Short-term resistance training and the older adult: the effect of varied programmes for the enhancement of muscle strength and functional performance

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Summary

Although it is well recognized that resistance training is an efficient strategy to enhance physical performance in older adults, less is known about the most effective type of resistive exercise or the role of functional training. This study compared the effectiveness of three varied short-term (8 weeks) training protocols on muscle strength and functional performance in older men and women aged 65–84 years. Participants underwent twice-weekly high-velocity varied-resistance training (HV), twice weekly slow to moderate-velocity constant-resistance training (CT), combined once weekly high-velocity varied-resistance and once weekly gymnasium-based functional training (CB) or no training (CO). Dynamic muscle strength (1RM) of six muscle groups was assessed using isotonic equipment and functional performance by a battery of tests. Following 8 weeks of training, whole-body muscle strength increased ($P<0{\cdot}001$) by 22·0 ± 12·5% (mean ± SD), 21·7 ± 11·0% and 26·1 ± 14·4% in HV, CT and CB, respectively, compared to CO (−1·8 ± 7·2%). In between group comparisons, only the HV group displayed greater chair rise ability ($P = 0{\cdot}010$) than the CO group, while differences among groups approached significance for the fast 6-m walk and the stair climb test ($P = 0{\cdot}017$ and 0·041 respectively). Within groups, the HV group significantly improved in stair-climbing and chair rise ability ($P \leq 0{\cdot}001$) while CB improved in the fast 6-m walk ($P = 0{\cdot}003$) and CT improved their static balance, as assessed by the functional reach test ($P<0{\cdot}001$). This study indicates that twice weekly high-velocity resistance training is superior to strength and combined functional and resistance training for improving some power-orientated functional tasks. Although other functional performance improvements were modest among the training protocols, short-term combined once weekly resistance and once weekly functional training in older adults was as effective in enhancing muscle strength as twice-weekly resistance training. These results have important implications for older adults who are unable or unwilling to frequently attend exercise facilities.

Introduction

The loss of muscle function that occurs with normal ageing has a significant impact upon an individual's ability to undertake tasks of daily living (Bassey *et al.*, 1992; Evans, 1997; Bean *et al.*, 2002), ensuring a transition to dependant care. The importance of resistance training in improving muscle function in older adults is well established (Fiatarone *et al.*, 1990; Chandler *et al.*, 1998; Maddalozzo & Snow, 2000; Rubenstein *et al.*, 2000). In addition to changes in muscle function following resistance training, varying increases in functional performance are reported (Cronin *et al.*, 2002; Puggaard, 2003). In contrast to gymnasium-based training, home-based training interventions result in limited improvement of muscle function (King *et al.*, 2000; Skelton & Beyer, 2003). However, home-based interventions have been shown to enhance an individual's functional ability (King *et al.*, 2000; Skelton & Beyer, 2003). Likewise, community-based training programmes as well as those in dependent-care settings using body weight and elastic tubing report significant increases in functional performance accompanied by limited change in muscle strength (Chandler *et al.*, 1998; Lazowski *et al.*, 1999). A possible explanation for this is that the exercises prescribed with home- and community-based programmes utilize movements more commonly undertaken in daily living. Given the specific adaptation of the neuromuscular system to a regularly undertaken stimulus, it is not surprising exercises such as stair-climbing and chair rising result in significant improvements in these activities (Cronin *et al.*, 2002). Furthermore, only a certain level of strength (threshold) is required for performance of physical activities, and strength enhancement beyond this may have only a modest effect on functional performance (Taaffe, 2004).

Gymnasium-based resistance training regimens have typically included movements performed at slow to moderate speeds, using moderate to near maximal forces, with the goal to primarily enhance muscle strength. However, it has been proposed that muscle power, the product of force and speed of contraction, may be more relevant for functional performance among older individuals (Foldvari *et al.*, 2000). Recent studies utilizing high-velocity movements have resulted in the enhancement of muscle power in this population (Fielding *et al.*, 2002; de Vos *et al.*, 2005), and we recently reported that resistance training that incorporates explosive movements results in significant improvement in physical performance (Henwood & Taaffe, 2005). However, little work has been performed to determine which form of training is the most beneficial for enhancing functional performance. Moreover, studies that have compared functional training with gymnasium-based exercise have used low intensity resistance in the form of elastic tubing, limiting improvements in muscle strength and power when compared with programmes utilizing specialized resistance training machines (de Vreede *et al.*, 2005).

