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Original Article

Prediction of gait independence by using the phase angle in postoperative patients with proximal femoral fractures: a retrospective study

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Abstract. [Purpose] This study was aimed at investigating the relationship between skeletal muscle mass and muscle quality by using bioelectrical impedance analysis and ambulatory independence in patients with proximal femoral fractures. [Participants and Methods] The study included 120 patients admitted to a recovery rehabilitation unit for whom follow-up assessments were available. Skeletal muscle mass and phase angle were assessed using bioelectrical impedance analysis upon admission. The patients were divided into the following two groups based on their Functional Independence Measure gait score at discharge: gait-independent group (gait score: ≥6; n=74) and gait-dependent group (gait score: ≤5; n=46). [Results] The phase angle was associated with gait independence. The cut-off values for the phase angle predicting gait independence were 4° and 3.8° for male and female patients, respectively, a more accurate assessment compared with skeletal muscle mass analysis. [Conclusion] The phase angle was associated with gait independence in patients with proximal femoral fractures. The results of this study suggest that the evaluation of the phase angle is important for predicting gait independence in patients with proximal femoral fractures.

Key words: Femoral proximal fracture, Phase angle, Gait

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INTRODUCTION

Most patients with femoral proximal fractures (FPF) are older, and their ability to walk after FPF is reduced, with only 33% of patients returning to their preinjury gait ability[1)]. Furthermore, the ability to walk after FPF surgery is strongly correlated with subsequent life expectancy[2)]. Regaining the ability to walk after surgery is important. Previous studies have shown that gait ability in patients with FPF is associated with age, sex, fracture site, presence of dementia, malnutrition, and lower limb muscle strength[3–5)]; another factor is a decrease in skeletal muscle mass[6)]. Loss of skeletal muscle mass occurs in 60% of FPF patients[7)], and it is reportedly associated with activities of daily living and survival[8)]. However, other studies have shown that muscle quality is more important than skeletal muscle mass in improving the ability to perform and improve lower limb muscle strength after FPF surgery[9)]. Evaluation should also focus on muscle quality after FPF. Bioelectrical impedance analysis (BIA) has recently been widely used to evaluate skeletal muscle[10)]. Bioelectrical impedance analysis is a noninvasive method for estimating body composition by applying a weak alternating current to the body and measuring impedance, which allows evaluation with high accuracy and reproducibility[11)]. Bioelectrical impedance analysis can evaluate skeletal muscle mass in each region as well as the appendicular skeletal muscle mass index (ASMI) and phase angle (PhA), which are considered indicators of aging and the nutritional status of cells and cell membranes[12, 13)]. The European Working Group 2019 Consensus Statement indicates that PhA may be an indicator of muscle quality[14)], and PhA has been associated

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with lower-extremity muscle strength and balance ability in FPF patients[10, 15]. Furthermore, studies involving older patients have shown that qualitative muscle loss occurs earlier than skeletal muscle volume loss[16, 17], suggesting the importance of early assessment of muscle quality. Therefore, muscle quality assessment should be performed in FPF patients, many of whom are elderly. Elucidating the relationship between muscle quality and walking independence is important for predicting gait outcomes. However, to the best of our knowledge, no previous study has investigated the relationship between gait independence and PhA in patients with FPF using BIA. We hypothesized that PhA may be more strongly related to gait independence compared with skeletal muscle mass, even in older patients with FPF. Therefore, this study aimed to determine the relationship between PhA and gait independence in patients with FPF and to calculate PhA cut-off values at admission to predict gait independence.

PARTICIPANTS AND METHODS

This is a retrospective study. Patients after FPF surgery who were admitted to the rehabilitation ward of Saiseikai Kibi Hospital between March 2022 and March 2024 were included in the study. Study inclusion criteria included: patients with FPF aged 65 years or older, patients who could not walk independently upon admission. Exclusion criteria was as follows: 4 patients with missing data, 14 patients who were unable to walk before the injury, and 4 patients who were transferred or discharged because of an acute exacerbation. This study was reviewed and approved by the Ethical Review Committee of the Okayama Saiseikai General Hospital (ID: 240402). Owing to the retrospective design of this study, all participants were offered the opportunity to exclude their data from analysis using an opt-out method.

