Exercise Training for Rehabilitation and Secondary Prevention of Falls in Geriatric Patients with a History of Injurious Falls

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OBJECTIVE: To determine the safety and efficacy of an exercise protocol designed to improve strength, mobility, and balance and to reduce subsequent falls in geriatric patients with a history of injurious falls.

DESIGN: A randomized controlled 3-month intervention trial, with an additional 3-month follow-up.

SETTING: Out-patient geriatric rehabilitation unit.

PARTICIPANTS: Fifty-seven female geriatric patients (mean age 82 ± 4.8 years; range 75–90) admitted to acute care or inpatient rehabilitation with a history of recurrent or injurious falls including patients with acute fall-related fracture.

INTERVENTION: Ambulatory training of strength, functional performance, and balance 3 times per week for 3 months. Patients of the control group attended a placebo group 3 times a week for 3 months. Both groups received an identical physiotherapeutic treatment 2 times a week, in which strengthening and balance training were excluded.

MEASUREMENTS: Strength, functional ability, motor function, psychological parameters, and fall rates were assessed by standardized protocols at the beginning (T1) and the end (T2) of intervention. Patients were followed up for 3 months after the intervention (T3).

RESULTS: No training-related medical problems occurred in the study group. Forty-five patients (79%) completed all assessments after the intervention and follow-up period. Adherence was excellent in both groups (intervention 85.4 ± 27.8% vs control 84.2 ± 29.3%). The patients in the intervention group increased strength, functional motor performance, and balance significantly. Fall-related behavioral and emotional restrictions were reduced significantly. Improvements persisted during the 3-month follow-up with only moderate losses. For patients of the control group, no change in strength, functional performance, or emotional status could be documented during intervention and follow-up. Fall incidence was reduced nonsignificantly by 25% in the intervention group compared with the control group (RR:0.753 CI:0.455–1.245).

CONCLUSIONS: Progressive resistance training and progressive functional training are safe and effective methods of increasing strength and functional performance and reducing fall-related behavioral and emotional restrictions during ambulant rehabilitation in frail, high-risk geriatric patients with a history of injurious falls. **J Am Geriatr Soc 49:10–20, 2001.**

Key words: geriatric patients; injurious falls; physical training

Falls are common in older people and become more frequent with advancing age, with a fall incidence of 40% per year in community dwellers aged 80 years or over.[1,2] Injurious falls leading to severe medical, psychological, and social sequelae are associated with high treatment costs. They lead to ongoing posttraumatic health problems, motor and psychological restriction, and a threatening loss of autonomy.[3,4] Although many factors, such as aging, chronic illness, sedentary lifestyle, and medication, may contribute to the risk of falling, preventable or reversible motor deficits seem to be a key to successful intervention by physical training. Lack of strength, coordination, and functional performance are well-known predictors of falls[1,5–8] and disability[9,10] in older people and the rehabilitation outcome of patients with a history of falls.[11,12]

Studies have shown that physical training is effective in improving strength and functional performance in older people.[13,14] However, there is little experience in applying physical training methods such as progressive resistance training in the acute rehabilitation of geriatric patients with a history of injurious falls, especially those patients suffering from hip-fracture.[15,16] The studies have so far either been uncontrolled or used a home-based training intervention that was one-dimensional and not comparable to the methods used in this study. Patients with a history of injurious falls present high fall-related medical costs, high prevalence of dependency, and high fall-related mortality.[5,17–19]

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In intervention trials designed to reduce the incidence of falls in older, community-dwelling populations, physical training has been unsuccessful or only partly successful, dependent on the kind and intensity of training, chosen outcome variables, study populations, and statistical power.[20–24] In other studies that successfully reduced the incidence of falls through physical training, motor function did not improve or so only partially.[25,26] Successful intervention programs combined intervention strategies of strength, coordination, or complex motor training and multifactorial interventions, including intensive motor training.[25–28] The efficacy of secondary prevention of falls in older patients with a history of injurious falls, who are at a high risk for subsequent falls, however, has not yet been studied.

We hypothesized that physical training covering strength, coordination, and functional performance would be safe and effective in the rehabilitation of geriatric patients with a history of injurious falls and could lead to secondary prevention of falls in this high-risk population of geriatric patients.

METHODS

Study Design

The study was designed as a randomized, placebo-controlled, 12-week ambulant clinical trial in which patients were assigned to participate either in lower-extremity progressive resistance training and progressive functional and balance training or in a motor placebo activity. Both groups received an identical additional physiotherapeutic treatment. Patients were followed for 3 months after cessation of intervention. The ethics committee of the local university approved the study in accordance with the Helsinki declaration, and written informed consent was obtained from each participant.

Study Population

Patients were consecutively recruited at the end of ward rehabilitation from a geriatric hospital providing acute and rehabilitation care. Inclusion criteria were: falls as the reason for admission to hospital and/or recent history of injurious falls that led to medical treatment, age over 75 years, female gender, residential status within the vicinity (<15 km) of the study community, consent of the orthopedic surgeon, orthopedic stability, and willingness to participate in the study. Patients 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 >New York Heart Association [NYHA] III, 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). Patients with syncopal falls or falls due to a single identifiable disease (e.g., stroke, hypoglycemia) or accident were excluded. Participants were recruited and randomly assigned to either the control or the intervention group after baseline testing at the end of ward rehabilitation. Randomization was stratified by lower-extremity- or hip-fracture patients and nonlower-extremity- or hip-fracture patients.

