Osteoporos Int (2013) 24:867–876
DOI 10.1007/s00198-012-2045-3

ORIGINAL ARTICLE

Effect of a multifactorial fall-and-fracture risk assessment and management program on gait and balance performances and disability in hospitalized older adults: a controlled study

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Received: 27 January 2012 / Accepted: 25 May 2012 / Published online: 26 July 2012

Abstract

Summary This controlled intervention study in hospitalized oldest old adults showed that a multifactorial fall-and-fracture risk assessment and management program, applied in a dedicated geriatric hospital unit, was effective in improving fall-related physical and functional performances and the level of independence in activities of daily living in high-risk patients.

Introduction Hospitalization affords a major opportunity for interdisciplinary cooperation to manage fall-and-fracture risk factors in older adults. This study aimed at assessing the effects on physical performances and the level of independence in activities of daily living (ADL) of a multifactorial fall-and-fracture risk assessment and management program applied in a geriatric hospital setting.

Methods A controlled intervention study was conducted among 122 geriatric inpatients (mean±SD age, 84±7 years) admitted with a fall-related diagnosis. Among them, 92 were admitted to a dedicated unit and enrolled into a multifactorial intervention program, including intensive targeted exercise. Thirty patients who received standard usual care in a general geriatric unit formed the control group. Primary outcomes included gait and balance performances and the level of independence in ADL measured 12±6 days apart. Secondary outcomes included length of stay, incidence of in-hospital falls, hospital readmission, and mortality rates.

Results Compared to the usual care group, the intervention group had significant improvements in Timed Up and Go (adjusted mean difference [AMD]=−3.7s; 95 % CI=−6.8 to −0.7; P=0.017), Tinetti (AMD=−1.4; 95 % CI=−2.1 to −0.8; P<0.001), and Functional Independence Measure (AMD=6.5; 95 %CI=0.7–12.3; P=0.027) test performances, as well as in several gait parameters (P<0.05). Furthermore, this program favorably impacted adverse outcomes including hospital readmission (hazard ratio=0.3; 95 % CI=0.1–0.9; P=0.02).

Conclusions A multifactorial fall-and-fracture risk-based intervention program, applied in a dedicated geriatric hospital unit, was effective and more beneficial than usual care in improving physical parameters related to the risk of fall and disability among high-risk oldest old patients.

Keywords Aged · Exercise · Fall prevention · Hospital · Interdisciplinary intervention · Physical function

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Introduction

Over one third of people aged 65 and older experience at least one fall each year. The rate of falls rises steadily with advancing age [1, 2]. As a result, such individuals are at increased risk for subsequent falls, decline in physical function, premature institutionalization, or death [3, 4]. Although most falls do not result in serious outcome, roughly 10 % of falls in this age group lead to a severe injury, with less than 1–2 % to a hip fracture, a dramatic expression of falls in terms of morbi-mortality [5–8]. Hence, falls and induced injuries represent a leading cause of hospital admissions [5, 9]. Among patients older than 65 years, 1 out of 20 hospital admissions is for fall-related trauma [5]. Hospital stay itself is associated with an increased risk of functional worsening, falls, and a loss of independence in geriatric patients [9–11].

There is a pressing need to implement strategies aimed at reducing fall-related health and social care consumption [12, 13]. Developing multidisciplinary interventions on falls and osteoporosis among older people is a recognized approach

[14, 15]. Given the complex etiology of falls, multifactorial fall risk assessment strategies followed by direct individualized interventions tailored to the identified intrinsic and extrinsic risk factors, in combination with a suitable exercise program, seem to be the most attractive approach for preventing falls and a decline in physical function in the elderly [16, 17]. Guidelines highlight the importance of targeting high-risk individuals for such a strategy, particularly those people who report an injurious fall or demonstrate abnormalities of gait and/or balance [16]. Gait and balance disorders consistently rank among the most frequent risk factors for falls [18]. More specifically, several alterations in gait patterns (e.g., reduced gait velocity or increased gait variability) are associated with an increased risk of falling in older individuals [19].

From a fall-and-fracture reduction perspective, fall risk should be addressed along the continuum of care of aging adults. Hospitalization affords a major opportunity for identifying high-risk individuals and for interdisciplinary cooperation to manage risk factors [20]. Yet, the hospital care setting is frequently restricted to the treatment of fall consequences instead of fall risk factors in daily clinical practice [21]. Furthermore, despite a large number of multifactorial fall prevention programs in community settings or long-term care facilities since Tinetti's seminal multifactorial intervention study [22], there is limited research regarding the feasibility and efficacy of such programs in a hospital setting, particularly on functional outcomes or postdischarge events (e.g., unplanned hospital readmission) [6, 9, 17, 23].

