Scand J Med Sci Sports 2002: 12: 186–192
Printed in Denmark . All rights reserved

SCANDINAVIAN JOURNAL OF
MEDICINE & SCIENCE
IN SPORTS

A randomized controlled trial of rehabilitation after hospitalization in frail older women: effects on strength, balance and mobility

Leena Timonen[1], Taina Rantanen[2], Olli-Pekka Ryynänen[3], Simo Taimela[4], Tero E. Timonen[5], Raimo Sulkava[6]

[1]*Health Center of the City of Joensuu, Joensuu, Finland,* [2]*Department of Health Sciences, University of Jyväskylä, Jyväskylä, Finland,* [3]*Department of Public Health and General Practice, University of Kuopio, Finland,* [4]*DBC International, Vantaa, Finland,* [5]*Department of Psychology, University of Joensuu, Joensuu, Finland,* [6]*Department of Public Health and General Practice, Kuopio University Hospital, Kuopio, Finland*
Corresponding author: Leena Timonen, M.D., General Practitioner, Health Center of the City of Joensuu, FIN-80130 Joensuu, Finland

Keywords: exercise; muscle force; balance; gait.

Accepted for publication 17 August 2001.

When frail older people become acutely ill, they are at increased risk of further functional deterioration and rehabilitation is needed to restore functioning. The effects of an out-patient multicomponent training program including strength training after hospitalization were studied in a randomized controlled trial. Sixty-eight women (mean age 83.0 ± 3.9 years) who were hospitalized due to an acute illness and were mobility impaired at admission were randomized into training ($N = 34$) and home exercise ($N = 34$) groups. Maximal voluntary isometric strength of knee extension and hip abduction, dynamic balance, and maximal walking speed were measured before and after the 10-week training period, and 3 and 9 months after the end of the intervention. After the intervention, significant improvements were observed in the training group compared to the home exercise group in the maximal voluntary isometric knee extension strength (20.8% vs. 5.1%, $P = 0.009$), balance scale (+ 4.4 points vs. − 1.3 points, $P = 0.001$) and walking speed ($+0.12\,\mathrm{m\,s^{-1}}$ vs. $-0.05\,\mathrm{m\,s^{-1}}$, $P = 0.022$). Effects on knee extension and hip abduction strength, balance and walking speed were observed 3 months later, and some effects on hip abduction strength (9.0% vs. − 11.8%, $P = 0.004$) and mobility were still apparent even 9 months after the intervention.

Frailty has been defined as a loss of the capacity to withstand even minor environmental stresses (Campbell, Buchner, 1997). Frail persons have decreased physiological reserve capacity and are thus at an increased risk of functional deterioration, institutionalization or even death following physical stress, such as an acute illness (Appelgate, Akins, Vander-Zvaag, Thonik, Baker, 1983). Treating the illness may not be sufficient to restore functional ability in frail patients, but more intensive approaches, such as exercise interventions, may be necessary to restore functioning and to increase reserve capacity (Pendergast, Fisher, Calkins, 1993; Campbell, Buchner, 1997).

Muscle weakness is a common feature in physical frailty, and immobility during hospitalization may cause further strength decline placing people at increased risk of disability (Creditor, 1993). Poor lower limb muscle strength has been found to be associated with such functional impairments as slow walking speed and balance problems (Young, 1986; Fiatarone, Marks, Ryan, Meredith, Lipsitz, Evans, 1990; Rantanen, Era, Heikkinen, 1994).

