Effects of Resistance- and Flexibility-Exercise Interventions on Balance and Related Measures in Older Adults

Marie-Louise Bird, Keith Hill, Madeleine Ball, and Andrew D. Williams

This research explored the balance benefits to untrained older adults of participating in community-based resistance and flexibility programs. In a blinded randomized crossover trial, 32 older adults ($M = 66.9$ yr) participated in a resistance-exercise program and a flexibility-exercise program for 16 weeks each. Sway velocity and mediolateral sway range were recorded. Timed up-and-go, 10 times sit-to-stand, and step test were also assessed, and lower limb strength was measured. Significant improvements in sway velocity, as well as timed up-and-go, 10 times sit-to-stand, and step test, were seen with both interventions, with no significant differences between the 2 groups. Resistance training resulted in significant increases in strength that were not evident in the flexibility intervention. Balance performance was significantly improved after both resistance training and standing flexibility training; however, further investigation is required to determine the mechanisms responsible for the improvement.

Keywords: strength, training, falls, mobility

Balance is defined as the ability to maintain an upright posture during both static and dynamic tasks (Benjuya, Melzer, & Kaplanski, 2004). Maintaining balance involves a complex interaction between intrinsic factors that include peripheral, visual, and vestibular sensation and muscle factors, as well as the interplay between the neural network and motor output, that are processed and mediated centrally (Dodd, Taylor, & Bradley, 2004). All of these factors are affected by normal aging processes.

Patterns of muscle use change as an individual ages (Schot, Knutzen, Poole, & Mrotek, 2003). Strength and power decline, and the speed of neural processing and number of sensory receptors both decrease. These changes result in alterations to both volitional and reflexive motion because neural processing and sensory receptors are major contributors to effective control of postural balance (Benjuya et al., 2004). Poor balance is a major risk factor for falls (Piirtola & Era, 2003).
Fall rates increase with age (Campbell et al., 1990), and the implications and costs of falling for individuals, and society, are high and projected to increase (Moller, 2003).

Research has focused on determining the most effective interventions for either improving balance or reducing fall risks, but the multisystem and multifactorial nature of balance means that prioritizing the importance of fall-risk factors for individuals in different contexts is difficult. A range of exercise interventions including those that have some focus on balance training (Province et al., 1995), combined exercise approaches such as Tai Chi (Li et al., 1995), or combinations of balance- and strength-training programs (Robertson, Campbell, Gardner, & Devlin, 2002) have been shown to reduce falls. However, the role of progressive resistance training alone has not shown consistent improvements in balance (Orr, Raymond, & Fiatarone, 2008).

Leg weakness is a commonly reported and important fall-risk factor. Individuals exhibiting this sign have 4.9 times the risk of falling than people with normal strength (Rubenstein, 2006). Resistance- or strength-training programs are gaining acceptability with older adults and have been reported to increase bone density, strength, and muscle mass with a concomitant decrease in physical limitation (Latham, Bennett, Stretton, & Anderson, 2004). However, the effect of this training modality on balance is less clear (Dodd et al., 2004), with no effect on an older individual’s flexibility reported. Many studies compare resistance training with a control or placebo group, but there is much less research comparing two different interventions (Latham et al.).

Flexibility training is the least researched of all exercise interventions in older adults (Frankel, Bean, & Frontera, 2006) and is often used as a pseudo (proposed) control (Liu-Ambrose et al., 2004). However, a longitudinal study that compared resistance training and flexibility training found significant improvements in balance with both interventions (Barrett & Smerdely, 2002). The mechanisms for the reported improvements were not discussed, although limitations of ankle range of motion have been demonstrated as an important factor affecting balance control (Menz, Morris, & Lord, 2005).

Consequently, the purpose of this study was to determine the effect of community-based resistance- versus flexibility-training programs on balance and related measures using a randomized crossover design.

**Methods**

**Population**

Print media were used to recruit sedentary older adults to this program. Sedentary status was defined as not being currently involved in any training and not having previously participated in a resistance-training program. Before their acceptance into the study, volunteers were screened for any medical problems that might affect their ability to complete the study by a trained interviewer using the Physical Activity Readiness Questionnaire (Thomas, Reading, & Shephard, 1992); medical clearance from their doctors was obtained. Exclusion criteria included a history of stroke or other neurological disease or current diabetes, cardiovascular...
disease, or uncontrolled hypertension. No participants used walking aids. Participants gave written informed consent to take part after an explanation of all risks and potential benefits associated with participation. Ethics approval was granted by the Health and Medical Human Research Ethics Committee (Tasmania) Network, and the study complied with the Declaration of Helsinki.

