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RESEARCH PAPER

The impact of cognitive function on physical activity, physical function and quality of life in older adults following a hip fracture

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Abstract

Objective: To determine the impact of cognitive function on physical activity (PA), physical function and health-related quality of life (HRQoL) in older adults within the first year after hip fracture (HF) surgery.
Methods: We included 397 home-dwelling individuals aged 70 years or older with the ability to walk 10 m before the fracture. Cognitive function was measured at 1 month and other outcomes were assessed at 1, 4 and 12 months postoperatively. Mini-Mental State Examination was used to assess cognitive function, accelerometer-based body-worn sensors to register PA, Short Physical Performance Battery to test physical function and EuroQol-5-dimension-3-level to estimate the HRQoL. Data were analysed by linear mixed-effects models with interactions and ordinal logistic regression models.
Results: Cognitive function, adjusted for the pre-fracture ability to perform activities of daily living, comorbidity, age and gender, had an impact on PA [$b = 3.64$, 95% confidence interval (CI): 2.20–5.23, $P < 0.001$] and physical function ($b = 0.08$, 95% CI: 0.04–0.11, $P < 0.001$; b = 0.12, 95% CI: 0.09–0.15, $P < 0.001$; and $b = 0.14$, 95% CI: 0.10–0.18, $P < 0.001$ at 1, 4 and 12 months, respectively). The cognitive function did not have a considerable impact on HRQoL.
Conclusions: For older adults with HFs, cognitive function 1 month postoperatively had a significant impact on PA and physical function in the first postoperative year. For the HRQoL, little or no evidence of such an effect was found.

Keywords: cognitive function, hip fracture, physical activity, physical function, health-related quality of life, older people

Key Points

- We investigated the impact of cognitive function on the outcome in the first year after hip fracture surgery.
- Our outcome measures were physical activity, physical function and health-related quality of life.
- We used accelerometer-based body-worn sensors, a performance-based test and a patient-reported outcome measure.
- Cognitive function was found to affect physical activity and physical function.
- For the health-related quality of life, there was little or no evidence of such an effect.

Introduction

The increasing global incidence of hip fractures (HFs), from an estimated 1.6 million per year in 2000 to 6.3 million people per year by 2050 [1], is an established public health concern. HF is one of the most harmful events in the life of older adults and is associated with functional decline, high morbidity rates and premature death [2]. As well as being a determinant for independence and thereby contributing to successful ageing [3], physical activity (PA) seems to be one of the most important factors involved in rehabilitation and prevention of functional decline in older adults [4], particularly for those recovering from an HF [5]. Very low levels of PA have been found following HF [6], and most improvement seems to occur in the following 3 months [7, 8]. Given the importance of PA to recovery, it is necessary to assess potential explanatory variables to establish appropriate rehabilitation approaches.

Functional recovery has been associated with age [9], pre-fracture function and health status, early mobility level, muscle strength, anaemia, pain, fracture type [10], delirium [11], surgery type, time to surgery, depression symptoms [12], cognitive impairment (CI) [13] and PA [5]. Less is known concerning explanatory factors for PA, although relationships with age [6], gender [14], comorbidity [6], frailty [15], resilience, total lean body mass, pain [16] and gait speed [14] have been indicated.

The prevalence of CI among HF patients reaches 40% [17]. CI, a feature of dementia and delirium, is defined as a disturbance in the patient's mental processes related to thinking, reasoning and judgement [18]. Rehabilitation interventions are considered to account for most functional recovery in improving patients' mobility and activities of daily living [19, 20], and at the same time, CI could be an important factor for rehabilitation outcomes. A major proportion of randomized controlled trials (RCTs) assessing HF management have excluded or ignored individuals with CI and consequently missed an opportunity to identify factors associated with improved prognosis [21]. This might cause systematic bias in existing knowledge, lowering the external validity of evidence for interventions intended to improve outcomes in this patient population [21]. Moreover, a perception that cognitively impaired patients are unable to benefit from rehabilitation persist among many health professionals [22], leading to a sort of therapeutic nihilism [23, 24]. Indeed, studies have suggested that cognitively impaired patients benefit from rehabilitation after an HF [25–27]. In addition, two systematic reviews have indicated that individuals with CI exhibit gains similar to individuals without CI [28, 29]. The pre-fracture function has been considered more important than the cognitive function in predicting short-term functional outcomes [9] and proposed as an underlying mechanism for the association between cognitive function and functional outcome [30]. To our knowledge, no studies exist considering the relationship between cognitive function and objective PA following HF. As PA in older people with impaired function is mostly performed as part of daily activities, measurement should include daily habitual activity.

We hypothesized that cognitive function would affect patient outcomes regarding objective PA, physical function and health-related quality of life (HRQoL) in older adults in the first year after HF surgery. Thus, the aim of our study was to examine the impact of cognitive function (not only the absence or presence of CI) on these outcome measures at 1, 4 and 12 months postoperatively, with PA as the primary outcome.

