Effects of a resistance exercise programme on the performance of inactive older adults

VI Kalapotharakos, M Michalopoulou, S Tokmakidis, G Godolias, N Strimpakos, K Karteroliotis

Although published studies have indicated the effectiveness of strength exercise for improving muscle strength and functional and neuromotor performance in older adults, there is limited evidence concerning the effects and the intensity of a resistance exercise programme. This study aimed to evaluate the effects of a 12-week high- and moderate-resistance exercise programme on functional and neuromotor performance in healthy, inactive older adults.

In total, 33 sedentary people (aged 60–74 years) were assigned to one of three groups: control; high resistance exercise; and moderate resistance exercise. All three groups were evaluated in the pre- and post-exercise period using the 6-minute walk test, whole body reaction time and one leg stance time. After the exercise period, both resistance exercise groups significantly improved their lower body strength, functional performance (as measured by the 6-minute walk test), whole body reaction time and one leg stance time. Functional and neuromotor performance improved similarly for both high- and moderate-resistance exercise after the training period. The high-resistance exercise was more effective in increasing the lower body strength than moderate-resistance exercise. Results suggest that functional and neuromotor performance can be significantly improved with both high- and moderate-resistance exercise protocols.

Key words: resistance exercise, intensity, functional performance, reaction time, static balance, older adults

Kalapotharakos VI, Michalopoulou M, Tokmakidis S, Godolias G, Strimpakos N, Karteroliotis K (2004) Effects of a resistance exercise programme on the performance of inactive older adults. Int J Ther Rehabil ***11****(7): 318–23*

VI Kalapotharakos is Research Associate, **M Michalopoulou** is Associate Professor and **S Tokmakidis** and **G Godolias** are Professors, Democritus University of Thrace, Department of Physical Education and Sport Science, PC 124 61, Komotini, Greece. **N Strimpakos** is Research Physiotherapist, Centre for Rehabilitation Science, University of Manchester, UK and **K Karteroliotis** is Associate Professor, National and Kapodistrian University of Athens, Athens, Greece.

Correspondence to: VI Kalapotharakos

With increasing age there is a deterioration of muscle strength, balance and reaction time, which is associated with a reduction in functional capacity and an increase in disability and number of falls in older adults (Whipple et al, 1987; Wolfson et al, 1995). During the last decade, strength exercise research has indicated that it is a safe and effective intervention to improve muscle strength and functional and neuromotor performance in older adults (Fiatarone et al, 1990; Rooks et al, 1997; Vincent et al, 2002).

Although previous studies have examined the effects of various strength exercise protocols such as resistance machines (Fiatarone et al, 1990), free weights (Rooks et al, 1997), aerobic balance (Wolfson et al, 1995) and flexibility exercises (Lord et al, 1995) on functional performance, static balance and reaction time, there is limited evidence concerning effects of resistance exercise programmes of different intensities (high *vs* moderate) on functional and neuromotor performance. The ideal intensity of a resistance exercise for older adults in enhancing functional and neuromotor performance remains to be determined.

This study was designed to evaluate the effects of resistance exercise programmes on functional and neuromotor performance in healthy, inactive older adults. It was hypothesized that both high- and moderate-resistance exercise programmes would have a beneficial effect on functional and neuromotor performance.

METHODS

Participants

In total, 46 independently living older adults (aged 60–74 years) volunteered to participate in this study. All participants signed a written approval consent form after being informed of all risks, discomforts and benefits associated with the procedures followed in this study. The research design and procedures of this study were approved by the investigational review committee of the Department of Physical Education and Sport Science of Democritus University of Thrace at Komotini, Greece.

Participants were included if they:

- Were non-smokers
- Were free of medication
- Had no symptoms of cardiovascular, orthopaedic or neuromuscular disease according to the medical questionnaire completed during an interview with a physician.

Participants were also physically inactive before the study according to the scores (below 9.4) obtained with the Modified Baecke Questionnaire for Older Adults (Voorrips et al, 1991). Further, participants completed the Older American Resources and Services Functional Assessment Questionnaire, (McCusker et al, 1999) according to which no limitations were observed in performing both basic and instrumental activities of daily living (scores ranging 13–14 for both basic and instrumental activities of daily living indices).