**Experimental Design**

Participants who met the inclusion criteria and were able to commit to the 32 weeks of training were randomly allocated at baseline testing, by an independent investigator using a randomized number system, to commence either the resistance-training or the flexibility-training protocol. Participants were asked to maintain their usual activity levels outside of the training intervention for the duration of the programs. Compliance with this request was measured with a Physical Activity Scale for the Elderly (PASE) questionnaire (Washburn, McAuley, Katula, Mihalko, & Boileau, 1999). The incidence of falling in the preceding year was recorded at baseline.

**Measurement of Balance**

Participants were able to practice assessment tasks during a familiarization session before baseline data collection. Balance was measured with participants standing on a foam pad (65-mm-high Airex pad) placed on an AMTI force platform (Accugait PJB 101, Watertown, MA) running Netforce software (Version 2.2) under two conditions, each for 30 s. The conditions involved participants’ looking straight ahead at a blank wall 3 m away or having their eyes closed. Under both conditions participants were asked to remain stationary with their arms by their sides. All data were collected at 50 Hz and passed through a 3-Hz filter, as recommended by the manufacturers. The platform was set 15 cm from the wall on the left side to provide some protection from falling if required but so that the assessor would be aware if a participant used the wall for support. The assessor closely supervised all tests.

Total sway path and range of excursion in the mediolateral direction were calculated from center-of-pressure data. Sway velocity for eyes-open and eyes-closed conditions were determined. Timed up-and-go (Podsiadlo & Richardson, 1991), 10 times sit-to-stand (Csuka & McCarty, 1985), and step test (Hill, Bernardt, McGann, Maltese, & Berkovits, 1996) were also measured according to previously described methods. The assessor was blinded to which training intervention participants had performed.

Lower limb strength was measured using a Cybex isokinetic dynamometer (Cybex 330, Lumex, Ronkonkoma, NY). Maximum torque for right and left knee-flexion and -extension strength was measured in Newton meters at a rotational velocity of 60°/s, after warm-up trials for each of the muscle groups were performed.

**Exercise Interventions**

Each exercise-training intervention consisted of 16 weeks of training with three sessions per week. For two of the weekly sessions participants attended a com-
Resistance- and Flexibility-Exercise Interventions

At the end of 16 weeks, there was a 4-week “washout” period before a second baseline test was conducted, after which participants commenced the alternate exercise program for the next 16 weeks. Four weeks was selected as the washout period based on other exercise-related physiological parameters concurrently being measured as part of a larger study (Toussaint, Polkinghorne, & Kerr, 2008).

The resistance-training intervention involved four core exercises focusing on major muscle groups and used free weights, pin-loaded exercise machines, and body weight for resistance. The home-based sessions exercised the same muscle groups as the gym-based sessions using body weight for resistance. Exercises selected depended on equipment available to the participant and included exercises such as lunges, push-ups, and step-ups. Participants were asked to perform two or three sets of 10–12 repetitions working at a perceived exertion of 14–17 on the 6- to 20-point Borg scale (Borg, 1982). The first two sets were a warm-up of 60% of the third set. Weights were increased under supervision when three sets of 12 were easily performed.

The flexibility program included commonly used stretching activities for the major muscle groups (including two stretches each for the hamstrings, quadriceps, back, and chest muscles). Each session lasted 40–45 min and included 16–20 stretches. The content presented by the facilitator varied depending on the ability of the participants, with narrow-stance calf stretches and one-legged quadriceps stretches included if participants were able. Standby or hand supports were only used when required. A large portion of the class was performed while standing. Each stretch was held for a period of 20 s and repeated twice.

Statistics

Data were analyzed using STATA software (version 9.0, Statacorp LP, College Station, TX). General linear modeling using repeated-measures ANOVA was performed to analyze differences between the two exercise interventions on performance of the clinical and force-platform tests of balance. Results were adjusted for order and period effect and are reported as means and mean differences, with 95% CI and p value. Effect size was calculated as described by Cohen (1969).

