JAMDA 19 (2018) 989–994

JAMDA

journal homepage: www.jamda.com

Original Study

The Role of Prefracture Health Status in Physical and Mental Function After Hip Fracture Surgery

Ka Keat Lim MPharm, MSc[a],
William Yeo BAppSc (Physiotherapy) Hons, MPhty (Manips)[b], Joyce S.B. Koh MD[c,d],
Chuen Seng Tan BSc(Hons), MSc, PhD[e], Hwei Chi Chong BAppSc (Physiotherapy)[b],
Karen Zhang BSc[b], Truls Østbye MD, MPH, PhD[a], Tet Sen Howe MD[c],
David Bruce Matchar MD[a,f,*]

[a] *Program in Health Services & Systems Research, Duke-NUS Medical School, Singapore*
[b] *Orthopaedic Diagnostic Centre, Singapore General Hospital, Singapore*
[c] *Department of Orthopaedic Surgery, Singapore General Hospital, Singapore*
[d] *Duke-NUS Medical School, Singapore*
[e] *Saw Swee Hock School of Public Health, National University of Singapore and National University Health System, Singapore*
[f] *Department of Medicine (General Internal Medicine), Duke University Medical Center, Durham, NC*

Keywords:
Aging
function recovery
hip fracture
longitudinal analysis

ABSTRACT

Objectives: To examine the associations of 3 measures of prefracture health status (physical function, mental function, and comorbidity count) with trajectories of physical and mental function at 1.5, 3, 6, and 12 months after hip fracture surgery.
Design: Single-center observational study.
Setting: Singapore General Hospital (an acute hospital).
Participants: Patients aged ≥60 years who underwent first hip fracture surgery between June 2011 and July 2016 (N = 928).
Intervention: None.
Measurements: We used data collected prospectively from the hospital's hip fracture registry. We used the Short Form–36 (SF-36) Physical Component Summary (PCS) and Mental Component Summary (MCS) as indicators of physical and mental function, respectively, collected at admission and at 1.5, 3, 6, and 12 months after hip fracture surgery. Comorbidity count at admission was the sum from a list of 10 common diseases associated with poorer physical function.
Results: Prefracture physical function and prefracture mental function demonstrated time-varying associations (interaction $P < .001$ and $P = .001$, respectively) with postfracture physical function; the associations were small initially but increased in strength up to 6 months and stabilized thereafter. In contrast, the strength of the association between comorbidity count and postfracture physical function were time-invariant (−0.52, $P = .027$). The strength of the associations between all 3 measures of prefracture health status and postfracture mental function were also constant over time (0.09, $P = .004$, for physical function; 0.38, $P < .001$, for mental function; −0.70, $P = .034$, for comorbidity count).
Conclusions/Implications: The time-varying associations between prefracture health status and postfracture physical function suggest that even for patients with good prefracture health status, initial recovery may be slow. Our findings can be useful to clinicians and therapists in their prognostic evaluations and in management of patients' expectation for recovery.

Hip fracture, usually occurring among older adults who fall from a standing position, is an acute debilitating health condition. Not only does it impose severe loss of physical function,[1,2] it also increases the risk of mortality, leading to a substantial reduction of healthy life years among older adults.[3] As hip fracture accounts for most fracture-related health care utilization and expenditure,[4,5] it has become a major public health concern with aging population worldwide.

The authors declare no conflicts of interest.

[*] Address correspondence to David Bruce Matchar, MD, Health Services & Systems Research, Duke NUS Medical School, Singapore.

E-mail address: david.matchar@duke-nus.edu.sg (D.B. Matchar).

https://doi.org/10.1016/j.jamda.2018.05.018
1525-8610/

Most hip fractures are treated surgically, with the aim to facilitate early mobilization and a return to prefracture level of function,[6,7] which may take up to a year depending on the functional domain.[8] Prefracture function as well as comorbidities are used by clinicians and therapists to advise patients on their prognosis and to guide the design of a patient's rehabilitation program.[7] It is generally accepted that better prefracture health status (ie, better prefracture physical function,[9,10] better prefracture mental function[9,11] and fewer comorbidities[12,13]) leads to better postfracture (physical and mental) function. However, as most studies examine their associations with postfracture function at a single time point, it is unknown whether the effect of prefracture health status changes over time. In addition, longitudinal analyses that account for multiple time points[14,15] usually assume that the effect (ie, the regression coefficient) is constant throughout the recovery period. The diverse ways of conceptualizing and measuring "function" in literature[2,16] further complicates efforts to compare the effect of prefracture health status on the trajectory of recovery. Having a more nuanced understanding of the temporal relationship between prefracture health status and postfracture function would allow clinicians and therapists to better advise patients on prognosis, to identify more realistic individual goals with the patients and to determine appropriate timing of interventions to promote maximal recovery.

To address these gaps in our understanding of recovery from hip fracture, we investigated the relationships of 3 measures of prefracture health status (physical function, mental function, and comorbidity count) with the trajectories of physical and mental function (at 1.5, 3, 6, and 12 months after surgery) by examining the interaction effects between each prefracture health status and time. We examined trajectories of mental function after surgery as older adults with hip fracture may also experience significant mental distress,[17,18] and persistently poor mental function after fracture even for the short term[19] can adversely affect physical function recovery. Only 2 studies[9,20] have examined the trajectory of postfracture mental function of these patients up to a year after hip fracture.