Methods

Study population

This a sub-study of the Trondheim Hip Fracture Trial, a prospective RCT performed at St. Olav University Hospital in Trondheim, Norway. Recruitment lasted from 17 April 2008 to 30 December 2010, with the final follow-up completed in January 2012. The protocol, the intervention and clinical outcomes from the study have been published previously [31–36]. We included 397 patients who presented with an HF, were aged 70 years or older, able to walk 10 m before the fracture and home-dwelling (i.e. living in their homes or sheltered housing, or staying temporarily in any kind of institution). Patients with pathological fractures, multiple traumas, short life expectancy or who were living permanently in nursing homes were excluded. Informed consent was obtained from patients or their next of kin before participation in the study. The Regional Committee of Ethics in Medical Research (REK4.2008.335), the Norwegian Social Science Data Services (NSD19109) and the Norwegian Directorate of Health (08/5814) approved the protocol.

Procedures and follow-up

Follow-up assessments were done on Day 5, and 1, 4 and 12 months postoperatively. PA, physical function and HRQoL were measured at 1, 4 and 12 months, and cognitive status was assessed at 1 month postoperatively. Assessments were performed by personnel who were not associated with patient care. If possible, 4- and 12-month assessments were undertaken at the hospital. All assessments at 1 month, and 4- and 12-months assessments in very sick patients, were done wherever the patient resided. Patients were the primary informant whenever possible during data collection. The exception was Nottingham extended instrumental activities of daily living (I-ADL) scores, which were collected from proxies by telephone for 10–20% of patients who were unable to provide the data. Trained study staff recorded the patients' demographic data (age and sex), type of fracture, pre-fracture Nottingham extended I-ADL score [37] and pre-fracture Charlson comorbidity index [38].

Main measures

Cognitive status was assessed with the Mini-Mental State Examination (MMSE), which ranges from 0 to 30 (a high score suggests better cognitive function) and is a commonly used tool in geriatric rehabilitation settings. The instrument has standardized instructions and examines attention, memory (i.e. orientation, word recall, sentence recognition and drawings) as well as initiation and maintenance of verbal and motor responses [39].

We used body-worn, single-axis accelerometer-based sensors (activPALs, PAL Technologies Ltd, Glasgow, UK) attached to the front of the participants' non-affected lower thigh with a waterproof tape to objectively measure PA. All participants attending the 4- and 12-month examination were asked to wear sensors for the following 4 days. Only data where there was minimum 24 h of continuous recording was included. The activPAL sensor system provides good validity for postures and transitions compared with video observations in older adults with impaired walking ability, including HF patients [40]. The outcome measure used was the daily (24 h) mean time in an upright (walking and standing) position, denoted hereafter as UPTIME.

Physical function was assessed by the Short Physical Performance Battery (SPPB) [41], a performance-based test consisting of a 4-m walk test, a standing balance test and a chair-stand test. The test has been found to be both valid and reliable for assessing physical function among older adults [42].

HRQoL was rated by the EuroQol-5-dimension-3-level (EQ-5D-3L) questionnaire [43]. The questionnaire comprises five key dimensions; mobility, performing self-care, usual activities, pain/discomfort and anxiety/depression using three levels of response: from level 1 (indicating no problems or the best state for that dimension) to 3 (indicating the worst state for that dimension). The EQ-5D-3L index was calculated using a published utility algorithm for the UK population based on the time-trade-off method [44]. Questionnaires were answered by the participants themselves.

Statistical analysis

Analyses were performed using SPSS 28.0 (IBM). Continuous variables are summarized as means and standard deviations (SDs), and categorical variables are presented as proportions and frequencies. Results were considered significant at $P < 0.05$. Histograms and Kolmogorov–Smirnov tests were used to assess the normality of the data.

We used linear mixed-effects models to examine the impact of cognitive function, adjusted for age, gender, pre-fracture ADL and comorbidity, on PA and physical function at given time points following surgery. Multilevel models were necessary since each outcome was measured repeatedly on the same participant. Assumptions of linearity, normally distributed residuals and constant SD of residuals for different magnitudes of fitted values were checked by plotting the data, using histograms and with Kolmogorov–Smirnov tests. Cognitive function, participant demographics, pre-fracture ADL score, comorbidity and time were included as fixed effects, and a random, subject-specific intercept was included to account for the repeated measurements. To test whether the effect of cognitive function on PA or physical function varied over the post-discharge period, interaction terms between cognitive function and measurement time were included. Interactions between cognitive function and gender were evaluated similarly. The magnitude of the interaction is not of practical interest, but the interest lies in the varying impact of cognitive function at different time points. Therefore, different estimates for each time point are reported when a significant interaction with time is found. The method of estimation for linear mixed-effects models allows for missing data at the outcome variable on one or more occasions, as long as the data are missing at random, such that data for all individuals with at least one observation are included in the analyses. Missing values in the predictor variables were handled by listwise deletion of individuals.

