

ORIGINAL ARTICLE

Cognitive Impairment as the Principal Factor Correlated with the Activities of Daily Living Following Hip Fracture in Elderly People

Teruhito Yoshitaka, MD, PhD ^{a,b} Yasunori Shimaoka, MD, PhD ^b Issei Yamanaka, MD ^b
Akira Tanida, MD ^b Junichi Tanimoto, MD ^b Naoki Toda, MD ^b Taro Akimori, MD ^b
and Junichi Hamawaki, MD, PhD ^b

Objectives: Hip fracture is a common injury occurring in elderly people and often impairs their activities of daily living (ADL). This study aimed to identify and analyze factors associated with ADL following hip fracture treatment. **Methods:** A total of 371 consecutive patients with hip fractures who were surgically treated in our hospital were enrolled. Among these, 103 patients who underwent acute- to recovery-phase postoperative rehabilitation at our hospital and whose motor scale of the functional independence measure (mFIM) score was ≥ 70 before the fracture were finally included in this study. Single and multiple regression analyses were performed to identify the factors correlated with ADL. The mFIM at hospital discharge was set as the outcome variable, and various clinical factors, such as fracture type, surgical technique, serum and biological data, mini-mental state examination (MMSE) score, and serial mFIM scores, were used as explanatory variables. **Results:** Only MMSE and preinjury mFIM scores were significantly correlated with mFIM at discharge, and MMSE had the larger effect on the outcome. Receiver operating characteristic curve analysis revealed an MMSE cutoff value of 20/21. Patients with an MMSE score of ≤ 20 showed a relatively poor recovery of mFIM from 2–3 weeks postoperatively compared with those with an MMSE score of ≥ 21 . **Conclusion:** Cognitive impairment and the preinjury ADL level were correlated with short-term ADL outcomes following hip fracture. Cognitive impairment was the most important factor affecting ADL; treatment and postoperative rehabilitation should be carefully considered for cognitively disturbed patients from the acute phase after hip fracture.

Key Words: activities of daily living; cognitive impairment; dementia; hip fracture

INTRODUCTION

Hip fractures are common in older adults and can have a severe effect on activities of daily living (ADL).^{1,2)} Moreover, the mortality rate associated with hip fractures is high. Neuman et al. reported that 36.2% of patients with hip fractures died within 6 months after the injury, and 53.5% of patients who were not totally dependent before the injury either died or became completely dependent within 6 months.³⁾ Among

the population aged >50 years, approximately 5% of the total mortality is attributable to hip fracture.⁴⁾

The usual treatment for hip fracture consists of surgery and postoperative rehabilitation, which are often carried out at different institutions. Orthopedic surgeons usually treat hip fracture surgically and focus on the bony alignment/stability after fracture reduction, and preventing surgical site infections, among others. After acute-phase treatment, most patients are transferred to another institute to undergo

Received: August 27, 2021, Accepted: March 25, 2022, Published online: May 18, 2022

^a Department of Orthopedic Surgery, Hiroshima City Rehabilitation Hospital, Hiroshima, Japan

^b Hamawaki Orthopaedic Hospital

Correspondence: Teruhito Yoshitaka, MD, PhD, Department of Orthopedics, Hiroshima City Rehabilitation Hospital, 1-39-1 Tomomina, Asaminami-ku, Hiroshima City, Hiroshima 731-3168, Japan, E-mail: tyoshi0115@gmail.com

Copyright © 2022 The Japanese Association of Rehabilitation Medicine



This is an open-access article distributed under the terms of the Creative Commons Attribution Non-Commercial No Derivatives (CC BY-NC-ND) 4.0 License. <http://creativecommons.org/licenses/by-nc-nd/4.0/>

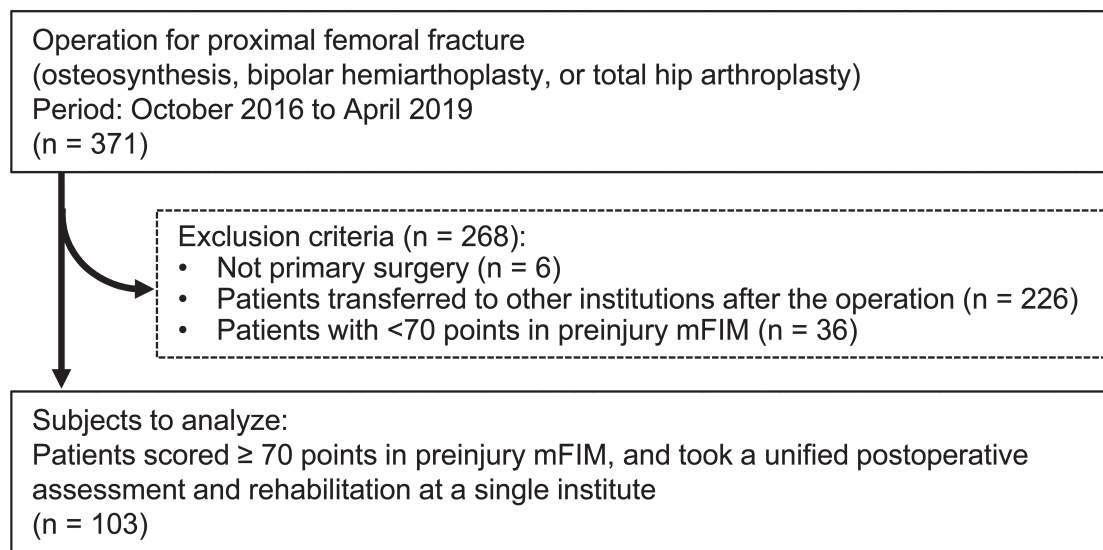


Fig. 1. Flow diagram depicting patient selection criteria.

subacute- and recovery-phase rehabilitation, where they undergo training to regain the preinjury ADL. Subsequently, they either return to their previous residence or live at a nursing home.

As an evaluation tool of basic ADL, the functional independence measure (FIM) is widely used. The FIM was developed by Granger et al. in 1983 to assess basic ADL⁵⁾ and comprises 18 items: each item is scored from 1 to 7 points according to the level of independence for basic ADL (1, complete assistance; 2, maximal assistance; 3, moderate assistance; 4, minimal contact assistance; 5, supervision or set-up; 6, modified independence; and 7, complete independence). The first 13 items have become known as the motor scale FIM (mFIM; range, 13–91 points) and assess the level of self-care (6 items), sphincter control (2 items), mobility (3 items), and locomotion (2 items). The remaining 5 of the 18 FIM items are recognized as the cognitive scale and cover communication (2 items) and social cognition (3 items).

Orthopedic surgeons tend to focus on the mechanical or biological aspects of the fracture. Furthermore, they do not pay much attention to ADL after recovery-phase rehabilitation because it is often performed at other institutions. To address the details of the clinical outcome focusing on ADL, this study aimed to identify and analyze the factors important for regaining ADL at the end of the recovery phase of rehabilitation following surgical treatment for hip fracture.

PATIENTS AND METHODS

Ethical Considerations

The Committee on the Ethics of Human Research at Hamawaki Orthopaedic Hospital, Japan, approved the study protocol (No. 201906–10), and written informed consent for the examination was obtained from all patients. All procedures performed in the study were conducted in accordance with the ethical standards of the institutional and national research committees and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Study Design and Setting

This study was designed as a retrospective observational chart review. We used mFIM as a general indicator of ADL in this study. Tsuji et al. divided the mFIM values of their stroke patients into five groups; for example, an mFIM score ranging from ≥ 70 to < 80 points represents independence in most self-care-associated items, whereas an mFIM score ranging from ≥ 80 to < 85 represents independence except for stairs.⁶⁾ In the current study, with reference to Tsuji et al. and other previous reports,^{6–10)} an mFIM score of ≥ 70 was set as the cutoff value for good ADL. All 371 consecutive hip fracture patients enrolled in this study were surgically treated at a single institution between October 1, 2016, and April 30, 2019 (**Fig. 1**). The excluded patients ($n = 268$) were as follows: patients who had undergone previous operation(s) on the affected hip ($n = 6$), patients who were transferred to other institutions after the operation ($n = 226$), and patients with a

preinjury mFIM score of <70 points (n = 36). The remaining 103 patients were included in this study. All patients with hip fractures undertook a consistent rehabilitation program at a single orthopedic institution. The rehabilitation program was as follows: patients started preoperative bedside generalized exercise, except for the affected hip–knee exercise, and started postoperative exercise within 48 h. Patients were allowed to stand/walk at the bedside while fully weighted according to their pain level with support provided by a physical therapist. The duration of the rehabilitation sessions was 80–120 min each day until the day before discharge.

Demographic and clinical variables, such as age; sex; body mass index (BMI); fracture type; surgical technique; American Society of Anesthesiologists (ASA) class; time between the fracture and operation; time between the fracture and the beginning of rehabilitation; length of hospital stay; levels of hemoglobin, serum albumin, total serum protein, and serum N-terminal pro-brain natriuretic peptide (NT-proBNP); left ventricular ejection fraction on heart sonography; serial mFIM scores (before the fracture, defined as “preinjury mFIM”; perioperative as “1st mFIM”; at the beginning of recovery-phase rehabilitation at about 2 weeks postoperatively as “2nd mFIM”; and at hospital discharge as “final mFIM”); and mini-mental state examination (MMSE) score, were extracted from the clinical records. In addition, the mFIM gain (points) was calculated by subtracting the earlier mFIM score from the later mFIM scores to assess the serial changes in ADL. Each mFIM gain was defined using the following equations: (overall-mFIM gain) = (final mFIM) – (preinjury mFIM), (initial loss-mFIM gain) = (1st mFIM) – (preinjury mFIM), (acute-mFIM gain) = (2nd mFIM) – (1st mFIM), and (recovery-mFIM gain) = (final mFIM) – (2nd mFIM). The time (days) between two time points of the mFIM assessment was expressed as follows: “time[1st-2nd]” = time between the 1st and 2nd mFIM assessments, “time[2nd-final]” = time between the 2nd and final mFIM assessments, and “time[1st-final]” = time between the 1st and final mFIM assessments. The FIM efficiency was also defined as a daily mFIM gain. The FIM efficiency (points/day) were defined as follows: (acute-mFIM efficiency) = {(2nd mFIM) – (1st mFIM)}/(time[1st-2nd]), (recovery-mFIM efficiency) = {(final mFIM) – (2nd mFIM)}/(time[2nd-final]), (acute+recovery-mFIM efficiency) = {(final mFIM) – (1st mFIM)}/(time[1st-final]). As described above, the cognitive condition of the patients was assessed using the MMSE. The MMSE, developed by Folstein et al. in 1975, has been widely used as a standard tool for screening cognitive impairment.¹¹⁾ It examines cognitive functions including orientation, registration, attention and

calculation, recall, language, and the ability to follow simple commands. MMSE scores range from 0 to 30 points, with lower scores indicating more severe cognitive problems. The MMSE has demonstrated good reliability and construct validity over time.¹²⁾ A cutoff value of 23/24 has been used to select patients with suspected cognitive impairment.^{12–14)} In the current study, MMSE scores were obtained at the beginning of recovery-phase rehabilitation approximately 2 weeks postoperatively. If a patient showed symptoms of delirium, such as the acute onset of cognitive disturbance or a circadian variation, the assessment of MMSE was delayed until multiple observers had confirmed the disappearance of symptoms. Trained physical therapists or occupational therapists evaluated the FIM and MMSE scores.