Identifying exercise regimens that have significant physiological benefits similar to those observed following gymnasium-based resistance training (Charette *et al.*, 1991) will assist in prolonging independence among older adults. However, factors such as transportation, membership costs and available time may restrict an older adult's ability to regularly undertake a gymnasium-based training programme. Therefore, it may be more convenient for some individuals to attend a gymnasium once per week or every 2 weeks and regularly complete a programme of functional exercises within their own home. To date, a protocol that combined both a gymnasium-based resistance component and exercises similar to tasks undertaken in daily living has not been investigated. As a result, the purpose of this study was to compare the effect of three short-term training protocols in older adults: high-velocity varied-resistance, slow to moderate-velocity constant-resistance, and combined high-velocity varied-resistance and gymnasium-based functional training to assess which had the greatest impact on muscle function and physical performance among older adults. We hypothesized that all three programmes would enhance muscle strength, but based on the importance of rapid force generation for functional tasks, that the high-velocity regimen and combined regimen would be superior for the enhancement of functional performance.

Materials and methods

Subjects and study design

Subjects in this study were initially recruited to participate in a 24-week exercise intervention comparing two resistance training regimes. Independent-living adults ($n = 67$) aged 65–84 years were randomized either to a high-velocity training (HV; $n = 23$, men = 9, women = 14), conventional resistance training (CT; $n = 22$, men = 11, women = 11), or to a non-training control (CO; $n = 22$, men = 10, women = 12) group for 24 weeks, with data collected at baseline, 8 weeks (short-term) and postintervention. Following the completion of the intervention, the CO group were invited to undertake an 8-week training regimen utilizing a gymnasium-based combined resistance and functional training protocol. Data collected from this group were then compared to the short-term (8-week) data collected from the HV, CT and CO groups. Therefore, the study reported here compared the short-term response of three training protocols; combined resistance and functional training (CB; $n = 15$, men = 6, women = 9), HV aimed at increasing muscle power, CT targeting muscle strength, to a non-training control group.

Briefly, participants were recruited using advertisements in a local newspaper, or were contacted from the Australasian Centre on Ageing 50+ registrar (University of Queensland, St Lucia, Qld, Australia). When potential subjects made contact, a short telephone interview took place to establish their appropriateness for the study. The exclusion criteria for the study included: (i) acute or terminal illness, (ii) moderate or severe cognitive impairment, (iii) unstable or ongoing cardiovascular/respiratory disorder, (iv) neurological or musculoskeletal disease or impairment, (v) resistance training experience within the previous 12 months, and (vi) the inability to commit to a period of time equivalent to the duration of the study. Following the telephone interview potential subjects were sent an information package detailing the study and requesting that they obtain their physician's approval for participation. Having obtained this, volunteers were then invited to attend two familiarization sessions and undertake baseline testing. The University of Queensland Medical Research Ethics Committee approved the study and all participants provided written informed consent.

Training programme

All exercise participants undertook twice weekly training and completed 16 training sessions. Resistance training was conducted using Extek resistance equipment (Extek Pty Ltd, Brisbane, Qld, Australia) and six exercises were undertaken: chest press, supported row, biceps curl, leg press, leg curl and leg extension. All sessions were separated by a minimum of 48 h. Subjects trained with partners in small groups of up to six persons and an exercise instructor supervised all sessions. Exercise instructors were responsible for maintaining a high level of motivation, ensuring the resistance remained challenging and that the correct movement speed was achieved. A minimum rest period of 1 min separated adjacent sets. All training sessions commenced with a 10-min warm-up that included stretching activities and concluded with a warm-down that included abdominal and lower-back exercises. Specifically, subjects conducted two sets of an abdominal crunch and a lower back superman exercise, aiming to complete 15 repetitions per set. Initially, some subjects had difficulty completing the prescribed number of repetitions; however, all subjects were able to complete the exercises by the end of the 8-week period. Sessions lasted approximately 1 h. Training was divided into two phases: 2 weeks conditioning and 6 weeks training.

Conditioning

All training participants completed 2 weeks conditioning prior to undertaking their specific training protocol to allow muscle adaptation and technique familiarization. During the first week, subjects completed three sets of eight repetitions at 65% of their one repetition maximum (1RM) for all six exercises. This was increased to 70% 1RM in the second week. Both the HV and CT groups followed the conditioning phase protocol twice per week, while the CB group followed it once per week and undertook functional conditioning once per week. During functional performance conditioning subjects were instructed to complete three sets of 10 repetitions for five of the six exercises and three sets of five repetitions for the stair climb (see below). All the resistance exercise movements during the conditioning phase of training were performed in a slow and controlled fashion with the concentric and eccentric phase each lasting approximately 3 s.

