Effects of resistance and flexibility exercise interventions on balance and related measures in older adults.

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Abstract

This research explored the balance benefits to untrained older adults of participating in community-based resistance and flexibility programs. In a blinded randomised cross-over trial, 32 older adults [mean=66.9 years] participated in a resistance exercise program and a flexibility exercise program for 16 weeks each. Sway velocity and medio-lateral sway range were recorded. Timed up and Go, Ten 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, Ten times sit-to-stand and Step test were seen with both interventions; with no significant differences between the two 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 programs, however further investigation is required to determine the mechanisms responsible for the improvement.
Background

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

The patterns of muscle use alter 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 as they are major contributors to effective control of postural balance (Benjuya et al., 2004). Poor balance is a major risk factor for falls (Piiritola & Era, 2006). 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 improving either balance or reducing fall risks, but the multisystem and multifactorial nature of balance means that prioritising the importance of fall risk factors for individuals in different contexts is a difficult task. 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, compared to 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 to a control or placebo group, however there is much less research into comparison of two different interventions (Latham et al., 2004).

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 & Smedely, 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 randomised crossover design.

**Methods**

*Population*

Print media was used to recruit sedentary older adults to this program. Sedentary status was defined as not currently involved in any training, and not having previously participated in a resistance training program. Prior to their acceptance into the study, volunteers were screened for any medical problems that may affect their ability to complete the study by a trained interviewer using the Physical Activity Readiness Questionnaire (PAR-Q) (Thomas, Reading & Shephard, 1992); medical clearance from their doctor was gained. Exclusion criteria included a history of stroke or other neurological disease, or diabetes, cardiovascular disease or uncontrolled hypertension. No participants used walking aids. Participants gave written informed consent to participate following an explanation of all risks and potential benefits associated with participation. Ethics approval was gained from the Health and Medical Human Research Ethics Committee (Tasmania) Network and 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 randomised number system, to commence either the resistance training (RT) or
flexibility training (FLX) protocols. Participants were requested to maintain their usual activity levels outside of the training intervention for the duration of the programs. Compliance to 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 previous year was recorded at baseline interview.

Measurement of Balance

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

Total sway path and range of excursion in the medio-lateral direction were calculated from centre of pressure data. Sway velocity for eyes open (EO) and eyes closed (EC) conditions were determined. Timed up and go (TUG) (Podsiadlo & Richardson, 1991), Ten times sit to stand (TTSTS) (Csuka & McCarty, 1985) and Step test (Hill, Bernhardt, McGann, Maltese & Berkovits, 1996) were also measured according to previously
described methods. The assessor was blinded to the training intervention that had been performed.

Lower limb strength was measured using a Cybex isokinetic dynamometer (Cybex 330; Lumex, Ronkokama, NY). Maximum torque for right and left knee flexion and extension strength was measured in Newton metres at a rotational velocity of 60° per second, 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 3 sessions per week. For two of the sessions per week participants attended a community gymnasium and the other session was a home based session. 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 wash out period based on other exercise related physiological parameters concurrently being measured as part of the 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 bodyweight for resistance. The home based sessions exercised the same muscle groups as the gym based sessions using bodyweight for resistance. Exercises selected depended on equipment available to the participant and included exercises such as lunges, push ups and step ups. Participants were requested to perform 2-3 sets of 10-12 repetitions working at a
perceived exertion of 14-17 on the 6-20 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 3 sets of 12 were easily achieved.

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

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Statistics

Data were analysed using STATA (version 9.0) software (Statacorp LP, College Station, TX USA). General linear modelling using repeated measures ANOVA was performed to analyse 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. Results are reported as means and mean differences, with 95% CI and \( p \) value. Effect size was calculated as described by Cohen (Cohen, 1969).
Results

Thirty two sedentary older participants (18 male, 14 female) volunteered to participate in this study. Their mean age was 66.9 years (CI 65.9 to 67.8), height 167.6 cm (CI 166.0 to 169.2), weight 77.4 kg (CI 74.5 to 80.1) and body mass index 27.5 kg m\(^{-2}\) (CI 26.6 to 28.4). Five out of the thirty two participants (15.6%) recorded a fall within the 12 months preceding the program. One participant fell during the study.

All participants completed at least 28 out 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 to 145.8) vs Flexibility Training 124.0, (CI 100.0 to 148.7)], or in any of the measured baseline variables prior to the training intervention. Overall, the sample at baseline assessment performed at a similar level to that reported elsewhere for healthy older people (Table 1) [(Csuka & McCarty, 1985; Hill et al., 1996; Isles, Low Choy, Steer & Nitz, 2004)].

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 \((p<0.001)\), but not the flexibility intervention. There was a significant difference in lower limb strength between the resistance and flexibility interventions \((p<0.001)\). There were no significant changes in reported physical activity during either intervention and no differences between the groups in this parameter \((p=0.361)\).
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 following both interventions with no significant difference between the two interventions. Both interventions resulted in decreased sway velocity irrespective of visual input (Table 4). Significant improvements in medio-lateral sway range with eyes open (EO) and eyes closed (EC) were seen in the flexibility protocol, with 18 percent improvement seen with the eyes closed ($p =0.007$).

