



Low intensity training for frail elderly women; Long-term effects on motor function and mobility

池添, 冬芽

(Degree)

博士 (保健学)

(Date of Degree)

2006-03-25

(Date of Publication)

2009-04-10

(Resource Type)

doctoral thesis

(Report Number)

甲3655

(URL)

<https://hdl.handle.net/20.500.14094/D1003655>

※ 当コンテンツは神戸大学の学術成果です。無断複製・不正使用等を禁じます。著作権法で認められている範囲内で、適切にご利用ください。



博 士 論 文

論文題目

Low intensity training for frail elderly women:
long-term effects on motor functions and mobility.

(虚弱高齢女性に対する低負荷トレーニング：
運動機能及び移動能力に及ぼす長期的効果)

平成18年1月11日

神戸大学大学院医学系研究科保健学専攻

池 添 冬 芽

Low Intensity Training for Frail Elderly Women: Long-term Effects on Motor Function and Mobility

TOME IKEZOE¹⁾, AKIMITSU TSUTOU²⁾, YASUYOSHI ASAKAWA³⁾, TADAO TSUBOYAMA¹⁾

¹⁾Department of Physical Therapy, School of Health Sciences, Faculty of Medicine, Kyoto University: 53 Kawahara-cho, Shogoin, Sakyo-ku, Kyoto 606-8507, Japan.
TEL +81 75-751-3964

²⁾Faculty of Health Sciences, Kobe University School of Medicine

³⁾Department of Physical Therapy, Faculty of Medicine, Gunma University

Abstract. The effects of a low intensity training programme for 12 months on motor functions and mobility of institutionalized elderly women were investigated. The subjects comprised 28 elderly women aged 80.4 ± 5.4 years, who were assigned to either the control group (CG) ($n=15$) or the training group (TG) ($n=13$). Training 4 to 6 days a week with each session for about 20 minutes a day was performed. After training, a significant increase in quadriceps strength was observed in TG ($P<0.05$), but not in CG (mean \pm S.D.% = 22.2 ± 14.1 v.s. -9.8 ± 19.4). Ability of balance tested by functional reach was decreased in CG ($P<0.05$), whereas there was no change in TG (mean \pm S.D.% = -15.3 ± 23.4 v.s. -2.1 ± 15.3). Ambulatory status was reduced in CG, whereas there was no change in TG. These results suggest that low intensity training is effective for increasing strength and maintaining balance and mobility in frail elderly persons.

Key words: Elderly, Resistance training, Long-term effects

(This article was submitted Jan. 4, 2005, and was accepted Mar. 4, 2005)

INTRODUCTION

Human muscle strength reaches its peak between the second and third decades, and begins to decline thereafter at a rate of approximately 12% to 15% per decade with more rapid losses above the age of 65¹⁻³⁾. Muscle weakness in the elderly contributes greatly to gait disturbances and other functional restrictions on daily living activities⁴⁻⁷⁾. In addition, loss of muscle strength is associated with an increased risk of falls, and adverse physiological changes such as loss of bone mineral density, which may result in a predisposition to osteoporosis-related fractures⁸⁻¹⁰⁾.

Since the end of the 1980s, a number of studies have been published each year to document the benefits of progressive strength training not only for

young and middle-aged adults but also for older men and women¹¹⁻¹³⁾. The trainability of the muscles of healthy elderly subjects has been established, but the effectiveness of exercise training for more severely impaired, frail elderly persons, as might be found in long-term care settings or nursing homes, has remained unclear. Our study focused on the residents of a nursing home because of the high prevalence of physical frailty, functional dependency, muscle weakness, and recurrent falls among nursing home residents as the result of physical inactivity and acceptance of a sedentary lifestyle¹⁴⁾. Although several authors have recommended that frail adults use lower-intensity for training, there is little information about whether a low-intensity stimulus with minimal progression leads in fact to a consistent

increase in strength in the frail institutionalized elderly population.

We therefore examined the effects of a low-intensity training programme on the motor functions and mobility of frail elderly persons.