A total of 11 subjects were not included because they did not meet the above inclusion criteria. After the baseline medical control, participants were randomly assigned to one of the two resistance exercise groups – high-resistance exercise (HRE) or moderate-resistance exercise (MRE) – or to a control group, which did not participate in any exercise programme. Participants who participated in the control group were not interested in taking part in an exercise programme.

Two participants refused to continue after the third week of exercise (one from the high-resistance exercise group and one from the control group) because of medical and personal problems and were excluded from any data analysis. A total of 11 people participated in the high-intensity resistance exercise group (mean age=67.1 years; seven women and four men) and 12 subjects participated in the moderate-intensity resistance exercise group (mean age=66.7 years; eight women and four men). Finally, 10 people (mean age=67.3 years; six women and four men) participated in the control group .

Interventions

The resistance exercise groups exercised for 3 days a week, on non-consecutive days, for 12 weeks. Warm-up, for 10 minutes, included cycling at 50% of maximum heart rate and stretching of the major upper (major/minor pectoralis, thoracic, rotator cuff, biceps and triceps) and lower (quadriceps, hamstrings and adductors) muscle groups (Frontera et al, 1988; Judge et al, 1993; Brandon et al, 2000). Resistance exercise included exercises on six universal machines for the major muscles of upper and lower body, namely:

- Leg extension
- Chest press
- Leg curl
- Latissimus pull-down
- Arm curls
- Triceps extension.

After the resistance exercises, participants performed abdominal crunches and low back exercises (three sets of 12 repetitions for weeks 1–6 and three sets of 20 repetitions for weeks 7–12). The one-repetition maximum (1-RM) on each resistance exercise was measured at the beginning of every week until the exercise period was completed.

By the beginning of the first week, the participants of HRE performed three sets of eight repetitions at 80% of 1-RM and remained at this level until the end of the exercise period (Frontera et al, 1988). The participants of MRE performed three sets of 15 repetitions at 60% of 1-RM and continued at the same intensity until the end of the exercise period. Before the start of the exercise period, all the participants performed three resistance sessions with no or little resistance. These sessions familiarized them with the equipment and the proper exercise techniques and controlled for the large increases in strength measurements during the initial phases of exercise (Hurley et al, 1994).

At the end of each exercise session, there was a 5-minute cool-down where the participants cycled at 40% of maximum heart rate. The control group did not exercise but participated only in the measurement procedures.

Measurements

All measurements took place the week before the exercise programme started (pre-test) and the week after the end of the programme (post-test).

Muscle strength: The muscle strength of the lower body was assessed by 1-RM. The maximal weight that could be lifted for one repetition only was used as the measure of dynamic concentric muscle strength 1-RM for knee extension and flexion (r=0.95) (Kalapotharakos et al, 2004).

6-minute walk: The 6-minute walk has been shown to be a valid, reliable, simple and safe measure for assessing the functional exercise capacity for the evaluation of an intervention programme in patients with cardiovascular pulmonary diseases (Swisher and Goldfarb, 1998) and older adults (Lord and Menz, 2002). The 6-minute walk test measured the distance (in metres) the participants could walk as quickly as they could during the allotted time. The test was performed in the indoor facilities of the department. Conditions under which the test took place were kept constant for both pre-exercise and post-exercise testing. During the application of the test, the supervisor (blinded to the subject's group) walked nearly 2 m behind the participant as to avoid influencing the subject's self-selected walking pace (Lord and Menz, 2002). Resting stops were allowed and participants were given standardized encouragement every 30 s. The time remaining was called every 2 mins and the supervisor stopped the participant when the 6 mins had finished (Lord and Menz, 2002).