Training

Following the conditioning period, the HV and CB groups undertook a high-velocity varied resistance programme aimed at increasing muscle power. Specifically, subjects completed three sets of eight repetitions at 45% (set 1), 60% (set 2) and 75% (set 3) of their one repetition maximum (1RM), a similar regimen to what we have previously used with older adults (Henwood & Taaffe, 2005). Subjects were instructed to move as explosively as possible during the concentric phase of the movement and approximately 3 s during the eccentric phase. The CT group used a constant resistance protocol (three sets of eight repetitions at 75% 1RM) and were instructed to move at approximately 3 s concentrically and 3 s eccentrically.

Once weekly functional performance exercises for the CB group were chosen to replicate daily tasks, and while the study training was performed in a controlled-gymnasium environment, the exercises were selected so that they could also be performed in a home-based setting. The exercises undertaken were as follows.

Fit-ball squats. Subjects place a fit-ball (exercise/Swiss ball) between their lower back and a flat-wall surface. With their hands on their hips, they rolled the ball down the wall, keeping their torso vertical to the ground, until they reached their maximum depth before returning to the starting position. Subjects positioned their feet in front of them so that at the bottom of the movement their knee's had not passed the line of their toes.

Chair rise to standing. Subjects were seated in a hard-back chair (seat height 43 cm) with their arms folded across their chest. One repetition was completed when they rose to their full-standing height and returned to the sitting position.

Stair climb. Subjects ascended and descended two flights of stairs (nine stairs per flight, with a 15-cm rise per stair) one stair at a time.

Calf raises. On the balls of their feet and their heals hanging over the edge of a step platform (10 cm rise; dorsi flexion), subjects where instructed to rise to their maximum height by pointing their toes (plantar flexion) while maintaining slightly bent knees. They then returned to the starting position.

Chair dips. By applying downward pressure through the armrests and extending their arms, subjects raised and lowered themselves from a hard backed chair (seat height 40 cm). During the movement, subjects where instructed to keep their feet together and on the ground.

Lateral shoulder exercise. Subjects commenced the exercise seated with their back against the chair and their arms by their side. Keeping a slight bend in their elbows, subject raised their arms laterally to shoulder height then returned them to the starting position.

All subjects undertook three sets of 10 repetitions for each exercise with the exception of the stair climb where five repetitions were performed as each repetition included two flights of stairs. During the conditioning phase, all movements were of a moderate velocity. In contrast, during the training phase each repetition of the second set was performed as explosively as safely possible, while the speed of moment during the first and third set was instructed to be moderate lasting approximately 3 s concentrically and eccentrically.

To ensure all training was progressive, resistance was increased when the repetitions a subject could complete in their third set were >8. This protocol has been described previously (Jozsi *et al.*, 1999). Briefly, during the third set of each exercise subjects were encouraged to work until failure. When subjects could complete 10 or 11 repetitions or ≥12 repetitions their 1RM was increased by 5% or 10%, respectively. Likewise, when CB subjects felt they could complete functional exercises with ease they were encouraged to increase their range of movement or add weight to the exercise through the use of small hand-held dumbbells. Resistance and range of movement adjustments were made on the participants training cards prior to the first session of each week.

Measures

Height, weight, muscle function and functional performance measures were collected at baseline and at 8 weeks. Height and weight were assessed using a stadiometer and electronic scale respectively. Body mass index (BMI) was calculated from weight (kg) divided by the square of height in metres. Measures collected for the control group after the 24-week intervention were used as baseline data for the CB group in this study.

Muscle function

The dynamic muscle strength of the upper- and lower-body was measured as the bilateral 1RM; this is the maximum resistance that a subject can move through a full range of movement once, with respect to proper technique (Taaffe *et al.*, 1996). Following a light warm-up and stretching, subjects commenced each exercise with 10 repetitions at a light resistance. Testing then commenced at a weight suspected to be close to the individual's maximum. Individual repetitions were performed at increasing resistances until no additional weight could be lifted with acceptable form. The resistance prior to the loss of correct form was taken as their 1RM. To avoid muscle fatigue, weights were set so that the 1RM lift was achieved within 3–5 attempts. The coefficient of variation for repeated 1RM measures in our laboratory are: chest press 7·9%, supported row 3·1%, biceps curl 8·8%, leg press 3·1%, leg curl 2·5% and leg extension 5·6%.