INTERVENTION

Resistance Training

To mobilize fracture patients and to warm up, patients exercised on stationary cycles (ECB Ergometer E405, Tunturi, Piispanristi, Finland) for 10 minutes with a minimal workload (<25 watts). The patients then underwent a regimen of high-intensity progressive resistance training of functionally relevant muscle groups 3 days a week for 12 weeks. Patients exercised at the beginning with minimal resistance, concentrating on good form and minimal substitution by other muscle groups. For trained muscle groups, the resistance was set at 70% to 90% of the maximal workload.[29] To maintain the intensity of the training stimulus, the load was increased at each training session, as tolerated by the patient. The resistive training was interrupted by breaks adjusted to the patients' physical capacity and lasted for 1.5 hours. All exercise sessions took place in training groups (4–6 patients) and were supervised by a therapeutic recreation specialist.

Knee and hip extensions were performed on a leg press (Kaphingst, Lahntal, Germany) in a sitting position. Three sets of 10 left and right lifts were performed unilaterally. Hip abduction and extension were performed in a standing position with the use of a cable pulley system engineered for this purpose. Constructional aids were added to stabilize patients while standing one-legged (Schnell, Peutenhausen, Germany). Two sets of 10 left and right lifts were performed. Ankle plantar flexion was performed by heel rises during erect standing. Patients initially performed 2 sets of 15 lifts of bilateral plantar flexion. To increase workload, patients' forefeet were placed on a 2-centimeter support, later increased to 4-centimeters. If tolerated, patients progressed to unilateral plantar flexion. Stretching of the trained muscle groups followed all sets of resistance training.

Progressive Functional-Balance Training

Participants were trained in basic functions such as walking, stepping, and sitting to modify unsafe or inefficient performance. Balance training was performed in static and dynamic positions. When they were stable in basic motor function, patients progressed to advanced levels of exercise. Complexity and challenge of tasks were increased by multifactorial performances, such as throwing and catching a ball with one person moving forward and one person moving backward. The trainer encouraged quality of motion and attendance. Group games, basic forms of dance, and basic forms of tai chi were used when patients' performance would allow it. The balance/functional training followed the resistance training and took 45 minutes per training session.

Placebo Activities

All patients assigned to the control group met 3 times a week for 1 hour of motor placebo activities. Typical activities were flexibility exercise, calisthenics, ball games, and memory tasks while seated.

Physiotherapy

Because of acute orthopedic problems following the fall and orthopedic surgery, both groups received identical physiotherapy 2 times a week for 25 minutes. Strength and balance training were excluded from physiotherapy and control group sessions. Physiotherapy consisted mostly of massaging, stretching, and application of heat or ice predominantly to areas affected by fall-afflicted orthopedic problems. Transportation of patients to training locations was provided. The training intervention started immediately after discharge from hospital.

Measurements

Baseline measurements were performed before randomization, 3 to 4 weeks after admission to the rehabilitation hospital (T1), at the end of training (T2), and after an additional 3-month follow-up period (T3). A person blinded to the patients' group assignment documented main outcome parameters. Some data for characterizing the study population were obtained by routine documentation in patient files for these study parameters (e.g., medication, Mini-Mental-State Examination (MMSE), fracture site, comorbidity).

Clinical Characteristics

Medical status, comorbidity, medication, and functional status, using the Barthel/Mahoney Activities of Daily Living Index (ADL)[30] and the Lawton/Brody Instrumental Activities of Daily Living Index (IADL)[31] and cognitive status, using the MMSE,[32] respectively, were documented. Standing height, measured to the nearest centimeter, was measured with a wall-mounted stadiometer. Body weight was measured to the nearest 0.1 kilogram.

Muscle Function

The One-Repetition-Maximum was used as a measure of maximal dynamic concentric muscle strength in hip and knee extensors (Leg press, Kaphingst, Lahntal). To minimize improvement related to motor learning, muscle strength of leg-extensor, leg flexor, and plantar flexors was documented using a measuring unit (Diagnos-40®, Schnell, Peutenhausen) not being used as a training machine. The dimension of strength was different in measurement (one-limb maximal static force) and training (functional multilimb, dynamic concentric-eccentric submaximal strength). Handgrip strength[33] was assessed by a dynamometer (Vigorimeter®, Kaphingst, Lahntal) to control for strength in untrained muscle groups. All baseline measurements of strength were documented as the better of two measurements. The sum of the unilaterally achieved results was then calculated. Strength of limbs that were afflicted by the fall was only measured to workloads the orthopedic stable patients would individually accept.

Physical Function

Maximal gait speed over a 15-meter course was measured to the nearest 0.1 second.[34,35] Stair-climbing performance was measured using banistered stairs with 13 stairs, each 15 centimeters high and 35 centimeters deep.[36] The ability to rise from a standardized chair was measured as the 3-repetition time to the nearest 0.1 second.[35,37] The maximal step height was documented using a device on which a stepping platform was heightened by 5-centimeter intervals until maximal step height was reached.[35] Patients were allowed to use a banister to stabilize when stepping. To assess more-complex motor function, a Timed-Up-And-Go Test[38] was carried out. Motor deficits common in elderly patients were documented using Tinetti's Performance Orientated Mobility Assessment (POMA).[39] Balance was measured by the Functional Reach Test[40] and a modified test battery[10,34] that examined the balance performance in five positions (feet apart, feet parallel side by side, semi-tandem, tandem, one-leg stance left, one-leg stance right), each under different conditions (eyes open; eyes open, hands stretched out in front of the body; eyes closed; eyes closed, hands stretched out in front of the body), for 15 seconds each. Each successful trial was scored with one point. Trials that lasted from 3 to 15 seconds were documented as half a point. The better of two trials was counted. A maximum of 20 points could be obtained.