We evaluated the effects of a multifactorial fall-and-fracture risk assessment and management program applied in a geriatric hospital setting. The program delivered evidence-based best practices for falls and osteoporosis prevention, in patients admitted for fall, or with a history of recurrent falls, or with gait and/or balance impairments. The primary objective of the study was to assess the effects of the program in improving gait and balance performances and the level of independence in activities of daily living (ADL) as compared to standard "usual care." Secondary objectives were to assess the impact on length of hospital stay (LOS), in-hospital fall outcomes, as well as rehospitalization and mortality rates within a 12-month period following discharge.

Methods

Study design and patients

This controlled study was conducted among geriatric inpatients at the Department of Rehabilitation and Geriatrics of a large public teaching hospital in Geneva, Switzerland (Geneva University Hospitals). This academic hospital consisted of a 294-bed acute and rehabilitation geriatric care ward. Enrolment took place between June 2006 and August 2008. Pre- and postintervention assessments of primary outcomes were planned while secondary outcomes were ascertained during hospital stay and through a 12-month post-discharge follow-up.

Inpatients aged over 65 admitted with a fall-related diagnosis were included in this study. Ninety-two patients admitted to a dedicated unit and consecutively enrolled into a multifactorial intervention program, implemented in addition to usual care, constituted the intervention group. The control group was made up of 30 consecutive patients admitted in the same geriatric hospital in a nondedicated unit, referred to an in-hospital "falls consultation," and who received standard usual care. Only patients who were deemed sufficiently medically stable and who satisfied the following criteria were included: (1) able to walk 10 m with or without assistive device, (2) able to follow simple instructions, and (3) able to participate in a goal-oriented rehabilitation intervention. Patients with acute confusional state or whose gait, standing balance, mobility, or strength was not impaired according to the assessments detailed below were excluded.

Ethical approval was granted by the institutional ethics review committee (Geneva University Hospitals). As the intervention was delivered at a cluster level in the frame of patients' regular care, individual informed consent was not required by the ethics committee. Data were collected in the course of clinical care and monitoring. Neither patients nor staffs of intervention and control units were aware of the nature of the study and the specific study outcomes.

Interventions

Multifactorial intervention program

The multifactorial intervention program (i.e., "Chutes Et OstéoPoroSe" program, CHEOPS) consisted of a multidisciplinary comprehensive assessment to address potential fall-and-fracture risk factors followed by an individually tailored intervention targeting each patient's individual risk factors and impairments. This program included an intensive targeted rehabilitation therapy, mainly based on exercise, delivered to all patients. The program was implemented in a dedicated unit who benefited from an additional 0.3 full-time equivalent physiotherapists staffing for 32 beds, compared to other units.

Key components of the multifactorial intervention program are outlined in Tables 1 and 2. A systematic battery of tests was administered weekly, in order to monitor patients' progresses and update the rehabilitation plan (Table 1). Multidisciplinary team meetings were held on a weekly basis to: review and discuss each new patient's case for inclusion, develop an individually tailored management plan based on assessment data, review the management plan deployment, revise the program goals, and discuss the

Table 1 Key components of the multifactorial intervention program: assessments

Multidisciplinary systematic comprehensive assessment to address potential fall-and-fracture risk factors	Components of the systematic battery of tests
Physician	
Medical history	
History of falls during the last year	
Medications	
Cardiovascular status	Electrocardiogram, orthostatic blood pressure measurement
Neurological function	
Cognitive status	Mini-Mental State Examination (MMSE®)
	Geriatric Depression Scale (GDS)
Absolute fracture risk	FRAX® tool[c]
Bone health status	Dual-energy X-ray absorptiometry (DXA)[a]
Vitamin D status	Blood test[a]
Vision and visual acuity	
Vestibular function	
Locomotor apparatus	
Physiotherapist	
Physical function[b]	Timed Up and Go (TUG) test
	Simplified Tinetti test
	Spatio-temporal gait analysis (GAITRite®)
	Five-Times-Sit-to-Stand test[c]
Foot, ankle, and footwear	
Assistive device	
Occupational therapist	
Fear of falling	Short Falls Efficacy Scale International (Short FES-I)[c]
Environmental hazards (including home safety assessment)	
Dietitian	
Nutritional status	Mini-Nutritional Assessment (MNA®) tool
Nurse	
Functional status	Functional Independence Measure (FIM®) instrument
Social worker	
Social environment	

[a] Whenever required

[b] Joint range of motion, sensory integrity, muscle strength, balance, and gait

[c] Added after study inception

Table 2 Key components of the multifactorial intervention program: rehabilitation

