

ORIGINAL ARTICLE

## The effects of muscle strength and power training on mobility among older hip fracture patients

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### Abstract

The incidence of hip fractures is growing in all Western societies. The mobility of hip fracture patients does not return to the pre-fracture level even 2 years after fracture. One reason for mobility limitation may be the persistent muscle weakness on the fractured leg. The purpose of this randomized controlled study was to examine whether 12-week muscle strength and power training twice a week has an effect on mobility in 60–85-year-old hip fracture patients. Forty-three persons were randomly assigned to an intervention ( $n=23$ ) and a control ( $n=20$ ) group. The intervention comprised 12-week supervised intensive progressive strength–power training twice per week. All the measurers were blinded. Mobility was assessed by the timed-up-and-go test (TUG), chair rise and stair climbing time, walking time and self-reported change in mobility. Data were analyzed using the intention-to-treat principle. In addition, an efficacy analysis was performed for those subjects with over 50% training compliance ( $n=20$ ). Fourteen of the subjects in the training group and only two controls felt that their mobility had improved during the intervention period ( $p=0.002$ ). Training had no significant effect on TUG, chair rise and stair climbing time and walking time. However, in the efficacy analysis, the average chair rise time improved by 5.4% in the exercise group compared with controls ( $p=0.005$ ). After intensive muscle strength and power training, the self-reported mobility improved. The chair rise improved in participants with higher training compliance.

**Key words:** Elderly, hip fracture, mobility, power training, strength training

### Introduction

The number of hip fractures in western societies has risen over the past four decades and thus burdens the healthcare system. For example, the number of hip fractures in Finland quadrupled between the years 1970 and 2000 (1). Multiple risk factors for hip fractures, such as gender, old age, low physical activity, osteoporosis, previous hip fracture, low body mass index and muscle weakness in lower extremities, have been identified (2–4). The primary costs for a hip fracture during the first year of treatment are about 14,000 euros while the secondary costs may be as high as 35,000 euros (5). People who have already had a fragility fracture are at greatly increased risk of sustaining a further fracture (6). Consequences of hip fracture include mobility

limitation and disabilities, increased risk of mortality, pain and other adverse health and economic consequences for patients, their families and the healthcare system (7). Therefore, better understanding the factors associated with the recovery from hip fractures as well as the different rehabilitation methods is essential.

The decline in muscle strength and power (8), balance (9) and their combined effects (10) increase the risk of mobility disability in older people. During the first year after a hip fracture, it has been shown that mobility, physical capacity and quality of life do not return to the pre-fracture level (11–13), and that decrements in these areas continue for at least 2 years (14). In addition, 4 months after a hip fracture, about 80% of patients need a walking aid or

the support of another person (15–17), and about half of all hip fracture patients are not able to move outside independently (12,15,17,18). One reason for mobility limitation may be the persistent muscle weakness especially on the fractured leg (19).

A systematic review by Handoll et al. showed that there is no clear evidence as to what type of rehabilitation (physical therapy, walking and home exercise, or intensive physiotherapy) is most effective with respect to mobility recovery in hip fracture patients (20). However, strength and power training seems to improve mobility in older people (21,22) and muscle power has been shown to be a significant indicator of physical performance in older people with mobility problems (23,24). A few randomized controlled trials suggest that older people suffering from muscle weakness and mobility problems may benefit the most from strength training. Intensive progressive resistance training has not been studied extensively in clinical populations, such as hip fracture patients.

The purpose of this study was to examine whether intensive muscle strength and power training over 12 weeks has an effect on mobility in 60–85-year-old people with a hip fracture history. The training program was designed to increase muscle strength and power in fractured and non-fractured side.

## Materials and methods

### *Participants and study design*

The present study is part of a larger randomized controlled trial concerning the effects of resistance training on muscle strength parameters, mobility and balance in older persons with hip fracture history (registered as ISRCTN34271567). Detailed description of the recruitment of the subjects has been reported earlier (25,26). To avoid confounding of acute recovery effects, community-living 60–85-year-old men and women with a femoral neck or trochanteric fracture within 6 months to 7 years prior to baseline were invited to participate in the study. In 2004 and 2005, all 452 surviving patients with hip fracture in the years 1998–2004 were identified using the patient records of the Central Hospital Central Finland. First, a letter informing them about the study was sent to all patients living independently in the Central Finland Health Care District area and patients who had no diagnosed dementia, and no progressive severe illnesses ( $n = 452$ ; Figure 1). Those willing to participate ( $n = 132$ ) were interviewed over the telephone to ensure that they conformed to the inclusion criteria: able to move outside without assistance from another person and no neurological diseases or lower limb