Patient medical records were analyzed for age, sex, body mass index (BMI), type of fracture (femoral neck fracture or femoral metaphyseal fracture), type of surgery (open fixation or femoral head replacement), onset-admission days, length of hospital stay, Charlson Comorbidity Index (CCI)[18], Mini-Mental State Examination-Japanese (MMSE-J)[19], and Mini Nutritional Assessment-Short Form (MNA-SF)[20]. The MMSE-J is an 11-item cognitive assessment tool that includes items on registration, immediate recall, attention, test performance, delayed replay, item naming, sentence recall, oral and written directions, spontaneous writing, and graphing ability[19]. The MNA-SF is used as a nutritional screening tool and consists of six items: food intake, weight loss, motor skills, physical/mental stress, neuropsychological problems, and BMI. The total score ranges from 0 to 14, with a score of 7 or less considered poor nutrition[20]. Gait independence at admission and discharge were assessed using the Functional Independence Measure Gait (FIM-G) score[21]. Patients were divided into two groups: a gait independent group (FIM-G score ≥6) and a gait-dependent cohort (FIM-G score ≤5). An FIM-G score ≥6 indicates that the patient can walk independently up to 50 m with the use of an assistive device. ASMI and PhA were assessed using the BIA method; ASMI was calculated by dividing the appendicular skeletal muscle mass by the height squared. Measurements were taken on admission by a physiotherapist using an InBody S10 body composition analyzer (Tokyo, Japan). Measurements were taken after a 10-minute rest period in the supine position at least 2 hours after a meal.

Age, BMI, CCI, ASMI at admission, PhA at admission, MMSE-J at admission, MNA-SF at admission, days from onset to admission, days in hospital, and FIM-G scores at admission were compared between the groups using Student's t-test. Sex, fracture, and type of surgery were compared between groups using Fisher's exact probability test. Multiple logistic regression analysis (forced entry method) was used to investigate associations among gait independence, ASMI, and PhA. For explanatory variables, we selected items that have been previously reported to be associated with gait independence in previous studies or items that were thought to be clinically related to gait. We selected ambulatory independence as the objective variable, and age, sex, BMI, CCI, admission MMSE-J, admission MNA-SF, admission FIM-G, days in hospital, ASMI, and PhA as explanatory variables. Furthermore, we confirmed the absence of multi-collinearity when the variance inflation factor between all variables was <5. The results of multiple logistic regression analysis were examined using odds ratios (ORs) and 95% confidence intervals (95% CI), and goodness-of-fit of the model was examined using the Hosmer–Lemeshow goodness-of-fit test. The discriminatory capacity of the model was examined using the area under the receiver operating characteristic (ROC) curve (AUC), and the Youden index was used to calculate cut-off values for PhA. Because ASMI and PhA values were higher in men than in women in previous studies[22, 23], ASMI and PhA analyses were performed separately for men and women. Easy R (Saitama, Japan)[24] was used for all statistical analyses. The statistical significance level was set at p<0.05.

RESULTS

A total of 142 patients with hip fractures were included in this study. Of these, 22 were excluded due to missing data or acute deterioration, and a total of 120 patients (mean age: 84.9 ± 8.3 years, mean BMI: 20.4 ± 3.4 kg/m^2) were included in the analysis. 74 patients (23 males, 51 females) were included in the ambulatory independence group and 46 patients (19 males, 27 females) in the non-independence group. The ambulatory independent group was younger (p<0.05) and had lower CCI scores (p<0.001) than the non-independent group. The independent walking group showed significantly higher MMSE-J (p<0.001), MNA-SF (p<0.001), ASMI (p<0.05), and PhA scores (p<0.001 for both males and females) than did the non-independent walking group (Table 1). Logistic regression analysis (multivariate model) showed that PhA (males, ORs: 0.07, CI: 0.007–0.69, p<0.05; females, ORs: 0.2, CI: 0.04–0.81, p<0.05) was associated with gait independence in both males and females (Table 2). The AUC was 0.91 (CI: 0.81–0.99) and 0.91 (CI: 0.82–0.97) for males and females, respectively. Model calibration was assessed using the Hosmer–Lemeshow goodness-of-fit test, which was p=0.18 and p=0.33 for males and females, respectively. ROC analysis of PhA showed AUC of 0.87 and 0.76 for males and females, with calculated cut-off values of 4.04° (sensitivity: 84.2%, specificity: 82.6%) and 3.82° (sensitivity: 70.3%, specificity: 70.5%), respectively. The AUC of the PhA was higher than that of the ASMI (0.55 for males and 0.63 for females).