We hypothesize that prefracture health status imposes a "ceiling" to which a patient can recover, and thus their effects on postfracture physical and mental function would mirror the trajectories of physical and mental function. Specifically, the strength of the associations (ie, the size of the regression coefficients) between prefracture health status and postfracture physical function would be time-varying, reflecting the trajectory of physical function that usually plateaus after 6 months.[1,2] Meanwhile, we hypothesize that the strength of the association between prefracture health status and postfracture mental function would be time-invariant, as postfracture mental function may exhibit little fluctuations over time.[9]

Methods

Data Source

We used data from the Singapore General Hospital Hip Fracture Registry (SGH-HFR), which routinely follows patients after hip fracture surgery as part of clinical management. Singapore General Hospital (SGH) is the oldest and largest tertiary acute hospital in Singapore. A team of physiotherapists and technicians in the Orthopaedic Diagnostic Centre collects the data from patients or proxies before surgery and at 4 time points (1.5, 3, 6, and 12 months) after surgery, via face-to-face or telephone interviews. Follow-up begins at 1.5 months after surgery in SGH-HFR because this is the time when most patients with hip fracture in Singapore are discharged from community care back to their prefracture residence. Functional status becomes important at this juncture to determine how much more care is required from their family members and whether additional assistance such as that provided by domestic helpers is required. Ethics approval for the study was obtained from SingHealth Centralized Internal Review Board.

We included patients $\geq$60 years old who received surgery between June 2011 (inception of SGH-HFR) and July 2016. We used 60 years as the cut-off because these patients are more likely to sustain low-energy hip fracture than those younger.[21,22] Locally, 60 years is also the lower age limit to be eligible for the hip fracture bundled payment by the Ministry of Health. We excluded patients with previous hip fracture. This resulted in a sample of 1019 patients, out of which 91 had missing values on the independent variables or covariates or dependent variables at all follow-up time points. Therefore, our final data for analysis included 928 patients.

Dependent Variables

We used Short Form-36 (SF-36) Physical Component Summary (PCS) and Mental Component Summary (MCS) scores as indicators of physical and mental functions, respectively.

SF-36 is a validated and internationally used questionnaire measuring health-related quality of life (HRQoL) in 8 domains of perceived health (physical functioning, bodily pain, general health, vitality, role-physical, role-emotional, mental health, and social functioning), consisting of 36 questions. We derived the PCS and MCS scores based on the contribution of the 8 domains to physical and mental health in Singapore.[23] Both PCS and MCS scores range from 0 to 100, with higher scores indicating better physical or mental function. Both scores are normed such that a score of 50 represents the population average, with each 10-point deviation from 50 representing 1 standard deviation.

Our dependent variables were physical function (PCS scores) and mental function (MCS scores) at 1.5, 3, 6, and 12 months after hip fracture surgery.

Independent Variables

Patients were interviewed before surgery to recall their prefracture physical function (PCS scores) and prefracture mental function (MCS scores). Ten comorbidities known to delay or limit recovery from hip fracture were assessed from the medical histories entered into the electronic medical record before surgery and were summarized as the comorbidity count. Nine of the comorbidities are reflected in the Functional Comorbidity Index[24] (type 2 diabetes mellitus, ischemic heart disease, stroke, arthritis, asthma, depression, Parkinson's disease, vascular disease, osteoporosis). In addition, based on hip fracture literature,[12,15] we included cognitive impairment in the comorbidity count. The same approach of summing the number of comorbidities present was also used by the Functional Comorbidity Index.[24]

Other Covariates

Our analyses adjusted for age, gender, ethnicity (Chinese, Malay, Indian/Others), type of fracture, type of surgery, and time of follow-up. We categorized fractures into 3 groups: neck-of-femur fracture, intertrochanteric fracture, and other fractures. We categorized type of surgery into 4 groups: bipolar hemiarthroplasty, intramedullary nail, dynamic hip screw with or without trochanteric plate, and others.

Statistical Analysis

We summarized the demographic characteristics of the cohort using counts and percentages for categorical variables, and means and standard deviations for continuous variables. We examined the difference between the included and excluded patients using *t* test for continuous variables and chi-square test or Fisher exact test for categorical variables.

To examine our hypotheses, we performed linear regression models with generalized estimating equations (GEEs), using the 4 repeated measures of physical or mental function at follow-up as continuous dependent variables. GEEs allow estimating the population-average mean effects of the independent variables of interest while accounting for the correlation among repeated measures within an individual.[25] The time of follow-up was a categorical variable in the models and the correlations between the repeated measures were assumed to be autoregressive of order 1 where correlations were higher between time points that are closer.

We performed model building, starting with adjusting each prefracture health status separately with time of follow-up (model 1), followed by further adjustment for age, gender, ethnicity, type of fracture, and type of surgery (model 2). Both models assumed that the association between each prefracture health status and postfracture physical function were time-invariant. To assess whether the strength of the associations varies with time, we added an interaction term between each prefracture health status and time (model 3). To obtain a parsimonious model (model 4), we performed a forward variable selection by sequentially adding interaction terms with $P < .05$ into model 3. We reported the coefficient estimates with their respective 95% confidence intervals (95% CIs) and *P* values.