The performances in specific motor tasks used in the study such as stair climbing,[41] chair rise,[1,6,10,42] functional reach,[40,43] timed up-and-go,[40] walking performance,[1,10,42] balance/sway,[1,10,42,44] Tinetti's motor test,[45] or use of assistive device[1,46] has been shown to correlate significantly with the risk of functional disability, dependence, and falls.

Training Events, Training Adherence, and Overall Physical Activity

Patients were asked frequently about musculoskeletal complaints. A geriatrician and a physiotherapist evaluated symptoms and, if necessary, modifications of the training were arranged. Training adherence was documented in training lists. Overall physical activity, including subscores for housework, leisure activity, and sports activity (including walking), was evaluated using a physical activity questionnaire for the elderly.[47]

Emotional Status

The short version of the Geriatric Depression Scale (15 items)[48] was administered, supplemented by the Philadelphia Geriatric Morale Scale (PGMS).[49] Posttraumatic emotional status following the fall was documented by subjective rating of walking steadiness, subjective rating of fear of falling,[34,50] and the falls handicap inventory (FHI),[51] which scores for posttraumatic fall-related emotional instability and behavioral changes.

Incidence of Falls

Falls were defined following standard definitions.[34,52] A hospital committee adjudicated questionable fall events. Syncopal falls were excluded. Patients were required to report all falls and document falls in a fall diary every day. The diary, given to the patients with a self-addressed, postage-paid envelope, was to be sent back every 2 weeks. During the intervention phase, reporting of falls was reinforced by verbal reminders and, during the follow-up phase, by written reminders and telephone calls. Documentation of falls was based only on patient reports in their fall diaries and personal interviews. Staff members documenting falls were blinded to the patients' group assignments.

Statistical Analysis

Statistical procedures were performed on SPSS 7.5 for Windows, using an intention-to-treat analysis.[53] Exploratory data analysis determined the variability and distribution of outcome variables. Unpaired t-tests and Mann and Whitney u-tests were used to compare baseline values between groups. The effect of intervention (T2) and follow-up (T3) was evaluated using analysis of covariance with the baseline measurement of age, medication/day, and baseline values of the dependent variable as covariates. Relative risk was calculated, and the chi-square test was used to evaluate the effect of intervention on fall incidence. Relations among baseline variables were analyzed using Pearson's correlation coefficients or Spearman's rank correlations coefficients, as appropriate. A two-sided *P*-value less than or equal to .05 was considered to indicate statistical significance. The local pool of eligible patients in hospital during the recruitment period of 15 months determined the size of the study population. The expected number of eligible patients met with the calculation of the study sample size that was based on a two-sided significance of α = 5%, statistical power β = 80%, and the effect size of the intervention δ = 47.5%, as achieved in a recent intervention study to reduce falls in community-dwelling elderly.[54]

RESULTS

Recruitment

The number of patients screened for participation was 696. Of 526 patients that were excluded in a first screening process, 72.2% were excluded because they were younger than 75 years old (35.3%), their residence was not near study location (6.9%), or they had a history of neurological disease (36.0%) that represented no training-specific criteria. Other patients were excluded because of severe medical criteria such as severe heart failure, terminal illness, amputation of lower extremities, or acute diseases (22.8%).

Of the patients who were hospitalized during the enrollment period, 170 were considered potentially eligible to participate in the study in a screening based on hospital patient files only. Fifty-seven of these patients (33.5%) consented to take part in the study. Of the 113 patients who did not take part in the study, lack of motivation, medical problems, such as pain, and logistics problems were the most common reasons for not consenting to the study (57%). Reasons given to explain declining to participate in the study included the perceived time commitment and inconvenience of the study, opposition from a spouse, or a temporary move away from the study location to be cared for by family members. One-third (35%) of the patients were excluded due to predominantly medical reasons, such as severe heart disease, cognitive impairment, major depression or new acute disease, that were not detected in the first screening process, or were lost to follow-up (7 %).

Patient Characteristics

The baseline characteristics of the patients (age: 82.2 ± 4.8 years) are summarized in Table 1. Eighty-six percent were admitted to hospital due to severe nonsyncopal falls. Seventy-four percent of all patients had fall-related fractures (16% arm or shoulder fractures, 14% leg fractures, and 46% hip fractures). For all patients not expressly admitted to the hospital because of acute injurious falls, a history of at least one injurious fall during the previous 3 years related to the cause of the hospital admission was documented (patients with a history of injurious falls but admitted to the hospital for elective hip surgery). Eighty-eight percent of the patients could remember having had at least one injurious nonsyncopal fall in the previous 3 years. The patients had a low physical performance at baseline; for the whole study group, gait speed averaged 0.53 meters/second; the timed up-and-go mobility test averaged 28.6 seconds, and Tinetti's POMA averaged 19.1. The timed up-and-go test initially performed by the patients gave mean results that may be predictive for functional disability.[38] Twelve percent of patients had cognitive impairment (MMSE $\leq$24),[55] 14% had depression (Geriatric Depression Scale >5),[48] and 37% were at risk of malnutrition (body mass index <24).[56] The mean duration of inpatient rehabilitation was 24 ± 7 days. After discharge, 87% of all patients lived at home (alone or with a spouse), 9% lived with family support, and 4% lived in a nursing home. All parameters examined showed no difference at baseline, except that the number of medications per day was higher in the intervention group than in the control group ($P \leq .05$). The use of psychotropic drugs and hypertensives was similar in both groups.