The demographic data and baseline characteristics of patients are summarized in **Table 1**. The median age was 86 (range, 65–97) years. Most of the subjects were women (95 women vs. 8 men). There were 50 medial fractures (i.e., cervical neck) and 53 lateral fractures (i.e., 50 trochanteric and 3 subtrochanteric). Osteosynthesis was performed in 63 patients, bipolar hemiarthroplasty in 31, and total hip arthroplasty in 9.

To elucidate the major factors affecting postoperative ADL after hip fracture, the final mFIM score was set as the outcome variable. Various explanatory variables were included in the data analysis, namely, age; sex; BMI; fracture type (cervical neck vs. trochanteric/subtrochanteric); surgical technique (osteosynthesis vs. bipolar hemiarthroplasty/total hip arthroplasty); ASA class (1/2 vs. 3/4); time between the fracture and operation; time between the fracture and the commencement of rehabilitation; the length of hospital stay; the levels of hemoglobin, serum albumin, total serum protein, serum hemoglobin A1c, and NT-proBNP; left ventricular ejection fraction; preinjury mFIM; and MMSE.

Statistical Analysis

First, single regression analysis was performed for each explanatory variable. Variables with a P-value of <0.100 in the F test for the regression coefficient then underwent multiple linear regression analysis. The variables identified in the multiple regression analysis were further analyzed to elucidate the conditions affecting the outcome. Receiver operating characteristic (ROC) curve analysis was used to calculate the cutoff value of the selected variable(s) for patients to achieve an mFIM score of ≥ 70 points at discharge. Additionally, the changes in mFIM during the hospital stay were assessed to evaluate the serial improvement of ADL with respect to the variable(s) identified by the multiple re-

Table 1. Demographic data and baseline patient characteristics

Variable	Median (range)
Age (years)	86 (65–97)
Sex (male/female)	95/8
Height (cm)	150 (133–170)
Body weight (kg)	45.3 (30.4–71)
BMI (kg/m ²)	20.3 (13.7–32.3)
Fracture type (medial/lateral) (n)	50/53
Surgical technique (osteosynthesis/BHA/THA) (n)	63/31/9
ASA class (1/2/3/4) (n)	3/85/15/0
Time between fracture and operation (days)	4 (1–26)
Time between fracture and beginning of rehabilitation (days)	5 (1–26)
Length of hospital stay (days)	46 (17–99)
Hemoglobin (g/dL)	11.4 (6.3–15.5)
Serum albumin (g/dL)	3.3 (2.1–4.4)
Serum total protein (g/dL)	6.6 (5–8.4)
Hemoglobin A1c (%)	5.9 (4.7–12.2)
NT-proBNP (pg/mL)	409.5 (29–3726)
Left ventricular ejection fraction (%)	75.8 (61.8–81.9)
mFIM before fracture	86 (70–91)

BHA, bipolar hemiarthroplasty; THA, total hip arthroplasty; ASA, American Society of Anesthesiologists; NT-proBNP, N-terminal pro-brain natriuretic peptide.

gression analysis, in which variables were selected with the stepwise method using the Bayesian information criterion. The mFIM and MMSE scores were analyzed as continuous variables, whereas, each item of the mFIM was analyzed as an ordinal variable in this study. Further, the ROC curve analysis calculated the area under the curve (AUC) and the 95% confidence interval (CI). The outcome variables in the two groups were compared using the Mann–Whitney *U* test for the continuous or ordinal variables and the chi-square test was used for the categorical variables. Statistical analyses were performed using the R program (version 3.4.3, <https://www.r-project.org/>) and EZR (version 1.37)¹⁵ on the R-commander package (version 2.4–0, <https://cran.r-project.org/web/packages/Rcmdr/index.html>). The statistical significance was set at $P < 0.05$.

RESULTS

Single regression analysis extracted seven parameters: MMSE ($P < 0.001$), preinjury mFIM ($P < 0.001$), age ($P < 0.001$), BMI ($P = 0.001$), serum albumin ($P = 0.047$), hemoglobin ($P = 0.077$), and fracture type ($P = 0.090$) (**Table 2**). These seven variables were subjected to multivariate analysis (**Table 3**); however, the following variables were excluded;

ASA class ($P = 0.160$), serum NT-proBNP ($P = 0.391$), serum total protein ($P = 0.511$), method of surgery ($P = 0.577$), left ventricular ejection fraction ($P = 0.578$), time between fracture and beginning of rehabilitation ($P = 0.741$), sex ($P = 0.743$), serum hemoglobin A1c ($P = 0.751$), and time between fracture and operation ($P = 0.872$). On multiple regression analysis, only two of the seven variables, namely MMSE ($P < 0.001$) and preinjury mFIM ($P = 0.012$), remained as factors significantly associated with the final mFIM (**Table 3**). The following multiple regression equation was established: (final mFIM) = $1.86 \times (\text{MMSE}) + 0.58 \times (\text{preinjury mFIM}) - 18.93$ (adjusted $R^2 = 0.503$). According to this equation, the MMSE score (range: 0–30 points, regression coefficient: 1.86) has a greater effect on the final mFIM than the preinjury mFIM (13–91 points, and 0.58, respectively).

ROC curve analysis was carried out to identify the cutoff value of MMSE for achieving an mFIM of ≥ 70 points at discharge (**Fig. 2**). The AUC was 0.91 (95% CI: 0.85–0.97), and the cutoff value for MMSE was 20/21 points, which yielded 89% sensitivity and 82% specificity. For reference, when the cutoff value of mFIM for acceptable ADL was set as ≥ 75 points, the cutoff value of MMSE was calculated as 23/24 (AUC: 0.93, 95% CI [0.89–0.98], sensitivity: 0.86, specificity: 0.87). Furthermore, if the cutoff value of the mFIM was

Table 2. Single regression analysis

Variable	Regression coefficient (95% CI)	Adjusted R^2	P
MMSE	2.11 (1.68, 2.55)	0.476	<0.001
Preinjury mFIM	1.34 (0.82, 1.86)	0.198	<0.001
Age (years)	-1.07 (-1.59, -0.56)	0.137	<0.001
BMI (kg/m ²)	0.69 (0.28, 1.11)	0.091	0.001
Serum albumin (g/dL)	8.84 (0.12, 17.56)	0.029	0.047
Hemoglobin (g/dL)	1.84 (-0.21, 3.88)	0.021	0.077
Fracture type (neck vs. trochanteric/subtrochanteric)	-6.44 (-13.91, 1.03)	0.019	0.090
ASA class (1/2 vs. 3/4)	-10.02 (-20.76, 0.34)	0.017	0.160
Length of hospital stay (days)	0.12 (-0.10, 0.35)	0.003	0.264
NT-proBNP (pg/mL)	0.00 (-0.01, 0.00)	-0.011	0.391
Serum total protein (g/dL)	2.00 (-4.02, 8.02)	-0.006	0.511
Surgical technique (osteosynthesis vs. BHA/THA)	-2.19 (-9.95, 5.57)	0.001	0.577
Left ventricular ejection fraction (%)	0.36 (-0.92, 1.63)	-0.011	0.578
Time between fracture and beginning of rehabilitation (days)	0.16 (-0.79, 1.1)	-0.009	0.741
Sex	-2.34 (-16.49, 11.8)	-0.009	0.743
Serum hemoglobin A1c (%)	-0.72 (-5.25, 3.8)	-0.014	0.751
Time between fracture and operation (days)	0.08 (-0.88, 1.04)	-0.010	0.872

Table 3. Multiple regression analysis

Variables before the BIC selection				Variables selected by BIC		
Variable	Regression coefficient (95% CI)	VIF	P	Variable	Regression coefficient (95% CI)	P
MMSE	1.71 (1.21, 2.21)	1.35	<0.001	MMSE	1.86 (1.40, 2.33)	<0.001
Preinjury mFIM	0.54 (0.03, 1.05)	1.43	0.039	Preinjury mFIM	0.58 (0.13, 1.03)	0.012
Age (years)	-0.27 (-0.73, 0.20)	1.36	0.263	Adjusted $R^2 = 0.503$		
BMI (kg/m ²)	0.30 (-0.49, 1.09)	1.17	0.453			
Serum albumin (g/dL)	-1.03 (-8.53, 6.47)	1.38	0.785			
Hemoglobin (g/dL)	-0.12 (-1.86, 1.63)	1.38	0.891			
Fracture type	-2.57 (-8.60, 3.46)	1.19	0.399			

BIC, Bayesian information criterion; VIF, variance inflation factor.

set as ≥ 80 points, the cutoff value of the MMSE was also calculated as 23/24 (AUC: 0.92, 95% CI [0.86–0.97], sensitivity: 0.90, and specificity: 0.83).

The relationship between MMSE and final mFIM is depicted in **Fig. 3A**. The single regression equation obtained was as follows: (final mFIM) = $2.11 \times (\text{MMSE}) + 24.67$ (adjusted $R^2 = 0.476$) (**Fig. 3A** and **Table 2**). When the patient group was divided into four subgroups according to cutoff values of 21 points for MMSE and 70 points for mFIM, the number of patients falling into each subgroup was 6 (MMSE ≤ 20 and final mFIM ≥ 70), 40 (MMSE ≤ 20 and final mFIM < 70), 9 (MMSE ≥ 21 and final mFIM < 70), and 48 (MMSE ≥ 21 and final mFIM ≥ 70). The chi-square test revealed a significant

difference between the groups ($P < 0.001$). Furthermore, we also focused on the relationship between the final mFIM and preinjury mFIM scores categorized by the MMSE score (≥ 21 or ≤ 20 ; **Fig. 3B**; **Table 2**). Analysis showed that the preinjury mFIM had a smaller effect on the final mFIM (adjusted $R^2 = 0.206$) than that of MMSE. The acute+recovery-mFIM efficiencies were calculated to analyze the effect on postoperative daily mFIM gain of MMSE and preinjury mFIM (**Fig. 3C** and **3D**, respectively). The MMSE had a stronger correlation with acute+recovery-mFIM efficiency (regression coefficient = 0.04, adjusted $R^2 = 0.152$) than the preinjury mFIM did (0.02, and 0.041, respectively). The relationship between the MMSE and time[1st-final] was evaluated to