For prefracture health status exhibiting time-varying associations (ie, interaction term $P < .05$ in model 4), we plotted the time-varying effect on postfracture physical or mental function using estimated marginal mean,[26] where each continuous confounder takes the value corresponding to its mean and each categorical confounder takes the value based on the proportion in the overall sample.

For sensitivity analyses, we applied the final model to 2 subsets: patients who had all 4 repeated measures ($n = 528$; 57% of total samples) and those who had at least 1 missing measure ($n = 400$; 43%).

We performed all statistical analyses using R version 3.4.3. We used the geeglm command in the geepack package[27] to perform linear regression modeling with GEE and the esticon command in the doBy package[28] to estimate an overall *P* value for each interaction term. A *P* value $< .05$ was considered statistically significant.

Results

Most of the 928 patients were females (71.1%), of Chinese ethnicity (87.2%), and experienced neck of femur fracture (63.1%). Bipolar hemiarthroplasty (49.6%) was the most common surgery. At admission, the patients were 78.2 years old, with an average of 1 comorbidity (Table 1). There was no statistically significant difference between these patients and the 91 patients excluded from analyses in all measured respects except for ethnicity. Compared to those included in the analysis, the excluded patients were less likely to be of Chinese (79.1% vs 87.2%) or Malay ethnicities (5.5% vs 6.8%) and more likely to be of Indian or other ethnicities (15.4% vs 6.0%).

Table 1
Patient Baseline Characteristics (N = 928)

	Mean (SD) or Count (%)
Age, mean (SD)	78.2 (8.1)
Gender, n (%)	
Male	268 (28.9)
Female	660 (71.1)
Ethnicity, n (%)	
Chinese	809 (87.2)
Malay	63 (6.8)
Indian or other	56 (6.0)
Type of fracture, n (%)	
Neck of femur	586 (63.1)
Intertrochanteric	314 (33.8)
Others	28 (3.0)
Type of surgery, n (%)	
Bipolar hemiarthroplasty	460 (49.6)
Dynamic hip screw ± trochanteric plate (TSP)	274 (29.5)
Intramedullary nail	101 (10.9)
Others	93 (10.0)
Chronic disease count, mean (SD)	1.0 (1.0)

SD, standard deviation.

Table 2
Physical and Mental Function Over Time (As Measured by SF-36v1 PCS and MCS Scores) With Respective Follow-up Rates

	Prefracture	1.5 mo	3 mo	6 mo	12 mo
Physical function, mean (%)	46.0 (10.3)	28.4 (8.5)	33.6 (10.4)	37.8 (11.1)	39.8 (10.7)
Mental function, mean (%)	55.7 (10.4)	54.0 (11.8)	54.0 (11.9)	55.2 (11.5)	55.7 (11.2)
Follow-up, n	928	825	785	756	669
Follow-up, %	100.0	88.9	84.6	81.5	72.1

Of the 928 patients at admission, 88.9% were seen at 1.5 months, 84.6% at 3 months, 81.5% at 6 months, and 72.1% at 12 months. Physical function was substantially lower at 1.5 months after surgery compared to that before fracture but rebounded to just below 40 at 6 months and remained stable at 12 months. In contrast, mental function exhibited little fluctuation overall, with a small dip at 1.5 and 3 months (Table 2).

Physical Function After Hip Fracture Surgery

Adjusting for time of follow-up alone, prefracture physical function, mental function, and comorbidity count were significantly associated with recovery in physical function after hip fracture surgery (model 1, Table 3). These associations remained statistically significant after further adjustment for age, gender, ethnicity, type of fracture, and type of surgery (model 2, Table 3).

To assess whether the strength of the associations was time-varying, an interaction term between each prefracture health status and time of follow-up was included into the multivariate models (model 3, Table 3). The interaction terms between all 3 prefracture health status and time variables had $P < .05$. Hence, they were added sequentially into model 3, starting with prefracture physical function (lowest *P* value), followed by prefracture mental function and comorbidity count.

The parsimonious model (model 4, Table 3) included interaction terms between prefracture physical function and time as well as between prefracture mental function and time. A 1 unit increase in prefracture physical function score was associated with 0.07 units (95% CI 0.01, 0.12) higher physical function score at 1.5 months, 0.20 units (95% CI 0.13, 0.27) higher score at 3 months, a 0.31 units (95% CI 0.24, 0.37) higher score at 6 months, and 0.30 units (95% CI 0.22, 0.37) higher score at 12 months; that is, the association became stronger over time up to 6 months. Prefracture mental function demonstrated a similar trend at a weaker strength: −0.01 units (95% CI −0.06, 0.05) at 1.5 months, 0.11 (95% CI 0.04, 0.17) at 3 months, 0.14 (95% CI 0.07, 0.21) at 6 months, and 0.14 (95% CI 0.07, 0.21) at 12 months. In contrast, the association between comorbidity count and postfracture physical function was time-invariant—an increase of 1 comorbidity count was associated with 0.52 units (95% CI 0.06, 0.97) lower physical function score over the 1-year trajectory.

