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FUNCTIONAL OUTCOMES OF FRAGILITY FRACTURE INTEGRATED REHABILITATION MANAGEMENT IN SARCOPENIC PATIENTS AFTER HIP FRACTURE SURGERY AND PREDICTORS OF INDEPENDENT AMBULATION

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Abstract: *Objectives:* To compare the changes in the functional level of patients with versus without sarcopenia who received by fragility fracture integrated rehabilitation management (FIRM) after hip fracture (HF) surgery over a 6-month follow-up period and to identify variables influencing independent ambulation (IA) at 6 months after HF. *Design:* Prospective observational study. *Setting:* Three in-hospital rehabilitation setting. *Participants:* Patients older than 65 years of age (N=80) categorized by the presence of sarcopenia. *Intervention:* The FIRM program during the-2 week hospital stay after surgery. *Measurements:* Main outcomes for ambulatory function (Koval score, Functional Ambulatory Category) and other secondary outcomes were measured at rehabilitation admission, at discharge, at 3 months and 6 months after surgery. Other secondary outcomes were measured. The possibility of IA at 6 months after surgery were also investigated. *Results:* Sarcopenia and non-sarcopenia patients did not differ significantly in terms of changes in ambulation or other functions over a 6-month follow-up ($p < 0.001$ or $p = 0.001$). The two groups did not differ significantly in terms of final functional status (6 months). The IA ratios of the two groups did not significantly differ at 6 months after surgery (sarcopenia [54.3%] and non-sarcopenia [64.5%]). IA before fracture ($p = 0.039$) and age (≥80 years) ($p = 0.03$) were independent predictors and sarcopenia was not a predictor for the possibility of IA at 6-months after surgery. *Conclusions:* The FIRM program was effective for promoting functional recovery in older patients with fragility HF, either with or without sarcopenia. The present findings provide evidence of the pressing need for integrated rehabilitation management in fragility fracture care to improve functional recovery in patients with sarcopenia.

Key words: Clinical pathways, geriatrics, hip fractures, rehabilitation, sarcopenia.

Introduction

Fragility hip fracture (HF) is a serious geriatric condition associated with poor outcomes, including a 1-year mortality rate of up to 30% after fracture (1) and impaired ambulation compared to before the fracture in 40–60% of patients (2). To improve outcomes after HF, multidisciplinary rehabilitation programs based on a critical care pathway are provided in several countries (3, 4). Additionally, our research group recently developed fragility fracture integrated rehabilitation management (FIRM), which is a standardized multidisciplinary fragility fracture care strategy implemented in the hospital setting (5).

Sarcopenia is characterized by a considerable loss of muscle mass and strength that occurs with advancing age (6). This disorder is also associated with limited ambulation in conjunction with a high risk of falls and fractures, impairments in activities of daily living (ADLs), and an increased risk of death (7). Several studies have investigated the association between sarcopenia and functional outcomes in patients with HF (8-10). Although patients with sarcopenia exhibit lower Barthel Index (BI) scores, at discharge from a rehabilitation unit and at 3-month follow-up assessments (8), the association between sarcopenia and poorer functional outcomes at discharge could not be confirmed and age is the only variable that has been reliably associated with loss of function (9). It has also been reported that sarcopenia is not related to either loss of mobility or recovery, which supports the idea that sarcopenia is not linked with changes in mobility over 1 year of follow-up (10).

A previous study by our research group found that the improvement rates of in-hospital functional outcomes following comprehensive and integrated rehabilitation management are similar between sarcopenia and non-sarcopenia groups after fragility HF (11). However, sarcopenia is also associated with poor physical performance and a poor prognosis after in-hospital rehabilitation (7, 8, 12). Thus, it was hypothesized in the present study that sarcopenia would affect the recovery of functional performance, especially in terms of ambulation, during long-term follow-up. To investigate the influence of sarcopenia on the long-term outcomes of FIRM, the present study compared changes in the functional level of patients with versus without sarcopenia who received FIRM after HF surgery over a 6-month follow-up period.

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Materials and Methods

Design

The present study was a prospective observational investigation of patients older who enrolled in the FIRM program and were followed-up with for up to 6 months after HF surgery. The rehabilitation program and functional evaluations were carried out according to methods previously reported by our research group (11). The trial was registered at ClinicalTrials.gov (Identifier: NCT03430193).