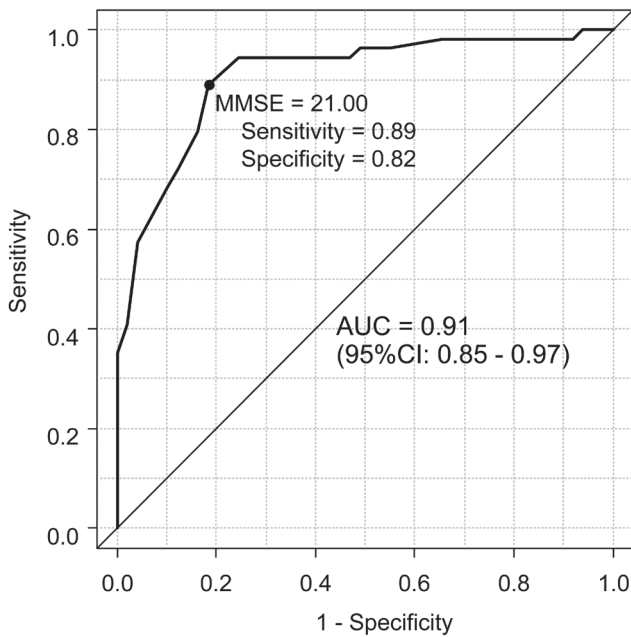


Fig. 2. Cutoff value of MMSE for ≥ 70 points of mFIM at discharge. Receiver operating characteristic curve to identify the cutoff value of MMSE for acquiring ≥ 70 points of mFIM at hospital discharge. The area under the curve and 95% confidence interval were calculated as the overall discriminative ability of MMSE.

determine whether cognitive impairment affected the length of hospital stay or the time of the final mFIM assessment (**Supplemental Fig. 1A**). Single regression analysis showed a weak correlation between MMSE and time[1st-final]; the regression coefficient was 0.31 (95% CI: $-0.22, 0.85$), and the adjusted R^2 was 0.004. Additionally, the relationship between the time[1st-final] and the final mFIM score is shown as a scatter plot (**Supplemental Fig. 1B**). There was a minimal correlation between the time[1st-final] and final mFIM score, as assessed by single regression analysis: the regression coefficient was 0.11 (95% CI: $-0.12, 0.33$), and the adjusted R^2 was -0.001 .

The relationships between the ADL improvement and cognitive impairment were assessed. Serial mFIM values were obtained at four time points, i.e., preinjury, perioperatively (1st mFIM), around 2 weeks postoperatively (2nd mFIM), and at discharge (final mFIM), and were compared with respect to the MMSE subgroups (**Fig. 4A and 4B; Table 4**).

At all time points except for 1st mFIM (assessed in the perioperative period), the mFIM scores were significantly different between the groups with MMSE scores of ≥ 21 and ≤ 20 (**Fig. 4A**). The details are as follows: preinjury mFIM

(median 82 [76–88 interquartile range] for MMSE ≤ 20 vs. 88 [84–90] for MMSE ≥ 21 , $P < 0.001$ using the Mann–Whitney U test), 1st mFIM (26 [19–38] for MMSE ≤ 20 vs. 31 [22–43] for MMSE ≥ 21 , $P = 0.096$), 2nd mFIM (43.5 [32–54] for MMSE ≤ 20 vs. 70 [57–78] for MMSE ≥ 21 , $P < 0.001$), and final mFIM (54 [44.5–63.75] for MMSE ≤ 20 vs. 85 [71–89] for MMSE ≥ 21 , $P < 0.001$) (**Table 4**, first column). The changes for each mFIM item are listed in **Table 4**. All items in the MMSE ≤ 20 group showed a significantly lower score than those in the MMSE ≥ 21 group at the 2nd mFIM and final mFIM assessment, except for the stairs item of the 2nd mFIM.

Additionally, the gain in FIM was assessed at different times based on the MMSE groups (≥ 21 or ≤ 20 , **Fig. 4B**). The overall-mFIM gain of the MMSE ≤ 20 group was significantly lower than that of the MMSE ≥ 21 group, indicating poor recovery of ADL. The largest difference between the two groups was observed for the acute-mFIM gain, and not for the initial loss-mFIM gain or recovery-mFIM gain. The details of the mFIM gains are as follows: overall-mFIM gain (median -26 [-36 to -16 interquartile range] for MMSE ≤ 20 group vs. -3 [-12 to 0] for MMSE ≥ 21 , $P < 0.001$ by Mann–Whitney U test), initial loss-mFIM gain (median -51 [-64 to -45] for MMSE ≤ 20 vs. -53 [-60 to -40] for MMSE ≥ 21 , $P = 0.808$), acute-mFIM gain (median 14 [2 to 22] for MMSE ≤ 20 vs. 31 [21 to 41] for MMSE ≥ 21 , $P < 0.001$), and recovery-mFIM gain (median 9 [4 to 17] for MMSE ≤ 20 vs. 12 [6 to 17] for MMSE ≥ 21 , $P = 0.213$). The scatter plots depicting the relationships between the MMSE and the phase-specific mFIM efficiencies are shown in **Fig. 4C and 4D**; MMSE had a positive effect on the acute-mFIM efficiency (regression coefficient = 0.11, adjusted $R^2 = 0.253$). In contrast, this MMSE-related positive effect disappeared and was slightly reversed for the recovery-mFIM efficiency (regression coefficient = -0.02 , adjusted $R^2 = 0.025$). The effect of the preinjury mFIM on the acute-mFIM and recovery-mFIM efficiencies are shown in **Supplemental Fig. 2A and 2B**, respectively. The effect of preinjury mFIM showed the same tendency as that of MMSE.

DISCUSSION

In this study, cognitive disturbance and preinjury ADL were highly associated with ADL at the end of the recovery phase of rehabilitation following surgical treatment for hip fracture. Multiple regression analysis established the following equation: (final mFIM) = $1.86 \times (\text{MMSE}) + 0.58 \times (\text{preinjury mFIM}) - 18.93$. To the best of our knowledge, no

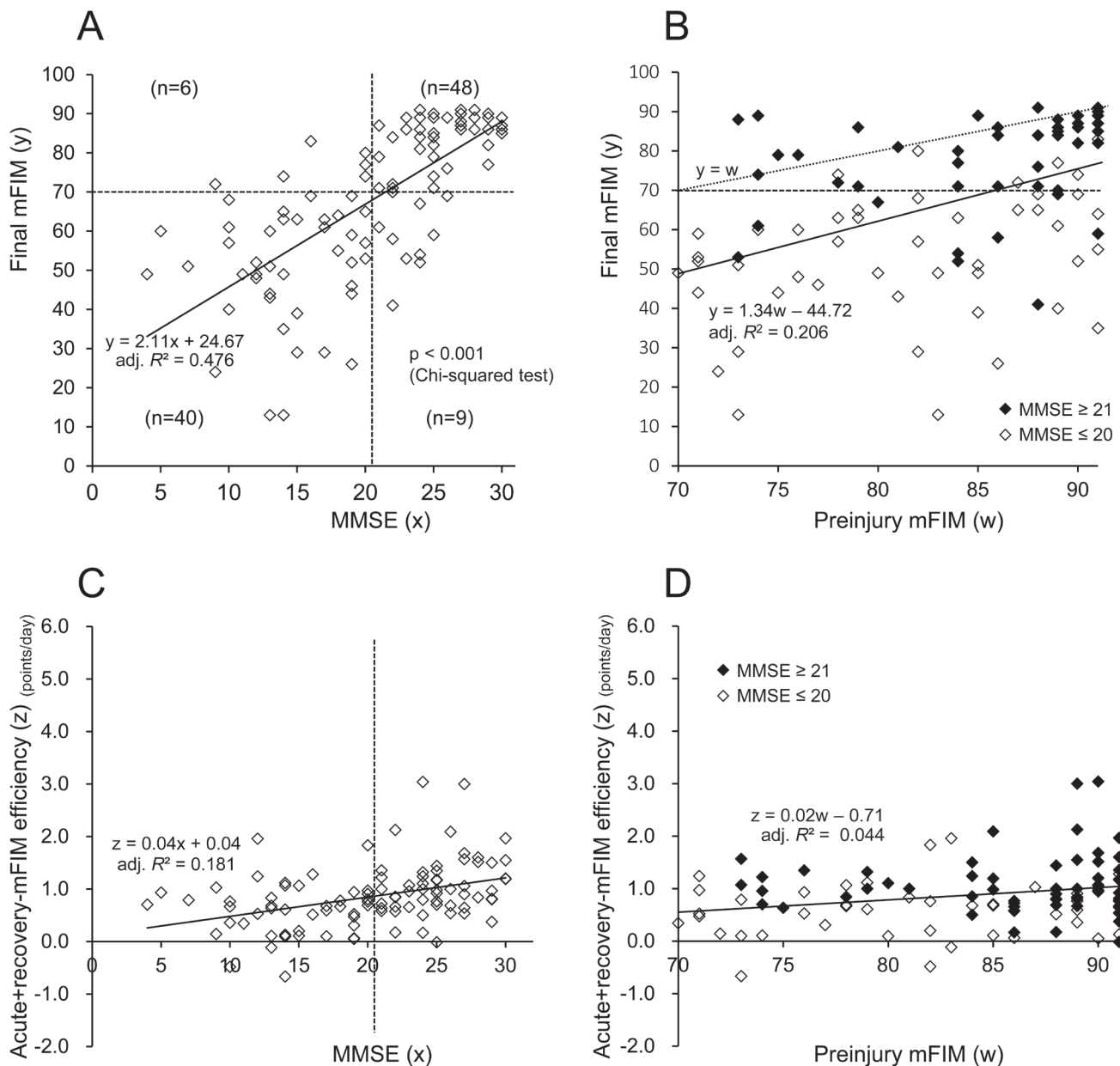


Fig. 3. The relationships between variables used in the single and multiple regression analyses. Broken lines indicate the cutoff point of final mFIM and MMSE values. The regression lines are depicted in each graph. (A) MMSE (= x) vs. final mFIM (= y); the regression equation was as follows: (Final mFIM) = $2.11 \times$ MMSE + 24.67. n = number of patients within the subgroup divided by these cutoff values. The chi-square test revealed a significant difference among these subgroups ($P < 0.001$). (B) Preinjury mFIM (= w) vs. final mFIM (= y). The dotted line “y = w” indicates that patients regained the preinjury ADL level at hospital discharge. Regression equation: (Final mFIM) = $1.34 \times$ (Preinjury mFIM) – 44.72. (C) MMSE (= x) vs. mFIM efficiency (acute + recovery phase) (= z). The mFIM efficiency was defined as follows: (acute+recovery-mFIM efficiency) = {(mFIM scores at the final mFIM assessment) – (mFIM scores at the time of initial rehabilitation in the perioperative period)} / (time between the two time points) (points/day). Regression equation: (acute+recovery-mFIM efficiency) = $0.04 \times$ MMSE + 0.04. The adjusted R^2 was 0.181. (D) Preinjury mFIM (= w) vs. mFIM efficiency (acute + recovery phase) (= z) (points/day). Regression equation: (acute+recovery-mFIM efficiency) = $0.02 \times$ (Preinjury mFIM) – 0.71. The adjusted R^2 was 0.044.