Figures 1 and 2 illustrate the trajectory of postfracture physical function over time for patients at 3 levels (third quartile, median, first quartile) of prefracture physical and mental function scores respectively.

Mental Function After Hip Fracture Surgery

In model 1, which assumed the strength of the associations to be time-invariant (Table 4), prefracture physical function, mental function, and comorbidity count were associated with mental function through 1 year after hip fracture surgery. The associations remained

Table 3
Effect of Prefracture Health Status on the Trajectory of Physical Function at 1.5, 3, 6, and 12 Months After Hip Fracture Surgery (n = 928)

Variables of Interest	Model 1			Model 2		
	Estimate	95% CI	*P* Value	Estimate	95% CI	*P* Value
Prefracture physical function (time-invariant estimates)	0.26	0.22, 0.31	<.001	0.23	0.19, 0.27	<.001
Prefracture mental function (time-invariant estimates)	0.14	0.10, 0.18	<.001	0.14	0.10, 0.18	<.001
Comorbidity count at admission (time-invariant estimates)	−1.76	−2.48, −1.05	<.001	−1.14	−1.60, −0.68	<.001
Variables of Interest	**Model 3**			**Model 4 (Final Model)**		
	Estimate	95% CI	*P* Value	Estimate	95% CI	*P* Value
Prefracture physical function (time-varying estimates)			<.001*			<.001*
1.5 mo	0.04	−0.01, 0.10	.115	0.07	0.01, 0.12	.020
3 mo	0.21	0.14, 0.28	<.001	0.20	0.13, 0.27	<.001
6 mo	0.32	0.26, 0.39	<.001	0.31	0.24, 0.37	<.001
12 mo	0.32	0.24, 0.39	<.001	0.30	0.22, 0.37	<.001
Prefracture mental function (time-varying estimates)			<.001*			.001*
1.5 mo	−0.05	−0.10, 0.01	.097	−0.01	−0.06, 0.05	.739
3 mo	0.10	0.04, 0.17	.001	0.11	0.04, 0.17	.001
6 mo	0.17	0.10, 0.23	<.001	0.14	0.07, 0.21	<.001
12 mo	0.16	0.09, 0.23	<.001	0.14	0.07, 0.21	<.001
Comorbidity count at admission (time-varying estimates)			.001*			
1.5 mo	0.48	−0.08, 1.04	.092			
3 mo	−0.36	−1.07, 0.34	.314			
6 mo	−1.27	−1.99, −0.54	.001			
12 mo	−1.36	−2.14, −0.59	.001			
Comorbidity count at admission (time-invariant estimate)				−0.52	−0.97, −0.06	.027

The final model (model 4) implies that prefracture physical function and prefracture mental function have time-varying association whereas comorbidity count at admission has time-invariant association with postfracture physical function.
Model 1: Adjusted for time alone, assuming that the effect of prefracture health status is time-invariant.
Model 2: Adjusted for age, gender, ethnicity, type of fracture, type of surgery, and time, assuming that the effect of prefracture health status is time-invariant.
Model 3: Adjusted for age, gender, ethnicity, type of fracture, type of surgery, and time, assuming that the effect of prefracture health status is time-varying.
Model 4: Adjusted for age, gender, ethnicity, type of fracture, type of surgery, and time, assuming that the effects of prefracture physical function and prefracture mental function are time-varying and the effect of comorbidity count is time-invariant.
*This is the *P* value for the interaction term between prefracture health status and time.

statistically significant after further adjustment for age, gender, ethnicity, types of fracture, and type of surgery (model 2, Table 4).

In model 3 (Table 4), the interaction terms between all 3 measures of prefracture health status and time were not statistically significant (interaction $P = .203$, .691, and .127 for prefracture physical function, prefracture mental function, and comorbidity count, respectively), implying that the strength of the associations were time-invariant. Thus, the parsimonious model (model 4, Table 4) includes all 3 measures of prefracture health status without the interaction terms with time. In the final model, a 1 unit higher prefracture physical function score was associated with 0.09s unit (95% CI 0.03, 0.15) higher postfracture mental function score; 1 unit higher prefracture mental function score was associated with 0.38s unit (95% CI 0.32, 0.44) higher postfracture mental function score; 1 unit higher comorbidity count was associated with 0.70 units (95% CI 0.05, 1.35) lower postfracture mental function score over the first year after hip fracture surgery.

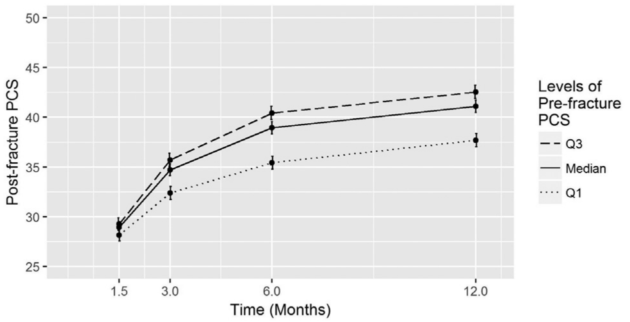

Fig. 1. The trajectories of postfracture physical function (SF-36 PCS score) at first quartile (Q1), median, and third quartile (Q3) of prefracture mental function.

In general, the estimates in our sensitivity analyses were similar in direction and strength to those in the main analyses (see Supplementary Tables 1 and 2), suggesting that our findings were robust.