Individually tailored sessions
3 to 5 weekly sessions of 30–45-min duration
■ Physiotherapy sessions emphasizing gait, balance, and strength retraining as well as functional activities
Group sessions
5 weekly sessions of 60-min duration
■ Physiotherapeutic groups (two weekly sessions on alternate days): (a) addressing the multiple dimensions of balance as a core component and designed to improve stability, range of motion, and mobility (e.g., balance on unstable or compliant surfaces, obstacles crossing, dynamic weight transfers) or (b) designed to improve muscular strength and power through moderate-intensity seated or supported standing position machine-based exercises
■ Jaques-Dalcroze eurhythmics workshops (two weekly sessions on alternate days) (i.e., varied multitask exercises performed to the rhythm of improvised piano music, sometimes involving the handling of objects) [48]
■ Workshop (one weekly session) led by an occupational therapist featuring various fixed topics and essentially aimed to tackle fear of falling; it focuses on beliefs about fall risk, fall risk behaviors, and coping strategies, including work on the ability to find a way to get up if a fall occurs

All patients included in the intervention group attended the individual and group sessions

discharge arrangements. If needed, additional specific assessments (e.g., measurement of the serum 25-hydroxyvitamin D level (25(OH)D) or dual-energy X-ray absorptiometry for bone and lean mass status) as well as specific interventions or consultations by other medical specialists (e.g., ophthalmologic and neurologic examination) were arranged.

The intensive targeted rehabilitation therapy combined general and individually tailored activities, both on an individual basis or in groups (Table 2). Whenever required, a home visit was undertaken before patient's discharge to assess environmental hazards and facilitate modifications.

Usual care

Control patients, who fulfilled the criteria detailed above, received usual care in their respective geriatric units. No restrictions were placed on medical, nursing, or allied health interventions. Thus, all control patients were referred for evaluation to a specialized "falls consultation" available for all geriatric patients hospitalized in the institution and which consisted of a comprehensive assessment aimed to assess potential modifiable fall-and-fracture risk factors. All patients underwent gait analysis and functional tests. Upon completion of the medical assessment, recommendations were made by the consulting physician to the unit's physician for the management and treatment of all identified individual fall-and-fracture risk factors.

Patients received the usual individually delivered physiotherapy at the discretion of the unit's physiotherapist. Levels of therapies varied from no additional therapy to usual physical (and/or occupational) therapy (i.e., 30-min duration, three times per week) which consisted mainly of functional activities (e.g., transfers, stepping), supervised walking, and assistive device adaptation.

Baseline demographic and clinical characteristics

Data on demographic characteristics, medical status, comorbidities, medication, or prehospitalization fall history during the year before evaluation were collected from medical records and face-to-face interviews with patients, using a standardized checklist of main risk factors for falls completed by a physician and a physiotherapist.

Follow-up and outcome measures ascertainment

Primary outcome measures

Primary outcome measures were gait and balance performances, as assessed by instrumental gait analysis and functional tests, and the level of independence in ADL. All assessments were carried out by trained physiotherapists, in a dedicated examination room, with appropriate rest breaks and using a standardized protocol, as detailed below. All patients were assessed by physiotherapists who were unaware of the study at the time of the assessments and who were blind to information from previous evaluation visits.

Spatial and temporal gait parameters, as well as gait variability characteristics, were collected using an electronic pressure-sensitive walkway (GAITRite; CIR Systems Inc., Havertown, PA) according to published guidelines [24]. Gait measurements obtained with this tool appeared to be reliable and valid in older adults [25]. The patients were asked to walk at a self-selected comfortable (or "usual"), and maximum speed over a 732-cm-long walkway, as a single task. Patients had to walk while simultaneously counting backward out loud from 50 by ones (i.e., each time subtracting 1: 50, 49, 48, 47…) until the end of the walkway. Coefficient of variation (CoV) was used as a measure of variability for stride length and stride time parameters (CoV=[standard deviation/mean]×100). The test–retest reliability of gait outcome measures was assessed in a subsample of 30 patients. Intraclass correlation coefficients (2, 1) for gait velocity parameter were above 0.90 for all conditions while standard error of measurement (SEM) values were all below 5 cm/s. The corresponding values for gait variability parameters were all below 2 %. Minimal detectable change was computed for each gait outcome and used to interpret progress in individual patients.

For functional tests, each patient underwent Timed Up and Go (TUG) [26] and simplified Tinetti tests [8, 27]. Both tests have been shown to be valid indicators of gait and balance functions and to be reliable in the elderly [28, 29]. In addition, the Functional Independence Measure (FIM®) instrument, a global measure of disability, was administered. This 18-item, 7-level scale measured the degree of independence in ADL [30].

