td>19.5 (14)</td>
<td>.55</td>
</tr>
<tr>
<td>Alternate stepping, s, ( M ) ( (SD) )</td>
<td>7.4 (1.1)</td>
<td>7.9 (1.8)</td>
<td>8.2 (1.6)</td>
<td>.42</td>
</tr>
</tbody>
</table>

\( p \) values refer to the one-way ANOVAs conducted to examine pretest differences between groups.
All procedures were reviewed and approved by the institutional review board of the university. All participants signed an informed consent and completed a medical-history form before the start of the study.

**Intervention**

We developed a progressive balance-training program using components of evidence-based protocols including the Fall Proof program developed by Rose (2003) and the Tai Chi for Arthritis program developed by Lam (2004). Six sessions were developed for group participation focusing on static and dynamic balance and mobility in both single- and dual-task conditions (see Table 2). The same instructor led all balance-training sessions. During each week of training, a new, progressively more challenging 20-min session was presented. The 3-day intervention group (referred to as 3-day) repeated the same session 3 days/week for a total of 60 min/week. The 1-day intervention group (referred to as 1-day) participated in the same balance sessions but only attended once per week for a total of 20 min, and this one session was identical to the session in which the 3-day group engaged. Thus, the intervention groups experienced the same balance exercises, but in varying doses. The control group did not participate in any additional balance training.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Six-Week Balance-Training Program</th>
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<tbody>
<tr>
<td>Week</td>
<td>Activities included</td>
</tr>
<tr>
<td>1</td>
<td>Tai Chi for Arthritis (5 min); single-leg stance with eyes open/eyes closed/on foam; tandem stance, static and with weight shifting; narrow stance on foam with smooth pursuit eye movement/head movement; heel-to-toe walking; grapevine walking; narrow-stance ankle strategy (weight shifting)</td>
</tr>
<tr>
<td>2</td>
<td>Tai Chi for Arthritis (5 min); single-leg stance with eyes open/eyes closed/while moving towel with foot; tandem stance with head turns/on foam; ankle strategy (weight shifting) with eyes closed; multidirectional reaching on foam (hip strategy); walking with head turns/abrupt starts &amp; stops/altered pace</td>
</tr>
<tr>
<td>3</td>
<td>Tai Chi for Arthritis (5 min); single-leg stance with eyes open/head turns/while moving opposite leg/on foam; tandem stance with eyes closed/on foam with multidirectional reaching; tossing a beanbag on foam; step strategy forward/backward; backward walking on hard surface/foam</td>
</tr>
<tr>
<td>4</td>
<td>Tai Chi for Arthritis (5 min); single-leg stance with eyes focused forward as head turns/while tossing a bean bag to partner; ankle strategy (weight shifting) on hard surface/foam; tandem on foam with head turns; narrow stance on foam with eyes closed; standing, walking, heel-to-toe, side stepping, and hip strategy on 1/2 foam roller; walking and grapevine on heels/toes on hard surface and foam</td>
</tr>
<tr>
<td>5</td>
<td>Tai Chi for Arthritis (5 min); single-leg stance while reading/on foam while moving alternate leg/without shoes; tandem standing without shoes; heel-to-toe walking with head turns, direction changes, abrupt stops; ankle strategy (weight shifting) with eyes closed; alternate stepping; obstacle course including stepping up and over obstacles on both foam and hard surfaces and heel-to-toe walking on 1/2 foam roller</td>
</tr>
<tr>
<td>6</td>
<td>Tai Chi for Arthritis (5 min); single-leg stance with arms across chest/while moving a ball with opposite leg; walking forward/backward/grapevine/heels &amp; toes/varied speeds while holding an egg on a spoon; hip circles while standing on foam with eyes open/eyes closed; reaching with hands clasped on foam with eyes open/eyes closed; tandem standing on foam with eyes closed; obstacle course (same as Week 5) while holding a lunch tray</td>
</tr>
</tbody>
</table>
All participants were asked to continue their regular exercise routine and to not engage in additional balance-training practice outside of scheduled training sessions. Most participants completed the balance training immediately after their regular workout session. Control and 1-day participants were offered the full 6-week balance-training program at the conclusion of the study.