Several studies have demonstrated the reversibility of age-related strength loss (Fiatarone, O'Neil, Ryan, Clements, Solares, Nelson, 1990; Grimby, Aniansson, Hedberg, Henning, Grangård, Kvist, 1992; Sauvage, Myklebust, Crow-Pan, Novak, Milington, Hoffman, 1992; Fiatarone et al., 1994) and loss of function, e.g. gait speed (Sauvage *et al*., 1992; Ettinger et al., 1997). In most of these studies, however, the research subjects comprised healthy elderly people (Frontera, Meredith, O'Reilly, Knuttgen, Evans, 1988; Brown, McCartney, Sale, 1990; Charette, McEnroy, Pylk, Show-Marter, Guido, Miswell, 1991; Grimby, 1992; Nichols, Hitzelberger, Sherman, Patterson, 1995; Sipilä & Suominen, 1995; Skelton, Young, Greig, Malbut, 1995). Few studies have focused on home-dwelling older persons with comorbidity and functional disabilities (Lord, Ward, Williams, Strudwick, 1995; Campbell, Robertson, Gardner, Norton, Tilyard, Buchner, 1997; Ettinger et al., 1997; Chandler, Duncan, Kochersberger, Studenski, 1998; Harridge, Kryger, Stensgaard, 1999). Although strength training has been proved to be safe and effective even among frail nursing home residents (Fiatarone et al., 1990; Sauvage et al., 1992; Fiatarone et al., 1994), its use as a means of secondary prevention in primary health care settings has not been addressed. Moreover, no previous studies have implemented strength-training interventions shortly after hospitalization in home-dwelling frail patients.

Muscular weakness (Skelton, SGreig, Davies, Young, 1994), as well as difficulties in daily activities are a common problem in older women (Katz, Branch, Branson, Pepsidero, Beck, Greer, 1983; Jylh, Jokela, Tolvanen Heikkinen, Koskinen, 1992; Guralnik & Simonsick 1993; Laukkanen, Kauppinen, Era, Heikkinen, 1993), and therefore it is important to develop effective interventions suitable for this group.

The aims of this study were (1) to investigate the effects of an outpatient multicomponent training program including strength training on muscle strength, balance and walking speed in old, home-dwelling, frail women recently discharged from a hospital ward, and (2) to determine how long such effects may last.

Materials and methods

Study design

This study was designed to evaluate the effects of a 10-week training program after hospitalization on lower limb muscle strength, gait speed, and balance. The baseline measurements were performed 1 week before the start of the intervention and the follow-up measurements were at 1 week, 3 months, and 9 months after the end of intervention.

Participants were recruited from a geriatric ward of a primary-care health-center hospital. The ward with approximately 500 admissions annually was designed for short-term hospitalization. The subjects were selected from successive female patients who were admitted for an acute illness, living in the center of Joensuu, a city of 50 000 inhabitants in Eastern Finland. The inclusion criteria were age 75 years or older and had difficulties in mobility and balance, such as dizziness or difficulty to walk independently. Exclusion criteria included severe heart or circulatory disease, severe dementia, acute bone fracture, malignant terminal disease or the inability to walk.

The number of eligible candidates was 79, of whom 11 refused to participate before randomization. Written informed consent was given by 68 women, who were then randomized after the baseline measurements into training ($N = 34$) and control ($N = 34$) groups using closed envelopes in blocks of four (Fig. 1).

Measurements

A nurse interviewed the subjects to collect information on functional capacity. Weight was measured during hospitalization and information on medication and diseases was obtained from medical records. Strength and physical performance tests were performed by two trained physiotherapists and a physician. Baseline measurements were performed during the final days of hospitalization in the Health Center. Follow-up tests were performed in the same place 1 week, and 3 and 9 months after the 10-week intervention.

The maximal voluntary isometric strength of knee extension was measured in a sitting position with knee flexed at an angle of 60 degrees from full extension using an adjustable dynamometer chair constructed at the Department of Health Sciences, University of Jyväskylä (Viitasalo, Era, Leskinen, Heikkinen, 1985). The measurement was performed separately for the left and right knee, and the best result of three trials was recorded for each knee. For the analyses, the average of the maximum left and right knee extension forces was calculated. The maximal isometric hip abduction strength was measured bilaterally using the training equipment with a measurement device attached to it (David Rehab System, David 330, Vantaa, Finland). During the test, the subject was seated on the training equipment with back supported and knees slightly bent. The test was performed at a hip abduction angle of 60 degrees, and the result was the force created when both hips were simultaneously abducted. For each test, three trials were conducted, with 1-min intervals. The best measurement was accepted as the final result. Subjects were encouraged to achieve their best performance. Performing the measurement in a sitting position gives actually the combined strength of hip abduction and flexion rather than the abduction strength alone. This was, however, the most convenient way of measuring hip abduction strength for our research subjects with poor standing balance.