Table 1. Demographic and clinical characteristics of 397 patients admitted with hip fracture

	Mean ± SD or *n* (%)
Age (years)	83.3 ± 6.1
Gender	
Female	293 (74)
Male	104 (26)
Charlson comorbidity index (CCI)	2.3 ± 2.1
Previous diagnoses	
Heart disease	186 (47)
Stroke	106 (27)
Diabetes	51 (13)
Dementia	53 (13)
Cancer	96 (24)
Kidney disease	27 (7)
Pre-fracture NEIADL score	42.2 ± 17.6
MMSE score, 1 month	22.9 ± 5.9
Fracture type	
Femoral neck	246 (62)
Trochanteric	124 (31)
Subtrochanteric	27 (7)
Surgical treatment	
Hemiarthroplasty	164 (41)
Screws	70 (18)
Bone plates and screws	132 (33)
Other	27 (7)
Died before surgery	4 (1)

Data are mean ± SD or *n* (%). NEIADL, Nottingham extended instrumental activities of daily living

Regarding HRQoL, the relationship between cognitive function and each of the five dimensions comprised by the EQ-5D-3L at 1, 4 and 12 months were investigated in unadjusted and adjusted ordinal logistic regression (OLR) analyses. We controlled for the same possible confounders as in the linear mixed-effect models. Statistics were based on cases with valid data for all variables in the model.

Results

Table 1 shows the participants' demographic and clinical characteristics. The average age was 83.3 years (SD = 6.1) and

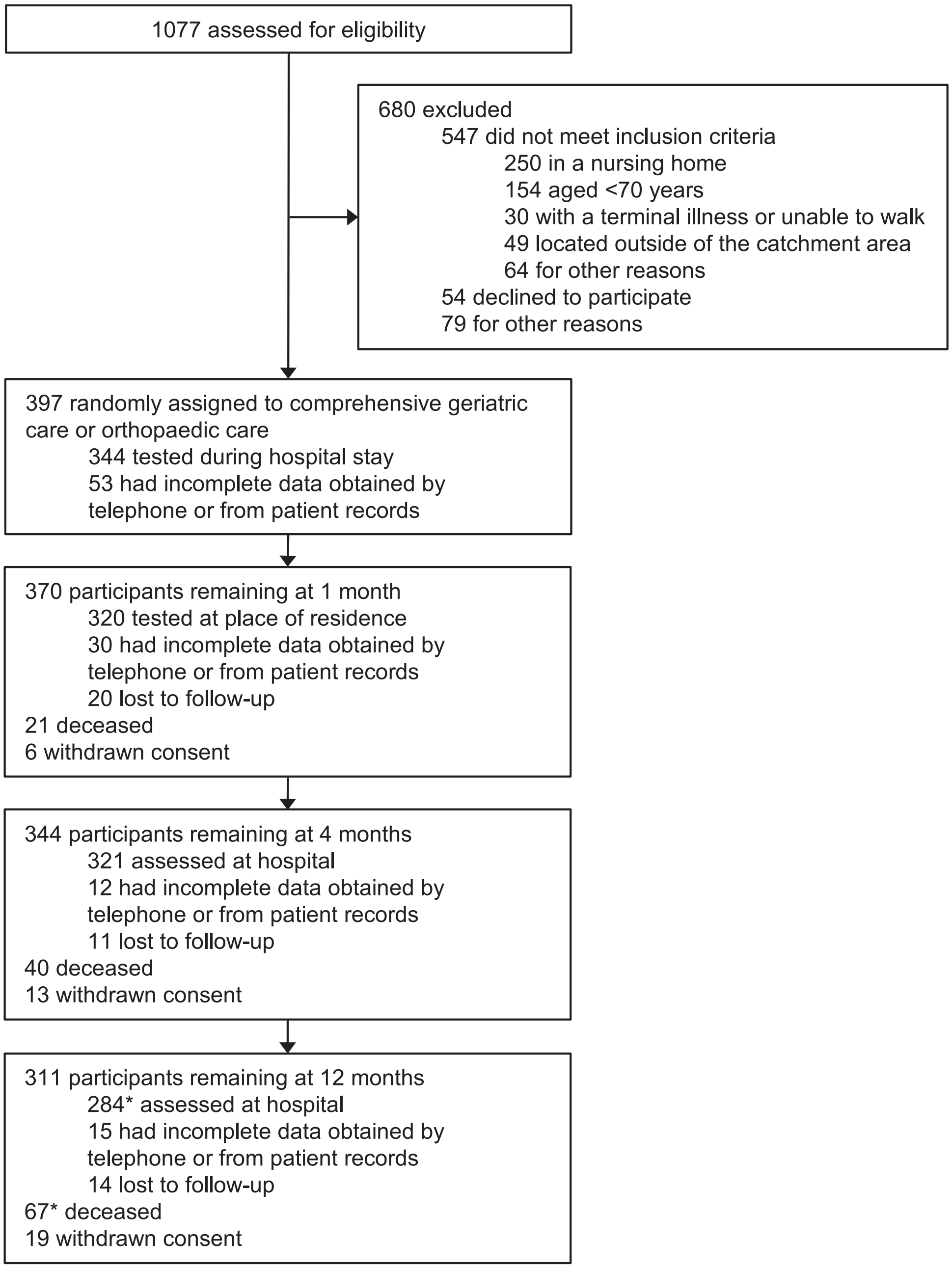

Figure 1. Participant study flow diagram. ∗Two participants registered as deceased finished their final tests before death.