If participants were unable to attend one of the regularly scheduled sessions, make-up sessions were arranged so that program adherence was maintained. Adherence to the balance-training program was excellent (99.6%), with only 2 participants missing one session each.

**Dependent Measures**

Measurements were taken at two times: within 2 weeks before the start of the intervention and 2–9 days after the conclusion of the last balance-training session, with the average for both intervention groups being 5 days. Participants were asked to engage in balance training only during formal sessions and, accordingly, were asked to stop balance training after their last session. Five people conducted the pretest and posttest, 4 of whom were blind to group assignment. Static balance and dynamic balance were assessed, and balance confidence was measured with the Activities-specific Balance Confidence Scale (ABC; Powell & Myers, 1995).

**Static Balance**

Single-leg-stance was measured on both the right (SLS-R) and left (SLS-L) leg with eyes open. Participants were asked to focus the eyes forward, cross the arms over the chest, and lift one leg off the floor to about ankle level without touching the support leg. Data were recorded as the number of seconds they were able to stand on one foot without putting their other foot down, touching the support leg, or uncrossing the arms (up to a maximum of 45 s). Two trials were completed, and the better trial was included in the analysis.

Tandem balance was measured with participants self-selecting position of their feet (which foot was in front of the other) and with arms crossed over their chest. Time in balance (up to a maximum of 45 s) was recorded as soon as the participant reported being stable and the researcher removed her hand from helping the participant gain a stable position. Two trials were completed, and the better trial was included in the analysis. If the first trial was 45 s, a second trial was not conducted.

**Dynamic Balance**

Alternate stepping was administered as described by Berg, Wood-Dauphinee, Williams, and Gayton (1992). Participants stood unsupported and, moving as quickly and safely as possible, placed each foot alternately on an 8-in.-high step. Times were recorded as the number of seconds required to complete eight steps. Two trials were completed, and the better trial was included in the analysis.

Limits of stability (LOS) were measured using a force platform (AMTI model OR6–5, Advanced Mechanical Technology, Inc., Watertown, MA). Our LOS procedures were modified from the original eight-position protocol (Clark, Rose, & Fujimoto, 1997) in a manner similar to that used by Brauer, Burns, and Galley (2000).
and Melzer, Benjuya, and Kaplanski (2004). Participants stood in a narrow stance with shoes off, feet touching, and heels on a premarked line. Arms were crossed over the chest with eyes focused on a fixed point. Participants were asked to lean as far as they could in a specified direction, without bending at the waist, hips, or knees or losing their balance and while keeping both feet with heels and toes on the platform. On verbal command, participants were instructed to lean in the following order: forward, backward, left, and right. After leaning in the specified direction, they held the position for approximately 2 s and then, on command, returned their weight to the center and waited for instructions to lean in the next direction. One practice trial on the floor was allowed before trials on the force platform.

Variables measured included maximum excursion (cm) in both anteroposterior (AP) and mediolateral (ML) directions. Two 30-s trials of each condition were sampled at a frequency of 50 Hz. An average of the two trials was included in the analysis. One participant in 1-day was unable to complete the leaning task on pre-test; therefore, data for this participant were excluded from the LOS analysis. The force-platform data were processed using custom MATLAB software (MathWorks, Natick, MA) and were smoothed using a fourth-order low-pass Butterworth filter with a cutoff frequency of 8 Hz. Center-of-pressure data were then computed from the filtered data.

Statistical Analyses

Data for 60 participants age 60–87 were entered into the analyses. Hypotheses were tested using a Group (control, 1-day, 3-day) × Session (pre–post) repeated-measures ANOVA. A Bonferroni adjustment was applied to account for multiple variables, so significance level was set at .008. Partial eta-squares were also reported for interactions, with .01 indicating a small effect, .06 a medium effect, and .138 a large effect. Because we were primarily interested in within-group changes in response to the intervention, significant interactions were further tested using one-way ANOVAs to test for changes from pre- to posttest within each group.

Results

Pre- and posttest values (means and standard deviations) for dependent measures are listed in Table 3 along with p values for Group × Session interactions.