METHODS

Subjects

The subjects comprised 28 elderly women, aged 80.4 ± 5.4 (range, 70–92) who were residents in the same nursing elderly home in Kyoto, Japan. None of the residents had any serious dementia or physical dysfunction that would affect activities of daily living. All were capable of ambulating with or without assistive devices and could follow simple directions. Subjects were excluded if they had an acute neurological impairment (acute stroke, Parkinson's disease, paresis of lower limbs), severe cardio-vascular disease (acute myocardial infarction, congestive heart failure, uncontrolled hypertension), unstable chronic or terminal illness (uncontrolled diabetes mellitus, malignancies), major depression, severe cognitive impairment (inability to follow training instructions), or severe musculoskeletal impairment (inability to participate in the training regimen).

After baseline assessment, thirteen women agreed to participate in the training programme for 12 months. Fifteen women who declined to join the training session composed the control group. They were instructed to continue their daily routines.

Measurements (Outcome Measures)

Quadriceps muscle strength, balance, grip strength, and mobility were assessed in all subjects at the beginning and the end of the 12-month intervention period. Functional Independence Measure (FIM)¹⁵ and ambulatory status were used for measuring mobility. Ambulatory status of the subjects were categorized into 3 stages as stated below.

1) Quadriceps strength

Quadriceps strength was measured by isometric dynamometer (GT-10, OG GIKEN Co.) during isometric contraction of the knee extensor. With the patient in a sitting position, the hip and knee were at angles of 90°, and the strap was placed 10 cm above the ankle. The maximal isometric strength was determined as the larger value of two repeated

measurements after pre-measurement trials with manual resistance. The measurements were performed bilaterally, and the average maximal strength of both sides was calculated. Torque was calculated by multiplying strength by the lever arm (distance between the lateral joint line and the point of force application), and expressed as the percentage of body weight (Nm/kg).

2) Balance

Balance was measured by using the functional reach test. Functional reach, the distance that subjects are able to reach forward while maintaining a fixed base, has been described by Duncan et al.^{16, 17}, who reported that it had good predictive validity for recurrent falls¹⁶ and high test-retest and interobserver reliability¹⁷. The position of the tip of the first metacarpophalangeal joint was determined, with the shoulder of the subject flexed at 90° along a wall. Then the subjects were instructed to reach as far forward as possible without moving her feet, thus moving the center of gravity forwards over a fixed base. Functional reach was defined as the difference between arm's length and maximal forward reach.

3) Grip strength

Grip strength was measured using a handgrip dynamometer (Takei Co.). The subject, holding a handgrip dynamometer with her arm by her side, squeezed with maximum force. The score used was the best of two trials. Both hands were tested, and the averages of both sides were used for analysis.

4) FIM

The FIM includes 18 items, each with a 7-point scale from 1 (minimal score: complete dependence) to 7 (maximal score: complete independence). In this study, five items in the areas of transfer and locomotion (moving to and from a chair or bed, toilet transfer, tub transfer, walking, stairs) were examined to evaluate mobility (possible total score range from 5 to 35).

5) Ambulatory status

Ambulatory status was evaluated with the following three-stage classification:

1. Indoor independence: can do basic living activities without help, but cannot go out alone.
2. Proximal outdoor independence: can go out into the neighbourhood without help, but cannot use

- public means of transportation.
3. Distal outdoor independence: can go out alone using public means of transportation.

Training (Intervention)

The training components were selected specifically to target physical impairments that are associated with frailty. The specific key muscle groups we chose for training are the hip flexors (HF), hip abductors (HAB), knee extensors (KE), and ankle plantar flexors (PF), because strength in these muscles of this population is closely related to functional capabilities such as gait speed, stair-climbing ability, and rising from a chair^{18, 19}). In addition, it has been demonstrated that a reduction in the strength of these muscles has been implicated as a factor contributing to an increase in the risk of falling^{20, 21}). One set of the training of HF, HAB, KE, and PF consisted of 10 lifts with or without ankle cuff weights of 0.5 to 3.0 kg. The exercises were performed as follows:

1. Hip flexors. With ankle weights in place, the subject stands sideways next to a chair. Without bending at the waist, one knee at a time is brought up as close to the chest as possible.
2. Hip abductors. With ankle weights in place, the subject stands erect holding onto the back of a chair. Without bending the knee or waist, one leg is brought out to the side with the toes kept pointed forward.
3. Knee extensors. The subject sits erect with the weights strapped around the ankles and the back of the knees resting on the chair seat. One leg at a time is raised until the knee is as straight as possible.
4. Plantar flexors. With ankle weights in place, the subject stands erect holding onto the back of a chair. The body is then elevated up on the toes as high as possible.