Discussion

In this study, we found that prefracture physical function and prefracture mental function had time-varying associations with postfracture physical function. The strength of association was weak soon after the surgery (at 1.5 months) but increased over time up to 6 months and subsequently stabilized between 6 and 12 months, suggesting that even for patients with good prefracture function, recovery may not be evident soon after surgery. Meanwhile, comorbidity count at admission had time-invariant association with postfracture physical function up to a year after surgery. All 3 measures of prefracture health status also had time-invariant associations with postfracture mental function.

To our knowledge, this is the first prospective study to investigate the temporal relationship between prefracture health status and postfracture physical and mental function among older adults with surgically treated hip fracture.

These findings generally support our hypotheses regarding the time-varying effects of prefracture physical and mental function on recovery. However, the findings did not support a time-varying effect of comorbidity count at admission on postfracture physical function. The time-invariant association suggests that physical impairment due to higher comorbidity count does not change over the first year after surgery. As the effects of prefracture physical function and prefracture mental function after hip fracture surgery manifest slowly over time, this implies a slower recovery for older adults with multiple comorbidities even if they have good prefracture function. It also means that those with higher comorbidity count would require higher prefracture

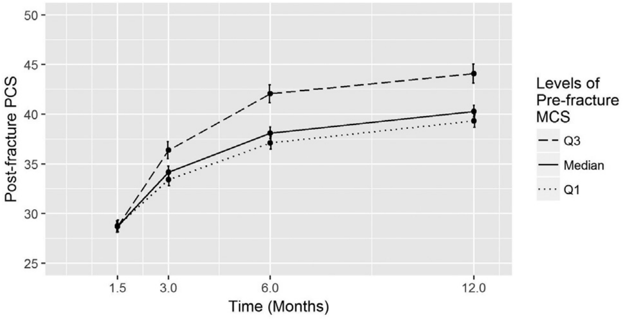

Fig. 2. The trajectories of postfracture physical function (SF-36 PCS score) at first quartile (Q1), median, and third quartile (Q3) of prefracture physical function.

physical and mental function to regain their physical function than those with fewer or no comorbidities, which corroborates earlier postulations that multiple comorbidities diminish physiological reserves and delay recovery.[29] It is notable that comorbidity count has a stronger association with postfracture mental function than with physical function in our sample, suggesting that a higher comorbidity count may impair postfracture mental function more than physical function.

In sensitivity analysis, we separately analyzed individuals with and without complete follow-up. Although the individuals in these 2 groups were similar in almost all measured respects and the results were substantively the same, postfracture mental function of individuals without complete follow-up was more strongly negatively associated with the effect of comorbidities than for individuals with complete follow-up (Supplementary Tables 1 and 2). In addition, although postfracture physical function of individuals without complete follow-up also had a significant association with prefracture mental function, the coefficient was smaller than for those with complete follow-up (Supplementary Tables 1 and 2). These support the robustness of the primary analysis. They also suggest that it may be worthwhile to further investigate whether patients who fail to follow up are especially vulnerable to poor outcomes and might benefit from special attention.

Several limitations of our study merit discussion. Physical and mental functions were self-reported. Due to the unexpected nature of hip fracture, prefracture physical and mental functions were based on recall before surgery. However, retrospective collection of patent-reported outcomes for pre-event health status has been shown to be comparable with contemporary collection.[30] Our data were also limited to patients who returned or were contactable for follow-up. The reasons for loss to follow-up are unknown, but probably because of multiple reasons such as reliance on caregivers for mobility or because patients did not know the values of follow-up. Another potential reason could be death.[31] Previous local studies[32,33] reported a 1-year mortality rate of 27%. As survival status is unknown among the subjects in our sample, our analyses were unable to account for a competing risk of death. In addition, our findings were based on a single institution in Asia and may therefore not be generalizable to patients in other countries or regions. Nevertheless, there is no evidence that hip fracture is a fundamentally different phenomenon in Asia. In fact, Asia is expected to experience the most rapid increase in hip fracture incidence in coming years due to rapid demographic changes. As our information on comorbidities was restricted to those systematically captured by the SGH-HFR, we may not have exhaustively considered all comorbidities associated with poorer recovery, such as visual impairment[24] or severity of the comorbidities. There may be some overlap between comorbidity count and prefracture physical and mental functions, as the comorbidity count includes

Table 4
Effect of Prefracture Health Status on the Trajectory of Postfracture Mental Status at 1.5, 3, 6, and 12 Months After Hip Fracture Surgery ($n = 928$)