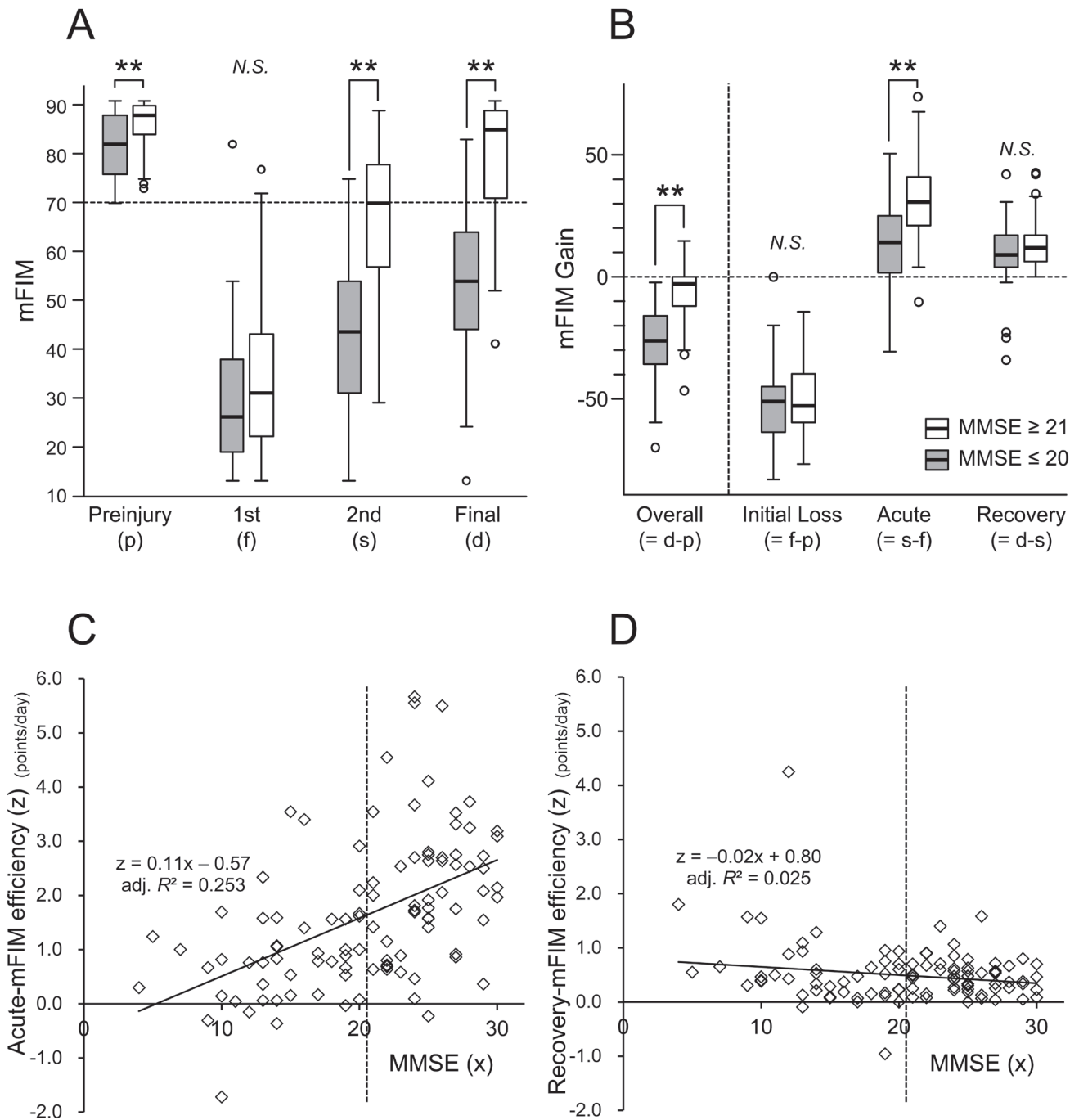


Fig. 4. Serial mFIM changes according to MMSE levels. (A, B) Patients were divided by MMSE scores (≥ 21 or ≤ 20). (A) mFIM scores were assessed at different periods: preinjury (= p, before the fracture), 1st (= f, at the time of initial rehabilitation in the perioperative period), 2nd (= s, at the start of recovery-phase rehabilitation 2–3 weeks postoperatively), and final (= d, at the time of hospital discharge). (B) mFIM gain scores were calculated by subtracting the serial mFIM scores as indicated: overall = d – p, initial loss = f – p, acute = s – f, recovery = d – s. (C, D) Shown are the scatter plots of mFIM efficiency (z) vs. MMSE (x). (C) The mFIM efficiency (acute phase) was defined as follows: (acute-mFIM efficiency) = (mFIM gain scores between f and s) / (time between f and s) (points/day). (D) The mFIM efficiency (recovery phase) is shown: (recovery-mFIM efficiency) = (mFIM gain scores between s and d) / (time between s and d) (points/day). * $P < 0.05$, ** $P < 0.01$, and N.S. = not significant, by Mann–Whitney U test.

Table 4. Serial changes in the mFIM for each item

mFIM total score	Preinjury mFIM				1st mFIM				2nd mFIM				Final mFIM							
	Overall	MMSE \geq 20	MMSE \geq 21	P	Overall	MMSE \geq 20	MMSE \geq 21	P	Score	Overall	MMSE \geq 20	MMSE \geq 21	P	Score	Overall	MMSE \geq 20	MMSE \geq 21	P		
Median	86	82	88	<0.001	29	26	31	0.096	56	43.5	70	85	<0.001	71	54	85	<0.001			
[1st, 3rd quartile]	[79, 89.5]	[76, 88]	[84, 90]		[21, 41.75]	[19, 38]	[22, 43]		[43.5, 71.5]	[32, 54]	[57, 78]	[44.5, 63.75]		[53.5, 86]	[71, 89]					
Each mFIM item	Score	Overall	MMSE \geq 20	MMSE \geq 21	P	Score	Overall	MMSE \geq 20	MMSE \geq 21	P	Score	Overall	MMSE \geq 20	MMSE \geq 21	P	Score	Overall	MMSE \geq 20	MMSE \geq 21	P
n (%)	103	46	57		102	45	57		103	46	57		103	46	57					
Self-care: eating	7	91 (88.3)	37 (80.4)	54 (94.7)	0.032	7	48 (47.1)	16 (35.6)	32 (56.1)	0.024	7	71 (68.9)	22 (47.8)	49 (86.0)	<0.001	7	79 (76.7)	25 (54.3)	54 (94.7)	<0.001
	6	8 (7.8)	7 (15.2)	1 (1.8)		6	17 (16.7)	8 (17.8)	9 (15.8)		6	12 (11.7)	5 (10.9)	7 (12.3)		6	7 (6.8)	5 (10.9)	2 (3.5)	
	5	3 (2.9)	2 (4.3)	1 (1.8)		5	19 (18.6)	9 (20.0)	10 (17.5)		5	13 (12.6)	12 (26.1)	1 (1.8)		5	13 (12.6)	12 (26.1)	1 (1.8)	
	4	1 (1.0)	0 (0.0)	1 (1.8)		4	9 (8.8)	7 (15.6)	2 (3.5)		4	6 (5.8)	6 (13.0)	0 (0.0)		4	1 (1.0)	1 (2.2)	0 (0.0)	
	3	0 (0.0)	0 (0.0)	0 (0.0)		3	2 (2.0)	2 (4.4)	0 (0.0)		3	0 (0.0)	0 (0.0)	0 (0.0)		3	1 (1.0)	1 (2.2)	0 (0.0)	
	2	0 (0.0)	0 (0.0)	0 (0.0)		2	0 (0.0)	0 (0.0)	0 (0.0)		2	0 (0.0)	0 (0.0)	0 (0.0)		2	0 (0.0)	0 (0.0)	0 (0.0)	
	1	0 (0.0)	0 (0.0)	0 (0.0)		1	7 (6.9)	3 (6.7)	4 (7.0)		1	1 (1.0)	1 (2.2)	0 (0.0)		1	2 (1.9)	2 (4.3)	0 (0.0)	
Self-care: grooming	7	82 (79.6)	32 (69.6)	50 (87.7)	0.025	7	6 (5.9)	1 (2.2)	5 (8.8)	0.067	7	24 (23.3)	1 (2.2)	23 (40.4)	<0.001	7	42 (40.8)	4 (8.7)	38 (66.7)	<0.001
	6	10 (9.7)	6 (13.0)	4 (7.0)		6	5 (4.9)	1 (2.2)	4 (7.0)		6	7 (6.8)	0 (0.0)	7 (12.3)		6	5 (4.9)	3 (6.5)	2 (3.5)	
	5	8 (7.8)	7 (15.2)	1 (1.8)		5	6 (5.9)	4 (8.9)	2 (3.5)		5	29 (28.2)	16 (34.8)	13 (22.8)		5	25 (24.3)	16 (34.8)	9 (15.8)	
	4	3 (2.9)	1 (2.2)	2 (3.5)		4	20 (19.6)	7 (15.6)	13 (22.8)		4	22 (21.4)	12 (26.1)	10 (17.5)		4	13 (12.6)	7 (15.2)	6 (10.5)	
	3	0 (0.0)	0 (0.0)	0 (0.0)		3	8 (7.8)	3 (6.7)	5 (8.8)		3	10 (9.7)	6 (13.0)	4 (7.0)		3	7 (6.8)	5 (10.9)	2 (3.5)	
	2	0 (0.0)	0 (0.0)	0 (0.0)		2	25 (24.5)	11 (24.4)	14 (24.6)		2	6 (5.8)	6 (13.0)	0 (0.0)		2	7 (6.8)	7 (15.2)	0 (0.0)	
	1	0 (0.0)	0 (0.0)	0 (0.0)		1	32 (31.4)	18 (40.0)	14 (24.6)		1	5 (4.9)	5 (10.9)	0 (0.0)		1	4 (3.9)	4 (8.7)	0 (0.0)	
Self-care: bathing	7	73 (70.9)	25 (54.3)	48 (84.2)	0.002	7	3 (2.9)	1 (2.2)	2 (3.5)	0.035	7	13 (12.6)	0 (0.0)	13 (22.8)	<0.001	7	35 (34.0)	1 (2.2)	34 (59.6)	<0.001
	6	13 (12.6)	9 (19.6)	4 (7.0)		6	3 (2.9)	0 (0.0)	3 (5.3)		6	9 (8.7)	0 (0.0)	9 (15.8)		6	6 (5.8)	3 (6.5)	3 (5.3)	
	5	4 (3.9)	4 (8.7)	0 (0.0)		5	2 (2.0)	1 (2.2)	1 (1.8)		5	7 (6.8)	1 (2.2)	6 (10.5)		5	7 (6.8)	4 (8.7)	3 (5.3)	
	4	9 (8.7)	6 (13.0)	3 (5.3)		4	9 (8.8)	4 (8.9)	5 (8.8)		4	19 (18.4)	9 (19.6)	10 (17.5)		4	19 (18.4)	9 (19.6)	10 (17.5)	
	3	4 (3.9)	2 (4.3)	2 (3.5)		3	15 (14.7)	3 (6.7)	12 (21.1)		3	27 (26.2)	14 (30.4)	13 (22.8)		3	14 (13.6)	11 (23.9)	3 (5.3)	
	2	0 (0.0)	0 (0.0)	0 (0.0)		2	22 (21.6)	10 (22.2)	12 (21.1)		2	14 (13.6)	12 (26.1)	2 (3.5)		2	14 (13.6)	11 (23.9)	3 (5.3)	
	1	0 (0.0)	0 (0.0)	0 (0.0)		1	48 (47.1)	26 (57.8)	22 (38.6)		1	14 (13.6)	10 (21.7)	4 (7.0)		1	8 (7.8)	7 (15.2)	1 (1.8)	
Self-care: dressing – upper body	7	83 (80.6)	31 (67.4)	52 (91.2)	0.004	7	11 (10.8)	1 (2.2)	10 (17.5)	0.017	7	34 (33.0)	2 (4.3)	32 (56.1)	<0.001	7	50 (48.5)	6 (13.0)	44 (77.2)	<0.001
	6	16 (15.5)	13 (28.3)	3 (5.3)		6	3 (2.9)	0 (0.0)	3 (5.3)		6	6 (5.8)	0 (0.0)	6 (10.5)		6	5 (4.9)	4 (8.7)	1 (1.8)	
	5	3 (2.9)	2 (4.3)	1 (1.8)		5	3 (2.9)	2 (4.4)	1 (1.8)		5	12 (11.7)	8 (17.4)	4 (7.0)		5	20 (19.4)	14 (30.4)	6 (10.5)	
	4	1 (1.0)	0 (0.0)	1 (1.8)		4	12 (11.8)	6 (13.3)	6 (10.5)		4	17 (16.5)	11 (23.9)	6 (10.5)		4	11 (10.7)	9 (19.6)	2 (3.5)	
	3	0 (0.0)	0 (0.0)	0 (0.0)		3	20 (19.6)	9 (20.0)	11 (19.3)		3	15 (14.6)	10 (21.7)	5 (8.8)		3	8 (7.8)	4 (8.7)	4 (7.0)	
	2	0 (0.0)	0 (0.0)	0 (0.0)		2	9 (8.8)	2 (4.4)	7 (12.3)		2	7 (6.8)	4 (8.7)	3 (5.3)		2	3 (2.9)	3 (6.5)	0 (0.0)	
	1	0 (0.0)	0 (0.0)	0 (0.0)		1	44 (43.1)	25 (55.6)	19 (33.3)		1	12 (11.7)	11 (23.9)	1 (1.8)		1	6 (5.8)	6 (13.0)	0 (0.0)	
Self-care: dressing – lower body	7	81 (78.6)	31 (67.4)	50 (87.7)	0.026	7	3 (2.9)	1 (2.2)	2 (3.5)	0.161	7	13 (12.6)	0 (0.0)	13 (22.8)	<0.001	7	34 (33.0)	0 (0.0)	34 (59.6)	<0.001
	6	16 (15.5)	13 (28.3)	3 (5.3)		6	0 (0.0)	0 (0.0)	0 (0.0)		6	14 (13.6)	0 (0.0)	14 (24.6)		6	12 (11.7)	3 (6.5)	9 (15.8)	
	5	3 (2.9)	2 (4.3)	1 (1.8)		5	1 (1.0)	0 (0.0)	1 (1.8)		5	2 (1.9)	2 (4.3)	0 (0.0)		5	15 (14.6)	12 (26.1)	3 (5.3)	
	4	3 (2.9)	0 (0.0)	3 (5.3)		4	5 (4.9)	3 (6.7)	2 (3.5)		4	7 (6.8)	2 (4.3)	5 (8.8)		4	9 (8.7)	5 (10.9)	4 (7.0)	
	3	0 (0.0)	0 (0.0)	0 (0.0)		3	9 (8.8)	3 (6.7)	6 (10.5)		3	21 (20.4)	9 (19.6)	12 (21.1)		3	11 (10.7)	7 (15.2)	4 (7.0)	
	2	0 (0.0)	0 (0.0)	0 (0.0)		2	25 (24.5)	8 (17.8)	17 (29.8)		2	23 (22.3)	18 (39.1)	5 (8.8)		2	14 (13.6)	12 (26.1)	2 (3.5)	
	1	0 (0.0)	0 (0.0)	0 (0.0)		1	59 (57.8)	30 (66.7)	29 (50.9)		1	23 (22.3)	15 (32.6)	8 (14.0)		1	8 (7.8)	7 (15.2)	1 (1.8)	