Adherence to Training and Adverse Events

As shown in Table 2, adherence to intervention was 85% (intervention 85.4 ± 27.8% vs control 84.2 ± 29.3%). All patients, including the majority of patients who had acute fall-related fractures (74%) could follow the intensive, individually adjusted training regimen. No major health problems, including cardiovascular or musculoskeletal complications, occurred during training sessions or testing. Minor problems included aching muscles after first training sessions, cramping, tenderness, and knee pain. All problems were managed easily by adjustment of training and physiotherapy, and improved during training.

Forty-seven patients completed the intervention-phase. Forty-five patients completed the trial. Five patients dropped out because of serious medical events, such as subsequent falls and re-operation unrelated to the training intervention (3 intervention and 2 control). Four patients who had given consent did not start the study after returning home (3 intervention and 1 control). Three patients dropped out during training.

To determine whether patients who dropped out produced a systematic bias in the patient groups, a statistical analysis was executed. Characterizing parameters to control for randomization were compared between the intervention and control group, considering only those patients who stayed in the trial until T3 (end of follow-up phase). There was no statistical difference between these dropout-adjusted groups in the examined parameters other than medication. This result is consistent with the statistical analysis for the whole group initially recruited (Table 1), suggesting no systematic bias of results by patient selection by dropouts. For all but one patient, follow-up data of the incidence of falls could be obtained.

Muscle Strength

As indicated in Table 3 and Figure 1, exercise significantly improved muscle strength for all muscles trained in the trial. Differences between groups were still significant 3 months after cessation of training because of the large initial gain in strength in the intervention group and the moderate, nonsignificant losses in the follow-up period. Patients

Table 1. Baseline Characteristics of Patients

Characteristic	Intervention (n = 31)	Control (n = 26)
Age [years]	82.2 ± 4.1 (75–90)	82.1 ± 4.8 (75–90)
Height [cm]	155.3 ± 7.2	156.6 ± 6.6
Weight [kg]	59.5 ± 10.9	61.2 ± 9.0
BMI [kg/m²]	24.8 ± 4.0	24.9 ± 3.1
MMSE [scores]	27 (21–30)	27 (21–30)
GDS [scores]	3.85 ± 2.73	3.35 ± 2.35
ADL [scores]	90 (75–100)	89 (70–100)
IADL [scores]	6 (3–8)	5 (2–8)
Admission to hospital because of falls	85%	86%
Recent history of injurious falls	86%	92%
Fall-related fracture of lower extremity/hip	61%	58%
Regular medication [no.]	4.0 ± 1.9	2.9 ± 1.9*
Diagnosis [no.]	9.1 ± 3.2	7.8 ± 2.9
Ambulatory assistance		
Indoor	77%	77%
Outdoor	100%	100%
Physical activity level [scores]	9.8 ± 5.4	8.1 ± 3.5
Timed up-and-go [sec]	30.3 ± 11.6	26.6 ± 8.1
Tinetti-score (POMA)	18.8 ± 4.1	19.4 ± 4.2
Leg-strength [kg]	105 ± 43	112 ± 31

*None of the variables except number of medications (P = .042) showed significant differences between groups at baseline. Normally distributed data are presented as means ± SD; skewed data are presented as medians. Values in parentheses represent ranges. Leg strength represents sum of single-leg strength measures. With the cable mechanism of the training device reducing the real workload, the average weight lifted with one leg correspons to 31.5 and 33.6 kg.
BMI = Body Mass Index.
MMSE = Mini Mental State Examination.
GDS = Geriatric Depression Scale.
ADL = Activities of Daily Living.
IADL = Instrumental Activities of Daily Living.
POMA = Performance Oriented Mobility Assessment (Range 1–28; higher scores indicate better performance).

in the control group did not improve their strength. Handgrip strength, representing untrained muscle groups, did not change in either group.

Functional Performance

Motor performance such as walking, stepping, standing up, balance performance, and complex performance documented in validated motor tests, improved significantly after the training intervention, as shown in Table 4. In the intervention group, the average performance in a test predictive for functional dependence (timed up-and-go) no longer met criteria for increased risk of functional disability. In the intervention group, the use of any indoor mobility assistance device was reduced from 77% to 36% at the end of follow-up, compared with almost no change (77% to 73%) in the control group. Training effects in the intervention group were partly lost in the follow-up period (chair rise: P = .016; timed up-and-go: P = .046; POMA: P = .002 for changes within the intervention group), but still remained for some performances at a significantly

Table 2. Patients Taking Part in the Intervention

	Total [n]	Intervention [n]	Control [n]	Drop Outs: Total (accumulative) [n]
Patients recruited	57	31	26	
Patients who did not begin with intervention after being recruited		3	1	4 (4)
Patients who dropped out during intervention		2	1	3 (7)
Patients who dropped out during intervention period because of serious medical events not related to training		2	1	3 (10)
Patients at the end of intervention period	47	24	23	
Drop outs during follow-up period because of serious medical events not related to training		1	1	2 (12)
Patients at the end of follow-up period	45	23	22	

n = number.