Results

Thirty-two sedentary older adults (18 men, 14 women) volunteered to participate in this study. Their mean age was 66.9 years (CI 65.9–67.8), height 167.6 cm (CI 166.0–169.2), weight 77.4 kg (CI 74.5–80.1), and body-mass index 27.5 kg/m² (CI 26.6–28.4). Five of the 32 participants (15.6%) had had a fall within the 12 months preceding the program. One participant fell during the study.

All participants completed at least 28 of the 32 face-to-face exercise sessions in each training protocol. There were no differences in baseline levels of physical activity between the two groups (PASE: resistance training 117.0 [CI 88.6–145.8] vs. flexibility training 124.0 [CI 100.0–148.7]) or in any of the measured baseline variables before the training intervention. Overall, the sample at baseline assessment performed at a level similar to that reported elsewhere for healthy older people (Table 1).
Table 2 shows the changes seen with the resistance and flexibility interventions for the parameters of activity level and strength. Strength in the lower limbs increased significantly in the resistance-training intervention \((p < .001)\) but not the flexibility intervention. There was a significant difference in lower limb strength between the resistance and flexibility interventions \((p < .001)\). There were no significant changes in reported physical activity during either intervention and no differences between groups in this parameter \((p = .361)\).

A comparison of clinical balance measures at the end of both interventions is presented in Table 3. Significant improvements in all three clinical tests were seen after both interventions, with no significant difference between the two. Both interventions resulted in decreased sway velocity irrespective of visual input (Table 4). Significant improvements in mediolateral sway range with eyes open and eyes closed were seen in the flexibility protocol, with 18% improvement seen with the eyes closed \((p = .007)\).

**Discussion**

Balance, measured clinically and by sway velocity, improved with both the resistance-training and the flexibility-training interventions. There was no significant difference between the two interventions. Mediolateral sway range improved after the flexibility-training intervention but not after resistance training. Strength improved after the resistance-training intervention only.

All three clinical measures (timed up-and-go, 10 times sit-to-stand, and step test) improved significantly with both exercise interventions (Table 3). The results support the findings of Barrett and Smerdely (2002), who found improvements in the measures of sit-to-stand and step test with both resistance and flexibility interventions. These tests rely on both adequate strength and dynamic balance (Dodd et al., 2004).

Sway velocity was found to significantly decrease in both interventions (Table 4). Fallers have higher sway velocity than nonfallers (Maki, Holiday, & Topper, 1994), so decreases in this parameter have implications for the stability of older adults.

Improvements in balance performance in the resistance-training cohort may be attributable to increases in strength. A significant difference \((p < .001)\) was seen in the change in measured lower limb strength between the two interven-
## Table 2  Activity and Strength Changes With Resistance and Flexibility Interventions

<table>
<thead>
<tr>
<th>Variable</th>
<th>Baseline RT, M (95% CI)</th>
<th>Endpoint RT, M (95% CI)</th>
<th>p</th>
<th>ES</th>
<th>Baseline FLX, M (95% CI)</th>
<th>Endpoint FLX, M (95% CI)</th>
<th>p</th>
<th>ES</th>
<th>Difference between ΔRT and ΔFLX, M (95% CI)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>PASE</td>
<td>117 (89–146)</td>
<td>113 (98–128)</td>
<td>1.000</td>
<td>0.1</td>
<td>124 (101–149)</td>
<td>112 (97–128)</td>
<td>.457</td>
<td>0.2</td>
<td>−9 (–29 to 10)</td>
<td>.361</td>
</tr>
<tr>
<td>Strength, Nm</td>
<td>410 (325–496)</td>
<td>459 (439–479)</td>
<td>&lt;.001</td>
<td>0.3</td>
<td>421 (343–500)</td>
<td>434 (420–448)</td>
<td>.143</td>
<td>0.1</td>
<td>−36 (–52 to −20)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