amputations. Inclusion criteria including Mini-Mental State Examination (MMSE) over 22 were checked by a nurse and physician in the baseline medical examination. Of the 79 persons who met these criteria, seven subjects were not willing to participate. In addition, 26 subjects were excluded because of new trauma or acute illness. Thus, 46 eligible subjects were randomized by gender and stratified by blocks of average age into the training (eight men, 16 women) and control groups (six men, 16 women). In the control group, one participant dropped out for personal reasons and one participant because of dissatisfaction with the randomization outcome. In the training group, one participant dropped out for personal reasons.

Data were collected in two phases, in autumn 2004 and autumn 2005. To enlarge initial sample size obtained in the year 2004, the study was repeated in the same season (August–December) of 2005 using the exact same protocol, infrastructure and staff. Only the recruitment area was enlarged in 2005. The study was approved by the Ethics Committee of the Health Care District Central Finland and all the participants signed an informed consent prior to the baseline examinations.

### *Measurements*

*Health assessment.* A physician and research nurse performed a thorough clinical examination at baseline. The presence of chronic conditions, use of medication and surgical procedure for hip fracture were established according to a questionnaire, current prescriptions and medical records. Potential contraindications for safe participation in the measurements and the strength training program were evaluated using the criteria for exercise participation proposed by the American College of Sports Medicine (27).

All measurements were taken before and after the 12-week intervention and the measurers were blinded to the patients' group assignment.

*Anthropometry and physical activity level.* Body height and weight were measured using standard protocols in the laboratory. Physical activity was evaluated with the Yale questionnaire (28). The questionnaire includes a physical activity dimension sum index, constructed from five weighted sub-indices [vigorous physical activity (weight 5), leisure walking (weight 4), duration of time spent moving around (weight 3), standing (weight 2) and sitting (weight 1)]. The frequency and duration scores and the weight of the respective activity were multiplied.