**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. Medio-lateral sway range improved after the flexibility training intervention, but not post resistance training. Strength improved after the resistance training intervention only.

All three clinical measures (Timed up and go, Ten times sit-to-stand and Step test) improved significantly with both exercise interventions (Table 3). The results support the findings of Barrett and Smerdely (Barrett & 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 increased sway velocity compared to non-fallers (Maki, 1994), so decreases in this parameter have implications for the stability of the participants in this program.

Improvements in balance performance in the resistance training cohort may be attributed to increases in strength. A significant difference ($p<0.001$) was seen in the change in measured lower limb strength between the two interventions. 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 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 1-leg stand and tandem stance as outcome measures in the Buchner study may have influenced the findings made by those authors. Our study includes dynamic balance measures as outcomes in the functional tests, and measures 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 measurement of this was not included in the study design. Consequently it would be useful to include these measurements in future research to determine the contribution of this factor to improved balance performance 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, where participants were able, quadriceps and hamstring stretches were performed in one-legged stance conditions. For safety, stand-by assistance or chairs were used when required. Any activity that requires the person to maintain a static position for a period of time on one or other leg will challenge balance control. One-legged standing, for as little as 60 seconds 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 differs 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.

Medio-lateral sway is strongly linked to fall rates (Stel, Smit, Pluijm & Lips, 2003). Results of studies using a foam insert have reported 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 regimes. The interesting improvements in the medio-lateral sway parameters seen with the flexibility group may therefore be clinically significant,
although the mechanism for this is not clear. It is possible this may be due to changes in
the strength in hip abductor muscles, as 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 with only 5 out of the 32 participants
falling in the year prior to recruitment, when double that would be expected for this age
group (Tinetti, Speechley & Ginter, 1988). Reasons for this difference are unclear.
Under-reporting 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 falls rates prior to commencement of a study. Thus the
potential preventative 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 centre based training is supported here. The benefits of flexibility
exercises on static and dynamic balance are presented in this paper. Flexibility programs
may be useful for older adults who do not find resistance training manageable or
appealing. The benefits of the inclusion of flexibility programs on alternate days with
resistance training warrants further investigation (Nelson et al., 2007).
Limitations to this study include the small size of the sample, which reduces the power to detect small between group changes. It is possible that the relatively short wash out period of four weeks was insufficient for the measured variables to return to baseline values which may also impact on our findings. However this appears unlikely as 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 minimised by a familiarisation session, but it needs to be recognised that some of the effort dependent variables may be improved post intervention by the subjects 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 looking to improve their stability and potentially reduce falls.

**Key points**

- Balance performance was significantly improved after both resistance training and standing flexibility training programs
• Strength was significantly improved after the resistance training program, but not after the flexibility training program
References:


Table 1. Comparison of baseline values for functional measures of balance and strength for study participants and healthy comparison samples.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value for our sample</th>
<th>Normative data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SE)</td>
<td>Mean (SE)</td>
</tr>
<tr>
<td>Ten times Sit to stand (s)</td>
<td>19.2 (1.0)</td>
<td>18.0 (2.8) *</td>
</tr>
<tr>
<td>Timed up and go (s)</td>
<td>7.0 (0.4)</td>
<td>7.2 (0.2) †</td>
</tr>
<tr>
<td>Step test (number)</td>
<td>14.8 (0.6)</td>
<td>15.6 (0.3) ††</td>
</tr>
</tbody>
</table>

SE=Standard error of the mean; s=seconds
*Calculated from (Csuka & McCarty, 1985)
†(Isles, Low Choy, Steer, & Nitz, 2004) scores for women only
††(Hill, Bernhardt, McGann, Maltese, & Berkovits, 1996)
<table>
<thead>
<tr>
<th>Variable</th>
<th>Baseline RT Mean (CI 95%)</th>
<th>Endpoint RT Mean (CI 95%)</th>
<th>p value</th>
<th>Effect Size</th>
<th>Baseline FLX Mean (CI 95%)</th>
<th>Endpoint FLX Mean (CI 95%)</th>
<th>p value</th>
<th>Effect Size</th>
<th>Difference between ΔRT and ΔFLX Mean (CI 95%)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>PASE</td>
<td>117 (89 to 146)</td>
<td>113 (98 to 128)</td>
<td>1.000</td>
<td>0.1</td>
<td>124 (101 to 149)</td>
<td>112 (97 to 128)</td>
<td>0.457</td>
<td>0.2</td>
<td>-9 (-29 to 10)</td>
<td>0.361</td>
</tr>
<tr>
<td>Strength</td>
<td>410 (325 to 496)</td>
<td>459 (439 to 479)</td>
<td>&lt;0.001</td>
<td>0.3</td>
<td>421 (343 to 500)</td>
<td>434 (420 to 448)</td>
<td>0.143</td>
<td>0.1</td>
<td>-36 (-52 to -20)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