the majority (74%) were females. Participants had variable levels of comorbidity, represented by health conditions such as heart disease (47%), stroke (27%), diabetes (13%), dementia (13%), cancer (24%) and kidney disease (7%). Participants were primarily recovering from femoral neck ($n = 246$) and trochanteric ($n = 124$) fractures. Operative interventions of hemiarthroplasty ($n = 164$), screws ($n = 70$) and bone plates and screws ($n = 132$) were most common. The number of deaths was 21 within the 1st month, 19 between the 1st and 4th month and 27 between the 4th and 12th month after surgery. From 397 included participants, 311 (78.3%) participants remained at the last follow-up (Figure 1). Table 2 displays the values of PA, physical function and HRQoL over time.

The linear mixed-effects model showed an impact of MMSE on PA, adjusted for age, gender, pre-fracture ADL and comorbidity (Table 3). For every unit of increase in MMSE, the time spent upright (UPTIME) increased by 3.64 min per day [95% confidence interval (CI): 2.20–5.23, $P < 0.001$]. Higher age, female gender, lower ADL score and higher comorbidity index were negatively related to PA. The interaction terms of MMSE with time and MMSE with gender turned out to be non-significant (Appendix 2).

Table 2. Values of PA (UPTIME), physical function (SPPB) and dimensions of HRQoL (EQ-5D-3L) at 1, 4 and 12 months after HF

	1 month		4 months		12 months	
Variable	*n*	Mean (SD)	*N*	Mean (SD)	*n*	Mean (SD)
UPTIME			283	215.3 (136.9)	252	216.3 (134.2)
SPPB	333	3.3 (2.7)	325	4.8 (3.2)	284	5.0 (3.3)
EQ-5D-3L	316	0.48 (0.33)	306	0.57 (0.31)	272	0.64 (0.30)
Mobility	318	1.8 (0.5)	307	1.7 (0.5)	275	1.6 (0.5)
Self-care	318	1.6 (0.6)	307	1.4 (0.6)	275	1.3 (0.5)
Usual activities	317	2.2 (0.7)	307	1.8 (0.7)	274	1.7 (0.7)
Pain/discomfort	317	1.9 (0.6)	307	1.8 (0.6)	276	1.7 (0.6)
Anxiety/depression	317	1.6 (0.6)	306	1.5 (0.6)	276	1.4 (0.6)

UPTIME represents the daily (24 h) mean time in upright (walking and standing) position in minutes.

In the linear mixed-effects model for physical function, MMSE and the adjustment variables had statistically significant effects in the same directions as in the model for PA, except for gender (Table 3). There was a significant interaction between time and MMSE, indicating a progressive increase in the mean change in physical function per unit increase of MMSE at later points in time ($P = 0.015$, Appendix 2). For every unit increase in MMSE, the mean increase in SPPB was 0.08 units at 1 month (95% CI: 0.04–0.11, $P < 0.001$), 0.12 units at 4 months (95% CI: 0.09–0.15, $P < 0.001$) and 0.14 units at 12 months (95% CI: 0.10–0.18, $P < 0.001$).

Table 4 presents the results of the unadjusted and adjusted OLR analyses used to estimate the odds ratio (OR) for an increase in EuroQol level (worse state for that dimension) per unit increase in MMSE for each of the five dimensions of the EQ-5D-3L questionnaire. The estimated ORs were all changed substantially towards 1 after adjustment. The only remaining statistically significant association was with the self-care dimension at 4 months (OR 0.92, 95% CI: 0.87–0.97, $P = 0.004$). However, at the other time points, the association was weaker and non-significant for self-care as well (OR 0.96, 95% CI: 0.91–1.01, $P = 0.081$ and OR 0.95, 95% CI: 0.89–1.01, $P = 0.108$ for 1 and 12 months, respectively).

Discussion

This Norwegian post-HF cohort showed mildly impaired functional and cognitive status, as denoted by the pre-fracture Nottingham extended I-ADL value and the MMSE score, respectively. Our results indicate that lower cognitive function has a negative impact on objective PA and physical function in older adults recovering from HF, after adjusting for the pre-fracture ability to perform ADL, comorbidities, age and gender. The adjustment variables also significantly affected PA, except for gender and physical function. Regarding dimensions of HRQoL, cognitive function was of less importance in affecting the outcome.

The minimally meaningful change in SPPB score has been found to be in the range of 0.3–0.8 points [45, 46]. Based on the lowest range value and the estimated impact of cognitive function on SPPB, our results imply that a difference in MMSE at 1 month of at least 3.8, 2.5 or 2.1 units could have a small, yet clinically meaningful impact on group level physical function at 1, 4 and 12 months, respectively. For objectively measured PA, less is known concerning clinically meaningful differences. A change of 3.64 min spent upright per day for each unit of MMSE itself may not be regarded as clinically meaningful. Still, the direct relationship indicates that cognitively impaired patients tend to be less active in their daily life. Daily PA has been associated with decreased risk of mortality and contributes to the maintenance and promotion of health in older adults [47, 48]. Although less is known concerning this relationship in patients with HF specifically, participation in appropriate PA after HF is important for functional recovery [5]. Considering PA in older adults with impaired function is mostly performed as part of daily activities, differences in PA levels between patients at different ends of the spectrum of cognitive function should not be neglected.