Maximal walking speed over 10 m was tested in the hospital corridor. Subjects were asked to walk as fast as possible and were given 1–2 m to accelerate their speed before timing with a stop-watch was started. The best of two trials was taken for analyses. Participants were allowed to use their walking aids.

For balance measurements, the 14-item Berg Balance Scale was used (Berg, Wood-Dauphinee, Williams, Maki, 1992). The scale includes both static and dynamic tasks, such as standing, turning, and picking up objects.

Statistical methods

The data were analyzed using the Statview 4.01 and SuperANOVA (Abacus Concepts, 1989) statistical packages. For strength measurements, the results from the 1-week, 3-month, and 9-month follow-up tests were compared to those from the baseline tests. A percentage change was calculated for each subject as follows: [(follow-up result—baseline result)/baseline result)] × 100. For the 10-m maximal walking speed test, individual changes relative to the baseline results were expressed as meter/s, and changes in the balance test as points. The differences in average individual change values between the groups were compared with analyses of covariance using weight as a covariate (posthoc-analyses Fisher's PLSD). Fisher's exact-test (two-sided) was used in both the intention-to-treat analyses and for all categorical data. The Mann–Whitney U-test was used to compare those who dropped out from the study to those who continued in the study.

Ethics

This study was approved by the Ethics committee of the Joensuu Municipal Health Center, and all participants gave written informed consent.

Intervention

Subjects assigned to a training group started training usually 1 week after discharge. Training classes were given twice a week, for a 10-week period (20 sessions, 90 min each), and the training sessions were supervised by two physiotherapists. Subjects were provided with transportation, and lunch was served after each

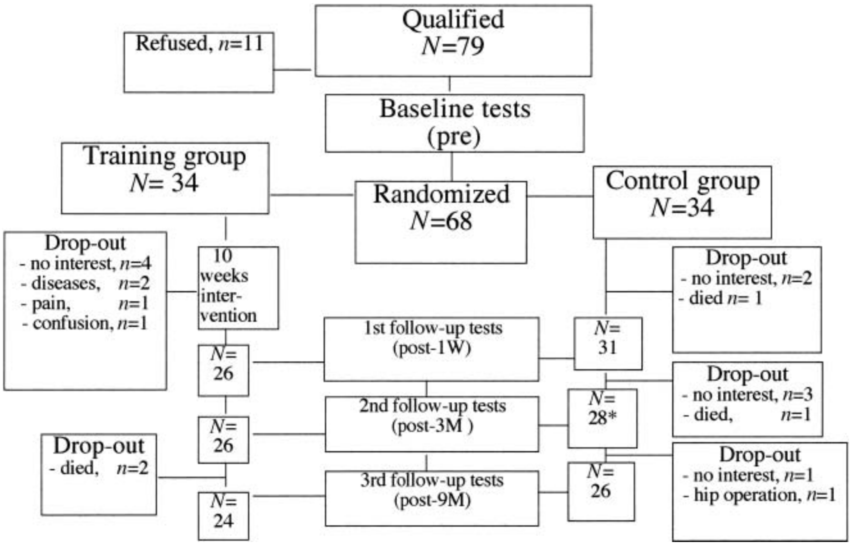

Fig. 1. Flow chart showing the numbers of the participants and drop-outs. Pre = baseline tests before intervention, post-1 W, post-3M, post-9 M = follow-up tests 1 week, 3 months and 9 months after the intervention. *One subject who refused to participate in the 1-week test, but subsequently participated in the study in the 3- and 9-month tests.

training session. There were 3–8 trainees in the group at the same time.

Each session started with a warm-up period of 15 min. Progressive resistance training for knee extension, knee flexion and hip abduction was performed on weight training equipment based on the principle of variable resistance (David 200, 300, 330, David Fitness and Medical Ltd., Vantaa, Finland). The training phase lasted about 30 min, During the first four sessions, only low weights were used with 20–30 repetitions. Thereafter, the loads were gradually increased to the point where the participant could accomplish only 8–10 repetitions in two sets with the encouragement of the trainer. To maintain the relative intensity of the stimulus, weight loads were further increased as muscle strength increased. Hip adduction was trained with low weights as a warm-up exercise.