Whole body reaction time: This was assessed by the Whole Body Reaction Timer (Takei Instruments, Japan). Participants, standing on a pair of pedals, had to react to one of four visual stimuli presented on a vertical screen that was adjusted to eye level. The stimuli were arrows indicating randomly forward, backward, left or right and were presented according to the testing protocol. Participants underwent four trials, in order to familiarize themselves with the test (one for each direction), followed by 16 test trials (Zisi et al, 2001). The whole body reaction time was recorded in seconds on the elapsed time between stimulus presentations and first peddle release. Cronbach's alpha coefficient for the 16 test trials was 0.85.

Static balance: Static balance was assessed using the one-leg stance test, which has been shown to be a useful measure of static balance in studies with older adults (Wolfson et al, 1995; Rooks et al, 1997). Each participant was asked to stand on the non-dominant leg, then to raise the other leg approximately 2 inches above ground, with the eyes open (Hu and Woollacott, 1994). The supervisor recorded the time (in seconds) from the instant the participant lifted the dominant foot until the raised foot touched the floor. Participants performed three trials for the non-dominant foot and the longest time was recorded.

Statistical analysis

Dependent variables in the present study were 1-RM lower body strength, 6-minute walk distance, whole body reaction time and one-leg stance time. Before the analysis, the distribution of the data was examined. Homogeneity and normality tests provided evidence for the normal distribution of the data.

A one-way analysis of variance was used initially, to examine if there were any differences among the three groups in the initial measurement values of each dependent variable. Further, a multivariate analysis of variance with repeated measures was conducted to examine any differences between time points (within each group) and between intervention (between groups) in the dependent variables.

Finally, a one-way analysis of variance was applied to examine the relative differences from pre- to post-exercise measurements. When F-values were significant, post-hoc comparisons of means were performed with the Scheffe's multiple comparison test. Pearson's correlation coefficient was used to express the relationship between measurements of interest. Statistical significance was accepted at $P<0.05$.

RESULTS

Baseline characteristics

The attendance rate was 98.5% for the 12-week programme in the 33 participants who completed the study. *Table 1* shows the baseline physical characteristics and physical activity levels of the experimental and control groups. No significant differences were found for the physical characteristics, physical activity levels and all pre-exercise values of 1-RM strength of lower body strength, 6-minute walk distance, reaction time and one-leg stance time between the HRE, MRE and control groups.

Outcome measurements

Table 2 presents the pre- and post-exercise values for the 1-RM lower body strength, 6-minute walk test, whole body reaction time and one-leg stance time in the three groups. MANOVA repeated measures (2 x 3) revealed significant interaction between the factors measure x group in 1-RM strength of the lower body body ($F_{2,30}$=89.548, $P<0.001$); 6-minute walk distance ($F_{2,30}$=71.091, $P<0.001$); whole body reaction time ($F_{2,30}$=8.655, $P\leq0.001$); and one-leg stance time ($F_{2,30}$=16.631, $P<0.001$). Further, Scheffe's tests were conducted to determine pre- and post-differences in each group (*Table 2*).

A one-way ANOVA revealed that the HRE and MRE groups improved significantly for all variables (6-minute walk test, whole body reaction time and

TABLE 1.
Physical characteristics of participants and physical activity levels according to the Baecke questionnaire for older adults (mean±standard deviation)

Intervention	Gender	Age (years)	Weight (kg)	Height (m)	Baecke score	Physical activity level
HRE (*n*=11)	7 women, 4 men	64.6±5.1	78.6±17.4	1.63±0.07	9.09±1.39	Low
MRE (*n*=12)	8 women, 4 men	65.7±4.2	78.7±10.6	1.59±0.07	9.21±1.27	Low
Control (*n*=10)	6 women, 4 men	64.4±3.4	75.0±11.6	1.59±0.08	9.10±1.24	Low

HRE=high-resistance exercise group; MRE=moderate-resistance exercise group one-leg stance time) when compared to the control group ($P<0.05$) (*Figures 1–3*). The HRE was more effective in increasing the 1-RM lower body strength when compared to MRE ($P<0.001$) and to the control ($P<0.001$) and MRE was more effective when compared to the control ($P<0.001$) (*Figure 4*).

A significant relationship was found between the change in 1-RM strength of lower body and the change in 6-minute walk test performance ($r=0.715$, $P<0.001$) for all participants.

