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ORIGINAL ARTICLE

Relationship between Trunk Muscle Mass Index at Admission and Walking Independence in Patients with Hip Fracture

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Objectives: This study aimed to investigate the relationship between trunk muscle mass index (TMI), appendicular skeletal muscle mass index (ASMI), and walking independence in patients aged 65 years and older undergoing rehabilitation for hip fracture. **Methods:** This retrospective, observational study was conducted in a convalescent rehabilitation ward and included 314 patients (aged ≥65 years) with hip fracture. The patients were classified into the independence group [functional independence measure (FIM)-walk score ≥6] or the non-independence group (FIM-walk score ≤5) according to the mobility item score among the motor FIM items at the time of discharge. Age, sex, TMI, ASMI, and Mini Nutritional Assessment-Short Form (MNA-SF) data were also extracted. Between-group and multivariate analyses were performed to evaluate the factors associated with walking independence. **Results:** The independence group had higher TMI (males: 6.6±0.9 vs. 5.6±1.0 kg/m^2, P <0.001; females: 6.1±0.8 vs. 5.7±1.0 kg/m^2, P <0.001), ASMI (males: 6.7±1.1 vs. 5.9±1.3 kg/m^2, P=0.004; females: 5.3±0.9 vs. 4.7±0.8 kg/m^2, P <0.001), MMSE-J (21.5±4.9 vs. 16.4±4.5 points, P <0.001), and MNA-SF [median (interquartile range): 8 (6–9) vs. 7 (5–8) points, P <0.001] than the non-independence group. Multivariate analysis showed that TMI at admission was significantly associated with walking independence (odds ratio: 1.86, 95% confidence interval: 1.28–2.72, P <0.001). **Conclusions:** This study suggests that a higher TMI at admission was important for acquiring walking independence in patients with hip fracture and shows the importance of early evaluation of TMI during hospitalization of patients with hip fracture.

Key Words: activities of daily living; rehabilitation; trunk muscle mass

INTRODUCTION

Most patients with hip fracture have a decreased walking ability after fracture.[1] After hip fracture, only 33% of patients achieve pre-fracture walking ability.[2] Factors such as patient age, cognitive function, pre-fracture walking ability, and pre-fracture activities of daily living (ADL) are related to the acquisition of walking independence after hip fracture.[3–6] In addition, decreased walking ability before hip fracture is associated with decreased ADL after fracture.[2] Therefore, to regain a quality of life similar to that experienced before injury, it is important for patients with hip fracture to achieve independent ambulation after injury.

Bioelectrical impedance analysis (BIA) is used to evaluate muscle mass[7] and is widely used in clinical practice because of its high accuracy and reproducibility in evaluating muscle mass and because it can be performed noninvasively.[8] BIA is especially useful for site-specific evaluation of appendicular and trunk muscle mass.[9,10] Previous studies investigating muscle mass using the BIA method reported decreased appendicular muscle mass (AMM) in about 60% of patients with hip fracture.[11] It has been reported that decreased

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AMM is associated with a decline in physical function[12] and that a decrease in AMM as evaluated by BIA is associated with decreased ADL and increased mortality.[11,13] Therefore, it is important to evaluate muscle mass using BIA in patients with hip fractures.

Recently, several studies investigated trunk muscle mass (TMM) using BIA.[10,14] Studies in older adults reported that a decrease in TMM as evaluated by BIA was associated with an increased incidence of femoral neck fracture.[10] In addition, a study of patients with cerebrovascular disease reported that a decrease in TMM at admission was associated with a decrease in motor function at discharge.[15] However, these studies were conducted in older individuals and patients with cerebrovascular disease, and there were no studies that used walking ability as an outcome in patients with hip fracture. Studies using computed tomography (CT) to evaluate muscle mass in patients with hip fracture have reported a decrease in TMM after hip fracture.[16] Another study in which the TMM was evaluated using ultrasonography in older adults reported that a decrease in TMM was associated with a decrease in walking ability.[17] Therefore, it is considered that TMM decreases after hip fracture and that decreased TMM is associated with decreased walking ability. These findings suggest that it is important to evaluate TMM in patients with hip fracture and that its relationship with walking ability should be clarified.

To date, no study has investigated the effects of TMM and AMM, as evaluated by BIA, on walking independence in patients after hip fracture. We hypothesized that a decrease in TMM, rather than AMM, would be more strongly associated with walking independence in patients with hip fracture. Therefore, the purpose of this study was to investigate the effect of TMM and AMM on walking independence, as evaluated by BIA.