Static Balance

SLS-R and -L. There was no main effect for SLS-R for group, $F(2, 57) = 0.40, p = .673, \eta^2 = .014$, but there was a main effect for session, $F(1, 57) = 10.65, p = .002, \eta^2 = .157$, with participants balancing longer at posttest. There was no interaction, $F(2, 57) = 2.95, p = .06, \eta^2 = .094$, although the 3-day group exhibited the greatest increase (40%, 10%, and 8% for 3-day, 1-day, and control, respectively). Similarly, there was no main effect for SLS-L for group, $F(2, 57) = 0.23, p = .796, \eta^2 = .008$, but there was for session, $F(1, 57) = 18.97, p < .001, \eta^2 = .25$. The interaction was also significant, $F(2, 57) = 5.67, p = .006, \eta^2 = .166$, with 3-day exhibiting a 67% improvement, 1-day a 21% improvement, and control a 6% improvement. Follow-up ANOVAs within group indicated that only the 3-day group exhibited a
Table 3  Changes in Dependent Measures With Frequency of Balance Training, $M$ (SD)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control</th>
<th>1-Day</th>
<th>3-Day</th>
<th>$p^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pretest Posttest</td>
<td>Pretest Posttest</td>
<td>Pretest Posttest</td>
<td></td>
</tr>
<tr>
<td>Static</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>single-leg stance, left (s)</td>
<td>25 (18) 26 (15)</td>
<td>21 (15) 25 (18)</td>
<td>20 (14) 33 (16)*</td>
<td>.006†</td>
</tr>
<tr>
<td>single-leg stance, right (s)</td>
<td>27 (17) 29 (16)</td>
<td>25 (16) 27 (18)</td>
<td>25 (15) 35 (16)</td>
<td>.060</td>
</tr>
<tr>
<td>tandem (s)</td>
<td>43 (9) 45 (2)</td>
<td>34 (19) 39 (12)</td>
<td>41 (14) 43 (9)</td>
<td>.520</td>
</tr>
<tr>
<td>Dynamic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>alternate stepping (s)</td>
<td>7.5 (1.1) 6.9 (0.9)</td>
<td>7.9 (0.4) 7.5 (0.3)</td>
<td>8.2 (1.6) 7 (1.2)</td>
<td>.060</td>
</tr>
<tr>
<td>limits of stability (cm)</td>
<td>12.7 (2.0) 13.8 (2.0)*</td>
<td>11.9 (2.0) 14.1 (2.0)*</td>
<td>11.3 (2.0) 14.2 (2.0)*</td>
<td>.004†</td>
</tr>
<tr>
<td>anteroposterior forward</td>
<td>7.0 (1.0) 7.4 (1.0)</td>
<td>6.6 (1.0) 7.6 (1.0)*</td>
<td>6.2 (2.0) 7.8 (1.0)*</td>
<td>.003†</td>
</tr>
<tr>
<td>anteroposterior backward</td>
<td>5.8 (1.0) 6.4 (1.0)</td>
<td>5.3 (1.0) 6.5 (1.0)</td>
<td>5.1 (1.0) 6.4 (1.0)</td>
<td>.049</td>
</tr>
<tr>
<td>mediolateral</td>
<td>9.9 (1.0) 10.9 (2.0)</td>
<td>9.5 (2.0) 11.5 (1.0)</td>
<td>9.8 (2.0) 11.3 (2.0)</td>
<td>.093</td>
</tr>
<tr>
<td>Activities-Specific Balance Confidence</td>
<td>96.8 (3.0) 97.9 (2.0)</td>
<td>95.2 (5.0) 93.9 (7.0)</td>
<td>92.7 (7.0) 95 (4.0)*</td>
<td>.001†</td>
</tr>
</tbody>
</table>

*From the Group $\times$ Session repeated-measures ANOVA for each variable. Included to provide a succinct summary of which analyses resulted in significant interactions.

*Significant pre–post within-group follow-up tests.