Functional performance

All subjects undertook a battery of seven physical performance tests designed to replicate tasks of daily living. Participants where instructed to move as fast as they could safely manage in each of the tests, except for the usual 6-m walk and the functional reach. Tests were performed in triplicate, apart for the 400-m walk which was performed once, and the best result used for analysis.

Floor rise to standing. Subjects were instructed to lie in a supine position, with their feet together and their hands palm down and at their side. On command, the subject rose to a standing position. The task was completed when the tester saw that the subject had risen to their full height and had come to a complete stop (Skelton *et al.*, 1994). The coefficient of variation for repeated floor rise to standing in this study is 5·3%.

6-m backwards walk. As a measure of dynamic balance, subjects were instructed to transverse a 6-m distance using a backward heal-to-toe protocol (Taaffe *et al.*, 1999). A 6-m line between two timing gates (HMS technology services, University of Queensland, Qld, Brisbane, Australia) was marked and subjects were asked to follow this line as closely as possible. If the subjects wavered from this marker, they were instructed to return to the line as quickly as possible before continuing. The coefficient of variation for the 6-m backwards tandem walk is 5·6%.

Usual and fast 6-m walk. Two measures of gait speed were undertaken: usual pace, in which subjects were instructed to walk at a pace similar to which they may use during common daily events, and a fast pace (Fiatarone *et al.*, 1990). Time was assessed using two timing gates (HMS technology services, University of Queensland, Qld, Australia). The coefficients of variation for repeated 6-m walking measures in this study are: usual 5·3% and fast 5·1%.

Chair rise to standing. Subjects were seated in a hard-backed chair with a seat height of 43 cm from the floor and their arms folded across their chest. They were instructed to rise as fast as possible to a full standing position then return to a full-sitting position five times (Fiatarone *et al.*, 1990). The coefficient of variation for repeated chair rise to standing time is 7·5%.

Functional reach. To measure static balance, subjects were instructed to place their feet behind a marked line and whilst maintaining a fixed base of support reach forward along a preplaced measure tape. The difference between the starting and end point was calculated in centimetres as the subjects functional reach (Duncan *et al.*, 1992). The coefficient of variation for functional reach is 3·8%.

Timed stair climb. Subjects were instructed to ascend a standard fight of stairs (11 stairs, with a 16 cm rise per stair) avoiding the use of the handrail (Skelton *et al.*, 1994). Time was assessed using a stopwatch and the coefficient of variation for stair-climbing time is 4·2%. In addition, stair-climbing power (SCP) was calculated using the individual functional performance times from the stair-climbing task and the following equation (Lazowski *et al.*, 1999):

$$\text{SCP (W)} = \frac{\text{body weight (kg)} \times \text{gravity (m s}^{-1}) \times \text{step height (m)} \times \text{number of steps}}{\text{time (s)}}$$

The coefficient of variation for repeated stair-climbing power was 4·2%.

400-m walk. To measure walking endurance, subjects undertook a timed 400-m walk using a 20-m corridor path. Participants were instructed to start with their feet behind a line and on command commence walking down a 20-m path, around a cone and back, 10 times (Simonsick *et al.*, 2001). The coefficient of variation for the 400-m walk is 2·0%.

Statistical analysis

Data were analysed using the SPSS (SPSS 13; SPSS Inc., Chicago, IL, USA) statistical software package. Analysis of variance (ANOVA) was used to compare groups at baseline and analysis of covariance (ANCOVA) was used to examine groups at week 8 adjusted for gender and baseline values. Chi-square was used to examine the proportion of men and women among groups and the effect of gender was assessed using ANOVA (group × gender × time). Repeated measures ANOVA was performed on those subjects that participated in both the CO and CB groups to determine if any differences between the control and training period existed. Where appropriate, Bonferroni-adjusted multiple t-tests were used to locate the source of significant differences in means. To examine the within group effect, paired t-tests were used. Percent change was calculated on individual data as (final − baseline)/baseline × 100, with the mean of the group change reported. All tests were two tailed and to adjust for multiple comparisons an alpha level of 0·01 was chosen for significance.

Results

Seven subjects dropped out of the study, two each from the HV, CT and CO, and 1 from the CB group. Those who dropped out were not distinguished from those who completed the 8-week measurements. Of those that dropped out, two individuals did so on the advice of their cardiologist and one on the advice of their ophthalmologist; however, no one reported the training protocol or intensity as the reason for leaving the study. There was no difference among the four groups prior to training for height, weight, or any measure of muscle strength or functional performance (Table 1). All subjects completed 16 training sessions within a 9-week period.