Table 3. Strength Performance

	Intervention			Control			*P*-Value		
Strength Tests	T1 (n = 31)	T2 (n = 24)	T3 (n = 23)	T1 (n = 26)	T2 (n = 23)	T3 (n = 22)	*P*-Value T1	*P*-Value T2	*P*-Value T3
Leg extension—1 RPM [kg]	100.29 ± 40.11	175.88 ± 64.39	168.41 ± 57.26	110.46 ± 31.68	114.00 ± 46.27	115.65 ± 44.79	$P = 0.344$	$P > .001$	$P > 0.001$
Knee extension [N]	97.97 ± 30.70	133.83 ± 32.27	127.41 ± 25.62	103.77 ± 29.11	109.57 ± 36.99	107.91 ± 30.71	$P = 0.753$	$P < .001$	$P < .001$
Knee flexion [N]	46.90 ± 18.47	60.99 ± 17.22	57.95 ± 14.77	54.50 ± 19.18	55.13 ± 17.43	51.41 ± 18.30	$P = 0.244$	$P = .002$	$P = .001$
Ankle plantar flexion [N]	114.68 ± 46.12	151.50 ± 48.48	148.05 ± 47.36	106.62 ± 43.94	111.78 ± 44.14	119.05 ± 48.68	$P = 0.351$	$P = .002$	$P = .023$
Handgrip strength [KPa]	101.68 ± 34.59	102.50 ± 28.14	103.18 ± 29.49	104.92 ± 28.95	107.13 ± 23.97	106.23 ± 29.35	$P = 0.927$	$P = 0.957$	$P = 0.738$

Data are means ± SD for baseline values (T1), values at the end of intervention (T2), or the end of follow-up (T3). Strength parameters were not significantly different between groups at baseline. Results of statistical analysis are adjusted for base-line age and medication. Values obtained at T2 and T3 are also adjusted for baseline strength. The values represent two-legged measurements (ankle plantar flexion, knee extension, knee flexion) or the sum of left/right sided measurements (leg extension, handgrip). In measuring ankle plantar flexion, knee extension, and knee flexion, the training device and the dimension of strength in measuring (one-limb, isometric measurement). Handgrip strength represents a nontrained muscle group in the trial.
1 RPM = one repetition maximum.
N = Newton.
Kpa = kilopascal.

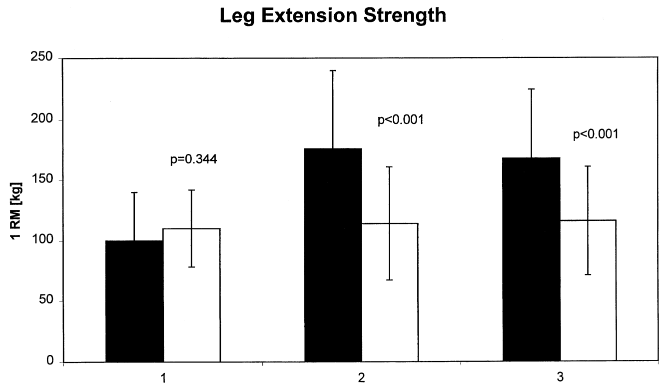

Figure 1. Leg strength measured initially (T1), at the end of intervention (T2), and follow-up (T3) for intervention and control group. Bars indicate the mean ± SD of the One Repetition Maximum for leg strength. Initial leg strength did not show significant differences between groups ($P = 0.344$). There was a significant effect of exercise on differences between groups after adjustment for age, initial leg strength, and medication at the end of intervention (T2) ($P > .001$) and follow-up (T3) ($P < .001$).

higher level than baseline levels or performances of the control group because of the large initial improvement during training. The control group failed to show significant improvement or, in some cases, presented functional decline at the end of intervention (T2) and follow-up (T3). ADLs and IADLs improved only marginally in both groups, with ceiling baseline values at the beginning of the intervention.

Physical Activity

As Table 5 indicates, physical activity before hospital admission revealed a sedentary lifestyle for the study population, typical of frail older women. Only a few patients performed physical leisure-time activities such as gardening. Housework and "sports" activity, which included walking, accounted for almost all the physical activity. Sports activity before hospital admission correlated significantly with functional performance (walking speed, $P = .01$; timed up-and-go, $P = .015$; chair rise, $P = .007$; Tinetti; $P = .027$) and fall-related emotional status (FHI, $P = .02$; fear of falling, $P = .035$) but not with strength and depression. While there were only minor changes in the average amount of housework and leisure time activity during the intervention phase, training intervention in the training group more than doubled total physical activity and sports activity. Even in the control group, motor activity (group sessions, physiotherapy) was sufficient to increase sports activity by 30% and total activity by 11% because of the low baseline level. During the follow-up period, physical activity in both groups as documented in the questionnaire returned to their low baseline levels.

Emotional Status

Fall-related emotional aspects, such as posttraumatic behavior and emotional status, documented in the FHI or in the subjective perception of walking unsteadiness, were significantly reduced during the intervention and remained significantly reduced in the follow-up period in the train-