Previous studies have demonstrated significant functional decline following HF, even in individuals with high pre-fracture function levels [49, 50]. Indeed, their functional status and length of disability can be improved by early and active mobilization. Despite high reported prevalence rates of CI [17], the role of cognitive status in affecting outcomes, especially objective PA, in older adults recovering from HF has not yet been extensively studied. Although participants in this study were home-dwelling and able to walk 10 m before the fracture, we included individuals who represented the whole spectrum of cognitive function. Our findings that cognitive function, adjusted for pre-fracture functional impairment, comorbidity, age and gender, appears to be an influencing factor of physical function and activity, might contribute to resolving the discordancy between existing studies. Concretely, the pre-fracture function has been proposed as an underlying mechanism for the association between CI and functional outcome [30]. Functional status and cognitive function have shown a strict correlation, confirming preceding findings of a cross-sectional relationship between different degrees of CI and disability [13]. Also, pre-fracture motor functional independence measure

Table 3. Estimates of fixed effects for the linear mixed-effects model evaluating the impact of cognitive function at 1 month on PA and physical function 1, 4 and 12 months after HF

	PA (UPTIME)		Physical function (SPPB)	
Variable	Estimate (95% CI)	*P*-value	Estimate (95% CI)	*P*-value
Cognitive function				
MMSE, overall effect on UPTIME	3.64 (2.20 to 5.23)	<0.001		
Interaction between MMSE and each measurement time for SPPB				
MMSE × 1 month after surgery			0.08 (0.04 to 0.11)	<0.001
MMSE × 4 months after surgery			0.12 (0.09 to 0.15)	<0.001
MMSE × 12 months after surgery			0.14 (0.10 to 0.18)	<0.001
Demographic characteristics				
Age	−1.71 (−2.91 to −0.56)	0.003	−0.11 (−0.13 to −0.09)	<0.001
Gender (female as reference)	53.61 (40.37 to 69.87)	<0.001	−0.20 (−0.46 to 0.02)	0.103
Health status				
NEIADL score	3.56 (3.13 to 3.97)	<0.001	0.07 (0.06 to 0.08)	<0.001
Charlson comorbidity index	−9.48 (−12.73 to −5.43)	<0.001	−0.10 (−0.15 to −0.05)	<0.001

Cognitive function measured according to MMSE; pre-fracture health status measured according to Nottingham extended instrumental activities of daily living (NEIADL) score and Charlson comorbidity index. Significant interaction between MMSE and time on SPPB gives three estimates for the effect of MMSE on SPPB, as SPPB was performed at 1, 4 and 12 months. Non-significant interaction between MMSE and time on UPTIME gives one estimate for the overall effect of MMSE across all levels (time points) of the time variable.

Table 4. Results from univariable and multivariable[a] OLR to assess the impact of cognitive function on HRQoL according to the five dimensions of the EQ-5D-3L questionnaire

	Unadjusted OLR			Adjusted OLR		
Variable	1 month			1 month		
	OR	95% CI	*P*-value	OR	95% CI	*P*-value
Mobility	0.09	(0.03–0.30)	<0.001	0.97	(0.92–1.03)	0.353
Self-care	0.10	(0.04–0.27)	<0.001	0.96	(0.91–1.01)	0.081
Usual activities	0.11	(0.04–0.28)	<0.001	1.01	(0.97–1.06)	0.619
Pain/discomfort	0.29	(0.10–0.83)	0.021	1.02	(0.97–1.07)	0.512
Anxiety/depression	0.25	(0.09–0.69)	0.007	0.98	(0.93–1.03)	0.452
	4 months			**4 months**		
	OR	**95% CI**	***P*-value**	**OR**	**95% CI**	***P*-value**
Mobility	0.29	(0.09–0.91)	0.034	1.02	(0.97–1.08)	0.431
Self-care	0.08	(0.02–0.24)	<0.001	0.92	(0.87–0.97)	0.004
Usual activities	0.07	(0.02–0.20)	<0.001	0.99	(0.94–1.04)	0.661
Pain/discomfort	0.38	(0.13–1.12)	0.079	1.00	(0.95–1.06)	0.958
Anxiety/depression	0.43	(0.14–1.31)	0.139	0.98	(0.93–1.03)	0.444
	12 months			**12 months**		
	OR	**95% CI**	***P*-value**	**OR**	**95% CI**	***P*-value**
Mobility	0.20	(0.05–0.71)	0.013	1.03	(0.97–1.10)	0.349
Self-care	0.21	(0.06–0.76)	0.017	0.95	(0.89–1.01)	0.108
Usual activities	0.06	(0.02–0.21)	<0.001	0.98	(0.93–1.04)	0.535
Pain/discomfort	0.88	(0.28–2.79)	0.821	1.00	(0.95–1.06)	0.894
Anxiety/depression	0.45	(0.13–1.53)	0.199	0.98	(0.92–1.04)	0.511