With respect to gender, there was no difference in the proportion of men and women among groups ($\chi^2 = 0{\cdot}765$). However, there was a group × gender and a gender × time interaction for the leg press ($P = 0{\cdot}005$ and $0{\cdot}004$) and leg extension (both $P<0{\cdot}001$), a group × gender × time interaction for the seated row ($P = 0{\cdot}004$), as well as a gender × time effect for the chair rise ($P = 0{\cdot}007$). Consequently, in addition to baseline values, analyses among groups were adjusted for gender.

As the CB group was derived from the CO group, sub-analysis was undertaken to determine if there were any differences in the CB group compared to themselves during the control period. However, for all muscle strength and functional performance measures, there was no difference ($P>0{\cdot}01$) between the baselines of the CB and CO periods.

Muscle strength

Following 8 weeks of training, there was a significant difference among the groups for all exercises except the chest press (Table 2). Muscle strength was greater for the exercise groups when compared with the CO group for the remaining five exercises, except for the biceps curl where only the CT and CB were significantly stronger than CO and for the leg press where the HV group was stronger than the CO group. In addition, for the supported row, the CB group were stronger than the HV

Table 1 Subject characteristics at baseline (mean ± SD).

	HV ($n = 23$)	CT ($n = 22$)	CB ($n = 15$)	CO ($n = 22$)
Age (years)	70·7 ± 5·5	70·2 ± 5·0	69·3 ± 4·1	69·1 ± 3·6
Height (cm)	164·1 ± 7·9	167·9 ± 7·5	167·0 ± 8·2	168·8 ± 7·6
Weight (kg)	73·0 ± 12·6	76·7 ± 10·9	72·7 ± 12·0	72·3 ± 11·1
BMI (kg m^{-2})	27·1 ± 4·2	27·2 ± 3·6	26·0 ± 3·9	25·4 ± 3·6
Muscle strength (kg)				
Chest press	30·3 ± 16·3	30·4 ± 14·5	32·4 ± 19·3	32·3 ± 18·2
Supported row	45·5 ± 14·3	53·3 ± 15·6	48·1 ± 20·2	51·5 ± 23·6
Biceps curl	19·0 ± 10·2	19·9 ± 9·2	19·9 ± 12·3	20·8 ± 10·8
Leg press	71·0 ± 23·2	69·7 ± 21·5	71·3 ± 35·9	68·2 ± 31·3
Leg curl	21·7 ± 6·4	27·0 ± 8·2	25·9 ± 9·2	25·5 ± 8·9
Leg extension	35·8 ± 10·6	36·7 ± 9·4	39·5 ± 20·5	40·3 ± 22·0
Functional Performance				
Floor rise to standing (s)	3·3 ± 0·8	3·8 ± 2·0	4·0 ± 1·4	3·5 ± 1·4
Stair climb (s)	4·8 ± 0·7	4·8 ± 0·9	5·0 ± 1·1	4·9 ± 1·2
Stair climbing power (W)	268·9 ± 68·8	285·4 ± 69·6	264·6 ± 85·6	265·4 ± 77·7
6-m walk (s)				
Usual	3·9 ± 0·4	4·0 ± 0·5	4·1 ± 0·2	4·0 ± 0·3
Fast	3·1 ± 0·5	3·1 ± 0·4	3·2 ± 0·4	3·1 ± 0·4
Backwards	19·1 ± 6·0	18·0 ± 5·8	15·9 ± 4·8	18·7 ± 6·4
Chair rise (s)	11·9 ± 2·0	12·1 ± 2·3	12·6 ± 2·0	12·0 ± 1·9
Functional reach (cm)	30·8 ± 5·3	29·0 ± 5·1	30·7 ± 6·2	32·9 ± 7·0
400-m walk (s)	256·9 ± 21·6	245·0 ± 28·0	246·1 ± 40·4	247·1 ± 33·9

Groups: HV, high-velocity varied resistance training; CT, conventional constant resistance training; CB, combined high-velocity varied resistance and functional training; and CO, non-training control. BMI, body mass index.

Table 2 Muscle strength and functional performance following 8 weeks training adjusted for baseline value and gender (mean ± SE).