In addition to strength training, functional exercises were also incorporated, such as rising from a chair, hip flexion and extension in a standing position and rising to a tiptoe position and elbow flexion using light (1–2 kg) ankle or wrist weights.Two sets of 15 repetitions of each of these exercises were performed in each session. The functional exercises took about 30 min.

At the end of each session, there was a relaxation period of 15 min on the floor with guided imagery employing the tension–relaxation method. The participants were taught a stretching program to be performed at home later during the same day.

Control subjects received one visit from a physiotherapist within 1 week after hospitalization at their homes. During the visit, a home exercise program including the functional exercises as described above was taught. The subjects were advised to perform two sets of 15 repetitions 2–3 times a week. No further encouragement to exercise was given to the control subjects.

Results

There were no differences in medications, diseases, or need for external help between the intervention group and the control group (Tables 1 and 2). The average age of the participants was 83.5 (SD 4.1) years in the training group and 82.6 (SD 3.7) years in the control group ($P = 0.334$). Groups did not differ in relation to functional abilities except in their need for walking aids. The training group subjects needed a walker more often than did the control subjects (17 vs. 8, $P = 0.027$). Subjects in the training group were slightly heavier at the baseline (65.3 kg vs. 60.8 kg, $P = 0.126$) but the weight difference declined over the 1-year follow-up (63.1 kg vs. 60.0 kg, $P = 0.444$). Consequently, weight was used as a covariate in statistical analyses.

Eight subjects dropped out from the training group during intervention (Fig. 1). Four subjects withdrew due to a lack of motivation, one was hospitalized because of an eye disease and one because of thoracic spine pain, which already existed before starting in the training group. One subject discontinued because of hip joint pain, and one because of confusion due to dementia. The drop-outs did not differ from those who continued to train in the baseline tests, diagnoses, medication or functional capacity. Those who continued training attended an average of 18 sessions (range 11–20). There were no unexpected health occurrences during the sessions. At the first follow-up measurements 22/32 (69%) control group subjects reported to have performed regular home exercises on average 68 min a week (median 61, IQR 35).

One week after the intervention, significantly greater improvements in the training group compared to the control group were observed for the knee extension strength (20.8% vs. 5.1%), walking speed ($0.12\,\mathrm{m\,s^{-1}}$. vs. $-0.05\,\mathrm{m\,s^{-1}}$.) and balance (4.4 points vs. −1.3 points) (Table 3). The 3-month test showed that in the training group, the average changes relative to the baseline in all the tests including the hip abduction strength, were significantly greater than in the control group. At the 9-month tests, the average changes in the

Table 1. Reasons for admission, diseases and medication in the training and control groups. Frequencies and percentages

	Training group $N = 34$		Control group $N = 34$		
	F	%	*F*	%	*P*
Reason for admission					
Musculoskeletal	13	38	14	41	0.810
Infections	10	29	8	24	0.597
Cardiovascular	7	21	6	18	>0.999
Gastrointestinal	2	6	5	15	0.428
Diabetes	2	6	1	3	0.619
Chronic conditions					
Cardiovascular	30	88	31	91	0.714
angina pectoris	17		18		
heart failure	10		11		
high blood pressure	12		8		
arrhythmia	8		7		
cerebrovascular	3		4		
Arthritis	16	47	12	35	0.339
Diabetes	7	21	6	18	>0.999
Pulmonary disease	4	12	8	24	0.341
Diseases of spine	4	12	7	21	0.349
Depression	8	24	3	9	0.115
Medication in use					
Drugs for cardiovasc. system	32	94	31	91	0.678
Painkillers	16	47	19	56	0.480
Sleeping pills	18	53	15	44	0.628
Antidepressants	7	21	3	9	0.305

Difference between the groups was calculated using Fisher's exact (two-sided) test.

Table 2. Characteristics of the participants at baseline, frequency (%)

	Training group $n = 34$		Control group $n = 34$		
	F	%	*F*	%	*P*
Live alone	29	85	27	79	0.752
Communal home help	14	41	19	56	0.238
Communal home care	11	32	9	26	0.608
Need a walker	17	50	8	24	0.027
Need help in ADL	17	50	11	32	0.218

Differences between the groups were calculated using the Fisher's exact test (two-sided). ADL = eating, bathing, toileting, or dressing.