Cognitive function measured according to Mini-Mental State Examination; HRQoL measured according to EuroQol 5-dimension 3-level instrument. [a]Adjusted for age, gender, Charlson comorbidity index and Nottingham extended instrumental ADL (activities of daily living) score.

and walking ability before the fracture and discharge to rehabilitation units, rather than cognitive status, have been identified as variables related to preserved walking ability at 4 months [9]. Conversely, other authors have reported that dementia can predict ambulatory status [51]. The use of different instruments and thresholds used to define CI might explain the discordancy in results regarding the role of cognitive function in influencing walking ability in the aforementioned studies.

Studies have demonstrated that the EQ-5D-3L is a good measuring tool for outcomes in patients recovering from HF, including cognitively impaired patients [52, 53]. Opposing our results, chronic CI has showed a negative impact on HRQoL after an HF [53–55].

Strengths and limitations

Some limitations must be addressed. First, the use of MMSE as the only tool for detecting CI might not account for the full complexity of the condition. Using MMSE as a global cognitive test did not allow the classification of deficits into cognitive domains, such as memory, attentive, functional and visuospatial deficits, which could have different roles in affecting outcomes. Second, MMSE has been found to be insensitive to CI resulting from right hemisphere dysfunction as well as mild cognitive impairments [56]. Nevertheless, the MMSE is a widely accepted and used clinical standard assessment that provides comparability with previously published reports. Third, the pre-fracture ADL score was collected retrospectively, which could introduce recall bias. Fourth, the comprehensive geriatric care regimen might influence both cognitive function and mobility in the same direction, potentially being a confounder. However, no statistically or clinically significant effect of group allocation on MMSE at 1 month was found in the main trial.

However, a strength of our study includes the timing of evaluating cognitive function 1 month after surgery, which prevents acute cognitive changes due to factors such as pain, fear, hospitalization and analgesic drugs from being assessed as chronic CI. Other strengths of our study include its large sample size and the use of well-validated instruments to measure mobility outcome, HRQoL and cognitive status. Furthermore, we included all types of HFs and operation methods, which makes the data more representative than a small sample of selected participants and accordingly increases the external validity. Previous studies have reported 1-year mortality of 23% [57], which is slightly higher than in our sample (21.7%) but could be an expression of a low risk of selection bias. Finally, our linear mixed-effects models explained high proportions of the variance; for instance, the models related to PA and physical function obtained Conditional R^2 of 0.851 and 0.789, respectively, and the deviance in the adjusted OLR for HRQoL ranged from 0.601 to 0.997.

Conclusion

Cognitive function 1 month postoperatively was found to affect PA and physical function the first year following HF in older adults. For HRQoL, there was little or no evidence of such an effect. Daily PA might be an important factor in the rehabilitation of older adults with HF, and cognitively impaired patients may require additional attention to participate in daily PA. Specific rehabilitative approaches according to cognitive function should be considered.

Supplementary Data: Supplementary data are available in *Age and Ageing* online.

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Declaration of Conflicts of Interest: None.

Data Availability Statement: Data can be made available upon reasonable request.

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References

1. Johnell O, Kanis JA. An estimate of the worldwide prevalence and disability associated with osteoporotic fractures. Osteoporos Int 2006; 17: 1726–33.
2. Leibson CL, Tosteson AN, Gabriel SE *et al.* Mortality, disability, and nursing home use for persons with and without hip fracture: a population-based study. J Am Geriatr Soc 2002; 50: 1644–50.
3. Lee WJ, Peng LN, Lin MH *et al.* Determinants and indicators of successful ageing associated with mortality: a 4-year population-based study. Aging 2020; 12: 2670–9.
4. Stessman J, Hammerman-Rozenberg R, Cohen A *et al.* Physical activity, function, and longevity among the very old. Arch Intern Med 2009; 169: 1476–83.
5. Talkowski JB, Lenze EJ, Munin MC *et al.* Patient participation and physical activity during rehabilitation and future functional outcomes in patients after hip fracture. Arch Phys Med Rehabil 2009; 90: 618–22.
6. Resnick B, Galik E, Boltz M *et al.* Physical activity in the post-hip-fracture period. J Aging Phys Act 2011; 19: 373–87.
7. Tu CY, Shields N, Gill SD *et al.* Longitudinal changes in physical activity levels and fear of falling after hip fracture. Physiother Res Int 2021; 26: e1884. https://doi.org/10.1002/pri.1884.
8. Taraldsen K, Thingstad P, Sletvold O *et al.* The long-term effect of being treated in a geriatric ward compared to an orthopaedic ward on six measures of free-living physical behavior 4 and 12 months after a hip fracture—a randomised controlled trial. BMC Geriatr 2015; 15: 160. https://doi.org/10.1186/s12877-015-0153-6.
9. Dubljanin-Raspopović E, Marković-Denić L, Matanović D *et al.* Is pre-fracture functional status better than cognitive level in predicting short-term outcome of elderly hip fracture patients? Arch Med Sci 2012; 8: 115–22.
10. Kristensen MT. Factors affecting functional prognosis of patients with hip fracture. Eur J Phys Rehabil Med 2011; 47: 257–64.
11. Uriz-Otano F, Uriz-Otano JI, Malafarina V. Factors associated with short-term functional recovery in elderly people with a hip fracture. Influence of cognitive impairment. J Am Med Dir Assoc 2015; 16: 215–20.
12. Buecking B, Bohl K, Eschbach D *et al.* Factors influencing the progress of mobilization in hip fracture patients during the early postsurgical period? A prospective observational study. Arch Gerontol Geriatr 2015; 60: 457–63.
13. Benedetti MG, Ginex V, Mariani E *et al.* Cognitive impairment is a negative short-term and long-term prognostic factor in elderly patients with hip fracture. Eur J Phys Rehabil Med 2015; 51: 815–23.