Variables of Interest	Model 1			Model 2		
	Estimate	95% CI	*P* Value	Estimate	95% CI	*P* Value
Prefracture physical function (time-invariant estimates)	0.22	0.16, 0.29	<.001	0.22	0.15, 0.28	<.001
Prefracture mental function (time-invariant estimates)	0.42	0.36, 0.48	<.001	0.42	0.36, 0.48	<.001
Comorbidity count at admission (time-invariant estimates)	−1.76	−2.48, −1.05	<.001	−1.68	−2.40, −0.97	<.001
Variables of Interest	Model 3			Model 4 (Final Model)		
	Estimate	95% CI	*P* Value	Estimate	95% CI	*P* Value
Prefracture physical function (time-varying estimates)			.203*			
1.5 mo	0.14	0.06, 0.21	.001			
3 mo	0.11	0.03, 0.18	.006			
6 mo	0.10	0.02, 0.18	.016			
12 mo	0.03	−0.06, 0.12	.500			
Prefracture mental function (time-varying estimates)			.691*			
1.5 mo	0.38	0.30, 0.46	<.001			
3 mo	0.38	0.30, 0.46	<.001			
6 mo	0.42	0.33, 0.50	<.001			
12 mo	0.37	0.28, 0.45	<.001			
Comorbidity count at admission (time-varying estimates)			.127*			
1.5 mo	−0.95	−1.77, −0.13	.024			
3 mo	−0.23	−1.09, 0.62	.601			
6 mo	−1.04	−1.85, −0.23	.012			
12 mo	−0.49	−1.43, 0.45	.304			
Prefracture physical function (time-invariant estimate)				0.09	0.03, 0.15	.004
Prefracture mental function (time-invariant estimate)				0.38	0.32, 0.44	<.001
Comorbidity count at admission (time-invariant estimate)				−0.70	−1.35, −0.05	.034

The final model (model 4) implies that prefracture physical function, prefracture mental function and comorbidity count at admission have time-invariant association with postfracture mental function.
Model 1: Adjusted for time alone, assuming that the effect of prefracture health status is time-invariant.
Model 2: Adjusted for age, gender, ethnicity, type of fracture, type of surgery, and time, assuming that the effect of prefracture health status is time-invariant.
Model 3: Adjusted for age, gender, ethnicity, type of fracture, type of surgery, and time, assuming that the effect of prefracture health status is time-varying.
Model 4: Adjusted for age, gender, ethnicity, type of fracture, type of surgery, and time, assuming that the effect of prefracture health status is time-invariant.
*This is the *P* value for the interaction term between prefracture health status and time.

diseases that are typically considered physical, such as, stroke, or mental disorders, such as, depression. However, the associations were weak (Pearson correlations were both at −0.19); removing comorbidities from the final model did not alter the strength of the temporal associations between the prefracture physical and mental function with postfracture physical and mental function (Supplementary Table 3). We could not adjust for socioeconomic characteristics such as educational level because of the lack of data. However, in previous studies, socioeconomic characteristics have not been significantly associated with trajectory of recovery after hip fracture.[14,34]

Our findings have several clinical and policy implications. Besides aiding clinicians and therapists to make better functional prognosis during triage for rehabilitation, our results underscore the importance or managing patients' expectations for recovery, including those with excellent prefracture function. Unrealistic expectations cause patients to feel disappointed in their progress[35] and may discourage participation in a rehabilitation program. Our results also suggest a potential for psychological interventions such as cognitive-behavioral therapy[36,37] during the acute stage of hip fracture. These interventions could be delivered by trained therapists together with rehabilitation program to target specific behavior,[38] such as adaptive emotional responses and coping strategies.

Conclusions/Relevance

Our findings imply that the role of prefracture health status in physical and mental function after hip fracture surgery may vary over time. Collectively, these insights on the time-varying and time-invariant associations between prefracture health status and postfracture physical and mental function could be used to improve prognostication for hip fracture and thus to promote realistic expectations for recovery. This study also points to the importance of investment in maximizing physical and mental capacity before a major stressor such as a hip fracture and suggests the potential value of psychological interventions to enhance recovery.

Acknowledgments

We thank all staff of Orthopaedic Diagnostic Centre who manage the Hip Fracture Registry.