Table 1. Characteristics of patients in the independent and non-independent gait groups

	All patients (n=120)	Independent group (n=74)	Non-independent group (n=46)
Age, years**	84.9 ± 8.3	83.3 ± 8.5	87.5 ± 7.6
Sex, n (%)			
Male	42 (35)	23 (31)	19 (41)
Female	78 (65)	51 (69)	27 (59)
BMI, kg/m^2	20.4 ± 3.4	20.8 ± 3.6	19.7 ± 3.0
Fracture type, n (%)			
Femoral neck fracture	61 (51)	33 (45)	28 (61)
Intertrochanteric fracture	59 (49)	41 (55)	18 (39)
Surgery, n (%)			
ORIF	52 (43)	35 (47)	17 (37)
FHR	68 (57)	39 (53)	29 (63)
Onset–admission, days	18.6 ± 6.1	18.1 ± 5.9	19.4 ± 6.3
Length of hospital, days	58.1 ± 16.3	56.8 ± 17.2	60.3 ± 14.8
CCI, points***	1 [1–2]	1 [0–1]	1.5 [1–2]
MMSE-J, points***	18.8 ± 8	22.3 ± 6.8	13.2 ± 6.6
MNA-SF, points***	8 [6–9]	9 [7–10]	6 [5–7]
ASMI, on admission, kg/m^2			
Male*	5.8 ± 0.7	5.9 ± 0.6	5.5 ± 0.6
Female*	4.5 ± 0.6	4.6 ± 0.5	4.3 ± 0.7
PhA, on admission, degrees			
Male***	4.0 ± 0.5	4.4 ± 0.3	3.7 ± 0.6
Female***	3.8 ± 0.6	4.0 ± 0.4	3.4 ± 0.6
FIM-G, on admission, points	1 [1–1]	1 [1–1]	1 [1–1]

*p<0.05, **p<0.01, ***p<0.001.
Mean ± standard deviation or quartiles [interquartile range], number (percentage) or shown as median.
BMI: Body mass index; CCI: Charlson comorbidity index; MMSE-J: Mini mental state examination-Japanese; MNA-SF: Mini nutritional assessment short-form; ASMI: Appendicular skeletal muscle mass index; PhA: Phase angle; FIM-G: Functional independence measure-gait; ORIF: Open repair and internal fixation; FHR: Femoral head replacement.

Table 2. Logistic regression analysis of gait independence

Factor	Male		Female	
	Univariate model	Multivariate model	Univariate model	Multivariate model
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Age	1.06 (0.98–1.16)	0.97 (0.84–1.12)	1.06 (1.00–1.14)*	0.96 (0.87–1.06)
BMI	1.01 (0.84–1.22)	1.35 (0.80–2.25)	0.83 (0.70–0.96)*	1.00 (0.72–1.40)
CCI	1.46 (0.74–2.87)	2.05 (0.47–8.94)	2.63 (1.50–5.10)**	1.56 (0.69–3.51)
Length of hospital	0.97 (0.93–1.02)	0.98 (0.91–1.05)	1.03 (1.00–1.06)*	1.01 (0.96–1.06)
MMSE-J	0.82 (0.70–0.92)**	0.93 (0.77–1.13)	0.83 (0.75–0.90)**	0.91 (0.80–1.05)
MNA-SF	0.57 (0.34–0.85)*	0.75 (0.24–2.29)	0.47 (0.33–0.67)**	0.55 (0.29–1.04)
ASMI	0.36 (0.11–0.91)*	0.30 (0.02–3.74)	0.44 (0.19–0.93)*	0.98 (0.29–3.34)
PhA	0.03 (0.02–0.21)**	0.07 (0.007–0.69)*	0.14 (0.05–0.37)**	0.20 (0.04–0.81)*
FIM-G on admission	0.95 (0.49–1.70)	1.02 (0.44–2.35)	0.74 (0.46–1.04)	1.13 (0.52–2.46)