Table 3. Changes in maximal voluntary strength measurements, maximal walking speed, and Berg Balance scale

	Maximal voluntary isometric strength of				Maximal walking		Berg Balance	
	Knee extension % (SD)		Hip abduction % (SD)		speed m/s (SD)		Scale score (SD)	
	Training	Control	Training	Control	Training	Control	Training	Control
Post-1 W vs. pre	20.8 (25.9)	5.1 (16.0)	13.2 (28.8)	5.6 (22.4)	0.12 (0.32)	−0.05 (0.23)	4.4 (7.2)	1.3(5.5)
(N=26+31) P	0.009		0.292		0.035		0.001	
Post-3M vs. pre	21.3 (23.9)	6.7 (25.2)	12.0 (19.9)	−4.5 (31.7)	0.11 (0.25)	−0.09 (0.28)	4.2 (6.2)	−0.3(7.2)
(N=26 + 28) P	0.038		0.037		0.011		0.018	
Post-9M vs. pre	7.9 (22.5)	−3.2 (16.3)	9.0 (19.7)	−11.8 (25.0)	0.05 (0.25)	−0.09 (0.18)	1.3 (7.6)	−0.7(6.0)
N=24+26) P	0.078		0.004		0.028		0.347	

Pre: baseline measurements prior to the intervention; **post-1W, post-3M, post-9M**: follow-up measurements 1 seek, 3 months, and 9 months after the end of intervention. Mean change values (SD) (**post-1W vs. pre, post-3M vs. pre, post-9M vs. pre**) have been calculated subtracting follow-up values from baseline values and the differences in average individual change values between the groups were compared with analyses of covariance (weight as a covariate). Numbers of subjects (training + control).

training group were still significantly better in walking speed and hip abduction strength compared to the control group. The absolute values of the measurements are presented in the Fig. 2.

When taking the drop-outs into account in the intention-to-treat analyses (Table 4), the improvements in balance and walking speed were significantly better in the training group than in the control group, and

Table 4 Number of subjects who showed distinct improvements at the measurements one week after the intervention

	Training group ($N = 34$)	Control group ($N = 34$)	*P*
Knee ext. strength > 20%	15	8	0.081
Walking speed > 0.1 m s^{-1}	16	4	0.003
Balance > 6 points	12	3	0.017
2–3 items	14	3	0.004

Knee ext. strength > 20% = number of subjects with increases over 20% in right or left knee maximal voluntary extension strength. Walking speed > 0.1 m s^{-1} = number of subjects with improvement over 0.1 m s^{-1} in 10-m walking speed. Balance > 6 points = number of subjects whose Balance Scale score improved by 6 points or more, 2–3 items = number of subjects whose performance improved in at least two of above items (knee extension strength, walking speed, or balance). Comparisons were made using the Fisher's exact test (two-sided).

strength test results approached statistical significance. There were significantly more subjects in the training group who could achieve distinct improvements in at least two of the three tests (maximal voluntary isometric knee extension strength, balance and walking speed) compared to those in the control group.

Discussion

This study showed that multicomponent training program including strength training soon after discharge from a geriatric ward was an effective form of rehabilitation for frail older women with mobility difficulties. The 10-week training program improved maximal voluntary isometric strength, balance and walking speed in the training group compared to the control group. Some of the improvements were present also at the 3- and 9-month follow-ups. To the best of our knowledge, no previous study has addressed progressive strength training as a secondary rehabilitation tool in frail, older women recuperating from an acute illness.

The percentage gains in muscle strength were comparable to those observed in other studies using isometric strength measurements as outcomes (Lord et al., 1995; Skelton et al., 1995; Chandler et al., 1998). Earlier studies have shown improved balance (Sauvage et al., 1992; Campbell et al., 1997; Nelson et al., 1994; Nichols et al., 1995) and mobility (Sauvage et al., 1992; Fiatarone et al., 1994; Skelton et al., 1995; Ettinger et al., 1997) after strength training interventions. However, how long the positive effects might last in home-dwelling, older women has not been studied before. In a study by Fiatarone et al. (1990) with institutionalized nonagenarians, 32% of the strength increase measured as a one-repetition maximum was lost 4 weeks after training. Our study indicated that the positive effects could last longer in community-dwelling elderly women. This difference in the duration of the strength gain may be due to differences in the methods of strength measurement (1RM vs.