References

1. Dyer SM, Crotty M, Fairhall N, et al. A critical review of the long-term disability outcomes following hip fracture. BMC Geriatr 2016;16:158.
2. 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;47:1369–1382.
3. Papadimitriou N, Tsilidis KK, Orfanos P, et al. Burden of hip fracture using disability-adjusted life-years: A pooled analysis of prospective cohorts in the CHANCES consortium. Lancet Public Health 2017;2:e239–e246.
4. Kanis JA. on behalf of the World Health Organization Scientific Group. Assessment of Osteoporosis at Primary Health-Care Level. Belgium: World Health Organization; 2007.
5. Ström O, Borgström F, Kanis JA, et al. Osteoporosis: Burden, health care provision and opportunities in the EU. Arch Osteoporos 2011;6:59–155.
6. Handoll HH, Parker MJ. Conservative versus operative treatment for hip fractures in adults. Cochrane Database Syst Rev 2008;3:CD000337.
7. National Clinical Guideline Centre. The Management of Hip Fracture in Adults. London, UK: National Clinical Guideline Centre; 2011.
8. Magaziner J, Hawkes W, Hebel JR, et al. Recovery from hip fracture in eight areas of function. J Gerontol A Biol Sci Med Sci 2000;55:M498–M507.
9. Tseng MY, Liang J, Shyu YIL, et al. Effects of interventions on trajectories of health-related quality of life among older patients with hip fracture: A prospective randomized controlled trial. BMC Musculoskelet Disord 2016;17:114.
10. Vochteloo AJ, Moerman S, Tuinebreijer WE, et al. More than half of hip fracture patients do not regain mobility in the first postoperative year. Geriatr Gerontol Int 2013;13:334–341.
11. Savino E, Martini E, Lauretani F, et al. Handgrip strength predicts persistent walking recovery after hip fracture surgery. Am J Med 2013;126:1068–1075.
12. Young Y, Xiong K, Pruzek RM. Longitudinal functional recovery after postacute rehabilitation in older hip fracture patients: The role of cognitive impairment and implications for long-term care. J Am Med Dir Assoc 2011;12:431–438.
13. Xu C, Mao Y, Wang L, et al. Factors affecting the outcome of hemi hip arthroplasty in elderly patients with femoral neck fractures. Int J Clin Exp Med 2016; 9:22282–22288.
14. Tseng MY, Shyu YI, Liang J. Functional recovery of older hip-fracture patients after interdisciplinary intervention follows three distinct trajectories. Gerontologist 2012;52:833–842.
15. McGilton KS, Chu CH, Naglie G, et al. Factors influencing outcomes of older adults after undergoing rehabilitation for hip fracture. J Am Geriatr Soc 2016; 64:1601–1609.
16. Hoang-Kim A, Beaton D, Bhandari M, et al. The need to standardize functional outcome in randomized trials of hip fracture: A review using the ICF framework. J Orthop Trauma 2013;27:e1–e8.
17. Chang CY, Chen WL, Liou YF, et al. Increased risk of major depression in the three years following a femoral neck fracture—A national population-based follow-up study. PLoS One 2014;9:e89867.
18. Kornfield SL, Lenze EJ, Rawson KS. Predictors of posttraumatic stress symptoms and association with fear of falling after hip fracture. J Am Geriatr Soc 2017;65: 1251–1257.
19. Zimmerman SI, Smith HD, Gruber-Baldini A, et al. Short-term persistent depression following hip fracture: A risk factor and target to increase resilience in elderly people. Soc Work Res 1999;23:187–196.
20. Cristancho P, Lenze EJ, Avidan MS, et al. Trajectories of depressive symptoms after hip fracture. Psychol Med 2016;46:1413–1425.
21. Koh LK, Saw SM, Lee JJ, et al. Hip fracture incidence rates in Singapore 1991-1998. Osteoporos Int 2001;12:311–318.
22. Banks E, Reeves GK, Beral V, et al. Hip fracture incidence in relation to age, menopausal status, and age at menopause: Prospective analysis. PLoS Med 2009;6:e1000181.
23. Thumboo J, Fong KY, Machin D, et al. A community-based study of scaling assumptions and construct validity of the English (UK) and Chinese (HK) SF-36 in Singapore. Qual Life Res 2001;10:175–188.
24. Groll DL, To T, Bombardier C, et al. The development of a comorbidity index with physical function as the outcome. J Clin Epidemiol 2005;58:595–602.
25. Fitzmaurice GM, Laird NM, Ware JH. Applied Longitudinal Analysis. 2nd ed. Hoboken, NJ: John Wiley & Sons; 2011.
26. Searle SR, Speed FM, Milliken GA. Population marginal means in the linear model: An alternative to least squares means. Am Stat 1980;34:216–221.
27. Højsgaard S, Halekoh U, Yan J. The R package geepack for generalized estimating equations. J Stat Software 2006;15:1–11.
28. Højsgaard S, Halekoh U. doBy: Groupwise statistics, LSmeans, linear contrasts, utilities. R package version 4.5-15 2016. Available at: https://CRAN.R-project.org/package=doBy. Accessed September 4, 2017.
29. Sheehan KJ, Sobolev B, Chudyk A, et al. Patient and system factors of mortality after hip fracture: A scoping review. BMC Musculoskelet Disord 2016;17:166.
30. Kwong E, Black N. Retrospectively patient-reported pre-event health status showed strong association and agreement with contemporaneous reports. J Clin Epidemiol 2017;81:22–32.
31. Abrahamsen B, van Staa T, Ariely R, et al. Excess mortality following hip fracture: A systematic epidemiological review. Osteoporos Int 2009;20: 1633–1650.
32. Lee AY, Tan J, Koh J, et al. Five-year outcome of individuals with hip fracture admitted to a Singapore hospital: Quality of life and survival rates after treatment. J Am Geriatr Soc 2012;60:994–996.
33. Lee AY, Chua BS, Howe TS. One-year outcome of hip fracture patients admitted to a Singapore hospital: Quality of life post-treatment. Singapore Med J 2007; 48:996–999.
34. Young Y, Xiong K, Pruzek RM, et al. Examining heterogeneity of functional recovery among older adults with hip fractures. J Am Med Dir Assoc 2010;11:132–139.
35. Sims-Gould J, Stott-Eveneshen S, Fleig L, et al. Patient perspectives on engagement in recovery after hip fracture: A qualitative study. J Aging Res 2017;2017:2171865.
36. Helmreich I, Kunzler A, Chmitorz A, et al. Psychological interventions for resilience enhancement in adults. Cochrane Database Syst Rev 2017;2: CD012527.
37. Leppin AL, Bora PR, Tilburt JC, et al. The efficacy of resiliency training programs: A systematic review and meta-analysis of randomized trials. PLoS One 2014;9: e111420.
38. Scheffers-Barnhoorn MN, van Haastregt JCM, Schols JMGA, et al. A multicomponent cognitive behavioural intervention for the treatment of fear of falling after hip fracture (FIT-HIP): Protocol of a randomised controlled trial. BMC Geriatr 2017;17:71.