*p<0.05, **p<0.01, ***p<0.001.
BMI: Body mass index; CCI: Charlson comorbidity index; MMSE-J: Mini mental state examination-Japanese; MNA-SF: Mini nutritional assessment short-form; ASMI: Appendicular skeletal muscle mass index; PhA: Phase angle; FIM-G: Functional independence measure-gait.

DISCUSSION

Previous studies have reported an association between PhA assessed by BIA and gait ability in older patients[25)], but not in patients with FPF. In this study, we investigated the relationship between PhA, assessed using BIA, and walking independence in patients with FPF admitted to a recovery and rehabilitation ward. The results showed that PhA in patients with FPF was more strongly associated with gait independence than with ASMI. These results suggest that PhA is a good predictor of gait independence in patients with FPF. Phase angle has been found to be an indicator of muscle quality[14)] and has been suggested to be related to lower limb muscle strength and balance in FPF patients[10, 15)]. Furthermore, studies involving older patients have shown that muscle quality declines more rapidly than skeletal muscle[16, 17)], and PhA is more sensitive to training compared with skeletal muscle mass[26)]. These findings suggest the importance of early assessment of muscle quality, and the results of this study suggest that PhA should also be assessed early in patients with FPF. Furthermore, the cut-off value of PhA calculated in this study had superior predictive ability for gait independence than ASMI, regardless of sex; this value can be used as an objective predictive index of gait independence. For example, if the PhA is below the cut-off value, the patient may have difficulty walking independently at the time of discharge, and appropriate support can be provided early after hospitalization. Other studies have employed ultrasonography and muscle biopsies for skeletal muscle assessment[16, 17)]; however, these techniques are not widely used because they are invasive and require examiner expertise. In contrast, BIA is widely used in clinical practice for simple and non-invasive skeletal muscle assessment[11)]. Furthermore, PhA is calculated using a simple formula that does not depend on a specific formula for each measuring instrument in the BIA method; thus, it has high affinity and is not easily affected by body weight, height, or body water content[13, 23)]. Therefore, we believe that PhA assessed using BIA can be effectively used in clinical practice as a simple and objective index to evaluate muscle quality. Finally, the cut-off values of PhA calculated in this study (males, 4.04°; females, 3.82°) were lower than those for normal Asian subjects (6.55°)[27)] and for the incidence of disability in the older population (males, 4.95°; females, 4.35°)[28)]. In previous studies, lower PhA values were associated with aging[27)], malnutrition[27)], and lower skeletal muscle mass[29)] which are characteristics associated with FPF patients. Notably, most of the participants in this study were older and had poor nutritional status. Furthermore, ASMI values of the study participants were below the diagnostic criteria for sarcopenia (7 kg/m^2 in men and 5.7 kg/m^2 in women)[12)], and their skeletal muscle mass was reduced. Therefore, the cut-off values in this study should only be applied to patients with hip fractures.

The present study had some limitations. The first this study is that it was a retrospective study, and thus could not examine potential confounders such as the amount of physical activity and gait prior to the injury or the details of the exercise therapy performed. Second, this was a single-center study, which may have introduced selection bias in the selection of subjects. Therefore, the results of this study cannot be applied to all patients who have sustained a proximal femur fracture. Future prospective or multicenter studies should be conducted to investigate potential confounding factors.

In conclusion, PhA was associated with walking independence in patients with FPF. The results of this study suggest that assessment of PhA is important in predicting walking independence in patients with FPF.

Conflicts of interest

The authors declare no conflicts of interest.

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