The training intensity was chosen by determining the rate effort during 10 lifts, using Borg's Rating Scale of Perceived Exertion (RPE). The weight of the ankle cuff was controlled to adjust the exercise at a rating of 13 (somewhat hard) which is equivalent to 60% of maximum lifting capacity. If a RPE score was less than 13, then the next higher weight available was used, until the appropriate range was reached. The speed of movement during the exercise was kept quite slow (4–6 s to lift and lower the weight) through its entire pain-free range of motion.

Table 1. Base-line characteristics of the subjects

	Training group n=13	Control group n=15
Age (years)	81.3 ± 6.2	79.5 ± 5.1
Weight (kg)	46.9 ± 6.2	46.9 ± 5.3
Height (cm)	144.4 ± 5.2	143.4 ± 6.0
BMI	22.5 ± 2.8	23.1 ± 3.4

The progressive resistance training was performed four to six times weekly and continued for 12 months, lasting approximately 20 minutes each time.

Statistical analysis

Unpaired t-tests were used to compare baseline characteristics between the training group and the control group. Quadriceps strength, balance, and grip strength of the two groups before and after intervention were compared using paired t-tests. Within each group, the results were analyzed similarly in the subgroups according to age (below and above 80 years). Statistical significance was set at $p < 0.05$.

RESULTS

Table 1 shows the base-line characteristics of the subjects. The anthropometric characteristics (age, weight, height) of the two groups were not significantly different. The training group completed the exercise program four or more times a week for the 12-month intervention period. No major health problems, including cardiovascular or musculoskeletal complications, occurred during training sessions or testing.

Quadriceps strength, functional reach and grip strength values at baseline and 1 year post-training are presented in Table 2. There were no significant differences in baseline values between the groups. After training, quadriceps strength significantly improved from 0.88 ± 0.29 Nm/kg to 1.01 ± 0.25 Nm/kg (22.2%, $p < 0.05$) in the training group, whereas that of the control group tended to decrease from 1.01 ± 0.27 Nm/kg to 0.87 ± 0.20 Nm/kg (−9.8%, $p = 0.075$). When the results were analyzed separately by age (below and above 80 years) in the training group and control group subjects, quadriceps strength improved significantly among the below 80 years subjects, but not among the

Table 2. Quadriceps strength, functional reach and grip strength values at baseline and 1 year post-training

	Training group (n=13)			Control group (n=15)		
	Baseline	1 Year	% Change	Baseline	1 Year	% Change
Quadriceps strength (Nm/kg)	0.88 ± 0.29	1.01 ± 0.25	22.2 ± 14.1*	1.01 ± 0.27	0.87 ± 0.20	-9.8 ± 19.4
Functional reach (cm)	22.2 ± 6.5	21.3 ± 7.1	-2.1 ± 15.3	23.4 ± 4.0	19.3 ± 5.1	-15.3 ± 23.4*
Grip strength (kg)	12.3 ± 3.1	13.3 ± 2.3	24.9 ± 21.7	12.1 ± 2.9	11.6 ± 2.5	0.81 ± 24.8

Values are expressed as means ± the standard deviation (SD). %Change=(after-before)/before × 100. The symbol *: represents significance at the 5% level between the baseline and 1 year.

Table 3. Comparison of motor function between below and above 80 years of age

	Quadriceps strength (Nm/kg)			Functional reach (cm)			Grip strength (kg)		
	Baseline	1 Year	p Value	Baseline	1 Year	p Value	Baseline	1 Year	p Value
Training group									
below 80 year (n=7)	0.98 ± 0.26	1.15 ± 0.23	0.034	26.0 ± 4.0	23.9 ± 6.2	0.468	14.7 ± 2.03	15.18 ± 2.61	0.495
above 80 year (n=6)	0.76 ± 0.24	0.84 ± 0.17	0.383	17.8 ± 6.8	18.3 ± 7.7	0.840	9.58 ± 2.89	11.79 ± 1.71	0.181
Control group									
below 80 year (n=6)	1.01 ± 0.17	0.78 ± 0.07	0.110	20.3 ± 3.7	17.3 ± 4.3	0.355	13.0 ± 1.00	12.5 ± 1.34	0.563
above 80 year (n=9)	1.02 ± 0.34	0.94 ± 0.25	0.414	25.4 ± 2.7	20.6 ± 5.3	0.093	11.6 ± 3.85	11.1 ± 3.10	0.714