	HV (1) (*n* = 21)	CT (2) (*n* = 20)	CB (3) (*n* = 14)	CO (4) (*n* = 20)	*P*-value	Comparison
Muscle strength (kg)						
Chest press	33·2 ± 0·7	34·2 ± 0·8	34·1 ± 0·9	31·3 ± 0·8	0·053	
Supported row	53·5 ± 1·8	54·2 ± 1·9	63·4 ± 2·3	44·4 ± 2·0	< 0·001	1, 2, 3 > 4; 3 > 1
Biceps curl	23·7 ± 1·0	24·9 ± 1·0	26·8 ± 1·2	19·8 ± 1·0	< 0·001	2, 3 > 4
Leg press	78·4 ± 1·5	77·2 ± 1·5	76·1 ± 1·8	70·3 ± 1·6	0·002	1 > 4
Leg curl	31·1 ± 1·1	30·4 ± 1·1	30·1 ± 1·3	23·5 ± 1·1	< 0·001	1, 2, 3 > 4
Leg extension	44·9 ± 1·3	46·7 ± 1·3	48·4 ± 1·6	36·0 ± 1·4	< 0·001	1, 2, 3 > 4
Functional performance						
Floor rise to standing (s)[a]	3·8 ± 0·1	3·7 ± 0·1	3·6 ± 0·1	3·9 ± 0·1	0·197	
Stair climb (s)	4·5 ± 0·1	4·7 ± 0·1	4·8 ± 0·1	5·0 ± 0·1	0·041	
Stair climbing power (W)	292·4 ± 7·8	284·1 ± 8·0	273·7 ± 9·5	262·8 ± 8·4	0·070	
6-m walk (s)						
Usual	3·8 ± 0·1	4·0 ± 0·1	3·9 ± 0·1	4·0 ± 0·1	0·547	
Fast	2·9 ± 0·1	2·9 ± 0·1	2·9 ± 0·1	3·2 ± 0·1	0·017	
Backwards	16·9 ± 0·9	16·3 ± 0·9	17·9 ± 1·1	16·8 ± 1·0	0·774	
Chair rise (s)	10·5 ± 0·3	11·4 ± 0·3	11·6 ± 0·4	12·0 ± 0·3	0·010	1 > 4
Functional reach (cm)	33·3 ± 1·0	34·2 ± 1·1	34·7 ± 1·2	30·7 ± 1·1	0·074	
400-m walk (s)	242·8 ± 7·1	248·4 ± 7·3	227·7 ± 8·7	254·2 ± 7·6	0·137	

Groups: HV, high-velocity varied resistance training; CT, conventional constant resistance training; CB, combined high-velocity varied resistance and functional training; and CO, non-training control.
[a]HV, n = 20.

group. The average muscle strength change (for the six exercises) was 22·0 ± 12·5% (mean ± SD), 21·7 ± 11·0% and 26·1 ± 14·4% in HV, CT and CB, respectively, and −1·8 ± 7·2% for CO.

Within groups, there was a significant increase in muscle strength for the six exercisers for most exercise groups following 8 weeks training (P<0·01; Fig. 1).

Functional performance

Following training the only significant difference among groups was for the timed chair rise test with the HV group performing better than the CO group (Table 2). For the fast 6-m walk and the stair climb test, differences among groups approached significance (P = 0·017 and 0·041, respectively). Training had no effect on stair-climbing power, usual 6-m walk, the 6-m backwards walk, floor rise to standing, functional reach or the 400-m walk.

Within group change for each of the four walking tasks is presented in Fig. 2. The only significant change was a decrease in the time it took the CB group to walk 6-m at a fast pace (P = 0·003). The CB group also approached significance for the usual 6-m walk (P = 0·014) while the HV group approached significance for the fast 6-m walk (P = 0·015). Percent change for the floor rise, stair climb, stair-climbing power, chair rise and functional reach are presented in Fig. 3. Only the HV group had a significant increase in stair-climbing ability following training (P<0·001) as well as the chair rise test (P = 0·001). In addition, the CT group improved their functional reach (P<0·001) while the change in functional reach for the HV group approached significance (P = 0·026).