RT=Resistance Training; FLX=Flexibility Training; CI=Confidence Intervals; Nm= Newton Metres. Effect size (Cohen, 1969)
Table 3. Changes in clinical balance parameters with resistance and flexibility interventions

<table>
<thead>
<tr>
<th>Variable</th>
<th>Baseline RT Mean (CI 95%)</th>
<th>Endpoint RT Mean (CI 95%)</th>
<th>p value</th>
<th>Effect size</th>
<th>Baseline FLX Mean (CI 95%)</th>
<th>Endpoint FLX Mean (CI 95%)</th>
<th>p value</th>
<th>Effect size</th>
<th>Difference between ΔRT and ΔFLX Mean (CI 95%)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sit to stand (s)</td>
<td>23.3 (21.0 to 25.5)</td>
<td>17.8 (15.8 to 19.7)</td>
<td>&lt;0.001</td>
<td>1.2</td>
<td>22.6 (20.3 to 25.0)</td>
<td>18.0 (15.9 to 20.1)</td>
<td>&lt;0.001</td>
<td>1.6</td>
<td>0.88 (-1.34 to 3.10)</td>
<td>0.439</td>
</tr>
<tr>
<td>Timed up and go(s)</td>
<td>7.8 (6.7 to 8.9)</td>
<td>6.7 (5.7 to 7.4)</td>
<td>0.006</td>
<td>0.6</td>
<td>7.6 (6.9 to 8.4)</td>
<td>6.6 (6.1 to 7.2)</td>
<td>&lt;0.001</td>
<td>1.2</td>
<td>0.33 (-0.23 to 0.88)</td>
<td>0.249</td>
</tr>
<tr>
<td>Step (number)</td>
<td>13.5 (11.7 to 15.3)</td>
<td>18.2 (16.8 to 19.5)</td>
<td>&lt;0.001</td>
<td>1.9</td>
<td>13.5 (11.9 to 15.2)</td>
<td>17.6 (16.4 to 18.8)</td>
<td>&lt;0.001</td>
<td>1.2</td>
<td>-0.58 (-1.98 to 0.81)</td>
<td>0.411</td>
</tr>
</tbody>
</table>

RT =Resistance Training; FLX =Flexibility Training; CI =Confidence Intervals. Effect size (Cohen, 1969)
Table 4. Changes in force platform measures with resistance and flexibility interventions

<table>
<thead>
<tr>
<th>Variable</th>
<th>Baseline RT Mean (CI 95%)</th>
<th>Endpoint RT Mean (CI 95%)</th>
<th>p value</th>
<th>Effect Size</th>
<th>Baseline FLX Mean (CI 95%)</th>
<th>Endpoint FLX Mean (CI 95%)</th>
<th>p value</th>
<th>Effect Size</th>
<th>Difference between ΔRT and ΔFLX Mean (CI 95%)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>EO sway range (cm)</td>
<td>3.74 (3.34 to 4.13)</td>
<td>3.08 (2.39 to 3.77)</td>
<td>0.125</td>
<td>0.2</td>
<td>4.16 (3.36 to 4.95)</td>
<td>2.97 (2.00 to 3.94)</td>
<td>0.050</td>
<td>0.5</td>
<td>-0.53 (-1.33 to 0.27)</td>
<td>0.195</td>
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<tr>
<td>M-L</td>
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<tr>
<td>EC sway range (cm)</td>
<td>6.79 (5.62 to 7.96)</td>
<td>5.65 (4.36 to 6.94)</td>
<td>0.164</td>
<td>0.5</td>
<td>6.87 (5.85 to 7.89)</td>
<td>5.64 (4.85 to 6.43)</td>
<td>0.007</td>
<td>0.7</td>
<td>-0.09 (-1.49 to 1.31)</td>
<td>0.901</td>
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<tr>
<td>M-L</td>
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<tr>
<td>EO sway velocity</td>
<td>96 (85 to 107)</td>
<td>82 (73 to 92)</td>
<td>0.019</td>
<td>0.6</td>
<td>101 (92 to 111)</td>
<td>81 (70 to 91)</td>
<td>&lt;0.001</td>
<td>0.7</td>
<td>-7 (-18 to 4)</td>
<td>0.210</td>
</tr>
<tr>
<td>(degrees/s)</td>
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<tr>
<td>EC sway velocity</td>
<td>194 (173 to 216)</td>
<td>164 (138 to 189)</td>
<td>0.051</td>
<td>0.7</td>
<td>201 (176 to 225)</td>
<td>173 (154 to 192)</td>
<td>0.009</td>
<td>0.5</td>
<td>3 (-27 to 34)</td>
<td>0.828</td>
</tr>
<tr>
<td>(degrees/s)</td>
<td></td>
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</table>

RT = Resistance Training; FLX = Flexibility Training; CI = Confidence; Intervals EO = eyes open; EC = eyes closed; M-L = Medio-Lateral. Effect size (Cohen, 1969)