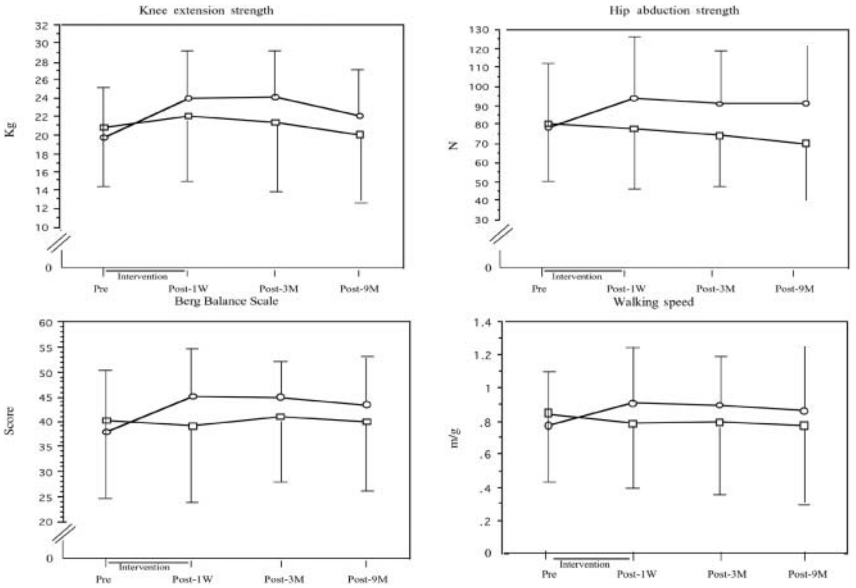

Fig. 2. The absolute values (± SD) of maximal voluntary isometric knee extension and hip abduction strengths, Berg Balance Scale, and maximal walking speed. 0: training group; □, control group. Pre = baseline tests before intervention, post-1 W, post-3M, post-9 M = follow-up tests 1 week, 3 months, and 9 months after the end of intervention.

maximal voluntary isometric strength) and to the differences in the amount of required daily physical activity among institutionalized and home-dwelling subjects.

There were two clinically important findings of this study. First of all, maximum walking speed improved as a result of training. Walking speed is a powerful predictor of future disability (Guralnik, Ferrucci, Simonsick, Salive, Wallace, 1995; Guralnik, Ferucci, Pieper, Leveille, Markides, Ostir, 2000). Consequently, improvement in walking speed may indicate a decrease in the risk of disability. Secondly, it was observed that for many women improvements following the training took place in multiple physiological systems. This may have a substantial effect on decreasing the risk of functional limitations and disability. It has been found that the presence of multiple physiological impairments places people at an increased risk of disability. In a study among older women, those who had both strength and balance impairments were 10 times more likely to have a severe walking disability as compared to those who had only one of the impairments (Rantanen, Guralnik, Ferrucci, Leveille, Fried, 1999). Consequently, multicomponent exercise programs aiming to improve strength, balance and skill as in the current study, may be efficient in decreasing risk of disability.

Our results demonstrate that multicomponent exercise programs for the elderly are applicable in the primary health care setting. As a form of rehabilitation, outpatient exercise sessions for groups are relatively inexpensive compared to traditional individual physiotherapy. The participants of the training group exhibited high motivation to exercise and had few prejudices towards the rehabilitation program, of which they had no previous experience. The attendance was satisfactory; despite the participants having multiple diseases, only eight of the initial 34 (24%) women withdrew from training classes. According to our clinical experience, the reasons for withdrawal from the study were the same as what may be expected to happen in a similar group over a period of one year.

