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Phase Angle as a Nutritional Assessment Method in Patients with Hip Fractures: A Cross-Sectional Study

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Background: Phase angle, which is associated with cellular health, has attracted attention as a noninvasive and objective method for nutritional assessment. However, the association between malnutrition and phase angle in older inpatients with hip fractures has not been reported. Therefore, this study investigated this association in older inpatients (aged ≥65 years) with hip fractures and determined the cutoff phase angle for determining malnutrition. **Methods:** This cross-sectional study retrospectively analyzed the data of 96 inpatients with hip fractures who were hospitalized in rehabilitation units after surgery (male, 29.4%; mean age, 82.4±6.2 years). Nutritional status was assessed using the Geriatric Nutritional Risk Index (GNRI), with malnutrition defined as a GNRI ≥98. Bioelectrical impedance analysis was used to measure phase angles. **Results:** The phase angle was associated with malnutrition (B=–1.173; odds ratio=0.310; 95% confidence interval 0.58–0.83; p=0.015). The area under the receiver operating characteristic curve was 0.71. The cutoff phase angle for malnutrition was 3.96° (sensitivity=0.85, specificity=0.63). **Conclusion:** Phase angle could be an indicator of malnutrition in older inpatients with hip fractures. Our findings will help formulate rehabilitation strategies for these patients.

Key Words: Aged, Hospitalization, Nutrition, Rehabilitation, ROC curve

INTRODUCTION

The incidence of hip fractures is increasing worldwide.[1] Hip fracture is associated with increased hospitalization and rehabilitation costs, a high societal burden given its association with adverse outcomes, including depression and cardiovascular diseases.[1] In Japan, the cost of treating patients with hip fractures leads to economic burdens on society.[2] Additionally, older adults with hip fractures have high mortality rates.[3] Therefore, effective rehabilitation measures are essential for older adults with hip fractures.

Due to insufficient recovery, many older adults with hip fractures require assistance in their daily activities. Specifically, 20%–60% of older adults with hip fractures require assistance for one year after treatment, despite having been independent in daily life before their injury.[4] Furthermore, >40% of individuals present with new-onset walking disability six months after a hip fracture,[5] indicating the insufficiencies of strategies to promote recovery in older patients with fractures.

Several factors, including age, sex, and comorbidities, can hinder recovery in patients with a hip fracture,[6] with malnutrition being a crucial modifying factor.[7,8] Malnutrition further increases the risk of institutionalization and mortality in older inpatients with hip fractures.[9] Therefore, the accurate assessment of the nutritional status of older inpatients with hip fractures and the provision of appropriate interventions are essential.

However, the subjective nutritional assessments recommended in inpatient and rehabilitation settings, including the Nutritional Form for the Elderly and Mini Nutritional Assessment Short Form

Version 1,[10] are dependent on changes in weight and food intake. Therefore, their ability to accurately assess patients with severe cognitive impairment may be limited. Additionally, these assessments demonstrate interobserver variability.[11] While objective nutritional assessments, including the Geriatric Nutritional Risk Index (GNRI),[12] are dependent on serum albumin concentration, which is measured using blood tests, blood tests are invasive and may not be performed routinely. Therefore, new objective and routine assessment methods are required.

Phase angle, which can be measured using bioelectrical impedance analysis, is associated with cellular health. The phase angle has recently received attention as a noninvasive and objective method for nutritional assessment.[13,14] Poor nutritional status damages cells, thus decreasing the phase angle; hence, the phase angle can reflect nutritional status. In particular, the phase angle is useful for nutritional assessment in older inpatients.[15]

Bioelectrical impedance analysis is a simple, low-cost, and reproducible tool,[16] and the phase angle is a versatile and practical method that can be used to assess nutrition. Phase angle may be influenced by certain diseases.[17,18] For example, postoperative edema in patients with hip fractures may affect body composition, which, in turn, influences the phase angle.[19] A previous study demonstrated a lower phase angle in patients with hip fractures admitted to rehabilitation units in Japan compared to that of healthy individuals.[20] However, the link between nutritional status and phase angle in older inpatients with hip fractures has not yet been investigated.

Nutritional assessment using bioelectrical impedance analysis may provide useful information for rehabilitation interventions in patients with hip fractures. Therefore, this study assessed the association between the phase angle measured using bioelectrical impedance analysis and malnutrition in older inpatients with hip fractures and ascertained the optimal cutoff phase angle for identifying malnutrition.