DISCUSSION

The results of this study indicate that both the HRE and MRE programmes improved functional performance (as measured by the 6-minute walk test, whole body reaction time and static balance) in healthy inactive older adults. It is important to note that the study design included healthy participants with low physical activity and strength levels according to the physical activity questionnaire and baseline strength values. Baseline levels of the above variables allowed further improvements in functional and neuromotor performance with a resistance exercise programme in inactive older adults.

The performance of a 6-minute walk test is a general indicator of physical performance and mobility in populations of older adults (Lord and Menz, 2002). According to the findings of this study, a 12-week resistance exercise programme, with high and moderate intensity, produced significant improvements in the 6-minute walk performance in older adults. The average improvement in the 6-minute walk test was 27% and 31% for the HRE and MRE groups respectively. These findings are comparable with previous studies (Ades et al, 1996, 2003; Cavani et al, 2001).

An additional important finding of this study was the presence of a significant correlation between the change in 1-RM strength of the lower limbs and the change in 6-minute walk performance. Ades et al (1996) reported a significant relationship between the change in leg strength and the change in walking endurance. Although there were significant differences in the effectiveness of 1-RM strength of the lower body between the two experimental groups, there were no significant differences in the effectiveness in the 6-minute walk performance among the exercise groups. Perhaps this was because of the existence of muscle thresholds and/or the duration of the exercise programme.

Whole body reaction time is a task with increased attentiveness demands (Zisi et al, 2001). Both the HRE and MRE groups improved their whole body reaction time. Previous studies reported similar results following a 4-choice reaction task (Hassmen et al, 1992) and a 2-choice

TABLE 2.
Pre- and post-exercise measurements on 6-minute walk test, whole body reaction time and one-leg stance time (mean±standard deviation)

Measurements		HRE group (n=11)	MRE group (n=12)	Control (n=8)
1-RM of lower body	Pre	43.1±10.7	40.1±12.2	34.9±9.1
	Post	76.7±19.1*	57.9±17.0*	35.1±9.8
6-MWT (m)	Pre	460.9±35.7	449.6±37.4	441.0±48.5
	Post	589.1±50.4*	590.0±61.1*	445.5±40.9
WBRT (s)	Pre	1.1±0.3	1.0±0.1	1.1±0.2
	Post	0.9±0.3*	0.8±0.1*	1.1±0.2
OLST (s)	Pre	50.9±25.1	37.4±14.4	54.2±19.3
	Post	85.4±42.7*	77.5±51.0*	55.0±20.0

1-RM=one-repetition maximum; 6-MWT=6-minute walk test; WBRT=whole body reaction time; OLST=one-leg stance time; HRE=high resistance exercise; MRE=moderate resistance exercise; *$P<0.01$ significant differences between pre- and post-exercise values

***Figure 1.** Changes (%) in 6-minute walk distance after the exercise period in the three groups (mean±standard deviation). 6 MWD=6-minute walk distance; HRE=high resistance exercise; MRE=moderate resistance exercise; C=control; *P <0.01 significant differences between HRE and C groups; #P <0.01 significant differences between MRE and C groups.*