Even though the current study was relatively small, it provides evidence that low-cost group exercise programs are feasible to carry out in primary care health centers. Multicomponent training program including strength training after an acute illness was an effective form of rehabilitation in frail women aged 75 years and over, and the benefits lasted at least for 9 months after training.

Perspective

Since an acute illness can be a turning point for a disabled old person, increasing the risk of further loss of independence, it is important to develop new rehabilitation methods for this patient group. Immobility during hospitalization can impair muscle strength to the point that everyday tasks such as rising from a chair or moving around indoors are not possible without assistance. Rehabilitation increasing muscle strength can produce positive effects on functions that are likely to deteriorate during an acute illness and hospital stay. Earlier studies have shown the effectiveness and safety of strength training among nursing home residents (Fiatarone et al., 1990, 1994; Sauvage et al., 1992). This study showed that exercise classes including strength training and functional exercises are applicable in the open care setting, improving muscle strength, balance and mobility.

The amount of home-dwelling older people is increasing in the near future and we need new and effective rehabilitation methods to keep them independent and to postpone institutionalization. Group-based training programs including both strength training and functional exercises could be a suitable method for those with mobility and balance problems.

Acknowledgements

This study was supported by grants from the Uulo Arhio Foundation. The authors want to thank David Fitness and Medical Ltd, Vantaa, Finland, for providing the resistance equipment and physiotherapists Marja Koivula and Katja Raiskio for their valuable contributions during our project.

References

Abacus Concepts. Superanova. Berkeley, CA: Abacus Concepts, Inc, 1989.

Appelgate WB, Akins D, Vander-Zwaag R, Thonik A, Baker MG. A geriatric rehabilitation and assessment unit in a community hospital. J Am Geriatr Soc 1983: 31: 206–210.

Berg KO, Wood-Dauphinee SL, Williams JI, Maki B. Measuring balance in the elderly. validation of an instrument. Can J Public Health 1992: 83 (Suppl. 2): S7–S11.

Brown AB, McCartney N, Sale DG. Positive adaptations to weight-lifting training in the elderly. J Appl Physiol 1990: 69: 1725–1733.

Campbell AJ, Buchner DM. Unstable disability and the fluctuations of frailty. Age Ageing 1997: 26: 315–318.

Campbell AJ, Robertson MC, Gardner MM, Norton RN, Tilyard MW, Buchner DM. Randomized controlled trial of a general practice programme of home based exercise to prevent falls in elderly women. BMJ 1997: 315: 1065–1069.

Chandler JM, Duncan PW, Kochersberger G, Studenski S. Is lower extremity strength gain associated with improvement in physical performance and disability in frail, community-dwelling elders? Arch Phys Med Rehabil 1998: 79: 24–30.

Charette SL, McEnvoy L, Pyka G, Snow-Marter C, Guido D, Wiswell RA, Marcus R. Muscle hypertrophy response to resistance training in older women. J Appl Physiol 1991: 70: 1912–1916.

Creditor MS. Hazards of hospitalization of the elderly. Ann Intern Med 1993: 118: 219–223.

Ettinger WH, Burns R, Messier SP, Applegate W, Rejeshi WJ, Morgen T, Shumaker S, Berry MJ, O'Toole M, Monu J, Craven T. A randomized trial comparing aerobic exercise and resistance exercise with a health education program in older adults with knee osteoarthritis. The Fitness Arthritis Seniors Trial (FAST). JAMA 1997: 227: 25–31.

Fiatarone MA, Marks EC, Ryan ND, Meredith CN, Lipsitz LA, Evans WJ. High-intensity strength training in nonagenarians. Effects on skeletal muscle. JAMA 1990: 263: 3029–3034.

Fiatarone MA, O'Neill EF, Ryan ND, Clements KM, Solares GR, Nelson ME, Roberts SB, Kehayias JJ, Lipsitz LA, Evans WJ. Exercise training and nutritional supplementation for physical frailty in very elderly people. N Engl J Med 1994: 330: 1769–1775.

Frontera WR, Meredith CN, O'Reilly KP, Knuttgen HG, Evans WJ. Strength conditioning in older men: skeletal muscle hypertrophy and improved function. J Appl Physiol 1988: 64: 1038–1044.