Secondary outcome measures

Patient LOS was measured as the number of overnight stays in the unit, from the day of admission until the day of discharge. Falls data during hospital stay were extracted from standardized incident report forms mandatorily completed after each fall by nurses and physicians. A fall was defined as "an event in which a patient suddenly and unintentionally came to rest on the floor." Data on hospital readmissions and mortality, over a 12-month period following discharge, were derived from automated databases of the institution's quality of care division. These tasks were completed by a statistician blind to patient allocation.

Statistical analysis

Descriptive data were expressed as mean and standard deviation (SD) for continuous variables and as number and percent for categorical variables. Baseline demographic and clinical characteristics of the two groups were compared using the Chi-square test, Student's t test, or Wilcoxon rank sum (Mann–Whitney) test, as appropriate.

For physical and functional outcomes, analyses of covariance (ANCOVA) were used to examine differences in change (calculated as follow-up minus baseline score) across groups, with the baseline value as covariate. Estimates of between-group mean differences, adjusted for baseline values, were computed, together with 95 % confidence intervals (CIs). No imputations were performed for missing data.

Regarding in-hospital fall outcomes, a log-binomial regression model was used to calculate relative risk comparing the number of patients with one or more falls during the stay in both groups. The incidence rate ratio for the number of falls was analyzed using a negative binomial regression model. Patient days of follow-up started on the day of admission until the day of discharge from the unit. In addition, survival analysis was conducted: hazard ratio was estimated from a Cox proportional hazards model for the time to first fall.

Three-month all-cause rehospitalization and 12-month all-cause mortality rates were both analyzed using a negative binomial regression model and a Cox proportional hazards model. Hospital readmission was defined as all-cause admission to an acute care hospital within 3 months of discharge. Additional multivariate Cox proportional hazards models were developed. Covariates were selected for a final model by a stepwise forward variable selection procedure, with entry and retention in the model set at a significance level of 0.20.

All analyses were performed using Stata software version 11.0 (Stata Corp., College Station, TX, USA). A *P* value <0.05 was considered statistically significant, and all statistical tests were two sided.

Results

Baseline characteristics and follow-up

Overall, 122 inpatients were enrolled in the study (92 in the intervention group and 30 in the control group). In the intervention group, there were 134 new patient's cases considered for inclusion. Forty two were not retained for the rehabilitation program: 13 unwilling to undertake the rehabilitation program, 13 considered as being without potential of rehabilitation, 8 because of being medically instable, 5 too cognitively impaired, and 3 without any physical impairment.

Patients were predominantly community-dwelling women (74 %) and had a mean±SD age of 84.3±6.6 years (Table 3). Most of them lived alone (67 %) and received home assistance (65 %). The two groups exhibited similar baseline characteristics except for a higher prevalence of patients with polyneuropathy in the control group (P=0.04) and dehydrated patients in the intervention group (P=0.03). Patients in both groups displayed similar cognitive, nutritional, and fall-related profiles at baseline and presented multiple risk factors for fall. Eighty-nine percent reported to have fallen at least once during the previous year.

The mean time from admission to baseline assessment was 12.4±9.2 and 13.8±11.2 days for intervention and control groups, respectively, with no differences between groups (P=0.47). Most patients had a fairly good level of independence (mean baseline total FIM score, 95.5±19.2). At baseline, altered gait patterns and impaired TUG and Tinetti test performances were present in both groups (Table 4). The groups were similar in all physical outcome measures with the exception of TUG where the control patients performed slightly better than the intervention patients (P=0.04).

Vitamin D supplementation was initiated during hospital stay in 66 (54 %) patients: 39 and 47 % of intervention and control patients, respectively, began treatment between hospital admission and the last follow-up assessment (P=0.97). There were no major events attributable to the multifactorial intervention program, and no training-related adverse outcomes occurred during the physical therapy sessions, such as falls or cardiovascular events.

Physical and functional outcome measures

Follow-up assessments took place at a mean of 11.6±6.0 and 11.6±4.4 days after baseline measurement for intervention