MATERIALS AND METHODS

Setting, Design, and Participants

This study was conducted at Tokai Memorial Hospital, Kasugai City, and Saishukan Hospital, Kitanagoya City, both located in Aichi Prefecture, Japan. Both facilities have 50-bed rehabilitation units used for the rehabilitation of patients who have completed treatment or surgery. This cross-sectional study retrospectively collected data from the medical records of hospitalized patients.

We included 103 inpatients with hip fractures aged ≥65 years who were admitted to the rehabilitation unit of Tokai Memorial Hospital between September 2017 and November 2021 or Saishukan Hospital between December 2019 and November 2021. The exclusion criteria were the presence of stroke, spinal cord injury, or other diseases that significantly impaired physical function; an inability to undergo bioelectrical impedance analysis; and missing values for the data required to calculate the GNRI, including height, weight, and serum albumin concentration. Finally, the analysis included 96 participants (Fig. 1).

Procedure

We collected data on age, sex, height, weight, comorbidities, cognitive function, muscle mass, activities of daily living, phase angle, serum albumin level, date of surgery, and the date on which the phase angle and serum albumin level were measured from the patients' medical records. The body mass index was calculated by dividing the weight (kg) by the height (m^2).

Comorbidities were assessed using the Charlson Comorbidity Index (CCI),[21] which is positively correlated with mortality risk. Cognitive function was assessed using the Mini-Mental State Examination (MMSE), a global cognitive function test used in clinical settings,[22] in which a lower score indicates more severe cognitive impairment. The skeletal muscle index (SMI) was calculated based on the skeletal muscle mass of the limbs, as measured using bioelectrical impedance analysis. The SMI was computed by dividing the total skeletal muscle mass of the limbs by the patient's height (m^2). For bioelectrical impedance analysis, both hospitals used InBody S10 devices (InBody Inc., Tokyo, Japan) and performed the measurements according to the manufacturer's instructions. After adequate rest, the InBody S10 was used with each participant in the supine position. The electrodes were attached to the thumb, middle finger, and ankle. All metal objects were removed from the patients to avoid measurement errors. The motor functional independence measure (mFIM) score was used to evaluate activities of daily living. The mFIM assesses self-care and mobility, with higher scores indicating greater independence.

The phase angle was calculated using the resistance and reactance values obtained from the non-fractured limbs and trunk using bioelectrical impedance analysis at a frequency of 50 kHz.[19]

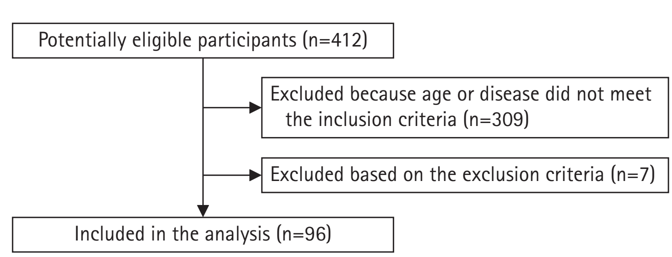

Fig. 1. Study flowchart.

The phase angle represents cellular health, and the higher the value, the better the condition. The phase angle is typically between 8° and 15° and decreases with poor health and disease.[20)]

The phase angle was computed using the following equation:

$$\text{Phase angle } (°) = \arctan(\text{reactance} / \text{resistance}) \times (180°).$$

We assessed nutritional status using the GNRI, an objective nutrition-related risk index developed for older adults based on the Nutritional Risk Index. The GNRI is used as a nutritional index for hospitalized adults[12)] and is an excellent indicator for older inpatients.[23)] In this study, we defined malnutrition as a GNRI of ≤ 98, as in previous studies.[12)] The GNRI was calculated using the following formulas[12)]:

GRNI = [14.89 × serum albumin (g/dL)] + 41.7 × [current weight (kg) / ideal weight (kg)],

where,

Ideal weight = height (cm) × 100 × [(height (cm) × 150) / 4] (for men),

Ideal weight = height (cm) – 100 – [(height (cm) – 150) / 2.5] (for women).

Cognitive function assessment, InBody S10 measurement to calculate muscle mass and phase angle, and assessment of activities of daily living were performed by physical and occupational therapists at each facility.