14. Fleig L, McAllister MM, Brasher P *et al.* Sedentary behavior and physical activity patterns in older adults after hip fracture: a call to action. J Aging Phys Act 2016; 24: 79–84.

15. Aboelmagd T, Dainty JR, MacGregor A *et al.* Trajectory of physical activity after hip fracture: an analysis of community-dwelling individuals from the English Longitudinal Study of Ageing. Injury 2018; 49: 697–701.

16. Resnick B, Hebel JR, Gruber-Baldini AL *et al.* The impact of body composition, pain and resilience on physical activity, physical function and physical performance at 2 months post hip fracture. Arch Gerontol Geriatr 2018; 76: 34–40.

17. Seitz DP, Adunuri N, Gill SS *et al.* Prevalence of dementia and cognitive impairment among older adults with hip fractures. J Am Med Dir Assoc 2011; 12: 556–64.

18. Söderqvist A, Miedel R, Ponzer S *et al.* The influence of cognitive function on outcome after a hip fracture. J Bone Joint Surg Am 2006; 88: 2115–23.

19. Lenze EJ, Munin MC, Dew MA *et al.* Adverse effects of depression and cognitive impairment on rehabilitation participation and recovery from hip fracture. Int J Geriatr Psychiatry 2004; 19: 472–8.

20. Fiedler RC, Granger CV, Russell CF. UDS(MR)SM: follow-up data on patients discharged in 1994–1996. Uniform data system for medical rehabilitation. Am J Phys Med Rehabil 2000; 79: 184–92.

21. Mundi S, Chaudhry H, Bhandari M. Systematic review on the inclusion of patients with cognitive impairment in hip fracture trials: a missed opportunity? Can J Surg 2014; 57: E141–5.

22. Davis EBJ, Cohen-Mansfield J. Hip fracture rehabilitation in persons with dementia: how much should we invest? Ann Long Term Care 2007; 15: 19–21.

23. Bellelli G, Frisoni GB, Pagani M *et al.* Does cognitive performance affect physical therapy regimen after hip fracture surgery? Aging Clin Exp Res 2007; 19: 119–24.

24. Morghen S, Gentile S, Ricci E *et al.* Rehabilitation of older adults with hip fracture: cognitive function and walking abilities. J Am Geriatr Soc 2011; 59: 1497–502.

25. Lenze EJ, Skidmore ER, Dew MA *et al.* Does depression, apathy or cognitive impairment reduce the benefit of inpatient rehabilitation facilities for elderly hip fracture patients? Gen Hosp Psychiatry 2007; 29: 141–6.

26. Huusko TM, Karppi P, Avikainen V *et al.* Randomised, clinically controlled trial of intensive geriatric rehabilitation in patients with hip fracture: subgroup analysis of patients with dementia. BMJ 2000; 321: 1107–11.

27. Rolland Y, Pillard F, Lauwers-Cances V *et al.* Rehabilitation outcome of elderly patients with hip fracture and cognitive impairment. Disabil Rehabil 2004; 26: 425–31.

28. Allen J, Koziak A, Buddingh S *et al.* Rehabilitation in patients with dementia following hip fracture: a systematic review. Physiother Can 2012; 64: 190–201.

29. Muir SW, Yohannes AM. The impact of cognitive impairment on rehabilitation outcomes in elderly patients admitted with a femoral neck fracture: a systematic review. J Geriatr Phys Ther 2009; 32: 24–32.

30. Sheehan KJ, Williamson L, Alexander J *et al.* Prognostic factors of functional outcome after hip fracture surgery: a systematic review. Age Ageing 2018; 47: 661–70.

31. Sletvold O, Helbostad JL, Thingstad P *et al.* Effect of in-hospital comprehensive geriatric assessment (CGA) in older people with hip fracture. The protocol of the Trondheim Hip Fracture Trial. BMC Geriatr 2011; 11: 18. https://doi.org/10.1186/1471-2318-11-18.