Table 3 Baseline characteristics of patients

	Intervention (n=92)	Usual care (n=30)
Age (years), mean (SD)	85 (6)	83 (7)
Sex, no. (%)		
Male	24 (26)	8 (27)
Female	68 (74)	22 (73)
Height (cm), mean (SD)	160 (10)	161 (10)
Body weight (kg), mean (SD)	62 (13)	63 (13)
BMI (kg/m^2), mean (SD)	24 (4)	24 (5)
Living status, no. (%)		
Live alone	65 (71)	17 (57)
Live with spouse	18 (20)	11 (37)
Live with another adult relative	9 (10)	2 (7)
Living condition, no. (%)		
Apartment	71 (77)	23 (77)
House	15 (16)	3 (10)
Nursing home	6 (7)	4 (13)
Home help services, no. (%)	62 (67)	17 (57)
Walking aid, no. (%)		
None	28 (31)	10 (33)
Cane	36 (39)	10 (33)
Walker	8 (9)	0 (0)
Rollator	10 (11)	5 (17)
Tricycle (3-wheeled walker)	9 (10)	5 (17)
History of falls, no. (%)	82 (89)	30 (100)
Fall(s) in the past 12 months, no. (%)	81 (88)	27 (90)
Mini-Mental State Examination score, mean (SD)[a]	22 (4)	21 (5)
Total number of medications >4, no. (%)	75 (82)	23 (77)
Current use of medication, no. (%)		
Psychotropic	54 (59)	17 (57)
Anxiolytic	44 (48)	13 (43)
Antidepressant	22 (24)	9 (30)
Neuroleptic	4 (4)	3 (10)
Anti-arrhythmic	6 (7)	1 (3)
Morphinic	3 (3)	1 (3)
Medical condition, no. (%)[b]		
Vision disorders	14 (15)	8 (27)
Polyneuropathy	33 (36)	17 (57)*
Dizziness	16 (17)	2 (7)
Cerebrovascular accident/vascular encephalopathy	19 (21)	6 (20)
Extrapyramidal syndrome	18 (20)	4 (13)
Impaired cognition	48 (52)	11 (37)
Incontinence	16 (17)	4 (13)
Orthostatic hypotension	31 (34)	6 (20)
Arrhythmia	12 (13)	1 (3)
Dehydration	18 (20)	1 (3)*
Hyponatremia	13 (14)	3 (10)
Infection	19 (21)	7 (23)
Malnutrition	33 (36)	10 (33)

Table 3 (continued)

	Intervention (*n*=92)	Usual care (*n*=30)
Alcohol	12 (13)	5 (17)
Mini-Nutritional Assessment—Short Form score, mean (SD)[c]	9 (3)	9 (3)
Serum 25-hydroxyvitamin D (25(OH)D) level, no. (%)[d]		
<25 nmol/L	7 (14)	3 (16)
<50 nmol/L	28 (56)	14 (74)
<75 nmol/L	41 (82)	18 (95)
Serum biological markers, mean (SD)[e]		
Calcium (mmol/L) [2.20–2.52]	2.3 (0.1)	2.3 (0.1)
Phosphate (mmol/L) [0.8–1.5]	1.1 (0.2)	1.0 (0.2)
Albumin (g/L) [35–48]	34.7 (4.0)	34.3 (3.9)
Prealbumin (mg/L) [223–380]	155 (106)	162 (71)
Parathyroid hormone (pmol/L) [1.1–6.8]	6.1 (3.9)	7.9 (3.6)
C-reactive protein (mg/L) [0–10]	13 (13)	15 (15)
FRAX® scores, mean (SD)[f]		
10-year risk of major osteoporotic fracture (%)	31 (13)	27 (12)
10-year risk of hip fracture (%)	18 (10)	15 (8)
Bone mineral density T-Score, no. (%)[g]		
Femoral neck		
≥−1.0	4 (8)	2 (29)
−1.0 to −2.5	21 (44)	3 (43)
≤−2.5	23 (48)	2 (29)
Lumbar spine		
≥−1.0	15 (31)	5 (71)
−1.0 to −2.5	20 (42)	1 (14)
≤−2.5	13 (27)	1 (14)
≤−2.5 at either sites	25 (52)	3 (43)

SD standard deviation, *BMI* body mass index

**P*< 0.05, significant difference between groups

[a] Cutoff score for cognitive impairment: <24/30

[b] Based on review of medical charts

[c] Cutoff scores: 0–7 "malnourished," 8–11 "at risk of malnutrition," 12–14 "normal nutritional status"

[d] Available for 50 intervention and 19 control patients

[e] Reference values are provided in brackets

[f] Calculated retrospectively without including the bone mineral density data and "parent fractured hip" risk factor being set to null for all patients due to recall bias in our oldest old population

[g] Available for 48 intervention and 7 control patients

and control patients, respectively (P=0.96). The intervention group demonstrated significant improvements in test performances and several gait parameters associated with fall risk, whereas no significant changes occurred in the control group, with statistically significant differences between groups (Table 4 and Fig. 1). Patients in the intervention group increased significantly their comfortable (P=0.003) and maximum gait velocity (P=0.006), compared with controls. Under dual-task condition, gait velocity also improved in the intervention group (P=0.001) while stride time variability decreased significantly (P=0.043). The time spent to complete TUG also decreased (P=0.017) in this group as did the Tinetti test score (P<0.001). Additional adjustments for variables that differed at baseline did not affect the results (data not shown).