†Significant Group $\times$ Session interaction.
significant increase, \( F(1, 19) = 19.1, p < .001, \eta^2 = .501; \) control \( F(1, 18) = 0.47, p = .502, \eta^2 = .025; \) 1-day \( F(1, 20) = 3.74, p = .067, \eta^2 = .158. \)

**Tandem Balance.** Almost everyone exhibited a ceiling effect; that is, they could balance for 45 s. There were no main effects for group, \( F(2, 57) = 2.71, p = .075, \eta^2 = .087, \) or session, \( F(1, 57) = 3.92, p = .053, \eta^2 = .064, \) and the interaction was not significant, \( F(2, 57) = .52, p = .60, \eta^2 = .018. \) These results indicate that tandem balance is not a sensitive measure for physically active older adults.

**Dynamic Balance**

**Alternate Stepping.** There was no main effect for group, \( F(2, 57) = 0.75, p = .477, \eta^2 = .026, \) but there was a main effect for session, \( F(1, 57) = 30.5, p < .001, \eta^2 = .348, \) with all groups improving from pre- to posttest. The 3-day group exhibited the greatest increase, 15% compared with 5% for 1-day and 8% for control. However, the interaction was not significant, \( F(2, 57) = 3.09, p = .053, \eta^2 = .098. \)

**LOS (ML and AP).** Examination of ML LOS maximum excursion revealed no main effect for group, \( F(2, 56) = 0.14, p = .871, \eta^2 = .005, \) but a main effect for session, \( F(1, 56) = 62.94, p < .001, \eta^2 = .529, \) with the posttest excursion greater than pretest. The 1-day group increased by 21%, 3-day by 15%, and control by 10%. However, the interaction was not significant, \( F(2, 56) = 2.48, p = .093, \eta^2 = .081. \) For AP LOS maximum excursion, there was no group effect, \( F(2, 56) = 0.37, p = .691, \eta^2 = .013, \) although there was a main effect for session, \( F(1, 56) = 95.22, p < .001, \eta^2 = .63. \) There was also an interaction, \( F(2, 56) = 6.26, p = .004, \eta^2 = .183, \) with the greatest increase in 3-day (26%), followed by 1-day (20%), then control (9%). Follow-up ANOVAs revealed significant changes in all groups: 3-day \( F(1, 19) = 42.9, p < .001, \eta^2 = .693; \) 1-day \( F(1, 19) = 60, p < .001, \eta^2 = .76; \) control \( F(1, 18) = 8.48, p = .009, \eta^2 = .32. \)

On examination of the AP data, there appeared to be a difference between forward and backward excursion. Thus, to better characterize the change in AP excursion, we conducted several post hoc analyses to examine forward excursion separately from backward excursion. For forward excursion there was no main effect for group, \( F(2, 56) = 0.15, p = .858, \eta^2 = .005, \) but there was for session, \( F(1, 56) = 64.83, p < .001, \eta^2 = .537. \) There was also an interaction, \( F(2, 56) = 6.46, p = .003, \eta^2 = .187. \) The 3-day group exhibited the greatest change (27%), then 1-day (16%), and the least change in the control group (9%). Follow-up one-way ANOVAs indicated that 3-day and 1-day exhibited a significant increase, \( F(1, 19) = 31.51, p < .001, \eta^2 = .624, \) and \( F(1, 19) = 40.65, p < .001, \eta^2 = .681, \) respectively. The control group did not exhibit a significant increase, \( F(1, 18) = 4.61, p = .046, \eta^2 = .204. \) In backward excursion, there was no main effect for group, \( F(2, 56) = 0.58, p = .565, \eta^2 = .02, \) but there was a main effect for session, \( F(1, 56) = 76.15, p < .001, \eta^2 = .576, \) with a greater excursion at posttest. The 3-day group increased by 25%, 1-day by 24%, and control by 11%; however, the interaction was not significant, \( F(2, 56) = 3.18, p = .049, \eta^2 = .102. \)
Balance Confidence

Balance confidence was very high in this physically active group (see Table 3 for means). There were no main effects for the ABC—group $F(2, 57) = 2.85, p = .066, \eta^2 = .091$; session $F(1, 57) = 3.03, p = .087, \eta^2 = .051$— but there was an interaction, $F(2, 57) = 7.31, p = .001, \eta^2 = .204$. The 3-day group improved by 2.6% and the control by 1.1%. The 1-day decreased by 1.4%. One-way ANOVAs showed a significant increase in confidence in 3-day, $F(1, 19) = 8.89, p = .008, \eta^2 = .319$, but no session differences in the other groups: control $F(1, 18) = 2.80, p = .111, \eta^2 = .135$; 1-day $F(1, 20) = 4.13, p = .056, \eta^2 = .171$.