Demographics and clinical characteristics

The present study included patients older than 65 years of age who had undergone surgery for HF (including femoral neck, intertrochanteric, or subtrochanteric fractures) and were then transferred to an acute rehabilitation unit at Seoul National University Bundang Hospital, Chung-Ang University Hospital, or Jeju National University Hospital between August 2016 and November 2018. Patients were excluded if they had undergone surgery for an infection, arthritis, implant loosening, avascular necrosis, a periprosthetic fracture, and/or a pathological fracture; if they had multiple fractures, had undergone revision surgery, or had severe cognitive dysfunction; if they had comorbid medical problems that would make rehabilitation difficult; and/or if they declined to participate in the clinical trial. Severe cognitive dysfunction was defined as an inability to follow the instructions necessary for rehabilitation.

Patient data, such as demographic characteristics, surgery type, pre-fracture ambulatory function, previous history of HF, comorbidities, and postoperative complications were collected using a standardized questionnaire, and by examinations and review of the medical records. Comorbidities were defined according to the Charlson Comorbidity Index (CCI) (13), weighted from 1 to 6 in terms of mortality risk and disease severity, and then summed to yield the total CCI score. Severity was categorized according to total score: none = 0, mild = 1–2, moderate 3–4, and severe ≥ 5.

Assessment of sarcopenia

The presence of sarcopenia was defined according to Asian Working Group for Sarcopenia criteria, which include decreased handgrip strength (HGS: men < 26 kg, women < 18 kg), and loss of muscle mass, as indexed by appendicular skeletal muscle mass (ASM) divided by height squared (ASM/height^2: men < 7.0 kg/m^2, women < 5.7 kg/m^2) (14). However, in the present study, gait speed was excluded from the diagnostic criteria for sarcopenia because this variable could not be assessed before fracture or surgery. Measuring gait speed after hip surgery is not appropriate for assessing normal gait speed because patients may not be able to walk, or will walk slowly, depending on the degree of weight bearing or pain.

HGS was estimated using a digital dynamometer (TKK 5401 Grip-D; Takei, Niigata, Japan) while the participant was in a sitting position without an armrest, and with the shoulders neutrally rotated and adducted, the elbow flexed at 90°, and the forearm and wrist in neutral positions. Each participant carried out three measurements; there was an interval of 1 min between the measurements. The maximum values of the three measurements for both hands were recorded and HGS was calculated using the mean of these values.

Body composition was measured using a tetrapolar bioelectrical impedance analysis (BIA) system (InBody S10; Biospace, Seoul, Korea) based on a standardized procedure according to the tetrapolar method, as previously reported (15,16). BIA was measured after surgery (mean time = 9.22 ± 3.77 days). It is recommended that the non-affected side of the body be measured if an orthopedic prosthesis or implant (metal) is used, because postoperative edema on the fracture side is likely to affect the body composition (17). Therefore, as described in our previous study (11), ASM was calculated as the sum of the lean soft tissue mass of the upper extremities and double the value of that of the lower extremities, excluding the extremities on the fracture side.

Interventions

Following surgery, all patients underwent comprehensive multidisciplinary rehabilitation via the FIRM clinical program (5). The FIRM program consists of 10 days of physical therapy (PT) (two 60-min sessions per day), 4 days of occupational therapy (OT), fall prevention education, discharge planning, and referral to community-based care during the-2 week hospital stay after surgery. During the FIRM program, PT (weight-bearing exercises, strengthening exercises, gait training, aerobic exercise, and functional training) gradually progressed based on the individual's functional level; OT for ADL (transfer, sit-to-stand, bed mobility, dressing, self-care, and use of adaptive equipment) was also provided. Intensive education based on an HF care manual was provided for patients and their families by members of the multidisciplinary rehabilitation team.

Functional outcome measures

The primary functional outcomes in the present study, including walking ability, were assessed using the KOVAL scores (18), on which scores range from 1–7; higher scores reflect lower walking ability. The Functional Ambulatory Category scale (19) was also applied, on which scores range from 0–5; higher scores indicate better ambulation. The instruments used to measure secondary outcomes included the Modified Rivermead Mobility Index (MRMI) for mobility (20), on which scores range from 0–40 and higher scores reflect greater mobility, the Berg Balance Scale (BBS) measuring balance and fall risk (21), on which scores range from 0–56 and higher scores indicate better balance, the Mini-Mental State Examination (MMSE) test of cognitive functioning (22), on which scores range from 0–30 and higher scores reflect better cognitive functioning, the Korean version of the Geriatric Depression Scale (K-GDS) (23), on which scores range from