Compared with the control group, the intervention group showed significantly greater improvement over time in FIM score (P=0.027).

LOS, falls, mortality, and hospital readmission outcomes

There was a nonstatistically significant trend toward improvement in secondary outcomes in the intervention group, compared with the control group. Mean LOS was 38±21 days in the intervention group versus 45±26 days in the control group (P=0.11). Eighty-five percent of intervention patients and 80 % of the controls were discharged directly from hospital to their preadmission place of residence (i.e., not discharged to another health care facility or nursing home) (P=0.54).

Twelve intervention patients (13 %) and 6 controls (20 %) experienced one or more falls during hospital stay, with a total of 22 versus 8 falls in the intervention and control groups, respectively. No significant intervention effect was found for the number of patients with at least one fall (relative risk, 0.65; 95 % CI, 0.27 to 1.59; P=0.35), the number of falls (unadjusted incidence rate ratio, 0.90; 0.26 to 3.11; P=0.86), and the time to first fall (unadjusted hazard ratio [HR], 0.74; 95 % CI, 0.28 to 1.98; P=0.54).

Fourteen patients (15 %) in the intervention group were readmitted to acute hospital care within a 3-month period compared with seven (23 %) in the control group. Three patients in both groups (10 and 3 % of control and intervention patients, respectively) were readmitted for fall-related causes (P=0.14), two control patients (7 %) with a fall-related fracture. The risk for rehospitalization (unadjusted HR, 0.55; 95 % CI, 0.22 to 1.40; P=0.21) and death within 12 months (unadjusted HR, 0.56; 95 % CI, 0.16 to 1.90; P=0.35) did not differ. By using a multivariate Cox proportional hazards model incorporating baseline characteristics developed by forward stepwise regression, the hazard ratio for rehospitalization reached significance (HR, 0.30; 95 % CI, 0.11 to 0.85; P=0.02), with the following variables remaining in the model: age, extrapyramidal syndrome, incontinence.

Discussion

This study evaluated the short-term effects on gait and balance performances and the level of independence in

Table 4 Baseline and change in physical and functional outcome measures by groups

Outcome measure	Intervention		Usual Care		Adjusted between-group mean difference (95% CI)[b]	Effect,[c] *P* value
	Baseline	Follow-up	Baseline	Follow-up		
Single-task condition—comfortable speed						
Gait speed						
Gait velocity, cm/s[a]	57.6±18.8	67.1±20.4	58.1±24.0	59.0±20.5	8.6 (3.0 to 14.1)	0.003
Cadence, steps/min	94.8±17.9	101.2±16.6	92.2±13.7	93.0±11.0	6.6 (1.9 to 11.3)	0.007
Dynamic balance						
Support base, cm	12.9±4.4	12.2±4.5	12.0±4.3	12.0±4.2	−0.6 (−1.6 to 0.4)	0.226
Gait variability						
Stride time variability, % CoV	5.7±3.8	4.3±2.6	6.6±4.7	5.7±3.7	−1.0 (−2.0 to 0.0)	0.055
Stride length variability, % CoV	7.8±4.5	6.7±3.8	6.9±3.6	7.3±4.4	−1.0 (−2.4 to 0.4)	0.166
Single-task condition—maximum speed						
Gait speed						
Gait velocity, cm/s	78.1±27.8	87.0±26.6	74.3±34.2	74.9±28.9	9.1 (2.7 to 15.4)	0.006
Dual-task condition						
Gait speed						
Gait velocity, cm/s	53.0±15.3	61.1±18.5	52.9±21.3	52.5±20.5	8.4 (3.4 to 13.5)	0.001
Gait variability						
Stride time variability, % CoV	8.6±8.7	6.9±5.3	9.1±8.2	9.5±7.5	−2.6 (−5.0 to −0.8)	0.043
Stride length variability, % CoV	8.6±4.9	7.4±4.0	8.8±7.1	7.7±4.0	−0.2 (−1.7 to 1.3)	0.788
Functional tests						
Timed Up and Go test, s	26.0±12.2*	20.7±10.3	21.5±8.0	21.7±8.0	−3.7 (−6.8 to −0.7)	0.017
Simplified Tinetti test score	3.9±2.0	2.4±1.9	3.2±1.8	3.30±1.7	−1.4 (−2.1 to −0.8)	< 0.001
Functional independence						
Functional Independence Measure score	97.0±18.3	104.8±13.3	91.1±21.4	95.3±21.4	6.5 (0.7 to 12.3)	0.027