Table 4. Functional Performance

	Intervention			Control			*P*-Values		
Functional Tests	T1 (n = 31)	T2 (n = 24)	T3 (n = 23)	T1 (n = 26)	T2 (n = 23)	T3 (n = 22)	*P*-Value T1	*P*-Value T2	*P*-Value T3
Tinetti POMA [scores]	18.86 ± 4.14	25.33 ± 2.71	23.02 ± 4.62	19.44 ± 4.23	20.96 ± 5.03	20.07 ± 4.83	$P = 0.995$	$P < .001$	$P = .004$
Timed up-and-go [sec]	30.26 ± 11.56	19.50 ± 4.36	24.73 ± 13.14	26.65 ± 8.06	29.96 ± 12.86	28.23 ± 11.37	$P = 0.298$	$P < .001$	$P = 0.189$
Walking velocity [sec]	0.52 ± 0.18	0.71 ± 0.18	0.68 ± 0.22	0.53 ± 0.17	0.51 ± 0.18	0.51 ± 0.16	$P = 0.713$	$P < .001$	$P = .002$
Chair-rise time [sec]	18.13 ± 6.57	13.42 ± 2.96	15.86 ± 4.86	17.15 ± 4.72	19.57 ± 6.17	20.14 ± 7.22	$P = 0.750$	$P > .001$	$P = .012$
Maximal box step [cm]	55.80 ± 12.12	75.21 ± 14.93	72.96 ± 13.86	62.00 ± 15.75	66.59 ± 17.07	65.95 ± 17.15	$P = .056$	$P = .006$	$P = .046$
Stair flight [cm]	25.19 ± 13.93	15.17 ± 4.56	17.18 ± 5.66	26.04 ± 13.94	24.48 ± 12.37	23.36 ± 9.41	$P = 0.931$	$P = .001$	$P = .005$
Functional reach [cm]	15.03 ± 5.44	20.19 ± 7.06	18.78 ± 6.60	15.61 ± 5.38	15.43 ± 5.47	17.20 ± 6.9	$P = 0.959$	$P = .008$	$P = .025$
Balance score [scores]	12.07 ± 2.85	13.67 ± 2.27	13.43 ± 1.94	12.06 ± 3.80	11.94 ± 3.82	11.52 ± 3.87	$P = 0.888$	$P = .007$	$P = .005$
ADL [scores]	90.5 ± 6.59	95.00 ± 4.63	94.76 ± 6.80	89.40 ± 8.33	93.18 ± 9.07	94.29 ± 7.63	$P = 0.527$	$P = 0.426$	$P = 0.823$
IADL [scores]	5.96 ± 1.57	6.90 ± 1.18	6.89 ± 1.49	5.41 ± 1.79	5.95 ± 2.14	6.30 ± 1.92	$P = 0.132$	$P = 0.217$	$P = 0.539$

Data are means ± SD and are calculated from baseline values (T1), values at the end of intervention (T2), and the end of follow-up (T3). Results of statistical analysis are adjusted for baseline age and medication. Values obtained at T2 and T3 are also adjusted for baseline functional performance. Box step values are summed results of left and right leg. Chair-rise time was counted for three sequential trials.
POMA = Performance Oriented Mobility Assessment.
ADL = Activities of Daily Living.
IADL = Instrumental Activities of Daily Living.

Table 5. Physical Activity

	Intervention			Control			*P*-Values		
Physical Activity [Scores]	T0 (n = 28)	T2 (n = 24)	T3 (n = 22)	T0 (n = 26)	T2 (n = 23)	T3 (n = 22)	*P*-Value T1	*P*-Value T2	*P*-Value T3
Housework	1.63 ± 0.64	1.54 ± 0.64	1.72 ± 0.66	1.52 ± 0.58	1.26 ± 0.74	1.60 ± 0.66	$P = 0.135$	$P = 0.244$	$P = 0.587$
Leisure activity	1.78 ± 3.53	0.50 ± 1.78	1.37 ± 2.96	0.61 ± 1.66	0.25 ± 1.12	0.61 ± 1.74	$P = 0.185$	$P = 0.607$	$P = 0.648$
Physical "sports" activity	6.78 ± 4.45	19.97 ± 3.40	8.46 ± 4.94	5.03 ± 2.64	6.80 ± 3.71	5.65 ± 4.42	$P = 0.116$	$P < .001$	$P = .087$
Total physical activity	9.79 ± 5.38	22.00 ± 4.38	11.56 ± 6.86	7.17 ± 5.34	8.32 ± 4.42	7.85 ± 5.54	$P = .063$	$P < .001$	$P = 0.335$

Data are means ± SD and are calculated from retrospectively documented baseline values before admission to hospital (T0), at the end of training intervention (T2), and at the end of follow-up (T3). Results of statistical analysis for group differences are adjusted for baseline age and medication. Values obtained at T2 and T3 are adjusted for baseline physical activity (T0).

ing group, as indicated in Table 6. Fear of falling was significantly reduced over time although differences between groups were not significant. Results of the FHI, fear of falling, and perceived walking steadiness were not significantly affected in the control group. In both groups, results of the Geriatric Depression Scale and the Philadelphia Geriatric Center Morale Scale were not significantly influenced during the intervention.

Fall Incidence

The incidence of falls during the 6-month observation period was 60% for the control group and 45% for the intervention group, equivalent to a 25% reduction of secondary falls in the intervention group. Relative risk (RR) is calculated as 0.753 (95% CI: 0.455–1.245) for fall incidence for patients in the intervention group compared with patients in the control group. The result calculated by the chi-square test for fallers versus nonfallers is not significant for the limited group size ($P = .20$). One patient in the control group was lost to follow-up because of moves to different hospitals and nursing homes and was not included in the calculation of fall incidence.

DISCUSSION

Information about the efficacy of physical training protocols in geriatric patients recovering from injurious falls including hip-fracture patients is scant,[15,16] although these patients have the highest medical costs, highest incidence of dependency, and highest mortality.[5,17–19] This study demonstrated that combined progressive high-resistance strength training and progressive functional training improved strength, balance, and functional performance without increasing the risk of training-related adverse clinical events in frail geriatric patients with a history of injurious falls. These changes were accompanied by an improvement in subjective awareness of postfall postural stability while walking, and fewer fall-related emotional and behavioral restrictions. The achieved nonsignificant reduction in subsequent falls may be clinically relevant but needs to be confirmed in a larger follow-up study with adequate statistical power.