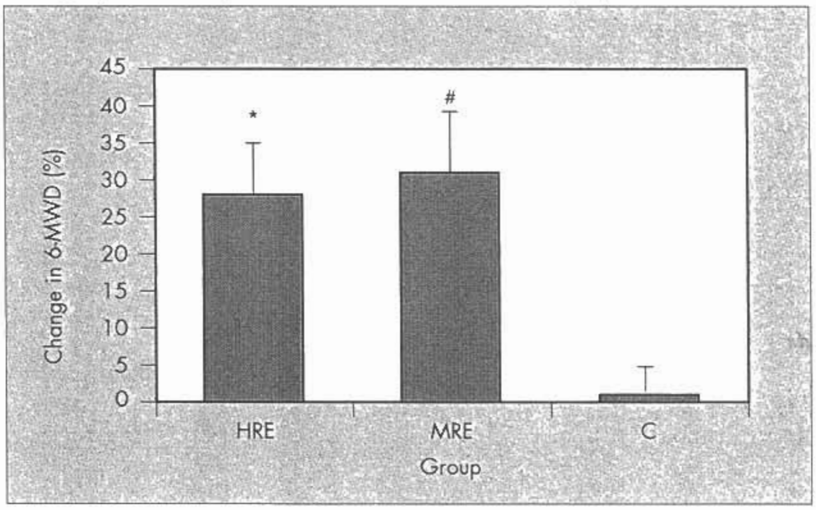
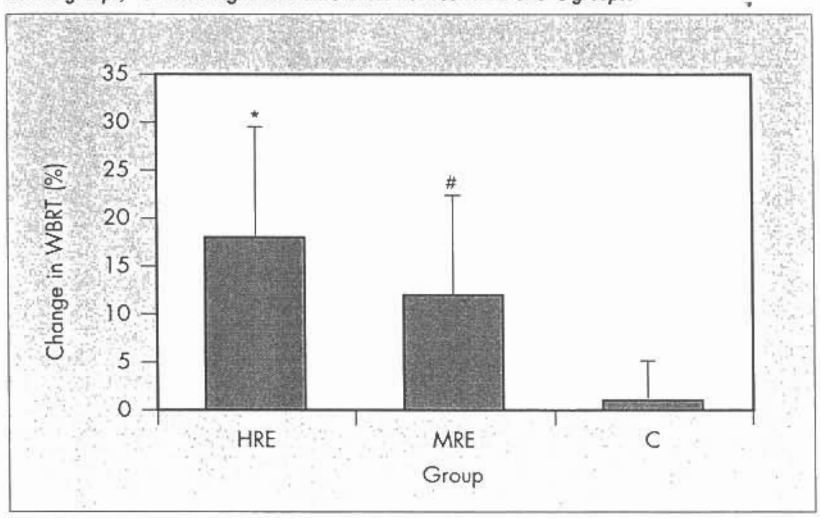


***Figure 2.** Changes (%) in whole body reaction time after the exercise period in the three groups (mean±standard deviation). WBRT=whole body reaction time; HRE=high resistance exercise; MRE=moderate resistance exercise; C=control; *P <0.01 significant differences between HRE and C groups; #P <0.01 significant differences between MRE and C groups.*



reaction task (Lord et al, 1995; Rooks et al, 1997) in using various programmes of exercise. The improvement of reaction time in older people through physical activity may be attributed to central processing in the pre-motor component, which suggests larger gains in cognitive processes involved in decision making (MacRae et al, 1996).

Muscle weakness may also be a factor in balance dysfunction (Woollacott and Shumway-Cook, 1990). One-leg stance time is one of the most commonly used measures of balance and is correlated with other measures of physical performance (Wolfson et al, 1995). According to the findings of this study, strength played an important role in the enhancement of static balance in healthy older adults with low physical activity and strength levels. Both resistance exercise groups significantly improved the one-leg stance time on the non-dominant leg.

Previous studies have shown that an exercise programme might enhance static balance (Wolfson et al, 1995; Rooks et al, 1997). One possible reason for the positive effect of resistance exercise on one-leg stance time was better neuromuscular control and synergy between the muscles; an effect that resulted from both resistance training programmes. A previous study reported that strength gains in hip abductor muscles led to better pelvic control of body weight during one-leg standing (Judge et al, 1993).

*Figure 3. Changes (%) in one leg stance time after the exercise period in the three groups (mean±standard deviation). OLST=one leg stance time; HRE=high resistance exercise group; MRE=moderate resistance exercise group; C=control group; *P <0.01 significant differences between HRE and C groups; #P <0.01 significant differences between MRE and C groups.*