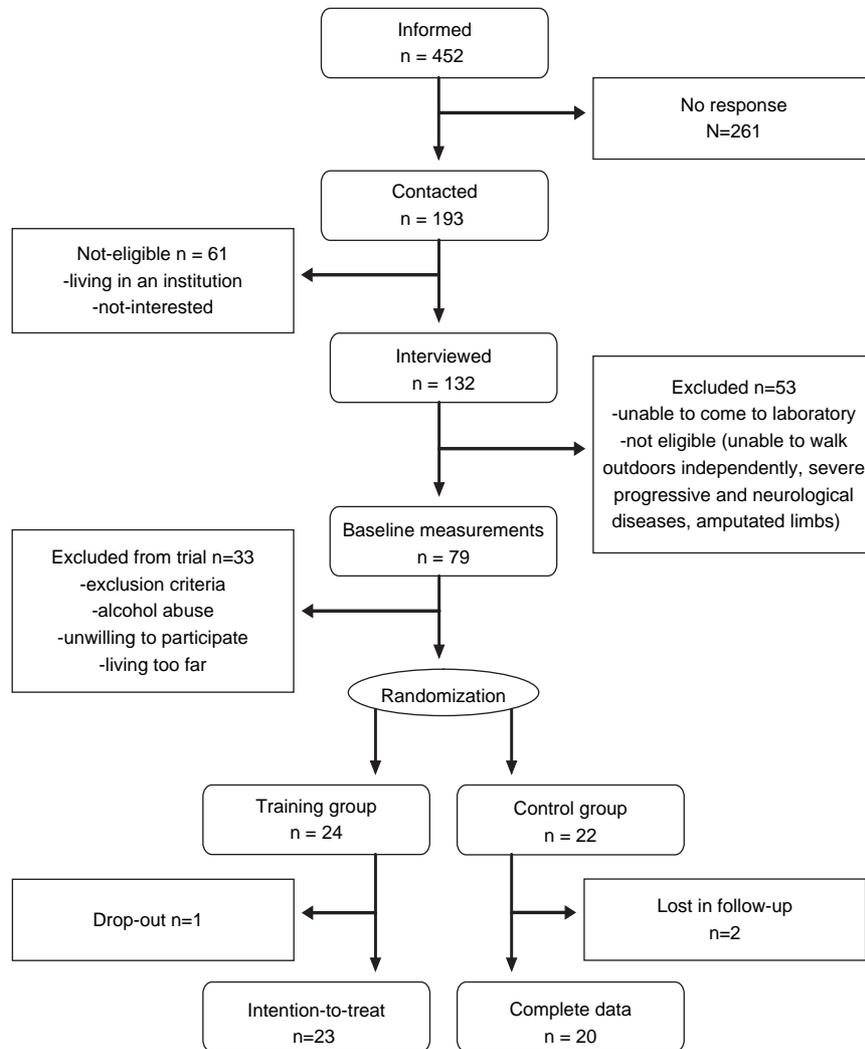


Figure 1. Recruitment of participants and process of study.

**Muscle strength measurement.** Maximal voluntary isometric knee extension strength was measured from both legs using an adjustable dynamometer chair (Good Strength, Metitur, Palokka, Finland). During the measurement, the ankle was attached to a strain-gauge system with the knee angle fixed at  $60^\circ$  from full extension. Participants were encouraged to extend the leg as hard as possible. After two to three practice trials, measurements were performed at least three times until no further improvement occurred. Each contraction was maintained for 2–3 s. The inter-trial rest period was 30 s. The best measured force of each leg was registered. The value of the leg with the highest force was used for analysis. The test-retest precision with a 2-week interval is  $6 \pm 6\%$  in our laboratory (29).

**Mobility measurements.** The self-reported change in mobility was elicited by a questionnaire. The exact question was: “Did you notice any change in your

mobility during the autumn?” The response alternatives were: “my mobility has improved”, “my mobility did not change” and “my mobility has deteriorated”.

**Timed-up-and-go test (TUG).** The TUG test measures the time that it takes for the person to rise from a chair, walk 2.44 m, circle around a cone and return to the chair. The time was measured from seated position (back against the backrest to seated position) with a stopwatch, which was started on the command “ready – go”. Participants were allowed to use a walking aid during this task if they normally used one. The test was performed so that the healthy lower extremity was closer to the cone while executing the turn. The TUG test has proven to be a reliable and valid way of assessing mobility and it can be used to measure clinical change (intra-class correlation coefficients, ICC 0.97–0.99) (30,31).

*Chair-rise time.* A chair without arms and with a seat height of 0.44 m from the floor was placed close to a wall for support and safety purposes. Each participant was instructed to sit in the chair with his or her back against the backrest, provided both feet remained flat on the floor, and to let the arms hang freely. One completed chair rise was defined as moving from a starting seated position to standing fully upright and returning to the seated position. The participant was then instructed to perform five repetitions as fast as possible. The performance was timed with a stopwatch. The ICC of a chair rise time has been reported to be 0.71 (23).

*Stair-climb time.* A standard flight of 10 stairs, with handrails on both sides, was used for this test. Participants were instructed to ascend the stairs as quickly as possible but safely and without running. If necessary, either handrail or walking aids could be used. The stopwatch was started when the participant moved his or her feet to begin climbing the stairs and was stopped when first foot landed on the top of the 10th step. Use of the left/right handrail or a walking aid was noted. The ICC of stair climbing time has been reported to be 0.96 (23).

*Walking time.* Ten-meter walking time was measured in the laboratory corridor. Participants were instructed to "walk as fast as possible, without compromising your safety." Timing was done using photocells. Three meters were allowed for acceleration. The ICC of maximum walking speed has been reported to be 0.94–0.96 (30,32).

#### *Training program*

The training took place at the senior gym twice a week for 12 weeks and was supervised by an experienced physiotherapist. Training sessions lasted for 60–90 min including a warm up (10 min) and cool down (5 min). The training program aimed to increase the muscle strength and power of the lower limbs. Each training session included both strength and power exercises. Pneumatic resistance equipment (Hur Finland Oy, Kokkola) was used for the leg press, knee extension, hip abduction and adduction exercises (33). The training equipment allowed for the range of motion to be individually limited for each leg. The ankle plantar flexion exercises, rising to the toes, were performed with a weighted vest.

The first two training sessions were used to familiarize the participants with the facility, equipment and staff. In the following sessions, the 1RM (1-repetition maximum) was estimated. Training intensity was adjusted individually and increased

progressively throughout the training period when tolerated. The assessment was repeated in weeks 6–8 and the training resistance was adjusted accordingly. The weaker leg was trained more intensively. The weaker leg was defined on the basis of the baseline measures for maximal knee extension strength, maximal rate of force production, maximal leg extension power and the 1RM test. The weaker leg (usually the fractured leg) was defined as the leg that had lower values in at least three of the measures.