Adherence and Safety

With the exclusion of unstable cardiac patients (congestive heart failure >NYHA III, acute myocardial infarction >3 months) patients were not screened routinely by stress testing. In all patients, maximal strength and functional performance were assessed. No serious medical problems, namely of cardiac or orthopedic origin, or other adverse events occurred during the intensive progressive physical training or measurements. This is remarkable because study participants were geriatric, frail, multimorbid, and suffering from acute injurious falls and orthopedic surgery. Even fracture patients (76% of all patients), including hip-fracture patients (46% of the study population), were able to follow the program without serious health problems. The excellent adherence rate evidently represented the broad acceptance of the training program by the involved patients.

Improvement of Strength and Function

The exercise group showed significant improvement in all trained muscle groups. Improvement was induced by the training intervention, since handgrip strength, controlling

Table 6. Emotional Status

Tests [Scores]	Intervention			Control			*P*-Values		
	T1 (n = 28)	T2 (n = 24)	T3 (n = 22)	T1 (n = 24)	T2 (n = 22)	T3 (n = 21)	*P*-Value T1	*P*-Value T2	*P*-Value T3
Falls handicap inventory (FHI)	29.33 ± 13.47	14.95 ± 12.95	11.60 ± 10.11	31.30 ± 13.00	30.00 ± 14.03	24.00 ± 14.99	$P = 0.558$	$P < .001$	$P = .001$
Walking reliability	2.14 ± 0.48	1.50 ± 0.61	1.57 ± 0.68	2.19 ± 0.68	2.05 ± 0.59	1.95 ± 0.58	$P = 0.268$	$P = .002$	$P = .014$
Fear of falling*	1.43 ± 0.98	0.91 ± 0.81	1.10 ± 1.09	1.62 ± 0.80	1.38 ± 0.92	1.68 ± 0.84	$P = 0.749$	$P = 0.100$	$P = 0.125$
Geriatric depression scale (GDS)	3.57 ± 3.59	3.23 ± 2.91	3.29 ± 3.27	3.45 ± 2.42	2.70 ± 2.00	3.59 ± 2.58	$P = 0.689$	$P = 0.766$	$P = 0.404$
Philadelphia Geriatric Center Morale Scale	6.24 ± 3.36	6.23 ± 3.87	6.63 ± 4.25	5.95 ± 3.61	5.90 ± 3.42	6.14 ± 3.85	$P = 0.693$	$P = 0.850$	$P = 0.628$

Data are means ± SD and are adjusted for baseline age and medication. Values obtained at T2 and T3 are adjusted for baseline emotional status.

*Fear of falling was significantly reduced within the intervention group over time.

for untrained muscles, did not increase in either group. Improvements in strength have been shown in previous studies in community-dwelling older people or nursing home residents.[13,14] In rehabilitation studies including frail geriatric patients with a history of injurious falls, motor performance has only been subjected to one-dimensional, simple training methods or were uncontrolled.[15,16] In the present study, the improvement in strength was measured not only as the maximal workload (functional, multilimb, concentric-eccentric, dynamic strength) achieved in the training device, but also as the maximal strength (one-limbed, isometric strength) measured in a nontraining measuring unit. In previous studies, improvement in the maximal strength achieved in the training device could not always be confirmed by measuring strength in nontraining measuring units.[57] Improvements in strength not bound to motor learning in a specific training situation, as achieved in this study, may be more relevant for functional every-day performance.

The improvements in strength in the training group were also accompanied by significant overall improvement in functional performance. As demonstrated by other studies, there was a strong relationship between functional performance and strength in the elderly.[13,58–61] For very frail people, such as geriatric patients suffering from acute sequelae of injurious falls, lack of strength limits functional performance, describing a curvilinear relationship between strength and function.[62] In this study, the improvement in strength, along with the functional training, laid the foundation for improvement in function and balance.

Functional performance of basic motor tasks such as walking or stepping are hallmarks of a mobility-related quality of life, and are often underestimated by younger, healthy people. Progress in walking velocity by 37%, as achieved by the patients in the intervention group, may represent a large improvement for patients who were not able to reach half the walking speed necessary to cross a street during a normal traffic light sequence[9] or only one-third of the walking speed of comparable healthy older women.[63] Initially, most of the patients were not able to step onto a bus or train, so a training improvement of 10 centimeters in step height, as achieved in the intervention group, is a significant measure of enhanced quality of life.[64] The 40% improvement in speed in ascending a flight of stairs represents not only improved speed but also quality of motion. This may be crucial for many everyday tasks, which were previously restricted in these geriatric patients.

The results of questionnaires documenting general functional performance (ADLs/IADLs) showed no differences between groups. The ceiling effect (basic values in both groups 90 out of 100 scores, with incontinence as the most-often remaining deficit in ADLs) may explain why the functional improvement in the intervention group documented by other tests was not reflected in ADL scores.

Specific motor tests such as stair climbing,[41] chair-rise,[1,6,10,42] functional reach,[40,43] timed up-and-go,[40] walking performance,[1,10,42] balance/sway,[1,10,42,44] Tinetti's motor test,[45] or use of assistive devices[1,46] were also chosen in this study because there is a significant correlation between performances on these tests and the risk of functional disability, dependence, or falls. Because disability, dependence, and recurrent falls are frequent sequelae of falls, performances on these motor tests may also predict the long-term consequences and risks of falls in high-risk patients with a history of injurious falls. Patients of the intervention group showed an overall improvement in all the above-cited tests. Most differences between groups remained significant after the end of the follow-up period despite the fact that motor performances declined after detraining in the intervention group with minor losses in strength and some significant losses in some functional tests (chair-rise time, timed up-and-go, POMA) in the training group. A practice effect of training functional movements could have helped to conserve the increase in function and strength obtained by training. Functions such as rising from a chair or climbing stairs were trained in the intervention. To perform these functions, it is necessary to lift one's body weight, which is an adequate training stimulus in frail geriatric patients not able to support their body weight before intervention. As patients in the intervention group became more confident and less fearful, the improvements in postfall emotional status would also support individualized physical activity at home.