Table 1
Patient characteristics

Characteristic	Sarcopenia group (n = 35)	Non-sarcopenia group (n = 45)	P-value
Age (years)	82.8 ± 7.5	79.7 ± 6.5	0.053
Age (≥ 80 years, n)	25 (71.4%)	22 (48.9%)	0.042*
Sex (M:F)	7:28	11: 34	0.637
Height (cm)	153.6 ± 8.4	157.6 ± 7.1	0.025*
Weight (kg)	48.5 ± 9.1	56.7 ± 8.1	< 0.001*
BMI (kg/m^2)	21.2 ± 3.4	22.9 ± 3.5	0.008*
ASM/height^2	5.0 ± 0.71	6.7 ± 1.1	< 0.001*
Handgrip Strength (kg)	14.0 ± 5.7	19.3 ± 6.7	< 0.001*
Type of fracture			
FN : IC : SC	21 : 14 : 0	22 : 21 : 2	0.471
Type of operation			
BH : THA : IF	21: 3 : 11	18 : 2 : 25	0.091
Pre-fracture walking ability			
IA : AA	26 (74.3%) : 9	40 (88.9%) : 5	0.137
Post-surgery walking ability (6 months)			
IA : AA	19 (54.3%) : 16	29 (64.5%) :16	0.358
Recovery to pre-fracture walking ability†	16 (61.5%)	28 (70%)	0.595
Charlson Comorbidity Index			
None	5 (14.3%)	10 (22.2%)	
Mild (1–2 conditions)	23 (65.7%)	23 (51.1%)	
Moderate (3–4 conditions)	2 (5.7%)	7 (15.6%)	
Severe (≥ 5 conditions)	5 (14.3%)	5 (11.1%)	
Cognitive dysfunction (yes)‡	22 (62.9%)	17 (39.5%)	0.040*
Postoperative complication (yes)	2 (5.7%)	2 (4.4%)	1.000
Previous history of hip fracture (yes)	3 (8.6%)	3 (6.7%)	1.000
Total admission day	22.3 ± 5.7	20.5 ± 5.6	0.166
Days to surgery	2.7 ± 2.5	2.1 ± 2.0	0.287
Days to rehabilitation	6.4 ± 1.7	6.9 ± 2.5	0.279

Values are mean ± SD or number of patients (%); BMI: body mass index, ASM: appendicular skeletal muscle mass; FN: femoral neck, IC: intertrochanteric, SC: subtrochanteric, BH: bipolar hemiarthroplasty, THA: total hip arthroplasty, IA: independent ambulation, AA: ambulation with physical assistance; † Among patients walking independently before fracture; ‡ Defined by the MMSE score adjusted for age and educational level; * Significant difference between groups, $p < 0.05$ by independent t-test and chi-square test

0–30 and higher scores indicate more depressive symptoms, the Euro Quality of Life Questionnaire 5-Dimensional Classification (EQ-5D) for assessing quality of life (24), on which scores range from 0–1 and higher scores indicate a better quality of life, the Korean version of the modified BI (K-MBI) for assessing ability to perform ADLs (25), on which scores range from 0–100 and higher scores reflect better ability to perform ADLs, the Korean Instrumental ADL (K-IADL) for assessing ability to perform ADLs (26), on which scores range from 0–3 and higher scores reflect lower ability to perform ADLs, and the Korean version of the Fatigue, Resistance, Ambulation, Illnesses, and Loss of Weight (K-FRAIL) scale of frailty and HGS (27), on which scores range from 0–5 and higher scores reflect greater frailty.

All functional outcomes (KovalL, FAC, EQ-5D, K-IADL, and K-FRAIL) were assessed on admission for rehabilitation, at discharge, and at the 3- and 6-month follow-up visits after surgery (or via telephone follow-up). The Koval and FAC were administered through patient and surrogate interviews to confirm pre-fracture ambulatory functioning, and the results were classified as either independent outdoor ambulation with or without use of an assistive device (IA) or ambulation with physical assistance (AA), where most patients were older than 80 years of age. These ambulatory categories were assigned

Table 2
Predictors of independent ambulation at 6 months after hip fracture surgery: results of univariate analysis