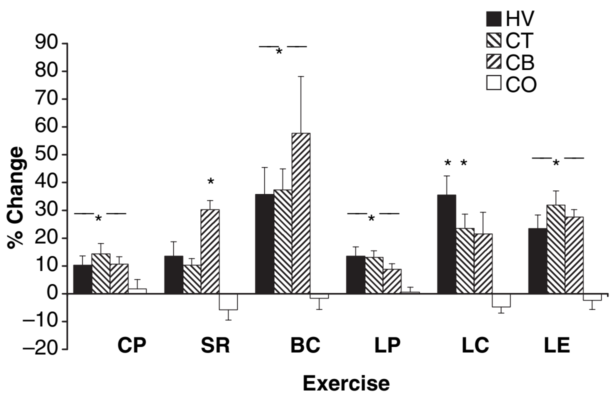

Figure 1 Percent change in muscle strength following 8 weeks training in older adults undertaking three varied training programmes: HV = high-velocity (n = 21), CT = conventional (n = 20), CB = combination (n = 14), and a non-training control group (CO, n = 20). Exercises: CP = chest press, SR = supported row, BC = biceps curl, LP = leg press, LC = leg curl, and LE = leg extension. *Significant (P<0·01) difference between baseline and postintervention. Values are the mean ± SE.

Discussion

The principal finding of this study is that short-term combined once-weekly resistance and once-weekly functional task training

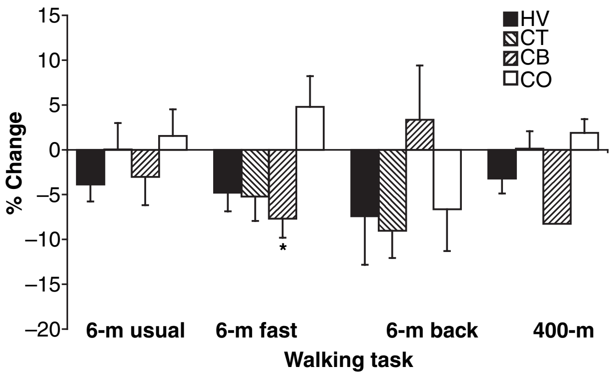

Figure 2 Percent change in four selected walking tasks following 8 weeks of training in older adults undertaking three varied programmes: HV = high-velocity (*n* = 21), CT = conventional (*n* = 20), CB = combination (*n* = 14), and a non-training control group (CO, *n* = 20). The walking tasks were: 6-m usual = 6-m usual walk, 6-m fast = 6-m fast walk, 6-m back = 6-m backwards walk, and 400-m = 400-m walk. *Significant ($P<0{\cdot}01$) difference between baseline and postintervention. Values are the mean ± SE.

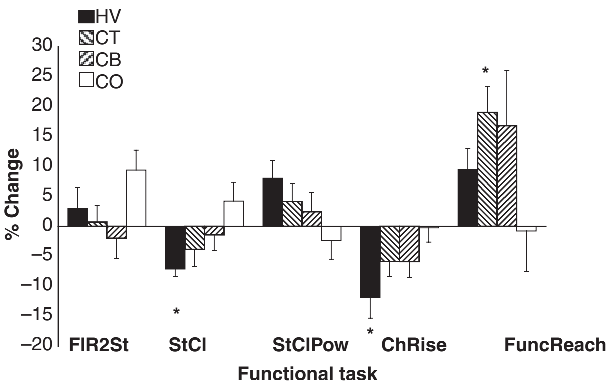

Figure 3 Percent change in five selected functional performance tests following 8 weeks of training in older adults undertaking three varied programmes: HV = high-velocity (*n* = 21), CT = conventional (*n* = 20), CB = combination (*n* = 14), and a non-training control group (CO, *n* = 20). The tasks were: FlR2St = floor-rise to standing, StCl = stair climb, StClPow = stair-climbing power, ChRise = repeated chair rise, and FuncReach = functional reach. *Significant ($P<0{\cdot}01$) difference between baseline and postintervention. Values are the mean ± SE.

in older men and women produced comparable improvements in upper and lower body muscle strength to those undertaking a twice-weekly programme specifically targeting either muscle strength or muscle power. Accompanying the changes in muscle strength were modest improvements in a few functional performance tasks, although it appears that the combined resistance and functional task training was less effective at increasing functional ability than resistance training alone. These results indicate that for those unable or unwilling to participate in frequent gymnasium exercise sessions, once-weekly resistance training combined with functional task training (that could be undertaken at home) is effective in improving muscle strength and is accompanied by some improvement in gait speed.