*Power training.* The leg press and ankle plantar flexion power exercises were performed at the beginning of training session in sets of 12 repetitions. Relatively low resistance was used and the concentric phase of the contraction was performed as fast as possible. The leg press exercise consisted of three to four sets for the weaker leg and two to three sets for the stronger leg with a resistance of 40–50% of 1RM. The ankle plantar flexion exercise was performed standing on both legs in two to three sets using a weighted vest with 0–10% of bodyweight added.

*Strength training.* Strength exercises were performed at a slower pace, with fewer repetitions (weaker leg: two to three sets of eight repetitions; stronger leg: one to two sets of 10 repetitions) and at a higher resistance. Leg press, knee extension, and hip abduction and adduction exercises were performed with a resistance of 60–80% of 1RM for the weaker leg and 50–70% of 1RM for the stronger leg. From week 8 onwards, the leg press strength exercise was performed only once a week. The ankle plantar flexion strength exercise was performed standing on one leg with 0–15% of body weight added using the weighted vest.

#### *Control group*

Participants were encouraged to continue their lives as usual and maintain their pre-study level of physical activity during the 12-week trial.

#### *Statistical analysis*

The results were analyzed with the SPSS 13.0 program. Differences in baseline characteristics between the study groups were tested using *t*-test for independent samples. Training effect was studied using analysis of covariance (ANCOVA) with baseline values as covariates, according to the intention-to-treat principle (ITT). An efficacy analysis was also performed; three participants were excluded, two because of low exercise compliance with the exercise regimen (less than 50% of the planned

exercise sessions) and one participant because of the inability to perform the knee extension exercise. Consequently, there were 20 subjects in both the exercise and control groups in the efficacy analysis. The relative change in mobility between the pre- and post-trial measurements was calculated as ((post-pre)/pre)100%. The self-reported change in mobility was analyzed with the chi-squared test.

**Results**

The background variables for the study groups are shown in Table I. There was no significant difference between the groups at baseline except for the surgical fixation of the fracture ( $p=0.001$ ). Seven participants in the exercise group had their fracture repaired with a screw or nail and 16 with prosthesis. The corresponding numbers in the control group were 16 and four.

The rate exercise compliance was 87% (SD = 24). After the trial, maximal isometric knee extension strength increased in the exercise group from 289 N (SD = 114 N) to 318 N (SD = 107 N) and decreased from 269 N (SD = 103 N) to 262 N (SD = 89 N) in the control group (ANCOVA  $p<0.001$ , effect 15.5%, 95% CI 3.0–28.1). The results for the self-reported changes in mobility are shown in Table II. Fourteen participants in the exercise group reported that their mobility had improved during the intervention period, which was significantly more than the corresponding number (two) among the controls ( $p=0.002$ ).

Table III and Figure 2 shows the training effect for TUG, chair rise time, stair climbing time and walking time. The training had no statistically significant effect on these measurements when all the participants were included in the analysis (ITT analysis). However, when only those with over 50% exercise compliance were included (efficacy analysis), the chair rise time improved significantly more (2.2 s) in the exercise group compared with controls ( $p=0.005$ ).

Table I. Baseline characteristics of the 60–85-year-old hip fracture patients (mean, SD).

	Exercise group <i>n</i> = 23	Control group <i>n</i> = 20	<i>p</i> -value
Age	74 (6)	74 (7)	0.89
Weight	71 (11)	73 (13)	0.58
Height	163 (9)	165 (9)	0.37
Body mass index	27 (4)	27 (4)	0.87
Yale (physical activity)	40 (20)	43 (19)	0.68
Number of diseases	3 (1)	2 (1)	0.09
Number of medications	4 (3)	3 (3)	0.18
Years from fracture	3.5 (2.1)	3.5 (2.4)	0.99

Table II. Self-reported changes in mobility in exercise and control groups after the 12-week training period.

	Exercise group <i>n</i> = 23	Control group <i>n</i> = 20
Improved ( <i>n</i> = 16)	14	2
Remained same ( <i>n</i> = 21)	6	15
Decreased ( <i>n</i> = 6)	3	3

Chi-square test  $p=0.002$ .