MATERIALS AND METHODS

This retrospective observational study included patients admitted to a convalescent rehabilitation ward in Okinawa, Japan, between April 2019 and March 2021. The study participants comprised patients with hip fracture (aged ≥65 years) who were admitted for rehabilitation post-fracture treatment. Patients who could not perform ADL independently before the injury, those with missing data, and those discharged owing to acute exacerbation were excluded (**Fig. 1**).

Data Collection

The data on age, sex, height, weight, body mass index (BMI), fracture type (i.e., femoral neck or intertrochanteric fracture), date of surgery, type of surgery (i.e., open reduction and internal fixation or femoral head replacement), Mini-Mental State Examination-Japanese (MMSE-J),[18] Mini Nutritional Assessment-Short Form (MNA-SF), onset–admission days, length of hospital stay, Functional Independence Measure (FIM) at admission and discharge, and rehabilitation volume (min/day) were collected from the patient medical records. MNA-SF was used as a nutritional screening tool and scores were assigned by a registered dietitian upon admission. MNA-SF consists of the following six items: food intake, weight loss, mobility, physical/mental stress, neuropsychological problems, and BMI; each scored from 0 to 2 (or 3), with a total score ranging from 0 to 14.[19] Rehabilitation volume was calculated using the rehabilitation minutes per day during the hospitalization period. Rehabilitation consisted of physical and occupational therapy for 60–180 min per day. Physical therapy included standing, transferring, and walking, whereas occupational therapy included ADL training, such as standing, transferring, toileting, and changing clothes.

ADL Assessment

FIM is an evaluation method that assesses the amount of assistance required by a patient for various activities. It uses a 7-point scoring scale to assess 13 motor items and 5 cognitive items, with a minimum total score of 18 (low ADL) and a maximum score of 126 (high ADL). ADL was assessed using the FIM scale, and the FIM scores were calculated by nurses at admission and discharge.[20] The patients were classified into groups of walking independence (FIM-walk score ≥6) and non-independence (FIM-walk score ≤5) according to the score of the mobility item among the motor FIM items during discharge. A score of 6 or higher on the mobility item of the motor FIM indicated that the patient could walk independently with aids to advance 50 m.

Calculation of Trunk Muscle Mass Index and Appendicular Skeletal Muscle Mass Index

Trunk muscle mass index (TMI) and appendicular skeletal muscle mass index (ASMI) were assessed using BIA. TMI and ASMI were calculated by dividing the TMM and AMM by the square of the height. Measurements were performed upon admission by a registered dietitian using an InBody S10 analyzer (InBody, Tokyo, Japan) and were recorded within 7 days. Measurements using the InBody S10 can be