Characteristic	All patients (n = 80)			Sarcopenia group (n = 35)			Non-sarcopenia group (n = 45)		
	P	OR	95% CI	P	OR	95% CI	P	OR	95% CI
IA (pre-fracture)	0.013	5.000	1.408-17.759	0.153	3.200	0.649-15.755	0.056	9.333	0.942-92.469
Sarcopenia (yes)	0.359	0.655	0.266-1.616						
Age (≥ 80 years)	0.018	0.307	0.115-0.817	0.067	0.196	0.035-1.118	0.179	0.424	0.121-1.483
Sex (Female)	0.513	0.692	0.230-2.084	0.318	0.400	0.066-2.418	0.949	1.048	0.254-4.315
Type of operation (IF)†	0.101	0.467	0.188-1.160	0.037	0.188	0.039-0.906	0.487	0.643	0.185-2.237
Type of fracture (IC)‡	0.094	0.456	0.182-1.144	0.077	0.278	0.067-1.150	0.455	0.622	0.179-2.163
Cognitive dysfunction (yes)	0.108	0.468	0.185-1.180	0.178	0.370	0.087-1.573	0.485	0.635	0.177-2.273
History of hip fracture	0.186	0.304	0.052-1.771	0.656	1.765	0.145-21.474	0.999	0.000	
CCI (mild)	0.253	0.473	0.131-1.708	0.971	1.037	0.144-7.477	0.146	0.273	0.047-1.573
CCI (moderate-severe)	0.353	0.500	0.116-2.158	0.286	0.267	0.024-3.020	0.781	0.750	0.099-5.693
ASM/height^2	0.468	1.146	0.793-1.654	0.216	1.875	0.693-5.073	0.543	0.834	0.465-1.497
Handgrip strength	0.018	1.102	1.017-1.193	0.035	1.196	1.013-1.412	0.262	1.060	0.957-1.174

OR: Odds Ratio, CI: confidence interval; †reference: arthroplasty (total hip replacement + bipolar hemiarthroplasty); ‡reference: femur neck fracture

based on a Koval score ≤ 3 and a FAC score ≥ 3, respectively. Cognitive dysfunction was defined using the MMSE score, corrected for age and educational level in accordance with previously reported guidelines (28).

Statistical analysis

The demographic, clinical and ambulatory function data are reported as means and standard deviations for continuous variables, and as proportions for categorical variables. Differences between the sarcopenia and non-sarcopenia groups were assessed by independent t-tests for normally distributed data and chi-square tests for categorical data. The Koval and FAC tests were administered to all patients at the follow-up visits, or by telephone survey. Two-way repeated-measures (time × group) analysis of variance (ANOVA) was conducted to compare the two groups at different assessment time points on the variables of interest. The sphericity of the data was verified with a Mauchly's test and the Greenhouse-Geisser correction was applied when the sphericity assumption was violated.

Functional outcomes for which there were missing data were assessed using a linear mixed model, because this is tolerant to missing data. When significant main or interaction effects (time × group) were observed in the repeated-measures analysis, post hoc Bonferroni tests were applied. Predictors of independent ambulation at 6 months after HF surgery were investigated using logistic regression analyses, which initially included all patients and then only those with sarcopenia. Multivariate regression models (forward stepwise method), including factors that were significant in univariate regression models (enter method) at $p < 0.10$, were performed to identify predictors of independent ambulation. All statistical analyses were conducted using IBM SPSS Statistics software (ver. 22.0; IBM Corp., Armonk, NY, USA) and p-values < 0.05 were considered to indicate statistical significance.

Results

After screening for eligibility, the present study included 159 patients who started the FIRM program. Of these patients, 23 did not complete the FIRM protocol and 38 were missing body composition data necessary for assessing sarcopenia. During the follow-up period, 13 patients were excluded from the sarcopenia group (9 at 3 months and 4 at 6 months) and 5 were excluded from the non-sarcopenia group (2 at 3 months and 3 at 6 months). Ultimately, a total of 80 patients were analyzed in this study; 35 sarcopenia patients (43.8%) and 45 non-sarcopenia patients (56.2%).