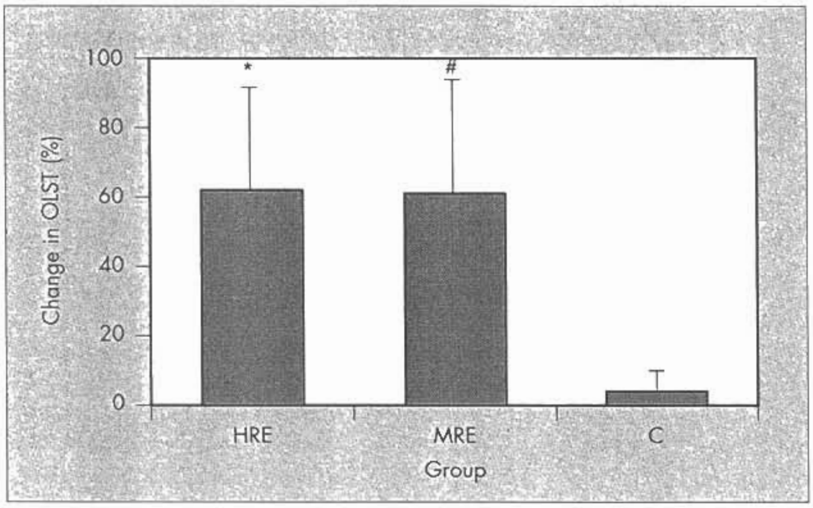
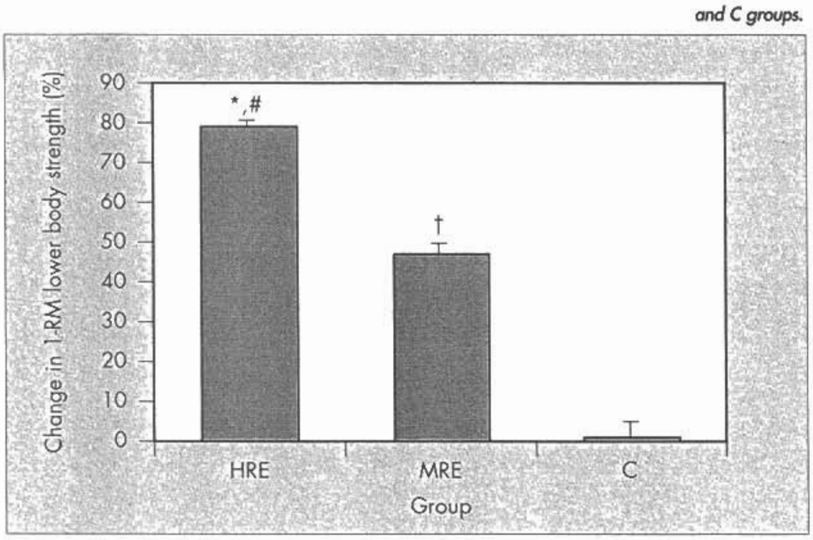


*Figure 4. Changes (%) in 1-RM lower body strength after the exercise period in the three groups (mean±standard deviation). HRE=high resistance exercise group; MRE=moderate resistance exercise group; C=control group; *P <0.01 significant differences between HRE and C groups; #P <0.01 significant differences between HRE and MRE groups; †P <0.01 significant differences between MRE and C groups.*



This study has provided information on the effectiveness of a high- and a moderate-resistance exercise programme in functional and neuromotor performance. Similar improvements were observed in the 6-minute walk test, whole body reaction time and one-leg stance time between the HRE and MRE groups after the exercise period. A previous study showed similar results (Vincent et al, 2002). Perhaps this is a result of the existence of minimum thresholds in muscle strength of lower limbs, required for the effective completion of functional performance tests (Buchner and de Lateur, 1991). It was also noticed that the absolute difference in the weight being lifted between the two intensities was small and the programme was of short duration. It is not known what differences in functional and neuromotor performance would be presented after long duration between the two intensities.

In conclusion, the findings indicate that a short high- or moderate-resistance exercise programme improved the functional performance, whole body reaction time and static balance in inactive older adults. This suggests that resistance exercise is an effective intervention to prevent reduction of functional capacity and disability in older adults. Future studies need to evaluate the long-term effects of resistance exercise with different intensities in older adults. IJTR

Conflict of interest: none.