**Discussion**

This study showed that self-reported mobility improved in older hip fracture patients after 3 months of intensive and progressive muscle strength and power training. Over 60% of the subjects participating in the training felt that their mobility had improved during the intervention period. In addition, the ability to rise from a chair, which is a strength- and power-demanding task, improved in participants with higher training compliance.

The current literature shows inconsistent results regarding the effects of exercise rehabilitation on mobility limitation in hip fracture patients. In some following studies the physical performance and mobility of hip fracture patients improved muscle strength and power training (34) and following muscle strength and endurance exercises (35,36). However, in other training studies, no significant effect on mobility limitation in hip fracture patients has been found (34). In the study by Sherrington et al. (37), functional motor performance was improved after training but training did not have any effect on gait. In the present study, we found a significant improvement after training in self-reported mobility and chair rise time, whereas walking and stair climbing were not affected by training. In most of the earlier studies, participants were assigned to an intervention no later than 4 months post-fracture. In our study, the training started on average 3.5 years after the fracture in order to avoid confounding acute recovery effects. We wanted to investigate the effects of training in a group of older people with high risk of decreased lower limb muscle strength and power and mobility limitation.

Muscle strength and power training of the lower limb muscles may be of great importance in physiotherapy for hip fracture patients. Sufficient lower limb extension power, during which effective force is produced quickly, is essential, especially during chair rising and stair climbing. According to our study and the study by Mitchell et al. (34), muscle strength and power training seem to improve, not only muscle power and strength in hip fracture patients, but also their own experiences of their mobility and thus walking confidence. This is important, since

Table III. Effect of strength and power training on mobility tests (mean, SD) in intention-to-treat (ITT) and efficacy analysis in 60–85-year-old hip fracture patients.

	Exercise group		Control group		Difference in change	95% CI	p-value
	Baseline	End	Baseline	End			
ITT analysis	(n=23)		(n=20)				
TUG (s)	7.9 (2.2)	7.9 (2.7)	9.3 (3.4)	8.9 (2.5)	0.14	(-0.7 to 1.0)	0.74
Chair rise time (s)	13.7 (4.9)	12.6 (3.7)	16.9 (8.0)	15.7 (4.4)	1.48	(-3.1 to 0.2)	0.07
Stair climbing time (s)	5.9 (1.7)	5.9 (1.8)	7.2 (2.9)	6.4 (1.8)	0.33	(-0.3 to 0.9)	0.27
Walking time (s)	7.3 (2.5)	7.0 (2.4)	7.7 (2.8)	7.0 (1.9)	0.27	(-0.3 to 0.8)	0.36
Efficacy analysis	(n=20)		(n=20)				
TUG (s)	7.8 (2.3)	7.6 (2.8)	9.3 (3.4)	8.9 (2.5)	0.04	(-0.9 to 0.8)	0.93
Chair rise time (s)	13.4 (4.8)	11.9 (2.9)	16.9 (8.0)	15.7 (4.4)	2.21	(-3.7 to -0.7)	0.005
Stair climbing time (s)	5.8 (1.8)	6.2 (0.2)	7.2 (2.9)	6.4 (1.8)	0.25	(-0.4 to 0.9)	0.43
Walking time (s)	7.2 (2.6)	6.8 (2.5)	7.7 (2.8)	7.0 (1.9)	0.09	(-0.5 to 0.7)	0.76

CI, confidence interval; TUG, Timed-up-and-go test.

self-reported increase in mobility may also help to sustain exercise motivation and decrease fear of falling.

Mobility tests require muscle strength and endurance on the part of the lower extremities, as well as balance and walking ability (38). For example, the TUG test, in particular, emphasizes walking ability and dynamic balance (31,39), whereas the chair rise test requires muscle strength and power of the lower extremities (40). In the present study, the effect of the strength and power training was seen only in one mobility test, i.e., in the chair rise test, during which five repetitions were performed as fast as possible. This is probably because the chair rise is a better indicator of muscle strength and power than the other mobility measurements. The chair rise takes place in a closed kinetic chain. In the chair rise, the participants' lower extremities stay on the ground in the same position the whole time, which renders this

test comparable with the leg press exercise. In contrast to open kinetic chain training, during closed kinetic chain training, the quadriceps activates faster and in a more balanced manner (41). The chair rise requires more control of static balance whereas the other mobility tests require dynamic balance (38,40). Improvement in the chair rise is clinically relevant as it is an important function for daily living. According to Bensen et al., the inability to rise from a chair without aid of the upper extremities is a strong risk factor for possible future hip fractures (42). Consequently, training regimens that include both strength and power training, such as in our study, are important factors in the rehabilitation and exercise training in terms of assisting them to maintain their ability to perform essential activities of daily living.