Table 4. FIM score at baseline

	Training group	Control group
below 80 year	33.4 ± 1.8	31.3 ± 2.7
above 80 year	30.0 ± 3.7	30.6 ± 2.6
Total subject	31.8 ± 2.8	30.9 ± 2.7

above 80 years subjects in the training group (Table 3). Although the increase did not reach statistical significance, the training group recorded an increase from 12.3 ± 3.1 kg to 13.3 ± 2.3 kg (24.9%, $p=0.058$) in hand-grip strength, whereas no such increase was seen in the control group. Functional reach, a parameter of balance, of the training group showed no change, whereas that of the control group decreased from 23.4 ± 4.0 cm to 19.3 ± 5.1 cm (-15.3%, $p<0.05$). When the results were separated by age, functional reach tended to decrease among the above 80 years subjects, but there was no change among the below 80 years subjects in the control group (Table 3).

The initial FIM scores of the two groups were not significantly different (Table 4). At the end of the 12-month study, the FIM scores for both groups had not changed. Table 5 shows the ambulatory status at baseline. After the 12-month intervention, all subjects in the training group maintained their ambulatory status at baseline. In contrast, 2 control

subjects (13.3%) aged 71 years and 85 years, showed a reduction from "proximal outdoor independence" to "indoor independence" in the ambulatory status.

DISCUSSION

At the end of the 1980s, Frontera et al.¹¹⁾ reported that a heavy-resistance training programme led to an increase in the knee extensor strength of elderly men, which was accompanied by muscle fibre hypertrophy. Since then, an annually increasing number of studies has continued to document the benefits of muscle strengthening exercises for elderly people, but most of these studies have focused on "healthy, active elderly" subjects and on their response to a programme of high-intensity strength training. Previous works also show that short-term effects of training can be observed in the elderly in as little as 6 to 12 weeks^{11, 22, 23)}, but less is known about the long-term effects of resistance training in physically frail elderly people. Generally, physical fitness such as muscle strength and balance in a group of nursing home residents is lower than that in older people living at home. As reported by other studies, for example, the mean values of grip strength and functional reach among community-dwelling older women was 25.4 kg²⁴⁾ and 26.7 cm¹⁷⁾, respectively, which were higher

Table 5. Ambulatory status at baseline

	Training group (n=13)			Control group (n=15)		
	Indoor independence	Proximal outdoor independence	Distal outdoor independence	Indoor independence	Proximal outdoor independence	Distal outdoor independence
below 80 year	0 (0)	4 (57.1)	3 (42.9)	0 (0)	3 (50.0)	3 (50.0)
above 80 year	3 (50.0)	3 (50.0)	0 (0)	1 (12.5)	4 (50.0)	3 (37.5)
Total subject	3 (23.1)	7 (53.8)	3 (23.1)	1 (6.7)	8 (53.3)	6 (40.0)

number (%)

than those of the population sample in this study. This study focused on a group of frail nursing home residents, and investigated whether long-term, low-intensity exercise can lead to improvement in motor function and mobility.

In the older adult, strength training programmes should target the major muscles of the lower extremities, the condition of which is a well-established predictor of falls and functional limitations in activities of daily living. Furthermore, muscle strengthening exercises need to be continued if exercise benefits are to be maintained, which means that they must be simple for participants to understand and perform, require no special equipment and only minimal space. To meet these requirements, we provided low-intensity strengthening exercises using ankle cuff weights for hip flexors, hip abductors, knee extensors, and ankle plantar flexors. However, it has not been well-documented whether low-intensity strengthening exercises are sufficient for optimizing improvements in strength and functioning of a frail, institutionalized elderly population.