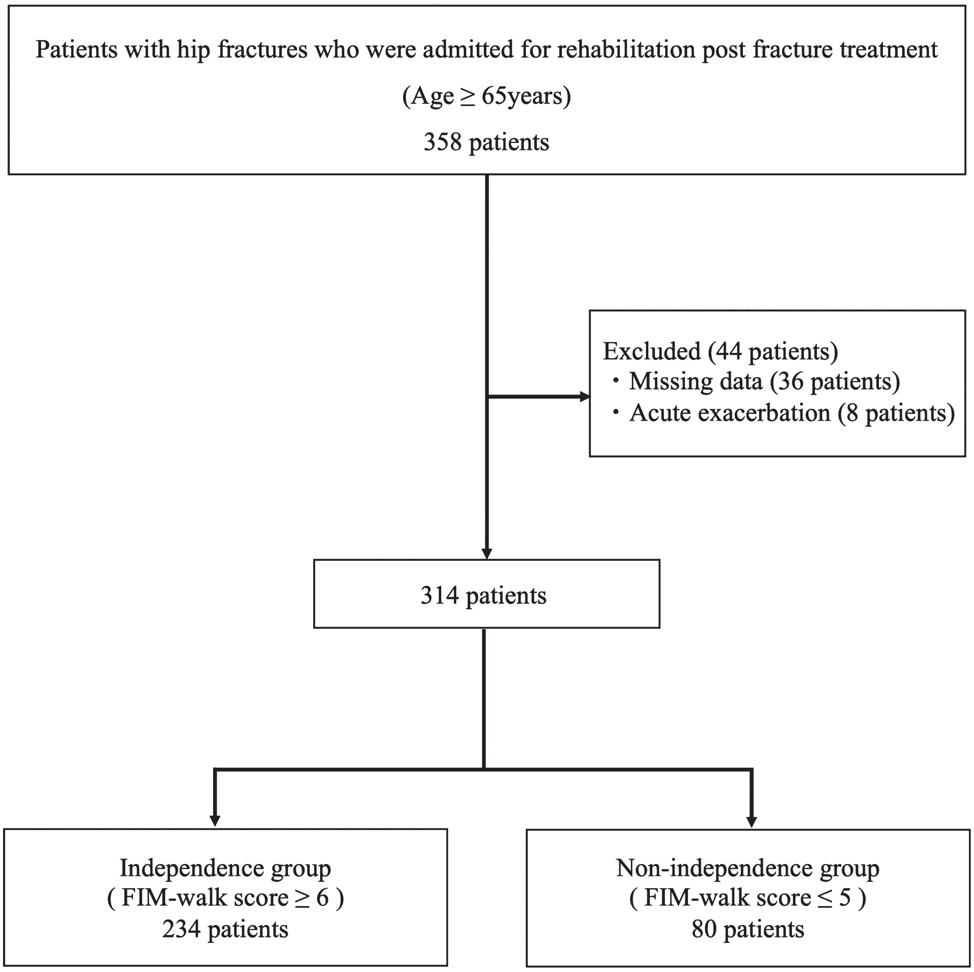

Fig. 1. Flowchart of the patient selection process.

performed by placing patients in the supine position without any burden to the patient. After 15 min of rest in the supine position, electrodes were placed on the thumbs, third fingers, and wrists of both hands for measurement.

Ethics Approval

This study was approved by the Chuzan Hospital Ethics Committee (ID: 22–21). Because of the retrospective design of the study, the opt-out procedure was used to provide all participants with the option to exclude their data from the analysis. All experimental procedures were performed in accordance with the principles of the Declaration of Helsinki (revised October 2013).

Statistical Analysis

The Shapiro–Wilk test was used to determine normality. Age, height, BMI, TMI at admission, ASMI at admission, MMSE-J at admission, MNA-SF at admission, onset–admission days, FIM score at admission and discharge, length of hospital stay, and rehabilitation volume were compared between groups using Student's *t*-test or the Mann–Whitney U test. Sex, fracture type, and surgery were compared between groups using Fisher's exact probability test. Quantitative variables, including parametric and nonparametric variables, were reported as mean ± standard deviation and median (interquartile range), respectively. Logistic regression analysis was used to investigate the association between walking independence, TMI, and ASMI at admission. Explanatory variables included those reported to be associated with walking independence in prior studies or those considered clinically relevant. The number and selection of explanatory variables were determined based on sample size and multicollinearity. To investigate the influence of TMI and ASMI in this study, TMI was input into Model 1, ASMI into Model 2, and both TMI and ASMI were input into Model 3. Other variables were age,[3] sex,[21] MMSE-J on admission,[22] MNA-SF on admission,[23] FIM on admission,[24] length of hospital stay,[25] and rehabilitation volume.[26] Furthermore, we confirmed the absence of multicollinearity when the variance inflation factor between all variables was less than 5. Discrimination of the model was measured using the area under the curve (AUC) of the receiver operating characteristic (ROC) curve, a measure commonly referred to as the C-statistic, including a 95% confidence interval (CI). The calibration of the model was examined using the Hosmer-Lemeshow goodness-of-fit test.[27] All statistical analyses were performed using JMP 15 (SAS Institute, Cary, NC, USA).

RESULTS

During the study period, 358 patients were enrolled in the study. Of these, 44 patients were excluded because of missing data or because of changes in their physical condition. A total of 314 patients (100 males and 214 females) were included in the analysis. The mean age of the patients was 80.0 ± 9.5 years; 234 patients (69 males and 165 females) were in the walking independence group, and 80 (31 males and 49 females) were in the non-independence group. The demographics and clinical characteristics of the patients are presented in **Table 1**. Compared with the non-independence group, the walking independence group was younger (80.0 ± 9.8 vs. 83.5 ± 8.0 years, P=0.005) and had a higher TMI (males: 6.6 ± 0.9 vs. 5.6 ± 1.0 kg/m^2, P<0.001; females: 6.1 ± 0.8 vs. 5.7 ± 1.0 kg/m^2, P<0.001), ASMI (males: 6.7 ± 1.1 vs. 5.9 ± 1.3 kg/m^2, P=0.004; females: 5.3 ± 0.9 vs. 4.7 ± 0.8 kg/m^2, P<0.001), MMSE-J (21.5 ± 4.9 vs. 16.4 ± 4.5 points, P<0.001), and MNA-SF [8 (6–9) vs. 7 (5–8), P<0.001] on admission. In addition, the FIM scores at admission (69.5 ± 14.6 vs. 54.0 ± 17.0 points, P<0.001) and discharge (105.1 ± 18.5 vs. 77.9 ± 20.5 points, P<0.001) were higher in the walking independence group than in the non-independence group.