Discussion

The underlying rationale for examining the effect of balance training in physically active older adults was to address balance proactively. Clearly, our participants were healthy and active, and according to current ACSM guidelines, balance training was not indicated. However, the current balance literature focuses primarily on either sedentary or at-risk populations—thus the need to examine the effect, and more specifically the dose-related effect, of short-term static and dynamic balance training in physically active older adults. We hypothesized that they would improve in balance after a 6-week balance-training program and there would be a dose-response relationship between the frequency of balance training and improvement in balance control. In general, the results from this study support these hypotheses. Older adults who regularly engaged in physical exercise and then added balance-specific training improved both static and dynamic balance; a dose-response relationship was observed for SLS, LOS forward AP excursion, and balance confidence.

Previous research indicated that physical activity or balance-training interventions improve SLS times for frail elderly and community-dwelling older adults, with improvement ranging from 43% to 123% (Cromwell et al., 2007; Gatts & Woollacott, 2006; Li et al., 2005; Nelson et al., 2004; Robitaille et al., 2005; Shimada, Uchiyama, & Kakurai, 2003). Our study extends these findings to suggest that healthy older adults who already meet the recommended physical activity guidelines can improve SLS time with training (3-day improved by 67% and 1-day, 21%). This increase occurred even though our sample exhibited higher pretest scores than reported in many studies of older adults (Drusini et al., 2002; Li et al., 2005; Nelson et al., 2004; Robitaille et al., 2005; Shimada et al., 2003). Group average pretest scores from these studies ranged from 4 to 15 s, while our average pretest time across groups was 23.1 s. Many balance-assessment tools use maximum SLS cutoff times of 10 s or less (Berg et al., 1992; Province et al., 1995), suggesting that these tools may not be sufficiently sensitive to evaluate balance in an active, highly functioning older adult population.

A measurable decline in single-leg balance may occur as early as the fifth decade of life (age 40–49; Isles et al., 2004; Nitz & Choy, 2004), with a marked decline occurring between the ages of 70 and 80 (Era, Heikkinen, Gause-Nilsson, & Schroll, 2002). The 3-day group increased their SLS-L and SLS-R times to an average of 33 and 35 s, respectively, similar to average norms for 60-year-olds (Vereeck, Wuyts, Truijen, & Van de Heyning, 2008). These findings are meaningful in light of the known associations between decreased SLS time and falls, as well as
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activities of daily living (Drusini et al., 2002; Hurvitz, Richardson, Werner, Rhul, & Dixon, 2000; Vellas et al., 1997).

LOS also showed a dose-related effect specifically in forward AP excursion. Previous studies relate AP excursion to falls. Melzer, Benjuya, and Kaplanski (2004) measured LOS maximum AP excursion in community-dwelling older adults and found significant differences between fallers (8.7 ± .08 cm) and nonfallers (10.4 ± .04 cm). Wallmann (2001) compared performance of elderly fallers and nonfallers in both reaching and leaning tasks and observed that poor performance in forward leaning correlated with poor balance, whereas reaching tasks did not.

Many of the measures used in this study place demands on ML stability and require lateral weight transference. Both SLS and alternate stepping additionally require active movement of the center of mass laterally in anticipation of the transition from a two-leg to a one-leg position. In addition to adequate strength, these tasks with ML stability demands require active, integrative central nervous system control for successful execution (Horak & MacPherson, 1996). Previous work indicates that impaired ML control is associated with increased risk of falling. A prospective study found that measures of ML balance control (ML sway and one-leg standing) best discriminated between fallers and nonfallers (Maki, Holliday, & Topper, 1994). Using a reaction-time rapid step task, Brauer et al. (2000) found that fallers had slower step times and delayed activation of the hip abductors, indicating impaired lateral weight transference. Together, these data suggest that maintaining or improving ML balance control may decrease the risk of falls.