Table 4. (Continued)

mFIM total score	Preinjury mFIM				1st mFIM				2nd mFIM				Final mFIM							
	Overall	MMSE \leq 20	MMSE \geq 21	P	Score	Overall	MMSE \leq 20	MMSE \geq 21	P	Score	Overall	MMSE \leq 20	MMSE \geq 21	P	Score	Overall	MMSE \leq 20	MMSE \geq 21	P	
Median	86	82	88	<0.001	29	26	31	0.096	56	43.5	70	54	85	<0.001	71	54	85	<0.001		
[1st, 3rd quartile]	[79, 89.5]	[76, 88]	[84, 90]		[21, 41.75]	[19, 38]	[22, 43]		[43.5, 71.5]	[32, 54]	[57, 78]	[44.5, 63.75]	[71, 89]		[53.5, 86]	[44.5, 63.75]	[71, 89]			
Each mFIM item	Score	Overall	MMSE \leq 20	MMSE \geq 21	P	Score	Overall	MMSE \leq 20	MMSE \geq 21	P	Score	Overall	MMSE \leq 20	MMSE \geq 21	P	Score	Overall	MMSE \leq 20	MMSE \geq 21	P
Self-care:	7	76 (73.8)	30 (65.2)	46 (80.7)	0.052	7	2 (2.0)	1 (2.2)	1 (1.8)	0.863	7	19 (18.4)	1 (2.2)	18 (31.6)	<0.001	7	38 (36.9)	3 (6.5)	35 (61.4)	<0.001
toileting	6	23 (22.3)	12 (26.1)	11 (19.3)		6	7 (6.9)	1 (2.2)	6 (10.5)		6	20 (19.4)	2 (4.3)	18 (31.6)		6	19 (18.4)	7 (15.2)	12 (21.1)	
	5	3 (2.9)	3 (6.5)	0 (0.0)		5	7 (6.9)	2 (4.4)	5 (8.8)		5	20 (19.4)	12 (26.1)	8 (14.0)		5	22 (21.4)	15 (32.6)	7 (12.3)	
	4	1 (1.0)	1 (2.2)	0 (0.0)		4	9 (8.8)	6 (13.3)	3 (5.3)		4	12 (11.7)	7 (15.2)	5 (8.8)		4	12 (11.7)	9 (19.6)	3 (5.3)	
	3	0 (0.0)	0 (0.0)	0 (0.0)		3	6 (5.9)	5 (11.1)	1 (1.8)		3	14 (13.6)	10 (21.7)	4 (7.0)		3	4 (3.9)	4 (8.7)	0 (0.0)	
	2	0 (0.0)	0 (0.0)	0 (0.0)		2	9 (8.8)	3 (6.7)	6 (10.5)		2	10 (9.7)	7 (15.2)	3 (5.3)		2	5 (4.9)	5 (10.9)	0 (0.0)	
	1	0 (0.0)	0 (0.0)	0 (0.0)		1	62 (60.8)	27 (60.0)	35 (61.4)		1	8 (7.8)	7 (15.2)	1 (1.8)		1	3 (2.9)	3 (6.5)	0 (0.0)	
Sphincter control:	7	92 (89.3)	38 (82.6)	54 (94.7)	0.050	7	24 (23.5)	6 (13.3)	18 (31.6)	0.064	7	51 (49.5)	8 (17.4)	43 (75.4)	<0.001	7	64 (62.1)	15 (32.6)	49 (86.0)	<0.001
bladder management	6	8 (7.8)	6 (13.0)	2 (3.5)		6	2 (2.0)	1 (2.2)	1 (1.8)		6	7 (6.8)	2 (4.3)	5 (8.8)		6	10 (9.7)	4 (8.7)	6 (10.5)	
	5	2 (1.9)	1 (2.2)	1 (1.8)		5	6 (5.9)	3 (6.7)	3 (5.3)		5	15 (14.6)	11 (23.9)	4 (7.0)		5	9 (8.7)	8 (17.4)	1 (1.8)	
	4	1 (1.0)	1 (2.2)	0 (0.0)		4	5 (4.9)	1 (2.2)	4 (7.0)		4	7 (6.8)	4 (8.7)	3 (5.3)		4	4 (3.9)	4 (8.7)	0 (0.0)	
	3	0 (0.0)	0 (0.0)	0 (0.0)		3	5 (4.9)	2 (4.4)	3 (5.3)		3	6 (5.8)	5 (10.9)	1 (1.8)		3	6 (5.8)	5 (10.9)	1 (1.8)	
	2	0 (0.0)	0 (0.0)	0 (0.0)		2	8 (7.8)	6 (13.3)	2 (3.5)		2	7 (6.8)	7 (15.2)	0 (0.0)		2	5 (4.9)	5 (10.9)	0 (0.0)	
	1	0 (0.0)	0 (0.0)	0 (0.0)		1	52 (51.0)	26 (57.8)	26 (45.6)		1	10 (9.7)	9 (19.6)	1 (1.8)		1	5 (4.9)	5 (10.9)	0 (0.0)	
Spincter control:	7	94 (91.3)	39 (84.8)	55 (96.5)	0.037	7	28 (27.5)	8 (17.8)	20 (35.1)	0.108	7	52 (50.5)	8 (17.4)	44 (77.2)	<0.001	7	62 (60.2)	14 (30.4)	48 (84.2)	<0.001
bowel management	6	8 (7.8)	6 (13.0)	2 (3.5)		6	2 (2.0)	1 (2.2)	1 (1.8)		6	9 (8.7)	3 (6.5)	6 (10.5)		6	12 (11.7)	5 (10.9)	7 (12.3)	
	5	1 (1.0)	1 (2.2)	0 (0.0)		5	6 (5.9)	5 (11.1)	1 (1.8)		5	17 (16.5)	13 (28.3)	4 (7.0)		5	10 (9.7)	9 (19.6)	1 (1.8)	
	4	0 (0.0)	0 (0.0)	0 (0.0)		4	9 (8.8)	2 (4.4)	7 (12.3)		4	4 (3.9)	3 (6.5)	1 (1.8)		4	4 (3.9)	4 (8.7)	0 (0.0)	
	3	0 (0.0)	0 (0.0)	0 (0.0)		3	6 (5.9)	3 (6.7)	3 (5.3)		3	7 (6.8)	6 (13.0)	1 (1.8)		3	6 (5.8)	5 (10.9)	1 (1.8)	
	2	0 (0.0)	0 (0.0)	0 (0.0)		2	8 (7.8)	4 (8.9)	4 (7.0)		2	5 (4.9)	5 (10.9)	0 (0.0)		2	4 (3.9)	4 (8.7)	0 (0.0)	
	1	0 (0.0)	0 (0.0)	0 (0.0)		1	43 (42.2)	22 (48.9)	21 (36.8)		1	9 (8.7)	8 (17.4)	1 (1.8)		1	5 (4.9)	5 (10.9)	0 (0.0)	
Transfer:	7	64 (62.1)	24 (52.2)	40 (70.2)	0.047	7	0 (0.0)	0 (0.0)	0 (0.0)	0.825	7	7 (6.8)	0 (0.0)	7 (12.3)	<0.001	7	24 (23.3)	1 (2.2)	23 (40.4)	<0.001
bed, chair, wheelchair	6	37 (35.9)	20 (43.5)	17 (29.8)		6	6 (5.9)	1 (2.2)	5 (8.8)		6	28 (27.2)	5 (10.9)	23 (40.4)		6	32 (31.1)	9 (19.6)	23 (40.4)	
	5	2 (1.9)	2 (4.3)	0 (0.0)		5	9 (8.8)	2 (4.4)	7 (12.3)		5	34 (33.0)	17 (37.0)	17 (29.8)		5	34 (33.0)	24 (52.2)	10 (17.5)	
	4	0 (0.0)	0 (0.0)	0 (0.0)		4	25 (24.5)	16 (35.6)	9 (15.8)		4	24 (23.3)	17 (37.0)	7 (12.3)		4	9 (8.7)	8 (17.4)	1 (1.8)	
	3	0 (0.0)	0 (0.0)	0 (0.0)		3	12 (11.8)	5 (11.1)	7 (12.3)		3	5 (4.9)	2 (4.3)	3 (5.3)		3	0 (0.0)	0 (0.0)	0 (0.0)	
	2	0 (0.0)	0 (0.0)	0 (0.0)		2	5 (4.9)	4 (8.9)	1 (1.8)		2	2 (1.9)	2 (4.3)	0 (0.0)		2	2 (1.9)	2 (4.3)	0 (0.0)	
	1	0 (0.0)	0 (0.0)	0 (0.0)		1	45 (44.1)	17 (37.8)	28 (49.1)		1	3 (2.9)	3 (6.5)	0 (0.0)		1	2 (1.9)	2 (4.3)	0 (0.0)	
Transfer:	7	62 (60.2)	24 (52.2)	38 (66.7)	0.091	7	0 (0.0)	0 (0.0)	0 (0.0)	0.836	7	7 (6.8)	0 (0.0)	7 (12.3)	<0.001	7	21 (20.4)	0 (0.0)	21 (36.8)	<0.001
toilet	6	38 (36.9)	19 (41.3)	19 (33.3)		6	7 (6.9)	1 (2.2)	6 (10.5)		6	30 (29.1)	5 (10.9)	25 (43.9)		6	35 (34.0)	9 (19.6)	26 (45.6)	
	5	2 (1.9)	2 (4.3)	0 (0.0)		5	10 (9.8)	2 (4.4)	8 (14.0)		5	32 (31.1)	18 (39.1)	14 (24.6)		5	32 (31.1)	23 (50.0)	9 (15.8)	
	4	1 (1.0)	1 (2.2)	0 (0.0)		4	23 (22.5)	16 (35.6)	7 (12.3)		4	21 (20.4)	13 (28.3)	8 (14.0)		4	10 (9.7)	9 (19.6)	1 (1.8)	
	3	0 (0.0)	0 (0.0)	0 (0.0)		3	6 (5.9)	4 (8.9)	2 (3.5)		3	7 (6.8)	4 (8.7)	3 (5.3)		3	1 (1.0)	1 (2.2)	0 (0.0)	
	2	0 (0.0)	0 (0.0)	0 (0.0)		2	1 (1.0)	1 (2.2)	0 (0.0)		2	1 (1.0)	1 (2.2)	0 (0.0)		2	2 (1.9)	2 (4.3)	0 (0.0)	
	1	0 (0.0)	0 (0.0)	0 (0.0)		1	55 (53.9)	21 (46.7)	34 (59.6)		1	5 (4.9)	5 (10.9)	0 (0.0)		1	2 (1.9)	2 (4.3)	0 (0.0)	