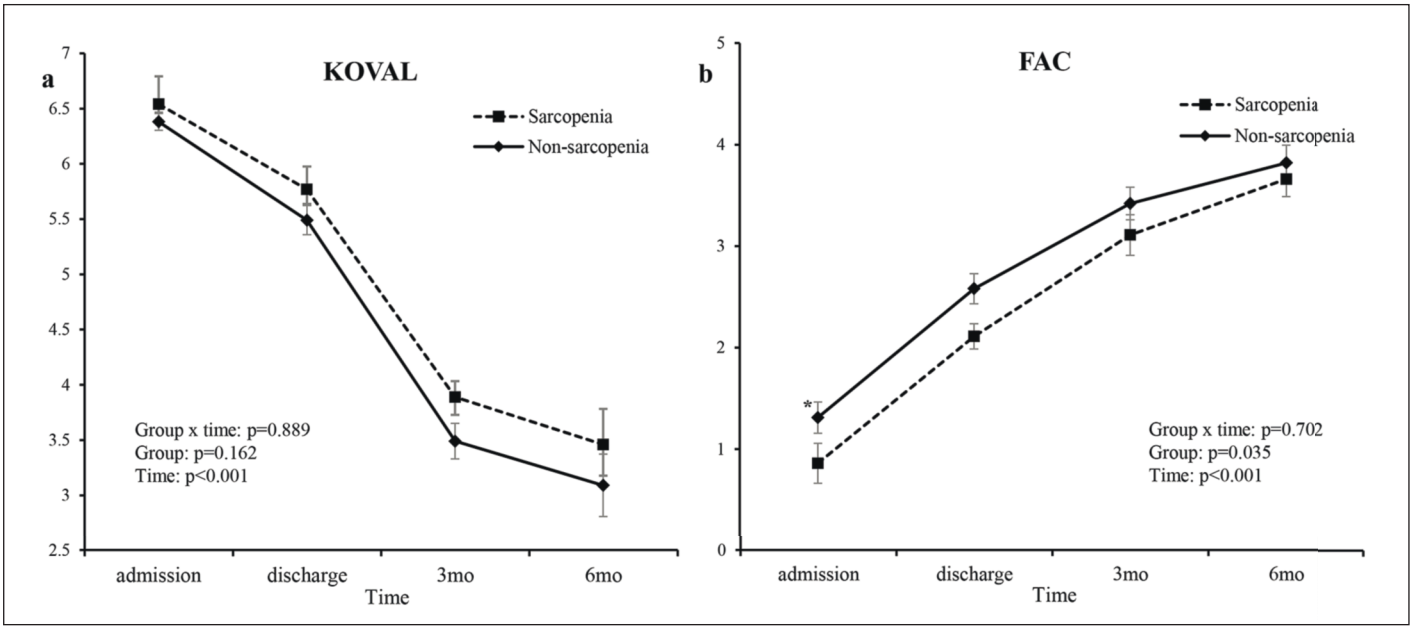
The mean age of the sarcopenia and non-sarcopenia groups was 82.8 ± 7.5 and 79.7 ± 6.5 years, respectively, and there were significantly more patients over the age of 80 years in the sarcopenia group ($p = 0.042$). Values for anthropometric and sarcopenic variables were significantly lower in the sarcopenia group. Pre-fracture ambulatory capacity, which was classified by the presence of independent ambulation, did not significantly differ between the groups (IA: 26 sarcopenia patients [74.3%] and 40 non-sarcopenia patients [88.9%], $p = 0.089$). The sarcopenia group contained significantly more patients with impairments in cognitive function than the non-sarcopenia group (22 [62.9%] vs. 17 patients [39.5%], respectively, $p = 0.040$) but the groups did not differ in terms of sex, total admission days, days to surgery, days from surgery to rehabilitation, type of fracture, type of operation, comorbidities, postoperative complications, or previous history of HF (Table 1).

Table 3
Predictors of independent ambulation at 6 months after hip fracture surgery: results of multivariate analysis

Characteristic	All patients (n = 80)			Sarcopenia group (n = 35)			Non-sarcopenia group (n = 45)		
	P	OR	95% CI	P	OR	95% CI	P	OR	95% CI
IA (pre-fracture)	0.039	4.055	1.074-15.308	0.495	-	-	0.048	10.182	1.021-101.517
Age (≥ 80 years)	0.030	0.313	0.110-0.892	0.201	-	-	0.128	-	-
Type of operation (IF) †	0.601	-	-	0.089	-	-	0.230	-	-
Type of fracture (IC)‡	0.450	-	-	0.059	-	-	0.204	-	-
Handgrip strength	0.254	-	-	0.035	1.196	1.013-1.412	0.414	-	-

OR: Odds Ratio, CI: confidence interval; †reference: arthroplasty (total hip replacement + bipolar hemiarthroplasty); ‡reference: femur neck fracture

Figure 1
Time-dependent changes in the a) Koval and b) FAC between groups after inpatient rehabilitation (Fracture Integrated Rehabilitation Management; FIRM)



Data are presented as mean ± SE. P-values were determined by two-way repeated measures ANOVA (treatment × time). *Significant difference between groups according to Bonferroni post-hoc test, $p < 0.05$.