Although our training activities incorporated the use of ML stability, we did not find differences between training groups for LOS in the ML direction or in alternate stepping. Similarly, Brauer et al. (2000) found no differences in either the ML LOS or the clinical step-up test between fallers and nonfallers. In addition, Horak, Wrisley, and Frank (2009) found that the alternate stepping task was one of the least difficult tasks performed by older adults with or without balance problems and was a less sensitive test than other clinical tests. Therefore, if ML LOS and alternative stepping did not differentiate between fallers and nonfallers, it is not necessarily surprising that balance training in physical active adults was less effective.

One overall observation is that the activities that were specifically and repeatedly practiced with increasing difficulty (leaning tasks 4 out of the 6 weeks and SLS while engaged in tasks, such as turning the head or moving a towel, every week for an average of 4–5 min/session) resulted in dose-related increases. In contrast, alternate stepping, which was practiced only 1 week, showed only a trend for the 3-day group to improve. These results support the position that specificity of practice for changes in postural control in older adults is needed (Wolfson et al., 1996). The dose-related response indicates that intensity is important, which is also in agreement with Wolfson et al., who underlined the importance of intensity for plasticity changes relative to postural control in older adults.

Balance-confidence scores improved in the 3-day group after training, with average scores increasing for each of the 16 items included on the ABC. The items that had a change of greater than 5% included Item 5, standing on tiptoes to reach; Item 15, stepping onto or off of an escalator without the use of hands; and Item 16, walking on icy sidewalks. Unexpectedly, the 1-day group showed a trend for a decrease in balance-confidence scores after training. Because our balance-training
program increased in difficulty each week, those in the 1-day group experienced only one training session for each level of difficulty. Some 1-day participants expressed frustration at not mastering some of the skills before trying the more difficult tasks the next week, and others communicated that the balance-training program increased their realization of their balance limitations. Thus, it is possible the lower balance-confidence scores of the 1-day group reflect an increased awareness of balance limitations because of training and, thus, are an indirect effect of training. However, we did not equate the groups on balance confidence, making it more difficult to determine the effect of the intervention on this measure.

We consider this study a first step in the process of examining balance training in physically active older adults. As such, there were several limitations in the study. Our sample size was small, and although we found significant effects and moderate to large effect sizes for most interactions, a larger sample would provide better representation and stronger statistical power. Since almost all variables showed an improvement from pre- to posttesting, suggesting a learning effect regardless of intervention group, an additional familiarization session should be provided before pretesting. In addition, we did not provide a nonbalance alternative for the 1-day and control groups, such as stretching or breathing exercises, thereby controlling for total time in exercise per week. However, given the practice-specific task improvement in SLS and the relatively high levels of physical activity of all the study participants, we do not think this influenced the group results. Finally, we did not control exercise before and during the training period other than asking that participants not change their exercise protocol or engage in balance tasks outside of balance-training sessions. Participating in balance training could have systematically influenced their exercise regimen and results. However, exercise changes based on pre- and posttest self-report did not indicate any systematic changes across groups in exercise regimens.

Further research needs to examine the effect of balance training in physically active older adults on long-term functional outcomes such as mobility disability and falls, as well as the intensity of practice necessary to maintain improved balance skills. One study indicates that a less intense maintenance program is sufficient once the initial, more intense program is completed (Wolfson et al., 1996). Another important question is the degree to which these balance improvements transfer to everyday tasks. To determine if improved balance in such healthy, highly active older adults affects functional tasks, motor control of challenging tasks such as stair climbing or descending without handrails or stepping over an obstacle must be examined.

**Conclusion**

The data indicate that a dose-related response in SLS and LOS occurred with three 20-min sessions of balance-specific training per week in physically active older adults. Furthermore, these results were obtained through an intervention that was safely administered in a community setting. While the current ACSM/AHA recommendations advocate balance training for older adults who are at substantial risk of falls, this study provides a foundation for future longitudinal studies examining the effects of balance training on functional outcomes for physically active older adults.
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