**Note.** RT = resistance training; FLX = flexibility training; PASE = Physical Activity Scale for the Elderly.

## Table 3  Changes in Clinical Balance Parameters With Resistance and Flexibility Interventions

<table>
<thead>
<tr>
<th>Variable</th>
<th>Baseline RT, M (95% CI)</th>
<th>Endpoint RT, M (95% CI)</th>
<th>p</th>
<th>ES</th>
<th>Baseline FLX, M (95% CI)</th>
<th>Endpoint FLX, M (95% CI)</th>
<th>p</th>
<th>ES</th>
<th>Difference between ΔRT and ΔFLX, M (95% CI)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sit-to-stand, s</td>
<td>23.3 (21.0–25.5)</td>
<td>17.8 (15.8–19.7)</td>
<td>&lt;.001</td>
<td>1.2</td>
<td>22.6 (20.3–25.0)</td>
<td>18.0 (15.9–20.1)</td>
<td>&lt;.001</td>
<td>1.6</td>
<td>0.88 (–1.34 to 3.10)</td>
<td>.439</td>
</tr>
<tr>
<td>Timed up-and-go, s</td>
<td>7.8 (6.7–8.9)</td>
<td>6.7 (5.7–7.4)</td>
<td>.006</td>
<td>0.6</td>
<td>7.6 (6.9–8.4)</td>
<td>6.6 (6.1–7.2)</td>
<td>&lt;.001</td>
<td>1.2</td>
<td>0.33 (–0.23 to 0.88)</td>
<td>.249</td>
</tr>
<tr>
<td>Step, n</td>
<td>13.5 (11.7–15.3)</td>
<td>18.2 (16.8–19.5)</td>
<td>&lt;.001</td>
<td>1.9</td>
<td>13.5 (11.9–15.2)</td>
<td>17.6 (16.4–18.8)</td>
<td>&lt;.001</td>
<td>1.2</td>
<td>−0.58 (–1.98 to 0.81)</td>
<td>.411</td>
</tr>
</tbody>
</table>

**Note.** RT = resistance training; FLX = flexibility training.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Baseline RT, $M$ (95% CI)</th>
<th>Endpoint RT, $M$ (95% CI)</th>
<th>$p$</th>
<th>ES</th>
<th>Baseline FLX, $M$ (95% CI)</th>
<th>Endpoint FLX, $M$ (95% CI)</th>
<th>$p$</th>
<th>ES</th>
<th>Difference between $\Delta$RT and $\Delta$FLX, $M$ (95% CI)</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>EO sway range, cm, ML</td>
<td>3.74 (3.34–4.13)</td>
<td>3.08 (2.39–3.77)</td>
<td>.125</td>
<td>0.2</td>
<td>4.16 (3.36–4.95)</td>
<td>2.97 (2.00–3.94)</td>
<td>.050</td>
<td>0.5</td>
<td>−0.53 (−1.33 to 0.27)</td>
<td>.195</td>
</tr>
<tr>
<td>EC sway range, cm, ML</td>
<td>6.79 (5.62–7.96)</td>
<td>5.65 (4.36–6.94)</td>
<td>.164</td>
<td>0.5</td>
<td>6.87 (5.85–7.89)</td>
<td>5.64 (4.85–6.43)</td>
<td>.007</td>
<td>0.7</td>
<td>−0.09 (−1.49 to 1.31)</td>
<td>.901</td>
</tr>
<tr>
<td>EO sway velocity, %/s</td>
<td>96 (85–107)</td>
<td>82 (73–92)</td>
<td>.019</td>
<td>0.6</td>
<td>101 (92–111)</td>
<td>81 (70–91)</td>
<td>&lt;.001</td>
<td>0.7</td>
<td>−7 (−18 to 4)</td>
<td>.210</td>
</tr>
<tr>
<td>EC sway velocity, %/s</td>
<td>194 (173–216)</td>
<td>164 (138–189)</td>
<td>.051</td>
<td>0.7</td>
<td>201 (176–225)</td>
<td>173 (154–192)</td>
<td>.009</td>
<td>0.5</td>
<td>3 (−27 to 34)</td>
<td>.828</td>
</tr>
</tbody>
</table>

Note. RT = resistance training; FLX = flexibility training; EO = eyes open; EC = eyes closed; ML = mediolateral.
tions. Significant increases in lower limb strength were recorded after resistance training but not after participation in the flexibility program (Table 2). Improvements in strength result from both increase in muscle volume and increased muscle activation (Morse et al., 2005). Although some authors describe a strong relationship between strength and balance (Wolfson, Judge, Whipple, & King, 1995), others report improvements in strength occurring with resistance training independently of changes in balance (Buchner et al., 1997). The use of the static-balance tests of one-leg stand and tandem stance as outcome measures in Buchner et al.’s study might have influenced the findings made by those authors. Our study included dynamic-balance measures as outcomes in the functional tests and measured static balance using the force platform.