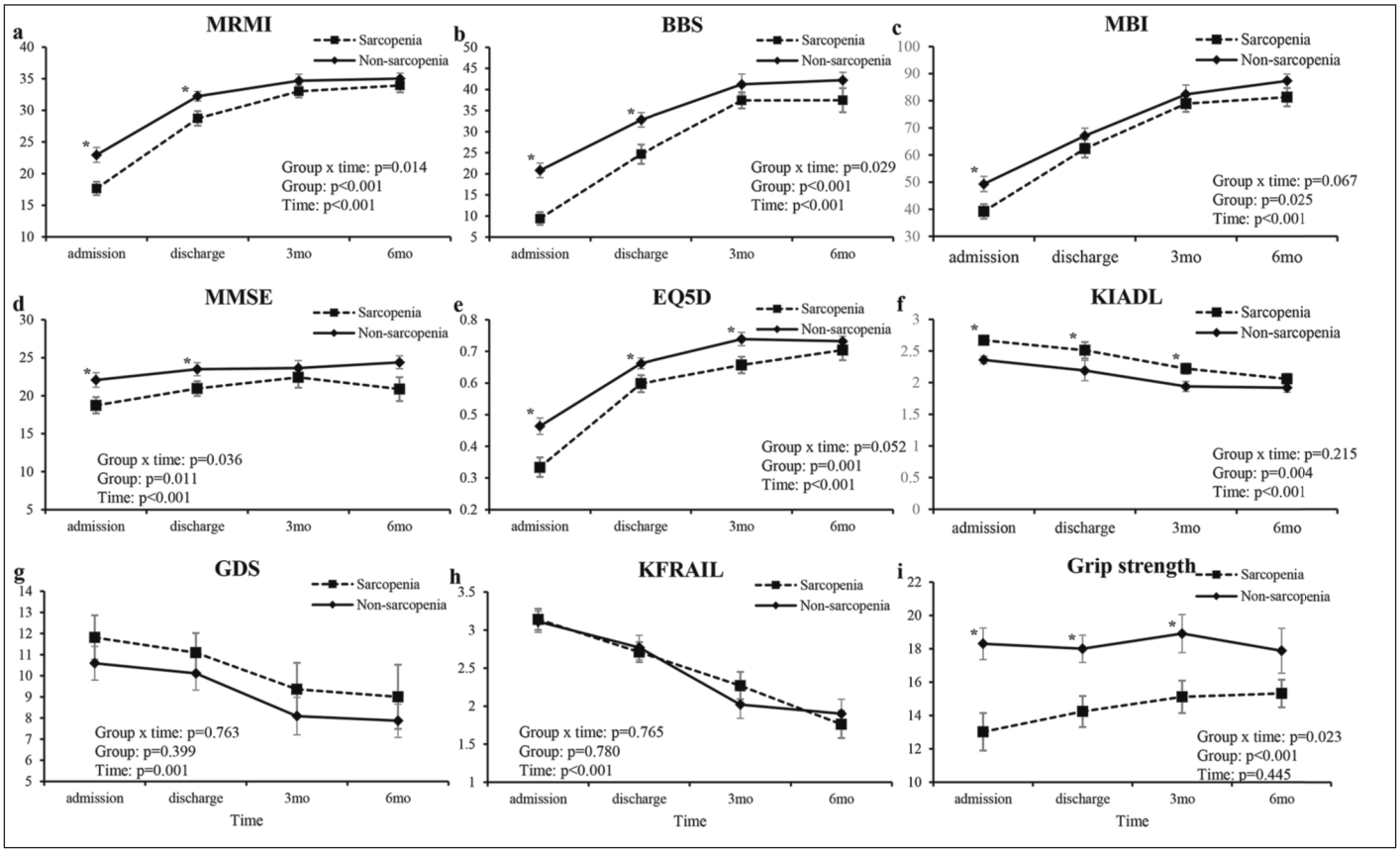
The IA ratios of the two groups did not significantly differ at 6 months after surgery (19 sarcopenia patients [54.3%] and 29 non-sarcopenia patients [64.5%]) and, although the Koval and FAC scores were lower in the sarcopenia group, the differences between the groups were not significant. Similarly, the proportion of patients who returned to their previous level of independent walking ability did not differ significantly between the sarcopenia and non-sarcopenia groups (61.5% vs. 70%, respectively, Table 1).