Table 4. (Continued)

mFIM total score	Preinjury mFIM			1st mFIM			2nd mFIM			Final mFIM				
	Overall	MMSE≤20	MMSE≥21	Overall	MMSE≤20	MMSE≥21	Overall	MMSE≤20	MMSE≥21	Overall	MMSE≤20	MMSE≥21	P	
Median	86	82	88	29	26	31	56	43.5	70	71	54	85	<0.001	
[1st, 3rd quartile]	[79, 89.5]	[76, 88]	[84, 90]	[21, 41.75]	[19, 38]	[22, 43]	[43.5, 71.5]	[32, 54]	[57, 78]	[53.5, 86]	[44.5, 63.75]	[71, 89]		
Each mFIM item	Score	MMSE≤20	MMSE≥21	P	Score	MMSE≤20	MMSE≥21	P	Score	MMSE≤20	MMSE≥21	P	Score	
Transfer:	7	43 (41.7)	14 (30.4)	29 (50.9)	0.012	7	0 (0.0)	0 (0.0)	0.791	7	4 (3.9)	0 (0.0)	4 (7.0)	<0.001
tub, shower	6	39 (37.9)	18 (39.1)	21 (36.8)		6	1 (1.0)	1 (2.2)		6	16 (15.5)	0 (0.0)	16 (28.1)	
	5	12 (11.7)	8 (17.4)	4 (7.0)		5	3 (2.9)	0 (0.0)		5	23 (22.3)	9 (19.6)	14 (24.6)	
	4	8 (7.8)	5 (10.9)	3 (5.3)		4	2 (2.0)	2 (4.4)		4	22 (21.4)	16 (34.8)	6 (10.5)	
	3	1 (1.0)	1 (2.2)	0 (0.0)		3	0 (0.0)	0 (0.0)		3	9 (8.7)	4 (8.7)	5 (8.8)	
	2	0 (0.0)	0 (0.0)	0 (0.0)		2	0 (0.0)	0 (0.0)		2	2 (1.9)	1 (2.2)	1 (1.8)	
	1	0 (0.0)	0 (0.0)	0 (0.0)		1	96 (94.1)	42 (93.3)		1	27 (26.2)	16 (34.8)	11 (19.3)	
Locomotion:	7	38 (36.9)	16 (34.8)	22 (38.6)	0.357	7	1 (1.0)	1 (2.2)	0.097	7	1 (1.0)	0 (0.0)	1 (1.8)	<0.001
walk, wheelchair	6	61 (59.2)	26 (56.5)	35 (61.4)		6	2 (2.0)	0 (0.0)		6	29 (28.2)	2 (4.3)	27 (47.4)	
	5	4 (3.9)	4 (8.7)	0 (0.0)		5	6 (5.9)	1 (2.2)		5	24 (23.3)	12 (26.1)	12 (21.1)	
	4	0 (0.0)	0 (0.0)	0 (0.0)		4	8 (7.8)	4 (8.9)		4	7 (6.8)	6 (13.0)	1 (1.8)	
	3	0 (0.0)	0 (0.0)	0 (0.0)		3	4 (3.9)	0 (0.0)		3	0 (0.0)	0 (0.0)	0 (0.0)	
	2	0 (0.0)	0 (0.0)	0 (0.0)		2	8 (7.8)	3 (6.7)		2	3 (2.9)	2 (4.3)	1 (1.8)	
	1	0 (0.0)	0 (0.0)	0 (0.0)		1	73 (71.6)	36 (80.0)		1	39 (37.9)	24 (52.2)	15 (26.3)	
Locomotion:	7	18 (17.5)	5 (10.9)	13 (22.8)	0.003	7	0 (0.0)	0 (0.0)	1.000	7	1 (1.0)	1 (2.2)	0 (0.0)	0.277
stairs	6	47 (45.6)	17 (37.0)	30 (52.6)		6	0 (0.0)	0 (0.0)		6	3 (2.9)	0 (0.0)	3 (5.2)	
	5	4 (3.9)	2 (4.3)	2 (3.5)		5	0 (0.0)	0 (0.0)		5	1 (1.0)	0 (0.0)	1 (1.8)	
	4	2 (1.9)	1 (2.2)	1 (1.8)		4	0 (0.0)	0 (0.0)		4	0 (0.0)	0 (0.0)	0 (0.0)	
	3	0 (0.0)	0 (0.0)	0 (0.0)		3	0 (0.0)	0 (0.0)		3	0 (0.0)	0 (0.0)	0 (0.0)	
	2	0 (0.0)	0 (0.0)	0 (0.0)		2	0 (0.0)	0 (0.0)		2	0 (0.0)	0 (0.0)	0 (0.0)	
	1	32 (31.1)	21 (45.7)	11 (19.3)		1	102 (100.0)	45 (100.0)		1	98 (95.1)	45 (97.8)	53 (93.0)	

The median scores are shaded. The P-value was calculated by using the Mann-Whitney U test to compare the two MMSE groups (≥21 and ≤20).

previous research has shown an equation predicting the ADL following hip fracture treatment. Interestingly, this equation excludes orthopedic-specific factors, such as fracture type, surgical technique, and the time between injury and operation. A certain level of surgical treatment may be enough for the reacquisition of basic ADL; however, orthopedic factors can affect higher activity levels; the likelihood of painless long-term living; or the prevalence of complications such as avascular necrosis of the femoral head, pseudoarthrosis, and muscle strength. The equation shows that the MMSE, ranging from 0 to 30 points, has a greater impact on ADL than does the preinjury mFIM, ranging from 13 to 91. In other words, in hip fracture, cognitive function is the principal factor related to the level of ADL achieved after recovery-phase rehabilitation.

Several research groups have investigated the association between cognitive disturbance and ADL decline in patients with hip fractures.^{16–25} Most reports have described a negative effect of cognitive impairment on ADL outcomes in patients with hip fracture. However, some reports showed good outcomes after hip fracture even in cognitively impaired individuals compared with cognitively normal individuals. Consequently, this point seems to be controversial. In their systematic review, Muir et al. reported no definitive conclusion on the relationship between dementia and ADL following hip fracture. The reason for this was likely the heterogeneity of methodologies, such as patient demographics, rehabilitation setting, and varying thresholds for determining cognitive impairment.²¹ Muir et al. mentioned that intensive multidisciplinary inpatient rehabilitation could allow even cognitively impaired individuals to achieve good physical function after hip fracture surgery.²¹ The subjects of the current study all received a serial operation-to-acute/subacute-phase rehabilitation program at a single specialized orthopedic institution. This program enabled patients to receive intensive treatment and consistent assessment. Nevertheless, in this study, cognitively impaired patients with hip fracture showed a net loss of ADL after surgery and rehabilitation.