Table 2 shows the results of the logistic regression analysis on the level of walking independence. Logistic regression analysis showed that TMI [odds ratio (OR): 1.86, 95% CI: 1.28–2.72, P<0.001] was associated with walking independence in Model 1 and ASMI (OR: 1.46, 95% CI: 1.01–2.12, P=0.011) was associated with walking independence in Model 2. TMI had a higher odds ratio than ASMI. In Model 3, TMI (OR: 1.25, 95% CI: 1.05–1.48, P=0.012) was the only factor associated with walking independence. The C statistic was 0.86 (95% CI: 0.81–0.90) and 0.85 (95% CI: 0.80–0.90) and 0.87 (95% CI 0.82–0.92) for Models 1 and 2 and 3, respectively. Assessment of the calibration of the models by the Hosmer-Lemeshow goodness-of-fit test gave values of P=0.69 and P=0.72 and P=0.81 for Models 1 and 2 and 3, respectively.

DISCUSSION

This study examined the association between TMI and ASMI, as assessed by BIA, and gait independence in hip fracture patients admitted to a convalescent rehabilitation ward. The results showed that TMI was significantly more associated with walking independence at discharge than ASMI in patients with hip fracture. Therefore, the results suggest that TMI is important for ambulatory independence at discharge in patients treated for hip fracture.

The TMI of patients with hip fracture was significantly associated with the degree of walking independence at discharge. In this study, we added ASMI to the covariates, and the results showed that TMI was a better predictor than ASMI, suggesting that TMM at admission was associated with walking independence in patients with hip fracture. In a previous study, the loss of TMM as evaluated by BIA was associated with decreased walking ability in patients with osteoporosis.[28] In another study, a decrease in TMM as evaluated by ultrasonography in older patients was associated with a decrease in walking ability.[17] These findings suggest that TMM is important for restoring walking independence. However, these studies included patients with osteoporosis and older patients, not those with hip fractures. Generally, TMM is not strongly affected by age-related atrophy.[29–32] Therefore, to regain independent walking, TMM may be maintained with slight muscle contractions during routine exercise, regardless of aging, without any specific exercise.

This study highlights the importance of evaluating TMM in patients with hip fracture. Previous studies that used CT to evaluate TMM in patients with hip fracture reported that patients with fractures have markedly lower TMM than those without fracture.[16] Moreover, the loss of TMM as evaluated by BIA was associated with an increased incidence of femoral neck fracture.[10] Therefore, in older patients with hip fractures, TMM should be evaluated early. Previous studies have investigated the relationship between loss of TMM and walking ability as evaluated by ultrasonography.[17] Although ultrasonography can evaluate muscle mass noninvasively, it is not yet widely used. BIA is the gold standard method of evaluating muscle mass and is widely used in clinical practice as a simple and noninvasive instrument for evaluating muscle mass.[33] Therefore, TMI as evaluated by BIA could be used effectively in clinical practice.

This study has some limitations. First, the statistical methods of this study do not show a causal relationship between TMM and walking independence. Therefore, further studies are required to verify this causal relationship. Second, the