CoV coefficient of variation, *SD* standard deviation, *CI* confidence interval

*$P<0.05$, significant difference between groups at baseline

[a] Plus–minus values are mean±SD

[b] Between-group mean difference in change, calculated as follow-up minus baseline scores, adjusted for baseline value of the outcome

[c] Analysis of covariance on change in outcome measure with the baseline value as covariate

ADL of a multifactorial fall-and-fracture risk assessment and management program, delivered to high-risk oldest old patients in a dedicated hospital unit. The multifactorial intervention program, with an intensive targeted rehabilitation therapy as a core component of the program delivered to all patients, was effective in improving fall-related physical performances and the degree of independence as compared with usual care. These findings may be of particular importance when considering physical and functional outcomes as surrogate markers of clinical relevance, predictive of a wide range of negative health outcomes, including hospital readmission and mortality [31, 32]. In this study, the intervention reduced the 3-month rehospitalization risk. LOS was not decreased, possibly in relation to insufficient power due to the small sample size.

Our findings are in line with studies suggesting that inpatient multidisciplinary rehabilitation programs specifically designed for geriatric patients may improve physical performances and accelerate functional gains; a general meta-analysis strongly supports the potential to improve outcomes related to function [33]. In contrast, studies on the effects of multicomponent fall prevention programs including an exercise training component, or exercise provided as a single intervention, on functional outcomes, have yielded inconsistent results in acute and subacute hospital setting, with poor evidence for efficacy on gait and balance [34, 35]. Haines et al. [35] failed to show improvements of gait and mobility outcomes in high-risk older subacute hospital inpatients following a fall-targeted multiple-intervention program including exercise (i.e., additional non-individually tailored 45-min sessions, three times per week).

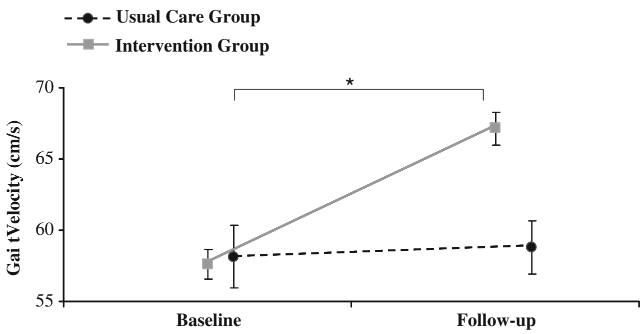

Fig. 1 Mean comfortable gait velocity (in centimeters per second) measured at baseline and at a mean follow-up interval of 11.6 days (SD, 5.6) for both the intervention and the usual care groups. *Error bars* represent standard error of the mean. *Significant difference between groups in change from baseline (P=0.003, ANCOVA with the baseline value as a covariate)

The mean time from baseline assessment to all physical and functional improvements was only 12 days. These results are in line with studies showing that geriatric rehabilitation can lead to improvements over the short time period of acute care [33]. Braden et al. [36] showed an increase in gait velocity to be already significant over a mean physical therapy of 2.0 days and total hospitalization period of 5.5 days in acutely hospitalized older patients. Due to the nature of the intervention, it remains unclear which specific components of the multifactorial intervention program were particularly effective to improve physical outcomes. A general limitation of multifaceted intervention studies that encompass a broad range of interventions is the inability to determine the independent effects of each of them [37]. The intervention was individualized based on patients' risk factors, physical impairments, and personal treatment goals; no specific effort was made to deliver the same interventions or durations. Several components may have contributed to the improvements observed, including not only intensification of physical therapy with a combination of group and individual sessions, but also social or psychological factors. Close monitoring of intervention patients' status throughout the rehabilitation process (i.e., through functional tests and quantitative gait analysis) may also have helped to update the rehabilitation plan and target-oriented patient management. Since psychological factors, such as fear of falling, may have a negative effect on physical capacities and induce a negative vicious circle, it may be assumed that work on these factors, with an increase in self-confidence, may have facilitated the rehabilitation process [38]. Also, since control patients did not necessarily receive the same amount of time and attention by physical or occupational therapists, benefits achieved on physical outcomes might, in part, be attributable to socialization or Hawthorne effects.

Physical outcomes were almost unchanged in patients who received usual care. Functional decline of older patients during hospitalization has been widely reported [11]. The specialized fall consultation may have benefited to control patients. Following the comprehensive assessment, the consulting physician made several recommendations, including intensification of physical therapy; this may have facilitated early intervention targeted toward improving patients' physical outcomes. It remains to be determined whether the short-term benefits achieved through the multifactorial intervention program on physical outcomes were maintained following discharge. Intervention patients in need of further rehabilitation were referred to outpatient-day rehabilitation or community-based physiotherapy services, with appropriate recommendations about a therapy program.