A 20/21 cutoff value was optimal for screening for patients having an mFIM score of ≥ 70 at discharge. Patients with a score of ≤ 20 points on the MMSE acquired a lower level of ADL at discharge than those with an MMSE score of ≥ 21 . Interestingly, the 20/21 cutoff MMSE value was close to the ordinal 23/24 cutoff value for dementia screening.¹⁴ In general, a score of 20/21 points on the MMSE is categorized as mild to moderate dementia.²⁶ To obtain better ADL, a higher MMSE score is needed. For example, when the cutoff

value of the mFIM indicating ADL independence was set at ≥ 80 , the cutoff value of the MMSE was 23/24 points in this study. An MMSE score of 20–24 points appears to be the critical range for regaining ADL after hip fracture treatment.

A significantly lower ADL in cognitively impaired patients was observed from ~ 2 weeks postoperatively, although cognitively impaired patients with preinjury mFIM scores of ≥ 70 had a physical potential comparable to that of cognitively intact patients until the acute to subacute phase after the hip fracture. Cognitively impaired patients showed a significantly lower gain on each item of mFIM at the final mFIM assessment. However, some mFIM items showed an interesting tendency: in cognitively impaired patients, the scores for tub transfer and walking/wheelchair items had a bimodal distribution. This bimodal distribution indicates the existence of two subgroups in cognitively impaired patients: one group could accomplish the above transfer/locomotive tasks comparably with cognitively intact patients and the other could not. Assuming that the physical potential in cognitively impaired patients was similar to that of cognitively intact patients for executing ADL items at approximately the subacute to recovery phase, the subgroup of cognitively impaired patients with the low ADL item scores might have particular issues in cognitive function, such as “understanding the needs for the ADL task” or “having internal motivation for executing the task.” Medical staff can address these issues by paying special attention to cognitively impaired patients. For example, strict pain control, appropriate nutritional support, a more accepting attitude for performing the task, or setting an attractive goal for the task execution may increase the gain in ADL in the low-scoring subgroup of cognitively impaired patients. Additional assessment of “understanding of a task” and “internal motivation” is needed to confirm this approach. We speculate that the relative decline in ADL among cognitively impaired patients is reversible during the acute or subacute phase; however, if the decline is prolonged, it will likely become irreversible because of new problems, such as muscle weakness or joint contracture. In patients with cognitive disturbance, the acute phase is more critical for regaining ADL than the recovery or later phases. However, patients with cognitive impairment still benefit from regaining ADL by continuing rehabilitation even after the acute phase because they have positive mFIM gain and mFIM efficiency in the recovery phase (**Fig. 4B and 4D**).

Benedetti et al. reported serial cognitive changes after hip fracture.²⁵ They found a slight decline in the cognitive condition from baseline to 1 year after the fracture. However, the changes in cognitive status were minimal, especially

over 1–6 months. Therefore, the equation we obtained in this study, i.e., $(\text{final mFIM}) = 1.86 \times (\text{MMSE}) + 0.58 \times (\text{preinjury mFIM}) - 18.93$, can provide a valuable indicator for undertaking countermeasures in cases of cognitively impaired people. For example, patients with hip fracture and cognitive impairment should be treated meticulously according to the degree of cognitive dysfunction, which may be evident before the operation or rehabilitation. In terms of countermeasures before hip fracture, fall/fracture prevention is essential in people with cognitive impairment because they are more susceptible to decreased ADL after hip fracture treatment, even if they are independent before the injury. Additionally, Muir et al. reported that in community- and institution-dwelling older adults, cognitive impairment is associated with an increased risk of falls.²⁷⁾ The US Preventive Services Task Force concluded that exercise is associated with a reduction in the number of individuals experiencing falls and a smaller number of injurious falls in older adults at average and high risk.²⁸⁾ Conversely, physical inactivity is a proven risk factor for dementia.²⁹⁾ Fractures resulting in a decline in ADL and cognitive impairment/dementia seem to be related. Therefore, countermeasures such as treatment of osteoporosis and physical exercise should be particularly beneficial for the cognitively impaired.

This study has several limitations. First, the follow-up period was short. It is possible that patients with cognitive disturbance acquire a satisfactory ADL after the hospital discharge. A longer follow-up study is needed.

Second, the length of hospital stay and time[1st-final] varied in this study; therefore, the background of the mFIM gain seems to be heterogeneous. Hospital discharge usually occurs when the improvement of ADL reaches a plateau or when the mFIM score is close to the maximum score of 91 points. The gain in mFIM that we used in this study was the “raw” mFIM gain, which is simply the later mFIM score minus the earlier mFIM score, i.e., it is not adjusted by the length of hospital stay or time[1st-final]. Because of a well-known ceiling effect of the FIM scoring system,³⁰⁾ if we adjust mFIM values in cases where full marks are achieved quickly, the adjusted mFIM score will decrease relatively; nonetheless, the real ADL achieved would be very good. Moreover, there remains a possibility that mFIM efficiency in the high-scoring MMSE group showed lower values because of the ceiling effect of raw mFIM scores (**Fig. 4D** and **Supplemental Fig. 1B**). We believe that the raw mFIM gain is preferable to detect the net improvement of ADL in this situation.

Third, the background of cognitive impairment is hetero-

geneous; therefore, MMSE was used for screening. Cognitive assessment by MMSE was performed at the beginning of the recovery-phase rehabilitation 2 weeks postoperatively or later. Although we believe that most patients no longer exhibited delirium at the time of the MMSE assessment, there remains the possibility that unobserved delirium, other than dementia, could have affected the measured cognitive condition. A preinjury MMSE assessment might provide more accurate information about an individual’s predisposing cognitive function; however, administering the MMSE before an accident is difficult. Furthermore, a detailed differential cognitive diagnosis was not performed in this study. Cognitive impairment can be caused by various types of dementia, such as Alzheimer’s disease, cerebrovascular disease, Lewy body disease, and frontotemporal dementia. Each type of dementia has specific characteristic features.³¹⁾ For example, Alzheimer’s disease typically presents with short-term memory loss, whereas motor function is relatively preserved early in the course of the disease. Lewy body disease is often accompanied by visuospatial problems or Parkinsonism, especially with bradykinesia and rigidity, but with relatively preserved memory. Further study with a precise differential diagnosis of the dementia type can provide more accurate information regarding the ADL prognosis in hip fracture patients. In addition, it is necessary to rule out delirium and depression using a particular assessment scale.

CONCLUSIONS

Among the various clinical variables tested, only MMSE and preinjury mFIM scores were identified as factors significantly correlated with short-term ADL following hip fracture treatment; moreover, MMSE had a larger effect on the final ADL than preinjury mFIM did. A reduced ADL regaining in cognitively disturbed patients was observed in the acute phase 2–3 weeks postoperatively. Treatment and postoperative rehabilitation should be carefully implemented especially for cognitively disturbed patients from the acute phase after hip fracture.

ACKNOWLEDGMENTS

The authors would like to thank Hitomi Tanaka, Jun Matsuhashi, and Mai Morikawa for their help with data preparation.

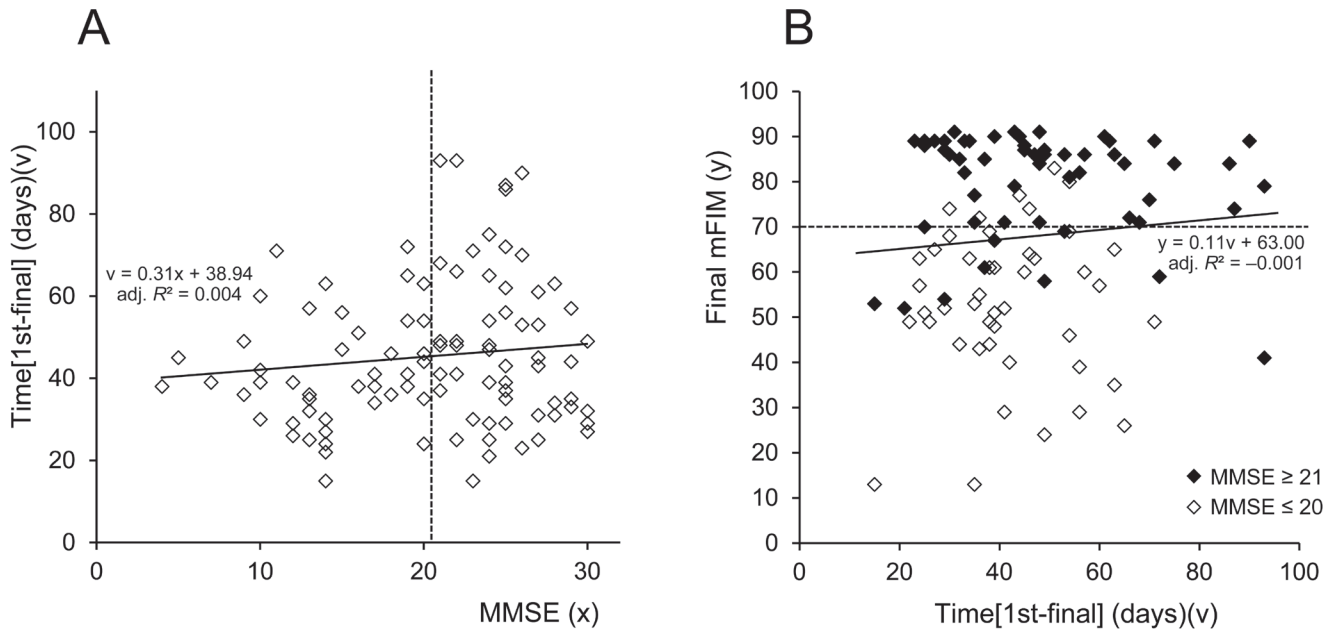
CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest.