Table 1. Patient characteristics in the independence and non-independence groups

	All patients (n=314)	Independence group (n=234)	Non-independence group (n=80)	P value
Age, years	80.0 ± 9.5	80.0 ± 9.8	83.5 ± 8.0	0.005
Sex, n (%)				0.129
Male	100 (32)	69 (30)	31 (39)	
Female	214 (68)	165 (70)	49 (61)	
Height, m	1.52 ± 0.1	1.52 ± 0.1	1.51 ± 0.1	0.326
BMI, kg/m^2	21.7 ± 4.0	22.1 ± 3.7	20.4 ± 4.6	<0.001
Fracture type, n (%)				0.466
Femoral neck fracture	230 (73)	174 (74)	56 (70)	
Intertrochanteric fracture	84 (27)	60 (26)	24 (30)	
Surgery, n (%)				0.667
ORIF	88 (28)	64 (27)	24 (30)	
FHR	226 (72)	170 (73)	56 (70)	
TMI on admission, kg/m^2				
Male	6.3 ± 1.0	6.6 ± 0.9	5.6 ± 1.0	<0.001
Female	6.0 ± 0.8	6.1 ± 0.8	5.7 ± 1.0	<0.001
ASMI on admission, kg/m^2				
Male	6.4 ± 1.2	6.7 ± 1.1	5.9 ± 1.3	0.004
Female	5.2 ± 0.9	5.3 ± 0.9	4.7 ± 0.8	<0.001
MMSE-J on admission, points	20.2 ± 5.3	21.5 ± 4.9	16.4 ± 4.5	<0.001
MNA-SF, points	8 [6–9]	8 [6–9]	7 [5–8]	<0.001
Onset–admission days	22.4 ± 9.7	21.9 ± 8.9	24.1 ± 12.8	0.083
FIM on admission, points	63.9 ± 17.6	69.5 ± 14.6	54.0 ± 17.0	<0.001
Length of hospital stay, days	65.3 ± 26.7	63.4 ± 25.5	70.9 ± 29.2	0.031
Rehabilitation volume, min/day	125.7 ± 22.4	128.1 ± 19.7	118.7 ± 27.9	<0.001
FIM at discharge, points	98.2 ± 22.4	105.1 ± 18.5	77.9 ± 20.5	<0.001

Continuous variables are displayed as mean ± standard deviation. Other data are presented as number (percentage) or median [interquartile range].
ORIF, open reduction and internal fixation; FHR, femoral head replacement.

results suggest that differences in rehabilitation programs affect the degree of walking independence at discharge. In this study, all patients received conventional rehabilitation from the day of admission. Rehabilitation programs consisted of physical and occupational therapy for 60–180 min per day. The rehabilitation program included standing, walking, and ADL exercises. However, the individual implementation of these exercises, such as frequency and intensity, were unclear and not standardized. Third, although muscle mass was evaluated using BIA in this study, the measured values of TMM may be subject to error owing to visceral mass and edema. Future studies adjusting for these confounding factors are needed.

CONCLUSION

TMI at admission in patients with hip fracture was significantly associated with walking independence at discharge. Maintenance of TMI should be considered important for patients to achieve walking independence after hip fracture.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

Table 2. Multivariate logistic regression of walking independence

Factor	Model 1			Model 2			Model 3		
	OR (95% CI)	P value	VIF	OR (95% CI)	P value	VIF	OR (95% CI)	P value	VIF
TMI on admission	1.86 (1.28–2.72)	<0.001	1.10	–	–	–	1.25 (1.05–1.48)	0.012	1.74
ASMI on admission	–	–	–	1.46 (1.01–2.12)	0.011	1.87	1.16 (0.74–1.82)	0.530	2.12
Age	0.97 (0.93–1.01)	0.098	1.07	0.97 (0.94–1.01)	0.160	1.08	0.98 (0.94–1.02)	0.330	1.08
Sex	0.49 (0.25–0.96)	0.039	1.12	0.32 (0.14–0.73)	<0.001	1.69	0.23 (0.08–0.62)	0.004	1.77
MMSE-J on admission	1.18 (1.09–1.28)	<0.001	1.16	1.19 (1.10–1.29)	<0.001	1.19	1.16 (1.06–1.28)	<0.001	1.25
MNA-SF on admission	0.94 (0.81–1.08)	0.360	1.26	0.92 (0.79–1.06)	0.240	1.43	0.91 (0.76–1.09)	0.300	1.40
FIM on admission	1.04 (1.01–1.06)	<0.001	1.31	1.03 (1.01–1.06)	0.003	1.33	1.03 (1.00–1.06)	0.042	1.38
Length of hospital stay	0.99 (0.98–1.00)	0.100	1.01	0.99 (0.97–1.00)	0.056	1.04	0.99 (0.98–1.01)	0.270	1.05
Rehabilitation volume	1.03 (1.01–1.04)	0.002	1.05	1.03 (1.01–1.04)	0.001	1.06	1.05 (1.03–1.07)	<0.001	1.09

For sex, male is coded as 0, female is coded as 1. Model 1, AUC 0.86 (95% CI 0.81–0.90), Hosmer-Lemeshow test P=0.69; Model 2, AUC 0.85 (95% CI 0.80–0.90), Hosmer-Lemeshow test P=0.72; Model 3, AUC 0.87 (95% CI 0.82–0.92), Hosmer-Lemeshow test P=0.81.

VIF, variance inflation factor.

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