32. Prestmo A, Hagen G, Sletvold O *et al.* Comprehensive geriatric care for patients with hip fractures: a prospective, randomised, controlled trial. Lancet 2015; 385: 1623–33.

33. Prestmo A, Saltvedt I, Helbostad JL *et al.* Who benefits from orthogeriatric treatment? Results from the Trondheim Hip-Facture Trial. BMC Geriatr 2016; 16: 49. https://doi.org/10.1186/s12877-016-0218-1.

34. Thingstad P, Taraldsen K, Saltvedt I, *et al.* The long-term effect of comprehensive geriatric care on gait after hip fracture: the Trondheim Hip Fracture Trial—a randomised controlled trial. Osteoporos Int 2016;27:933–42.

35. Saltvedt I, Prestmo A, Einarsen E *et al.* Development and delivery of patient treatment in the Trondheim Hip Fracture Trial. A new geriatric in-hospital pathway for elderly patients with hip fracture. BMC Res Notes 2012; 5: 355. https://doi.org/10.1186/1756-0500-5-355.

36. Taraldsen K, Sletvold O, Thingstad P *et al.* Physical behavior and function early after hip fracture surgery in patients receiving comprehensive geriatric care or orthopedic care—a randomized controlled trial. J Gerontol A Biol Sci Med Sci 2014; 69: 338–45.

37. Gladman JR, Lincoln NB, Adams SA. Use of the extended ADL scale with stroke patients. Age Ageing 1993; 22: 419–24.

38. Sundararajan V, Henderson T, Perry C *et al.* New ICD-10 version of the Charlson comorbidity index predicted in-hospital mortality. J Clin Epidemiol 2004; 57: 1288–94.

39. Folstein MF, Folstein SE, McHugh PR. "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res 1975; 12: 189–98.

40. Taraldsen K, Askim T, Sletvold O *et al.* Evaluation of a body-worn sensor system to measure physical activity in older people with impaired function. Phys Ther 2011; 91: 277–85.

41. Guralnik JM, Simonsick EM, Ferrucci L *et al.* A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. J Gerontol 1994; 49: M85–94.

42. Mijnarends DM, Meijers JMM, Halfens RJG *et al.* Validity and reliability of tools to measure muscle mass, strength, and physical performance in community-dwelling older people: a systematic review. J Am Med Dir Assoc 2013; 14: 170–8.

43. Brooks R. EuroQol: the current state of play. Health Policy 1996; 37: 53–72.

44. Dolan P. Modeling valuations for EuroQol health states. Med Care 1997; 35: 1095–108.

45. Kwon S, Perera S, Pahor M *et al.* What is a meaningful change in physical performance? Findings from a clinical trial in older adults (the LIFE-P study). J Nutr Health Aging 2009; 13: 538–44.

46. Perera S, Mody SH, Woodman RC *et al.* Meaningful change and responsiveness in common physical performance measures in older adults. J Am Geriatr Soc 2006; 54: 743–9.

47. Besson H, Ekelund U, Brage S *et al.* Relationship between subdomains of total physical activity and mortality. Med Sci Sports Exerc 2008; 40: 1909–15.

48. Takayanagi N, Kitamura K, Yamauchi T *et al.* Effects of promoting daily physical activity on physical and mental health in older individuals. J Phys Ther Sci 2018; 30: 1315–22.

49. Koval KJ, Skovron ML, Polatsch D *et al.* Dependency after hip fracture in geriatric patients: a study of predictive factors. J Orthop Trauma 1996; 10: 531–5.
50. Marottoli RA, Berkman LF, Cooney LM Jr. Decline in physical function following hip fracture. J Am Geriatr Soc 1992; 40: 861–6.
51. Hirose J, Ide J, Yakushiji T *et al.* Prediction of postoperative ambulatory status 1 year after hip fracture surgery. Arch Phys Med Rehabil 2010; 91: 67–72.
52. Parsons N, Griffin XL, Achten J *et al.* Outcome assessment after hip fracture: is EQ-5D the answer? Bone Joint Res 2014; 3: 69–75.
53. Peeters CM, Visser E, Van de Ree CL *et al.* Quality of life after hip fracture in the elderly: a systematic literature review. Injury 2016; 47: 1369–82.
54. Alexiou KI, Roushias A, Varitimidis SE *et al.* Quality of life and psychological consequences in elderly patients after a hip fracture: a review. Clin Interv Aging 2018; 13: 143–50.
55. Kristoffersen MH, Dybvik EH, Steihaug OM *et al.* Patient-reported outcome measures after hip fracture in patients with chronic cognitive impairment: results from 34,675 patients in the Norwegian Hip Fracture Register. Bone Jt Open 2021; 2: 454–65.
56. Naugle RI, Kawczak K. Limitations of the Mini-Mental State Examination. Cleve Clin J Med 1989; 56: 277–81.
57. Kristoffersen MH, Dybvik E, Steihaug OM *et al.* Cognitive impairment influences the risk of reoperation after hip fracture surgery: results of 87,573 operations reported to the Norwegian Hip Fracture Register. Acta Orthop 2020; 91: 146–51.

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