Intervention was associated with a trend to a reduction in the risk for patients to experience at least one fall during their hospital stay. A recent Cochrane review showed that multifaceted programs implemented by a multidisciplinary team and designed to lower fall rates and/or fall risk in acute/subacute settings may slightly reduce rate of falls and risk of falling [17], while other meta-analyses reported limited evidence for reduction amongst hospitalized patients [9, 39]. Data may not be generalizable to settings where lengths of stay are short (i.e., less than 3 weeks). Haines et al. [40] observed a reduction in fall rates, but differences were achieved after 45 days of intervention. In a pooled analysis from three studies in the subacute setting, supervised exercises were revealed to be effective in reducing the risk of falling [17]. In addition, improvements in physical function may also have helped to delay the onset of fall events following discharge. Owing to the absence of prospective fall-and-fracture ascertainment following discharge, the impact of the multifactorial intervention program on these relevant outcomes cannot yet be discussed. To our knowledge, no study to date has reported long-term effects of an in-hospital multifactorial individually tailored program on falls and fractures.

Results achieved in other secondary outcomes provide encouraging data that justify further studies with larger sample sizes. We observed a trend toward shorter LOS, suggesting that the interdisciplinary collaborative work may have facilitated rapid and effective provision of care. It has been previously shown that multidisciplinary intervention that includes exercise can reduce length and cost of hospital stay for acutely hospitalized older medical patients [41]. The complexity and diversity of factors that influence hospital LOS of oldest old patients, however, may prevent the detection of the benefit of an in-hospital intervention program aimed at falls and fractures on such outcome [41]. The multifactorial intervention program has been embedded into the existing practice and implemented with minimal additional resources. A further study is warranted to determine whether this intervention is cost effective or even cost saving.

The multifactorial intervention program, as designed, may be strongly advocated for the management of high-risk patients as compared with an in-hospital specific consultation. Recent guidelines strongly endorsed that a direct intervention should be privileged rather than a referral without directly intervening [42]. Our study reinforces evidence that highly functioning multidisciplinary care teams may ameliorate prevention as well as rapid and effective delivery of care [43, 44]. Such interdisciplinary work in dedicated units may also facilitate maintenance of partnerships with patients and reinforce in them the development of a “fall safety culture.”

Although a major strength of this study was that it was conducted under real-life conditions of clinical practice, several limitations should be acknowledged. First, patients were not randomized. This study was based on a prospective and consecutive series of patients; patients were assigned to either dedicated or control units by an allocating office who was unaware of the study, essentially depending on bed availability. Although not randomized, the two groups had similar baseline characteristics regarding major fall-related risk factors and medical conditions. It is worth noting that the study design allowed us to recruit patients with mild cognitive impairment, which are often not included in studies with individual randomization. Second, as stated above, the study was insufficiently powered to detect differences on secondary outcomes, and as such, these data should be interpreted with caution. Third, owing to the nonsystematic documentation of the patient’s medical records by physical therapists, the mean number of physiotherapy sessions per patient per week was not known. Fourth, a substantial proportion of patients did not enter the rehabilitation program, either because they were found ineligible or were unwilling to participate.

Conclusion

A multifactorial fall-and-fracture risk assessment and management program, delivered during hospitalization in a dedicated unit, was effective and more beneficial than usual care in improving physical parameters related to the risk of fall and the level of independence in activities of daily living among high-risk older patients. Significant gains in physical performance measures, including gait velocity under single- and dual-task conditions, as well as time taken to complete TUG, may have important implications because of their association with fall risk and the ability to cope with basic and more advanced activities of daily living [29, 45–47]. Improvements achieved in gait velocity as well as gait variability (i.e., two parameters strongly associated with fall risk) under cognitive–motor dual-task condition may also be particularly relevant in this population given the omnipresence of multitask/divided attention situations in everyday life. Such improvements in physical outcomes are likely to improve quality of life following discharge [29, 46], but this aspect remains to be verified.

Acknowledgments We thank all past and current members of CHEOPS staff for their dedication and professionalism. We are especially indebted to Christiane Dunand-Perrier and Anne-Sophie Pacaud-Valette (physiotherapists), Hedi Baba (occupational therapist), Anne Winkelmann (social worker), and Alain Hurry (nurse unit manager) for their enthusiastic collaboration and hard work on the project since the beginning. We are also very grateful to Yvette Registe-Rameau (head nurse) and Didier Marcant (head physiotherapist) for their continued support. We acknowledge the editorial assistance of Mrs. Katy Giroux.

Conflicts of interest None.

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