We were able to demonstrate that the training group showed significant improvement in quadriceps strength. Handgrip strength, though not specifically trained, also tended to improve in the training group. Following a 1-year exercise trial involving 25 individuals aged between 61 and 78, Pyka et al.²⁵⁾ measured increases in strength ranging from 30 to 97% over the first 3 months, which then maintained a plateau during the remaining months of the experiment. In the case of our study population, it is not clear whether muscle strength gains were obtained during the early weeks of training, but our results indicate that a prolonged low-intensity training programme can lead to improvements in muscle strength over the long term, even in frail elderly persons. Progressive resistance training appears to be an effective way of

improving muscle strength in elderly people both below^{11, 13)} and above¹²⁾ 80 years of age. Our results of separate analysis by age group showed that the increase in quadriceps strength was due primarily to an increase seen among the below 80 years subjects rather than among the above 80 years subjects. The efficacy of the intervention for above 80 years of age is limited by the fact that there is no consensus on the appropriate quantity, quality, or intensity of resistance exercise necessary to promote improved strength, especially in this population. Future studies will be need to evaluate the long-term effects of resistance training in this very elderly population with larger numbers, and to clarify most effective intervention for improving strength. As for balance, the functional reach of the training group showed no change, possibly because the applied task was not hard enough to improve balance. However, we found that a reduction in balance had occurred in the control group at the end of the study. This was due to a decrease among the above 80 years subjects ($p < 0.093$); no decrease was seen among the below 80 years subjects. This finding suggests that an age-related decline of balance becomes greater after the age of 80 years, and that long-term resistance training may help to prevent reductions in balance that are commonly associated with aging.

Our results also indicate that the improvements of strength in the training group and the reduction of balance in the control group were not accompanied by change in FIM score after intervention. To change FIM score, it may be essential to obtain greater muscle strength and to follow a long term period. The ambulatory status was maintained in the training group, whereas it showed decrease in some of the control group subjects. Lack of strength and balance are well-known predictors of severe walking disability²⁶⁾. Furthermore, it has been pointed out that poor balance may lead to a

decrease in emotional stability, with a loss of confidence in functional performance as one of its symptoms²⁷⁾. In the control group subjects, the decline in balance contributed to gait disorders or loss of confidence, which may lead to restrictions on physical behavior.

None of the subjects showed any serious medical problems, that is, of cardiac or orthopedic origin, or any other adverse events during the progressive resistance training or measurements. This is remarkable because the study participants were all geriatric, frail and multi-morbid. Our study demonstrated that gradually-progressive, low-resistance strength training is safe and effective for improving or maintaining the strength, balance and mobility of frail elderly people. In addition to safety and effectiveness, it is also extremely important that this kind of training regimen can be reasonably expected to be complied with over the long term, especially by older persons. Our exercise programme using ankle weights requires no special equipment, is easily implemented, and does not need assistance by highly skilled professional staff. Our results also show that such simple and easy resistance training can be carried out for a long term by the frail elderly with reasonable compliance, and that prolonged training leads to sustained improvements in motor function, and thus to a reduction in functional limitations.

CONCLUSION

Progressive resistance training has been thought of as a relatively risky form of exercise for physically frail elderly individuals. Therefore, there is little information on whether it is safe for debilitated elderly persons to perform resistance training and whether such training can result in long-term improvements in strength, balance and function for this population. Our findings indicate that a sustained programme of progressive strength training can be safely performed and can lead to sustained improvement in muscle strength, balance, and level of physical activity, even among frail elderly people.