Among all participants, the Koval and FAC scores improved over time ($p < 0.001$). The two groups did not differ in terms of the time course of improvement in Koval scores. There was no difference between the groups regarding the time course for improvement in FAC scores after discharge. The main effect of group in FAC scores ($p = 0.035$) was attributable to the difference between the groups at baseline ($p = 0.027$) (Figure 1). In addition, all secondary functional outcomes, except for HGS, significantly improved over time in both the sarcopenia and non-sarcopenia groups, even though the functional status of the sarcopenia group was lower at both the 3- and 6-month follow-up evaluations. However, the two groups did not differ significantly in terms of final functional status (Figure 2).

The univariate analysis revealed that IA before fracture, age (≥ 80 years), and HGS were significantly associated with IA at 6 months after surgery in all patients. Additionally, type of operation (internal fixation [IF]) and high HGS were significantly associated with post-surgery IA at 6 months in the sarcopenia group (Table 2).

The multivariate logistic regression analysis revealed that IA before fracture (odds ratio [OR]: 4.055, $p = 0.039$) and age (≥

Figure 2
Time-dependent changes in a) MRMI, b) BBS, c) K-MBI, d) MMSE, e) EQ-5D, f) K-IADL, g) K-GDS, h) K-FRAIL, and i) HGS scores of the two groups after inpatient rehabilitation (Fracture Integrated Rehabilitation Management; FIRM)



Data are presented as mean standard error P values were determined by two way repeated measures ANOVA (treatment × time). *Significant differences between groups according to Bonferroni post hoc test, $p < 0.05$.

80 years; OR: 0.313, p = 0.03) were independent predictors of IA at 6 months after surgery in all patients. Furthermore, HGS (OR: 1.196, p = 0.035) and IA before fracture (OR: 10.182, p = 0.048) were independent predictors of IA at 6 months after surgery in the sarcopenia and non-sarcopenia groups, respectively. However, sarcopenia was not a predictor of IA at 6 months after surgery.

Discussion

The present study demonstrated that sarcopenia and non-sarcopenia patients did not differ significantly in terms of changes in ambulation or other functions over a 6-month follow-up after HF surgery while participating in the FIRM program. These findings indicate that the FIRM program was effective for promoting long-term functional recovery in older patients with or without sarcopenia who suffered from fragility HF. Additionally, multivariate regression analysis revealed that IA at 6 months after surgery in all patients could be predicted by IA before fracture and patient age. Additionally, IA at 6 months after surgery was predicted by HGS in the sarcopenia group, and by IA before fracture in the non-sarcopenia group. However, sarcopenia was not a negative predictor of IA at 6 months after surgery.

Although older patients with HF often experience disabilities following an event such as a fall, approximately 40–60% of HF survivors are likely to recover their pre-fracture level of mobility (2). On the other hand, it has also been reported that less than one-third of HF patients return to pre-fracture levels of ADL and mobility (29). Another study showed that, compared to community-dwelling aged adults, an HF cohort exhibited excessive disabilities that accounted for 26 additional cases of disability per 100 persons between the 12- and 24-month follow-up time points (30). In the present study, 48 patients (60%) could walk independently at 6 months after HF surgery and, of the patients who were able to walk independently before fracture, 44 (66.7%) recovered their pre-fracture walking ability. Inpatient rehabilitation specifically designed for geriatric patients with HF has the potential to improve function (31); similarly, the comprehensive multidisciplinary rehabilitation conducted in the present study might contribute to relatively superior functional recovery compared to previous

studies.

A previous study by our research group indicated that such patients are capable of improving their functional levels during in-hospital rehabilitation, and that FIRM was effective for short-term functional recovery after HF regardless of the presence of sarcopenia (11); In the present study, sarcopenic patients showed lower levels of physical performance, including ambulation, as well as reductions in cognitive function and the other secondary outcomes before fracture and at rehabilitation admission compared to non-sarcopenic patients. However, the difference in functional status at 6 months after surgery between the groups was not significant, which suggests that the functional improvements after FIRM were similarly maintained for a longer period in both groups. Additionally, some functional variables that significantly differed between the two groups in the early stages did not differ at the 6-month follow-up assessment, which suggests that FIRM had better therapeutic efficacy in the sarcopenia group. However, sarcopenia was not associated with IA at 6 months, and the ratio of patients who could walk independently did not significantly differ between the two groups, contrary to our hypothesis.