Ades PA, Ballor DL, Ashikaga T, Utton JL, Nair KS (1996) Weight training improves walking endurance in healthy elderly persons. *Ann Intern Med* **124:** 568–72

Ades PA, Savage PD, Cress EM et al (2003) Resistance training on physical performance in disabled older female cardiac patients. *Med Sci Sports Exerc* **35:** 1265–70

Brandon LJ, Boyette LW, Gaasch DA, Lloyd A (2000) Effects of lower extremity strength training on functional mobility in older adults. *J Aging Phys Activity* **8:** 214–27

Buchner DM, de Lateur BJ (1991) The importance of skeletal muscle strength to physical function in older adults. *Ann Behav Med* **13:** 91–8

Cavani V, Tummers N, Musto AA, Mier CM (2001) Effects of a progressive resistance training program on functional abilities in older men and women. *Med Sci Sports Exerc* **33:** S254

Fiatarone MA, Marks EC, Ryan ND, Meredith CN, Lispitz LA, Evans WJ (1990) High intensity strength exercise in nonagenarians: effects on skeletal muscle. *JAMA* **263:** 3029–34

Frontera WR, Meredith CN, O'Reilly KP, Knuttgen HG, Evans WJ (1988) Strength conditioning in older men: skeletal muscle hypertrophy and improved function. *J Appl Physiol* **64:** 1038–44

Hassmen P, Ceci R, Backman L (1992) Exercise for older women: a training method and its influences in physical and cognitive performance. *Eur J Appl Physiol* **64:** 460–6

Hu MH, Woollacott MH (1994) Multisensory training of standing balance in older adults: postural stability and one

leg stance balance. *J Gerontol* **49:** M52–61
Hurley BF, Redmond RA, Pratley RE, Treuth MS, Rogers MA, Goldberg AP (1994) Effects of strength training on muscle hypertrophy and muscle cell disruption in older men. *Int J Sports Med* **16:** 378–84
Judge JO, Underwood M, Gennosa T (1993) Exercise to improve gait velocity in older persons. *Arch Phys Med Rehabil* **74:** 400–6
Kalapotharakos VI, Michalopoulos M, Godolias G et al (2004) The effects of high and moderate resistance training on muscle function in the elderly. *J Aging Phys Activity* **11:** 131–42
Lord SR, Menz HB (2002) Physiologic, psychologic, and health predictors of 6-minute walk performance in older adults. *Arch Phys Med Rehabil* **83:** 907–11
Lord SR, Ward JA, Williams P, Strudwick M (1995) The effect of a 12-month exercise trial on balance, strength, and falls in the older women: a randomized controlled trial. *J Am Geriatr Soc* **43:** 1198–206
MacRae PG, Morris C, Lee CY et al (1996) Fractionated reaction time in women as a function of age and physical activity level. *J Aging Phys Activity* **4:** 14–26
McCusker J, Bellavance F, Cardin S, Belzile E (1999) Validity of an activities of Daily Living Questionnaire among older patients in the emergency department. *J Clin Epidemiol* **52:** 1023–30
Rooks DS, Kiel DP, Parsons C, Hayes W (1997) Self paced resistance training and walking exercise in community dwelling older adults: effects on neuromotor performance. *J Gerontol* **52:** M161–8
Swisher A, Goldfarb A (1998) Use of the six minute walk/run test to predict peak oxygen consumption in older adults. *Cardiopulm Phys Ther* **9:** 3–5
Vincent KR, Braith RW, Feldman RA et al (2002) Resistance exercise and physical performance in adults 60–83. *J Am Geriatr Soc* **50:** 1100–7
Voorrips LE, Ravelli ACJ, Dongelmans PCA, Deurenberg P, Van Staveren WA (1991) A physical activity questionnaire for the elderly. *Med Sci Sports Exerc* **23:** 974–9
Whipple RH, Wolfson LL, Amerman PM (1987) The relationship of knee and ankle weakness to falls in nursing home residents: an isokinetic study. *J Am Geriatr Soc* **35:** 13–20
Wolfson L, Judge J, Whipple R, King M (1995) Strength is a major factor in balance, gait, and the occurence of falls. *J Gerontol* **50:** 64–7
Woollacott MH, Shumway-Cook A (1990) Changes in posture control across the life span – a system approach. *Phys Ther* **70:** 799–807
Zisi V, Michalopoulou M, Tzetzis G, Kioumourtzoglou E (2001) Effects of a short term exercise program on motor function and whole body reaction time in the elderly. *J Hum Movement Stud* **40:** 145–60