We have previously reported that muscle strength gains from a once weekly high-intensity resistance programme are comparable with those achieved with more frequent training in older adults (Taaffe *et al.*, 1999). In the present study, once weekly high-velocity resistance training combined with once weekly functional task training was as effective at increasing muscle strength as twice weekly high-velocity or conventional resistance training. Further, the results suggest that combined training may have additional benefits to back strength when compared to the alternative methods of training undertaken. However, four participants in the CB group with low baseline biceps strength increased their strength by >115% compared with only 1 each in the HV and CT groups. These individuals also displayed large changes in the supported row, an exercise where the elbow flexors act as accessory muscles. As with the large strength increases achieved in studies targeting frail populations (Fiatarone *et al.*, 1990, 1994), the low baseline values for these individuals may have contributed in the discrepancy among training groups.

Although the CB regimen included weekly functional tasks, this training mode was no more effective than resistance training alone at enhancing functional performance. Moreover, the twice weekly high-velocity varied-resistance training regimen, targeting muscle power, appeared to be more successful at enhancing the ability to perform power-related tasks of stair climbing and chair rising. It has previously been reported that a muscle power programme among older adults has a greater ability to increase functional capacity (Miszko *et al.*, 2003) when compared with a muscle strength programme, however, this study is the first to show an advantage when compared with a combined once weekly muscle power and once weekly functional task programme.

The functional results reported in this study are in contrast to those presented by de Vreede *et al.* (2005), who found that 12 weeks of functional performance training was more effective at increasing functional ability than resistance training alone. However, unlike the present study, the resistance used by de Vreede *et al.* (2005) was of a low-intensity nature (elastic tubing and body weight). Similarly, Skelton *et al.* (1995) did not observe significant functional change following short-term low-intensity resistance training. The muscle strength changes that are reported following low-intensity training (Skelton *et al.*, 1995; de Vreede *et al.*, 2005), although significant, are smaller than those reported following high-intensity resistance training, such as was undertaken in this study. In the present study, the change in muscle strength experienced by the training groups is similar to those reported previously following short-term resistance training in older adults (Pyka *et al.*, 1994; Schlicht *et al.*, 2001; Henwood & Taaffe, 2005). These gains in strength would not only permit small improvements in function to result, but would also enhance the individual's reserve capacity (Buchner & de Lateur, 1991).

The present results indicate that short-term once weekly resistance and once weekly functional training have similar benefits to twice weekly resistance training in relation to muscle strength. While the functional benefits are modest when compared with those experienced by the twice weekly high-velocity training group, significant enhancement in muscle strength and in walking speed occurred. Given the barriers to gymnasium-based resistance training, such as availability of transport, time, access to a training facility and the associated costs, these results have important implication for the older adult, and imply that those unable to attend or afford two or more gymnasium visits per week can still achieve similar strength gains from more limited gymnasium attendance and exercise that could be undertaken at home.

Several limitations of this study are worthy of comment. Although subjects were initially randomly assigned to the HV, CT and CO groups, subjects in the combined training group were derived from the CO group. As such, past exposure to tests may have affected their baseline values and subsequent gains from the 8-week exercise trial. However, there was a non-testing period of 16 weeks prior to the assessment of the CB group at the commencement of the 8-week training period. For those subjects undertaking the CB training regimen, there was no difference in any muscle strength or functional performance measure at baseline with that performed at the beginning of the control period. In addition, the comparison among the exercise regimens was based on an 8-week intervention and extending the duration beyond 8 weeks may have resulted in a greater impact on the muscle function and functional performance response, resulting in differences among groups. It is also possible that it was only the once weekly resistance training that contributed to the gains in the CB group, with little or no contribution from functional task training. However, additional study groups would have been needed to clarify this issue. The volume of work performed was also not constant among the exercise groups, nevertheless gains were similar. Regarding movement speed, it should also be recognized that although the HV group produced rapid movements in the first two sets at 45% and 60% of 1RM, towards the end of their third set (75% 1RM) movement speed, although maximal, was reduced because of the resistance and fatigue. Lastly, participants in this study were community-dwelling adults aged 65–84 years, and are therefore not representative of all older adults. Therefore, care should be taken when extrapolating our findings to the very old and frail elders; however, greater functional outcomes could possibly result due to their lower functional status (Fiatarone Singh *et al.*, 2000).

In summary, short-term once weekly high-velocity resistance exercise and a once weekly functional training programme is an effective strategy to significantly improve muscle strength, comparable with twice-weekly resistance training regimens, as well as fast walking speed in community-dwelling older adults. For those with limited time or access to exercise facilities, a modest gymnasium training frequency combined with some home- or community-based exercise is sufficient to enhance muscle function and may improve some aspects of physical performance.

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