The relative inability of sarcopenia to predict the influence of sarcopenia on functional progress at 6 months could be explained by the effects of the comprehensive multidisciplinary rehabilitation program. Based on information on pre-fractures, baseline physical and functional status, and other factors that could affect functional outcomes during standardized evaluations after surgery, the patients in the present study were provided with more comprehensive qualitative and quantitative treatment than those who received conventional rehabilitation. These patients received customized intensive interventions with an individualized rehabilitation goal. Additionally, because the patients with sarcopenia were provided with intensive treatment appropriate for their individual level of function, their functional improvements might have been similar to those of the non-sarcopenic patients. Although it was difficult to compare the effects of FIRM with those of conventional rehabilitation in the present study because only patients that received FIRM were assessed, the present results indicate that the standardized, comprehensive, and intensive FIRM rehabilitation program had positive short- and long-term effects in patients with HF. Additionally, sarcopenic patients received additional therapeutic benefits due to the provision of physical training coupled with emotional and environmental support. Intensive multidisciplinary rehabilitation is thought to be sufficiently sensitive for improving the functional prognoses of sarcopenic patients.

It has been reported that various factors, including age, sex, walking ability before the injury, type of fracture, type of surgery, comorbidities, and dementia, influence post-operative ambulatory capacity (32-35); Ambulatory functioning before fracture, and age, predict the short-term outcomes of in-hospital rehabilitation after HF surgery (32), as well as long-term outcomes (i.e., at the 1-year follow-up assessment) (33). Our research group showed that pre-fracture ambulatory capacity is significantly correlated with short-term ambulatory functional recovery (11); similarly, the present study showed that IA before fracture, and age (≥ 80 years), were independent predictors of recovery at 6 months after surgery in all patients. It has been reported that HGS can predict both incident and persistent walking recovery in patients after HF (36). Likewise, the present study found that HGS was a better predictor of IA at 6 months after surgery in the sarcopenia group, which suggests that greater muscle strength (as indexed by HGS) may have had positive effects on the rehabilitation outcomes even for patients with sarcopenia who had lower muscle power. These relationships could be important to consider for population-specific standardization of rehabilitation programs and appropriate goal-setting as it pertains to ambulation.

Our univariate analysis revealed a significant correlation between type of operation and IA at 6 months after surgery in the sarcopenia group. Arthroplasty (AP) may be a more suitable surgical option for patients with femur neck fracture (37). because it yields superior functional outcomes based on earlier partial weight bearing than IF in elderly patients (38). The inability to regain independence, in terms of mobility, is associated with larger edemas and reduced knee-extension strength in patients with an intertrochanteric femoral fracture (32, 39). In the present study, 34 of 43 patients with femur neck fractures, and 31 of 37 patients with peritrochanteric femoral fractures, were treated with AP and IF, respectively. Thus, type of operation and fracture type are collinear variables so it is difficult to distinguish their effects. Sarcopenic patients treated with IF show relatively limited mobility in the early rehabilitation phase, which could in turn lead to greater loss of muscle mass and strength.

The present study had several limitations. First, there might have been a temporal limitation with respect to the timing of the classification of sarcopenia, where variables assessed after surgery could have affected the classification. In the clinical setting, it is difficult to measure normal gait speed before surgery and BIA before surgery or fracture. In the present study, gait speed measured after surgery was affected by the degree of weight bearing or pain, and more than half of the patients could not walk in the early stage of rehabilitation; thus, it was difficult to measure gait speed after hip surgery accurately. Additionally, BIA has some inherent limitations, in that relative increases in total body water and extracellular water result in an underestimation of body fat percentage and overestimation of fat-free mass (15). Additionally, postoperative edema in a fractured limb alters body composition and leads to overestimation of muscle mass in the fractured limb (11, 16). Although the muscle mass of the non-fractured extremity was used to calculate ASM in the present study, to reduce measurement error, it was difficult to eradicate this error completely. Second, although the 6-month follow-up period was not sufficient to assess long-term outcomes,

previous reviews have shown that functional recovery and the primary response to rehabilitation largely occur within 6 months in older patients with HF (30, 40, 41). However, considering the fragile condition of the present patients due to their advanced age, there is a need for longer-term follow-up of functional changes. Third, the present study included only patients with fragility HF who were then treated using FIRM; thus, future research will be necessary to compare the clinical effects of FIRM with those of conventional rehabilitation.

Conclusions

The present study found that the FIRM program was effective for promoting functional recovery in older patients with fragility HF, either with or without sarcopenia. Additionally, sarcopenia did not affect the likelihood of IA at 6 months after surgery following completion of the FIRM program. Although HF and sarcopenia are major causes of disability in older people, the present findings provide evidence of the pressing need for comprehensive and integrated rehabilitation management in fragility fracture care to improve functional recovery in patients with sarcopenia.

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