In previous studies with hip fracture patients (35–37), apart from that by Mitchell et al. (34), training

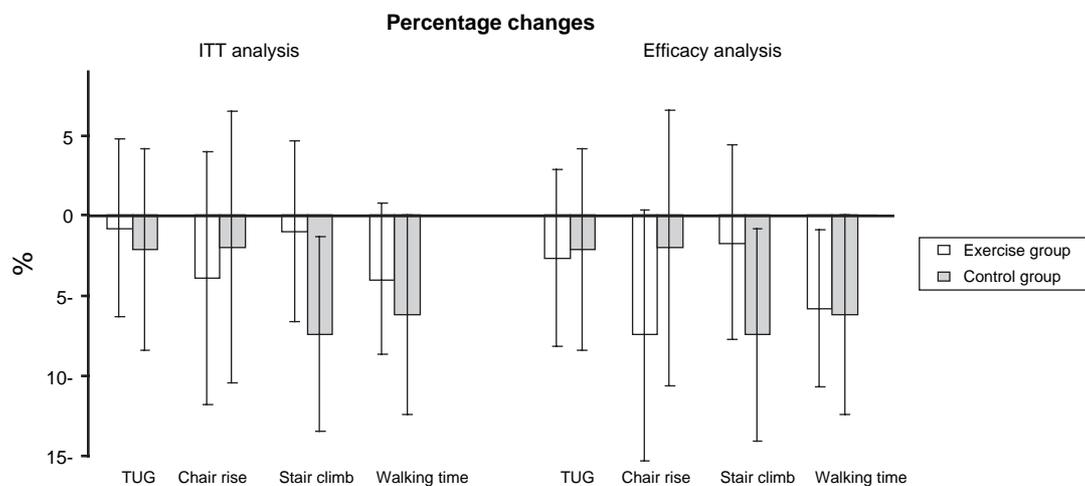


Figure 2. Effect of strength and power training on mobility tests. The intention-to-treat (ITT) test results, efficacy analysis and percentage change at the end of the training period with 95% confidence interval are given. Timed-up-and-go test (TUG), five times chair rise (chair rise), a 10-stair climb (stair climb) and 10-m walking time (walking time).

sessions have taken place at least three times a week. In our study, the training was planned twice a week, which may have been too little. In addition, our efficacy analysis showed that in subjects who trained regularly the training effects were clearer. This may also indicate that a training frequency of twice a week was slightly too low in our relatively healthy and mobile, although hip-fractured participants. On the other hand, muscle strength increased significantly in our subjects, none of whom earlier engaged in training of a strength and power type. Muscle strength may also increase significantly in beginners who train only once a week (43).

Our training program did not include any mobility exercises and most of the strength and power exercises were performed while seated. According to McArdle et al. (43), acquired muscle strength rarely transfers fully to other movements besides the specific ones trained, even though the same muscles are activated. To obtain maximum benefit from muscle strength training the training would have to be specific as on the tests used to measure strength, speed and power. This might explain the fact that in the present study the full effect of the muscle strength and power training was not observed in the mobility tests. Mobility may be improved further by training in the upright position and with functional exercises (37). This should be taken into consideration when rehabilitation programs are being planned for hip fracture patients.

This study has several strengths. First, it was a randomized, controlled exercise intervention trial with only very few dropouts. Second, the measures were done blinded towards the group assignment, and same physiotherapist performed the baseline and post-trial measurements. Third, the general training compliance was excellent. However, the study has some limitations. The sample size was relatively small ( $n = 43$ ) although everyone in the target population who met the inclusion criteria had the opportunity to join the study. Despite the strengths of the study, the results cannot be generalized to all older hip fracture patients, since the participants were clinically healthy and had fairly good self-rated physical functioning, and were able, therefore, to engage in quite intensive strength-power training.

In conclusion, this study shows that muscle strength and power training twice a week over a period of 3 months increases muscle strength, improves self-reported mobility and the ability to rise from a chair among 60–85-year-old hip fracture patients. Muscle strength and power training should be considered as part of the rehabilitation process to improve or regain mobility, even several years after injury, in older hip fracture patients.

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