REFERENCES

- 1) Larsson L, Grimby G, Karlsson J: Muscle strength and speed of movement in relation to age and muscle morphology. *J Appl Physiol*, 1979, 46: 451–456.
- 2) Metter EJ, Conwit R, Tobin J, et al.: Age-associated loss of power and strength in the upper extremities in women and men. *J Gerontol*, 1997, 52: B267–B276.
- 3) Lindle RS, Metter EJ, Lynch NA, et al.: Age and gender comparisons of muscle strength in 654 women and men aged 20–93 yr. *J Appl Physiol*, 1997, 83: 1581–1587.
- 4) Guralnik JM, Ferrucci L, Simonsick EM, et al.: Lower-extremity function in persons over age of 70 years as a predictor of subsequent disability. *N Engl J Med*, 1995, 332: 556–560.
- 5) Avlund K, Schroll M, Davidsen M, et al.: Maximal isometric muscle strength and functional ability in daily activities among 75-year-old men and women. *Scand J Med Sci Sports*, 1994, 4: 32–40.
- 6) Skelton DA, Greig CA, Davies JM, et al.: Power and related functional ability of healthy people aged 65–89 years. *Age Ageing*, 1994, 23: 371–377.
- 7) Foldvari M, Clark M, Laviolette LC, et al.: Association of muscle power with functional status in community-dwelling elderly women. *J Gerontol*, 2000, 55A: M192–M199.
- 8) Wolfson L, Judge J, Whipple R, et al.: Strength is a major factor in balance, gait, and the occurrence of falls. *J Gerontol*, 1995, 50A (Spec No): 64–67.
- 9) Aniansson A, Zetterberg C, Hedberg M: Impaired muscle function with ageing: a background factor in the incidence of fractures of the proximal end of the femur. *Clin Orthop*, 1984, 191: 192–210.
- 10) Sinaki M, McPhee MC, Hodgson SF, et al.: Relationship between bone mineral density of spine and strength of back extensors in healthy postmenopausal women. *Mayo Clinic Proc*, 1986, 61: 116–122.
- 11) Frontera WR, Meredith CN, O'Reilly KP, et al.: Strength conditioning in older men: skeletal muscle hypertrophy and improved function. *J Appl Physiol*, 1988, 64: 1038–1044.
- 12) Fiatarone MA, Marks EC, Ryan ND, et al.: High intensity strength training in nonagenarians. *JAMA*, 1990, 263: 3029–3034.
- 13) Brown AB, McCartney N, Sale DG: Positive adaptations to weight-lifting training in the elderly. *J Appl Physiol*, 1990, 69: 1725–1733.
- 14) Whipple RH, Wolfson LI, Amerman PM: The relationship of knee and ankle weakness to falls in nursing home residents: an isokinetic study. *J Am Geriatr Soc*, 1987, 35: 13–20.
- 15) Guide for the Uniform Data Set for Medical Rehabilitation (adult FIM), State Univ New York, Buffalo, 1993.
- 16) Duncan PW, Studenski S, Chandler J, et al.: Functional reach: predictive validity in a sample of elderly male veterans. *J Gerontol*, 1992, 47: M93–M98.
- 17) Duncan PW, Weiner DK, Chandler J, et al.: Functional reach: a new clinical measure of balance. *J Gerontol*, 1990, 45: M192–M197.
- 18) Ikezoe T, Asakawa Y, Aoki N, et al.: Muscle strength

- and muscle endurance required for independent walking in the elderly. *J Phys Ther Sci*, 1997, 9: 19–22.
- 19) Bassey EJ, Fiatarone MA, O'Neill EF, et al.: Leg extensor power and functional performance in very old men and women. *Clin Sci (Lond)*, 1992, 82: 321–327.
 - 20) Ikezoe T, Asakawa Y, Tsutou A: The relationship between quadriceps strength and balance to fall of elderly admitted to a nursing home. *J Phys Ther Sci*, 2003, 15: 75–79.
 - 21) Nevitt MC, Cummings SR, Kidd S, et al.: Risk factors for recurrent nonsyncopal falls. A prospective study. *JAMA*, 1989, 261: 2663–2668.
 - 22) Moritani T, deVries HA: Potential for gross muscle hypertrophy in older men. *J Gerontol*, 1980, 35: 672–682.
 - 23) Charette SL, McEvoy L, Pyka G, et al.: Muscle hypertrophy response to resistance training in older women. *J Appl Physiol*, 1991, 70: 1912–1916.
 - 24) van Heuvelen MJ, Kempen GI, Brouwer WH, et al.: Physical fitness related to disability in older persons. *Gerontology*, 2000, 46: 333–341.
 - 25) Pyka G, Lindenberger E, Charette SL, et al.: Muscle strength and fiber adaptations to a year-long resistance training program in elderly men and women. *J Gerontol*, 1994, 49A: M22–M27.
 - 26) Rantanen T, Guralnik JM, Ferrucci L, et al.: Coimpairments: strength and balance as predictors of severe walking disability. *J Gerontol A Biol Sci Med Sci*, 1999, 54: M172–M176.
 - 27) McAuley E, Mihalko SL, Rosengren K: Self-efficacy and balance correlates of fear of falling in the elderly. *J Aging Phys Activity*, 1997, 5: 329–340.