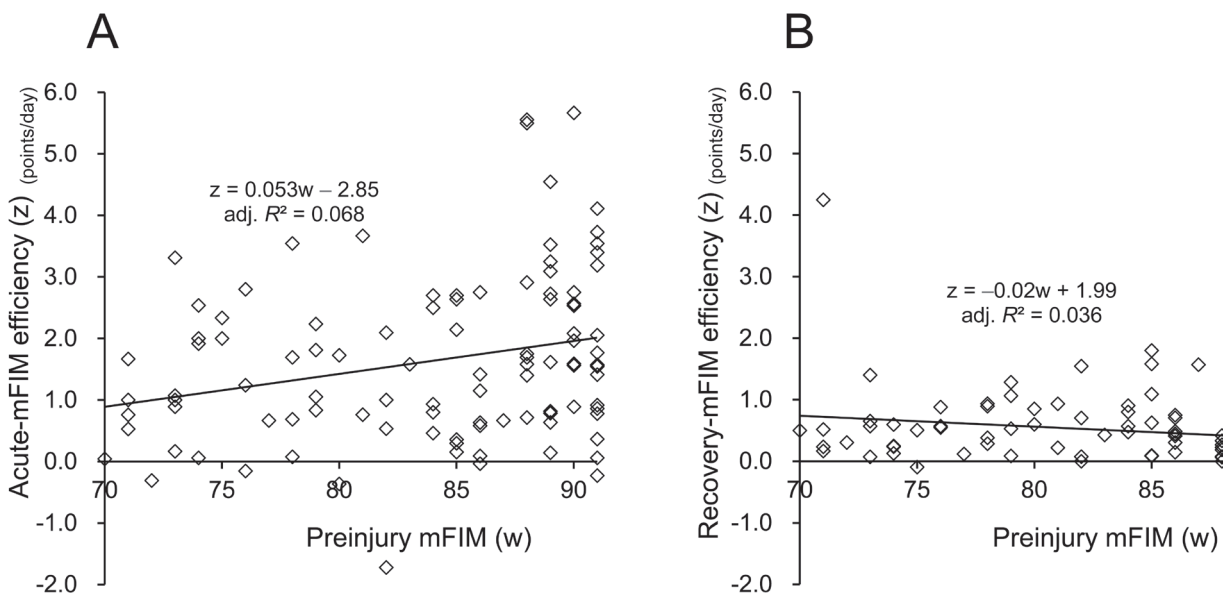
REFERENCES

1. Veronese N, Maggi S: Epidemiology and social costs of hip fracture. *Injury* 2018;49:1458–1460. DOI:10.1016/j.injury.2018.04.015, PMID:29699731
2. Bergström U, Jonsson H, Gustafson Y, Pettersson U, Stenlund H, Svensson O: The hip fracture incidence curve is shifting to the right. *Acta Orthop* 2009;80:520–524. DOI:10.3109/17453670903278282, PMID:19916682
3. Neuman MD, Silber JH, Magaziner JS, Passarella MA, Mehta S, Werner RM: Survival and functional outcomes after hip fracture among nursing home residents. *JAMA Intern Med* 2014;174:1273–1280. DOI:10.1001/jamainternmed.2014.2362, PMID:25055155
4. Omsland TK, Emaus N, Tell GS, Magnus JH, Ahmed LA, Holvik K, Center J, Forsmo S, Gjesdal CG, Schei B, Vestergaard P, Eisman JA, Falch JA, Tverdal A, Sogaard AJ, Meyer HE: Mortality following the first hip fracture in Norwegian women and men (1999–2008). A NOREPOS study. *Bone* 2014;63:81–86. DOI:10.1016/j.bone.2014.02.016, PMID:24607943
5. Granger C: Guide for the use of the uniform data set for medical rehabilitation. Buffalo, NY: Buffalo General Hospital; 1986.
6. Tsuji T, Sonoda S, Chino N: The ADL structure for stroke patients at admission and discharge based on the functional independence measure. *Jpn J Rehabil Med* 1996;33:301–309. DOI:10.2490/jjrm1963.33.301
7. Tsuji T, Sonoda S, Domen K, Saitoh E, Liu M, Chino N: ADL structure for stroke patients in Japan based on the functional independence measure. *Am J Phys Med Rehabil* 1995;74:432–438. DOI:10.1097/00002060-199511000-00007, PMID:8534387
8. Alexander MP: Stroke rehabilitation outcome. A potential use of predictive variables to establish levels of care. *Stroke* 1994;25:128–134. DOI:10.1161/01.STR.25.1.128, PMID:8266360
9. Kwon S, Hartzema AG, Duncan PW, Min-Lai S: Disability measures in stroke: relationship among the Barthel Index, the Functional Independence Measure, and the Modified Rankin Scale. *Stroke* 2004;35:918–923. DOI:10.1161/01.STR.0000119385.56094.32, PMID:14976324
10. Wang CY, Graham JE, Karmarkar AM, Reistetter TA, Protas EJ, Ottenbacher KJ: FIM motor scores for classifying community discharge after inpatient rehabilitation for hip fracture. *PM R* 2014;6:493–497. DOI:10.1016/j.pmrj.2013.12.008, PMID:24389348
11. 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;12:189–198. DOI:10.1016/0022-3956(75)90026-6, PMID:1202204
12. Tombaugh TN, McIntyre NJ: The mini-mental state examination: a comprehensive review. *J Am Geriatr Soc* 1992;40:922–935. DOI:10.1111/j.1532-5415.1992.tb01992.x, PMID:1512391
13. Anthony JC, LeResche L, Niaz U, Von Korff MR, Folstein MF: Limits of the ‘Mini-Mental State’ as a screening test for dementia and delirium among hospital patients. *Psychol Med* 1982;12:397–408. DOI:10.1017/S0033291700046730, PMID:7100362
14. Patnode CD, Perdue LA, Rossom RC, *et al*: Screening for cognitive impairment in older adults: an evidence update for the U.S. Preventive Services Task Force. Agency for Healthcare Research and Quality (US); 2020. Accessed December 31, 2021. <http://www.ncbi.nlm.nih.gov/books/NBK554654/>
15. Kanda Y: Investigation of the freely available easy-to-use software ‘EZR’ for medical statistics. *Bone Marrow Transplant* 2013;48:452–458. DOI:10.1038/bmt.2012.244, PMID:23208313
16. Adunsky A, Lusky A, Arad M, Heruti RJ: A comparative study of rehabilitation outcomes of elderly hip fracture patients: the advantage of a comprehensive orthogeriatric approach. *J Gerontol A Biol Sci Med Sci* 2003;58:M542–M547. DOI:10.1093/gerona/58.6.M542, PMID:12807926
17. Ariza-Vega P, Lozano-Lozano M, Olmedo-Requena R, Martín-Martín L, Jiménez-Moleón JJ: Influence of cognitive impairment on mobility recovery of patients with hip fracture. *Am J Phys Med Rehabil* 2017;96:109–115. DOI:10.1097/PHM.0000000000000550, PMID:27196384
18. Bellelli G, Frisoni GB, Pagani M, Magnifico F, Trabucchi M: Does cognitive performance affect physical therapy regimen after hip fracture surgery? *Aging Clin Exp Res* 2007;19:119–124. DOI:10.1007/BF03324677, PMID:17446722

19. 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;16:215–220. DOI:10.1016/j.jamda.2014.09.009, PMID:25441099
20. Moncada LV, Andersen RE, Franckowiak SC, Christmas C: The impact of cognitive impairment on short-term outcomes of hip fracture patients. *Arch Gerontol Geriatr* 2006;43:45–52. DOI:10.1016/j.archger.2005.09.003, PMID:16256217
21. 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. DOI:10.1519/00139143-200932010-00006, PMID:19856633
22. Yoshii I, Satake Y, Kitaoka K, Komatsu M, Hashimoto K: Relationship between dementia degree and gait ability after surgery of proximal femoral fracture: Review from Clinical Pathway with Regional Alliance data of rural region in Japan. *J Orthop Sci* 2016;21:481–486. DOI:10.1016/j.jos.2016.03.005, PMID:27075586
23. Seematter-Bagnoud L, Frascarolo S, Büla CJ: How much do combined affective and cognitive impairments worsen rehabilitation outcomes after hip fracture? *BMC Geriatr* 2018;18:71. DOI:10.1186/s12877-018-0763-x, PMID:29530014
24. Bliemel C, Lechler P, Oberkircher L, Colcuc C, Balzer-Geldsetzer M, Dodel R, Ruchholtz S, Buecking B: Effect of preexisting cognitive impairment on in-patient treatment and discharge management among elderly patients with hip fractures. *Dement Geriatr Cogn Disord* 2015;40:33–43. DOI:10.1159/000381334, PMID:25896170
25. Benedetti MG, Ginex V, Mariani E, Zati A, Cotti A, Pignotti E, Clerici F: Cognitive impairment is a negative short-term and long-term prognostic factor in elderly patients with hip fracture. *Eur J Phys Rehabil Med* 2015;51:815–823. PMID:25998064
26. Perneckzy R, Wagenpfeil S, Komossa K, Grimmer T, Diehl J, Kurz A: Mapping scores onto stages: mini-mental state examination and clinical dementia rating. *Am J Geriatr Psychiatry* 2006;14:139–144. DOI:10.1097/01.JGP.0000192478.82189.a8, PMID:16473978
27. Muir SW, Gopaul K, Montero Odasso MM: The role of cognitive impairment in fall risk among older adults: a systematic review and meta-analysis. *Age Ageing* 2012;41:299–308. DOI:10.1093/ageing/afs012, PMID:22374645
28. Guirguis-Blake JM, Michael YL, Perdue LA, Coppola EL, Beil TL, Thompson JH: Interventions to prevent falls in community-dwelling older adults: a systematic review for the U.S. Preventive Services Task Force. Agency for Healthcare Research and Quality (US); 2018. Accessed August 19, 2019. <http://www.ncbi.nlm.nih.gov/books/NBK525700/>
29. Livingston G, Huntley J, Sommerlad A, Ames D, Ballard C, Banerjee S, Brayne C, Burns A, Cohen-Mansfield J, Cooper C, Costafreda SG, Dias A, Fox N, Gitlin LN, Howard R, Kales HC, Kivimäki M, Larson EB, Ogunniyi A, Orgeta V, Ritchie K, Rockwood K, Sampson EL, Samus Q, Schneider LS, Selbæk G, Teri L, Mukadam N: Dementia prevention, intervention, and care: 2020 report of the Lancet Commission. *Lancet* 2020;396:413–446. DOI:10.1016/S0140-6736(20)30367-6, PMID:32738937
30. Coster W, Haley S, Jette A: Measuring patient-reported outcomes after discharge from inpatient rehabilitation settings. *J Rehabil Med* 2006;38:237–242. DOI:10.1080/16501970600609774, PMID:16801206
31. Arvanitakis Z, Shah RC, Bennett DA: Diagnosis and management of dementia: review. *JAMA* 2019;322:1589–1599. DOI:10.1001/jama.2019.4782, PMID:31638686



Supplemental Fig. 1. (A) MMSE (= x) vs. time[1st-final] (= v). The regression coefficient of the MMSE for the time[1st-final] was 0.31 (95% confidence interval: $-0.22, 0.85$), and the adjusted R^2 was 0.004. (B) Time[1st-final] (= v) vs. final mFIM (= y). The regression coefficient of time[1st-final] for the final mFIM was 0.11 (95% confidence interval: $-0.12, 0.33$), and the adjusted R^2 was -0.001 . Time[1st-final] is the time between initial rehabilitation in the perioperative period and the final mFIM assessment before hospital discharge.



Supplemental Fig. 2. mFIM efficiency according to preinjury mFIM levels. Scatter plots of mFIM efficiency (z) vs. preinjury mFIM (w) are shown. (A) The mFIM efficiency (acute phase) was defined as follows: (acute-mFIM efficiency) = (mFIM gain scores between f and s) / (time between f and s) (points/day). (B) The mFIM efficiency (recovery phase): (recovery-mFIM efficiency) = (mFIM gain scores between s and d) / (time between s and d) (points/day). f = time point of initial rehabilitation in the perioperative period, s = time point of the mFIM assessment at the starting of recovery-phase rehabilitation 2–3 weeks postoperatively, d = time point of the final mFIM assessment before the hospital discharge.