Appendix

Supplementary Table 1
Effect of Prefracture Health Status on the Trajectories of Physical and Mental Function Among Those With Full Follow-up (n = 528)

Variables of Interest	Postfracture Physical Function[*]			Postfracture Mental Function[†]		
	Estimate	95% CI	*P* Value	Estimate	95% CI	*P* Value
Prefracture physical function (time-varying estimates)			<.001[‡]			
1.5 mo	0.09	0.02, 0.16	.015			
3 mo	0.21	0.12, 0.30	<.001			
6 mo	0.29	0.20, 0.38	<.001			
12 mo	0.29	0.20, 0.38	<.001			
Prefracture mental function (time-varying estimates)			.008[‡]			
1.5 mo	0.00	−0.07, 0.08	.822			
3 mo	0.13	0.05, 0.21	.001			
6 mo	0.17	0.08, 0.25	<.001			
12 mo	0.14	0.06, 0.23	.001			
Prefracture physical function (time-invariant estimate)				0.08	−0.00, 0.15	.058
Prefracture mental function (time-invariant estimate)				0.41	0.33, 0.49	<.001
Comorbidity counts at admission (time-invariant estimate)	−0.70	−1.30, 0.10	.022	−0.19	−0.94, 0.57	.474

The estimates for the final model (model 4) are similar to those from the main analyses.

[*] Adjusted for age, gender, ethnicity, type of fracture, type of surgery, and time, assuming that the effects of prefracture physical function and prefracture mental function are time-varying and the effect of comorbidity counts is time-invariant.

[†] Adjusted for age, gender, ethnicity, type of fracture, type of surgery, and time, assuming that the effect of prefracture health status is time-invariant.

[‡] This is the *P* value for the interaction term between prefracture health status and time.

Supplementary Table 2
Association of Prefracture Health Status With the Trajectories of Physical and Mental Function Among Those Without Full Follow-up (n = 400)

Variables of Interest	Postfracture Physical Function[*]			Postfracture Mental Function[†]		
	Estimate	95% CI	*P* Value	Estimate	95% CI	*P* Value
Prefracture physical function (time-varying estimates)			<.001[‡]			
1.5 mo	0.03	−0.05, 0.12	.449			
3 mo	0.18	0.07, 0.30	.002			
6 mo	0.34	0.23, 0.46	<.001			
12 mo	0.27	0.11, 0.43	.001			
Prefracture mental function (time-varying estimates)			.085[‡]			
1.5 mo	−0.02	−0.09, 0.06	.673			
3 mo	0.06	−0.04, 0.16	.237			
6 mo	0.09	−0.02, 0.21	.101			
12 mo	0.17	0.03, 0.31	.019			
Prefracture physical function (time-invariant estimate)				0.10	0.00, 0.19	.043
Prefracture mental function (time-invariant estimate)				0.33	0.24, 0.43	<.001
Comorbidity counts at admission (time-invariant estimate)	−0.27	−0.99, 0.45	.465	−1.54	−2.62, −0.46	.005

The estimates for the final model (model 4) are similar to those from the main analyses.

[*] Adjusted for age, gender, ethnicity, type of fracture, type of surgery, and time, assuming that the effect of prefracture physical function and prefracture mental function are time-varying and the effect of comorbidity counts is time-invariant.

[†] Adjusted for age, gender, ethnicity, type of fracture, type of surgery, and time, assuming that the effect of prefracture health status is time-invariant.

[‡] This is the *P* value for the interaction term between prefracture health status and time.

Supplementary Table 3

Association of Prefracture Health Status on the Trajectories of Physical and Mental Function, Without Considering Comorbidity Count ($n = 928$)

Variables of Interest	Postfracture Physical Function*			Postfracture Mental Function†		
	Estimate	95% CI	*P* Value	Estimate	95% CI	*P* Value
Prefracture physical function (time-varying estimates)			<.001‡			
1.5 mo	0.08	0.02, 0.13	.005			
3 mo	0.21	0.15, 0.28	<.001			
6 mo	0.32	0.25, 0.38	<.001			
12 mo	0.31	0.23, 0.38	<.001			
Prefracture mental function (time-varying estimates)			.088‡			
1.5 mo	0.00	−0.05, 0.05	.956			
3 mo	0.11	0.05, 0.17	.001			
6 mo	0.14	0.08, 0.21	<.001			
12 mo	0.14	0.07, 0.22	<.001			
Prefracture physical function (time-invariant estimate)				0.10	0.04, 0.16	.001
Prefracture mental function (time-invariant estimate)				0.39	0.33, 0.45	<.001

The estimates for the final model (model 4) are similar to those from the main analyses.

*Adjusted for age, gender, ethnicity, type of fracture, type of surgery, and time, assuming that the effect of prefracture physical function and prefracture mental function change over time and the effect of comorbidity counts is time-invariant.

†Adjusted for age, gender, ethnicity, type of fracture, type of surgery, and time, assuming that the effect of prefracture health status is time-invariant.

‡This is the *P* value for the interaction term between prefracture health status and time.