In the absence of strength gains, improvements in balance seen in the flexibility intervention require a different explanation. Our flexibility protocol included stretches for the gastrocnemius and soleus muscles, which would be expected to increase dorsiflexion range of motion. Previously, correlations have been reported between reduced ankle-dorsiflexion range of motion and increased incidence of falling (Menz et al., 2005). Improvements in balance seen with this intervention may be related to changes in ankle range of motion, although this was not measured in the study. It would be useful to include these measurements in future research to determine the contribution of this factor to improved balance and falls prevention.

The flexibility program did incorporate some degree of balance training because of the nature of the flexibility tasks used in this study. For example, when participants were able, quadriceps and hamstring stretches were performed in one-legged stance. For safety, stand-by assistance or chairs were used when required. Any activity that requires a person to maintain a static position for a period on one leg will challenge balance control. One-legged standing, for as little as 60 s three times a day, has been found to reduce fall rates in older adults in residential care (Sakamoto et al., 2006). Although balance and agility differ between community-dwelling and residential-care-dwelling adults, training by this method may be useful in altering balance mechanisms, which are reflected in the force-platform parameters.

Mediolateral sway is strongly linked to fall rates (Stel, Smit, Pluijm, & Lips, 2003). Results of studies using a foam insert have indicated improvements in sway with multimodal exercise regimes (Hue, Seynnes, Ledrole, Colson, & Bernard, 2004; Lord, Ward, Williams, & Strudwick, 1995), although there is little literature in this area with single-mode exercise regimens. The interesting improvements in the mediolateral sway parameters seen with the flexibility group may therefore be clinically significant, although the mechanism for this is not clear. It is possible that this is a result of changes in the strength of hip-abductor muscles, because they are more important than the thigh muscles in controlling movement in that direction (Johnson, Mille, Martinez, Crombie, & Rogers, 2004). A measure of this may be useful to include in future studies.

Fall rates for this cohort were lower than expected; only 5 of the 32 participants had fallen in the year before recruitment, when double that would be expected for this age group (Tinetti, Speechley, & Ginter, 1988). Reasons for this difference are unclear. Underreporting of falls when using retrospective self-report has been described (Cumming, Kelsey, & Nevitt, 1990), which may be a
contributory factor. Prospective reporting of falls, using falls calendars, are considered the gold standard but are not possible when establishing fall rates before commencing a study. Thus the potential preventive role of these programs warrants longer term investigation in a larger sample to determine the impact on fall rates.

Older people have low rates of participation in formal exercise programs (Sims, Hill, Davidson, Gunn, & Huang, 2007), and the benefits to balance of a program that includes home-based, as well as center-based, training are supported here. The benefits of flexibility exercises on static and dynamic balance are presented in this article. Flexibility programs may be useful for older adults who do not find resistance training manageable or appealing. The benefits of including flexibility programs on alternate days with resistance training warrant further investigation (Nelson et al., 2007).

Limitations of this study include the small size of the sample, which reduces the power to detect small between-groups changes. It is possible that the relatively short washout period of 4 weeks was insufficient for the measured variables to return to baseline values, which may also affect our findings. However, this appears unlikely because no effect of intervention order was observed in any of the variables measured. The possibility of a detection of false improvement in both groups was minimized by a familiarization session, but we must recognize that some of the effort-dependent variables may have been improved postintervention by the participants’ being influenced by the Hawthorne effect.

Conclusion

Significant improvements in balance performance were achieved with both resistance-training and standing flexibility-training programs in healthy untrained older adults. However, improvements in leg-muscle strength were only associated with the resistance-training program. Consequently, it appears likely that the mechanisms behind the observed improvements in balance varied between training protocols. Results from this study suggest that both resistance-exercise programs and flexibility-training programs will be of value to older adults wishing to improve their stability and potentially reduce falls.

Acknowledgments

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References