KEY POINTS

- Resistance exercise can prevent or delay the development of functional limitations in older adults.
- Short high- and moderate-resistance exercise programmes improve functional performance, whole body reaction time and static balance in inactive older adults.
- High- and moderate-intensity resistance exercise improves functional and neuromotor performance in older adults after a 12-week period of exercise.
- Both high- and moderate-resistance exercises can be safely applied in healthy older adults with low levels of physical function.

COMMENTARY

More than 10 years have elapsed since Fiatarone et al's (1990) seminal work, which suggests that even frail nonagenarians could benefit from resistance exercise training (RET) by gaining muscle strength. Although a volume of research on the effects of exercise among the elderly has accumulated in that time, too little of it has focused on RET and on the merits of different levels of intensity.

This article makes a valuable point by demonstrating that moderate- as well as high-intensity RET yields significant improvement in neuromuscular function. Given the benefits attributable to RET for elderly people as demonstrated in empirical research – from increased metabolism and body weight management, to insulin regulation, to increased muscle mass and the reversal of sarcopenia (Dutta and Hadley, 1995), to improvements in function – it has been somewhat puzzling that RET has not, as yet, become popular among older people. This may be owing to notions that RET is only effective if performed at high levels of intensity – and this might lead many elderly to choose other exercise options because of concerns about safety, tolerability and capability.

The ideal level of intensity for any RET programme will depend on a number of factors and thus could be highly variable across different populations. Nevertheless, some resistance training is better than none, even if this requires beginning with minimal levels of resistance and frequency.

The development of resistance training products such as elastic bands has helped eliminate many of these concerns. These products have proven indispensable for testing the use and effectiveness of resistance training in special populations, such as people with dementia. Research shows that even in such populations, gains in neuromuscular strength and function can be achieved with RET (Thomas and Hageman, 2003).

The benefits of RET can be obtained by all people, even bedbound frail elderly. Adhering to a number of basic tenets regarding resistance-training can improve the yield from the exercise:

1. Resistance exercise protocols should be designed to be specific to the physiological systems targeted and strength should be developed through training of the targeted muscle group.
2. Less muscle is activated as strength increases with training unless resistance is also progressively increased.
3. Varying the resistance as well as the number of sets and/or repetitions tends to be associated with greater increases in strength.

This article demonstrates that among sedentary older people, RET gains can be realized at even a moderate intensity level. RET for the elderly continues to gain credibility, whether in combating depression (Singh et al, 2001) or, as new research suggests (Thomas and Petzel, 2004), in maintaining cognition.

Although exercise is not a panacea, resistance exercise may emerge as a very efficient therapeutic strategy for maintaining the bone health and muscle mass that underlie physical function and simultaneously stirring the neurogenic pathways associated with the maintenance of cognitive function. 'Starting low and going slow' will allow the maximum number of people to benefit by identifying a level of intensity that encourages adherence.

Vince S Thomas
Assistant Professor
Center for the Aging, Center for the Evaluative Clinical Sciences
Dartmouth Medical School
Hanover NH 03755
USA

Dutta C, Hadley EC (1995) The significance of sarcopenia in old age. *J Gerontol A Biol Sci Med Sci* **50:** 1–4
Thomas VS, Hageman PA (2003) Can neuromuscular weakness in people with dementia be rehabilitated using resistance exercise training? Results from a preliminary intervention study. *J Gerontol A Biol Sci Med Sci* **58**(8): 746–51
Thomas VS, Petzel JB (2004) Can (resistance) exercise training improve cognitive and physical function in an elderly patient with dementia? A case report. *Brain Aging* **4:** 41–5
Singh NA, Clements KM, Singh MA (2001) The efficacy of exercise as a long-term antidepressant in elderly subjects: a randomized, controlled study. *J Gerontol* **56**(8): M497–504