In the control group, however, strength remained at the low baseline level. Functional performance documented in the chair-rise test and timed up-and-go test even declined during the study period, although control patients received more than usual care, with additional attention, activating group sessions, and physiotherapy. In patients receiving usual care, only functional decline is even more pronounced.[65]

Physical Activity

Physical activity is a key to functional performance and perhaps represents the most cost-effective effort to combat disability in old age.[9] Bed rest and restricted physical activity lead to accelerated deconditioning and loss of function[66,67] and characterize the sequelae of injurious falls. In this study, physical activity before hospital admission was typically low for the study population. Total physical activity was further restricted by sequelae of fall injuries and orthopedic surgery. Physical activity before the fall correlated significantly with baseline functional performance. The training intervention more than doubled total physical activity compared with the activity before the fall and increased sports activity by 170%. The program of the control group was sufficient to increase total activity by 10% and sports activity by 30%. Although it was not the aim of the study, patterns of documented physical activity were minimally influenced after training intervention. Some patients were still limited in their ability to join out-of-home training sessions. The opportunity to continue the training regimen was not available at the time of the study intervention because training facilities adequate for older hip-fracture patients that were not related to hospital or study service were not yet established.

The activity questionnaire for the elderly used in this study is validated for older people and allowed a detailed quantification of activity status and change of physical activity during the intervention and follow-up period in domains of physical activity such as housework, leisure activity, and "sports" activity.[47] A comprehensive documentation of the intensity, quantity, and frequency of the training intervention was possible using this questionnaire, which has not been achieved in comparable studies. The training of everyday activities, that would be performed only occasionally, might not be explicitly mentioned by the patients in interviews and might therefore not be documented.

Emotional Status

Overall emotional status, represented by the results of the Geriatric Depression Scale and the Philadelphia Geriatric Center Morale Scale, was not influenced by the training intervention. The preselection of study patients by excluding depressed and unmotivated patients may explain the deviating result from a recent study that documented an antidepressive effect of progressive resistance training in older people.[68] Fall-related emotional status, such as fear of falling or confidence in not falling (self-efficacy), is closely associated with poor functional performance and the incidence of falls[50,69–72] and might be improved by increasing physical performance. In this study, physical activity before hospital admission correlated significantly with fall-related emotional variables such as fear of falling and fall-related emotional restrictions or behavior documented by the FHI suggesting more confidence in the physically active. The training intervention significantly improved fall-related variables such as walking reliability, fear of falling, and FHI, documenting that emotional stabilization increased with growing confidence in functional performance. Such a growing sense of mastery or self-efficacy as proposed by Bandura[73] induces psychological improvements and has been confirmed in previous fall-studies in older people.[28,71,72] In a feed-back mechanism, emotional stabilization may in its turn lead to less physically restricted behavior, a more active lifestyle, and better physical performance.[72]

Fall Incidence

Motor deficits, such as lack of strength, poor functional performance, and emotional restrictions, are well known as risk factors for and consequences of falls. Patients with a history of multiple falls or injurious falls are at a high risk for recurrent falls.[6,41] This was confirmed by the high incidence of falls in the study population. In the control group, 60% of the patients fell at least once during the 6 months of the follow-up, which is more than double that of community-dwelling older people at the age of 80 with no known history of falls.[1,2] In this study, the nonsignificant reduction (RR:0.753 CI:0.455–1.245) of falls was accompanied by an overall improvement in strength and functional performance that was not always achieved in other studies that were successful in reducing the incidence of falls in older people by motor intervention.[25,26] The magnitude of the achieved effect of the intervention in reducing falls is comparable to other trials that successfully reduced the incidence of falls in community-dwelling older people in larger sample sizes.[25–28] The 25% reduction in fall incidence in the intervention group, however, did not reach statistical significance in the restricted sample size of the study ($n = 57$). The effect of the described training regimen on secondary fall prevention nevertheless may be clinically relevant and should be confirmed by a larger, longer-term follow-up study with adequate statistical power.

CONCLUSION

The training regimen and its organization were highly acceptable to the patients. The training significantly improved motor performances that are known risk factors for falling and led to successful rehabilitation in patients with a history of injurious falls. Significant changes were noted in a limited time frame, but even more pronounced improvements as well as conservation of achieved improvements may be possible with a reduced but ongoing exercise program to prevent the detraining effects that occur after training cessation. The high intensity and duration of the training, the use of specific training equipment, and the motivating group organization as used in the study represented adequate training stimuli for the rehabilitation of geriatric patients with a history of injurious falls and differ substantially from home-based rehabilitation concepts previously suggested.[15,16] The training organization and the training regimen may represent a model for ambulant rehabilitation organized in semistationary care in a day hospital and in public or commercial health-oriented sports clubs, as now established in the study location. The strictly individualized training, the adequate social framework of small training groups led by a therapeutic recreational trainer for older people, and transportation aid for very-immobility-restricted patients will ensure that not only highly selected patients could take part in such ambulant physical training programs. Although the patients that took part in this study were old, frail, multimorbid, significantly limited in their motor performance, and handicapped by acute sequelae of serious falls, they still represent a positive selection within geriatric patients suffering from injurious falls. For these patients with a realistic chance of defending or regaining their independence such a training program is recommended.

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