Grimby G, Aniansson A, Hedberg M, Henning G-B, Grangård U, Kvist H. Training can improve muscle strength and endurance in 78- to 84-yr-old men. J Appl Physiol 1992: 73: 2517–2523.

Guralnick JM, Ferrucci L, Pieper CF, Leveille SG, Markides KS, Ostir GV, Studenski S, Berkman LF, Wallace RB. Lower extremity function and subsequent disability: consistency across studies, predictive models, and value of gait speed alone compared with the short physical performance battery. J Gerontol Biol Sci Med Sci 2000: 55: M221–M231.

Guralnik JM, Ferrucci L, Simonsick EM, Salive ME, Wallace RB. Lower extremity function in persons over the age of 70 years as a predictor of subsequent disability. N Engl J Med 1995: 332: 556–561.

Guralnik JM, Simonsick EM. Physical disability in older Americans. J Gerontol 1993: 48: 3–10.

Harridge SD, Kryger A, Stensgaard A. Knee extensor strength, activation, and size in very elderly people following strength training. Muscle Nerve 1999: 22: 831–839.

Jylhä M, Jokela J, Tolvanen E, Heikkinen E, Heikkinen R-L, Koskinen S, Leskinen E, Lyyra A, Pohjolainen P. The Tampere longitudinal study on ageing. Description of the study. Basic results on health and functional ability. Scand J Soc Med 1992: 47: 1–58.

Katz S, Branch LG, Branson MH, Papsidero JA, Beck JC, Greer DS. Active life expectancy. N Engl J Med 1983: 309: 1218–1224.

Laukkanen P, Kauppinen M, Era P, Heikkinen E. Factors related to coping with physical and instrumental activities of daily living among people born in 1904, 1923. Int J Ger Psych 1993: 8: 287–296.

Lord SR, Ward JA, Williams P, Strudwick B. The effect of a 12-month exercise trial on balance, strength, and falls in older women: a randomized controlled trial. J Am Geriatr Soc 1995: 43: 1198–1206.

Nelson ME, Fiatarone MA, Morganti CM, Trice I, Greenberg RA, Evans WJ. Effects of high-intensity strength training on multiple risk factors for osteoporotic fractures. A randomized controlled trial. JAMA 1994: 272: 1909–1914.

Nichols JF, Hitzelberger LM, Sherman JG, Patterson P. Effects of resistance training on muscular strength and functional abilities of community-dwelling older adults. JAPA 1995: 3: 238–250.

Pendergast DR, Fisher NM, Calkins E. Cardiovascular, neuromuscular, and metabolic alterations with age leading to frailty. J Gerontol 1993: 48: 61–67.

Rantanen T, Era P, Heikkinen E. Maximal isometric strength and mobility among 75-year-old men and women. Age Ageing 1994: 23: 132–137.

Rantanen T, Guralnik JM, Ferrucci L, Leveille SG, Fried LP. Coimpairments. strength and balance as predictors of severe walking disability. J Gerontol: Med Sci 1999: 54A: M172–M176.

Sauvage LR, Myklebust BM, Crow-Pan J, Novak S, Millington P, Hoffman MI, Hartz AJ, Rudman D. A clinical trial of strengthening and aerobic exercise to improve gait and balance in elderly male nursing home residents. Am J Phys Med Rehabil 1992: 71: 333–342.

Sipilä S, Suominen H. Effects of strength and endurance training on thigh and leg muscle mass and composition in elderly women. J Appl Physiol 1995: 78: 334–340.

Skelton DA, Greig CA, Davies JM, Young A. Strength, power and functional ability of healthy people aged 65–89 years. Age Ageing 1994: 23: 371–377.

Skelton DA, Young A, Greig CA, Malbut KE. Effects of resistance training on strength, power, and selected functional abilities of women aged 75 and older. J Am Geriatr Soc 1995: 43: 1081–1087.

Viitasalo J, Era P, Leskinen AL, Heikkinen E. Muscular strength and anthropometry in random samples of men aged 31–35, 51–55 and 71–75 years. Ergonomics 1985: 28: 1563–1574.

Young A. Exercise physiology in geriatric practice. Acta Med Scand 1986: 771: 227–232.