Data Analysis

Patient characteristics are described using descriptive statistics. We analyzed the relationship between malnutrition and other factors using Spearman rank correlation coefficients. To assess the association between the phase angle and malnutrition, we performed a binomial logistic regression analysis with malnutrition as the dependent variable and variables correlated with malnutrition as independent variables.

Subsequently, we performed receiver operating characteristic (ROC) curve analysis to determine the cutoff phase angle for malnutrition and calculated the area under the ROC curve (AUC) as an indicator of model accuracy, in which a value of ≥ 0.7 indicates acceptable accuracy.[24,25)] The cutoff value was the point on the ROC curve closest to 1 for "sensitivity" and closest to 0 for "1–specificity". The statistical analyses were performed using IBM SPSS Statistics, version 28.0 (IBM, Tokyo, Japan). Statistical significance was set at $p < 0.05$.

Ethical Considerations

This study was approved by the Institutional Review Boards of the Tokai Memorial Hospital (Approval No. 2019-004), Saishukan Hospital (Approval No. 059), and Seijoh University (Approval No. 2022C0017). All the study procedures conformed to the principles outlined in the Declaration of Helsinki. The results were reported following the Strengthening the Reporting of Observational Studies in Epidemiology statement. Also, this study complied the ethical guidelines for authorship and publishing in the *Annals of Geriatric Medicine and Research*.[26)]

RESULTS

The mean ± standard deviation age of the patients was 82.4 ± 6.2 years, the mean phase angle was 3.96° ± 0.76°, and 76 patients (79.2%) had malnutrition (GNRI of ≤ 98). The patient characteristics are listed in Table 1.

Spearman rank correlation coefficient revealed significant correlations between malnutrition and SMI ($r = -0.210$, $p = 0.041$) and phase angle ($r = -0.29$, $p = 0.004$) but not between malnutrition and the other variables—age ($r = 0.014$, $p = 0.893$), sex ($r = -0.093$, $p = 0.37$), CCI ($r = 0.046$, $p = 0.654$), MMSE ($r = -0.097$, $p = 0.366$), and mFIM ($r = 0.051$, $p = 0.619$).

Binomial logistic regression confirmed the association of phase angle with malnutrition—crude model (odds ratio [OR] = 0.35, 95% confidence interval [CI] 0.17–0.72) and adjusted model (adjusted by age, sex, and SMI; OR = 0.31, 95% CI 0.12–0.80) (Table 2). The ROC curve analysis revealed an AUC of 0.71 (95% CI

Table 1. Demographic characteristics of the patients (n=96)

Characteristic	Value
Age (y)	82.44 ± 6.18
Sex, male	30 (29.41)
Height (cm)	151.97 ± 47.90
Weight (kg)	47.90 ± 9.16
BMI (kg/m^2)	20.70 ± 3.29
Charlson Comorbidity Index	1.00 (0.0–2.0)
Mini-Mental State Examination[a)]	21.48 ± 5.95
SMI (kg/m^2)	5.51 ± 1.01
Motor functional independence measure	50.33 ± 14.96
Phase angle (°)	3.96 ± 0.76
Serum albumin (g/dL)	3.45 ± 0.48
Geriatric Nutritional Risk Index	90.07 ± 9.98
Malnutrition (presence)[b)]	76 (79.17)
Days from surgery to bioelectrical impedance analysis	26.97 ± 13.69
Days from surgery blood test	18.91 ± 13.60

Values are presented as mean±standard deviation or number (%) or median (interquartile range).
BMI, body mass index; SMI, skeletal muscle index.
[a)]Missing rate: 8 (8.3%).
[b)]Malnutrition was defined as a Geriatric Nutritional Risk Index of ≤98.

Table 2. Results of the binomial logistic regression analysis for malnutrition[a)]

	Crude model			Adjusted model		
	B	OR (95 CI)	p-value	B	OR (95 CI)	p-value
Phase angle (°)	-1.065	0.345 (0.165–0.720)	0.005	-1.173	0.310 (0.120–0.796)	0.015
SMI	-	-	-	-0.772	0.462 (0.241–0.887)	0.020

SMI, skeletal muscle index; OR, odds ratio; CI, confidence interval.
Hosmer-Lemeshow test: crude model (p=0432) and adjusted model (p=0.834).
The model was adjusted for age and sex.
[a)]Malnutrition was defined as a Geriatric Nutritional Risk Index of ≤98.

0.58–0.83, p = 0.001). The cutoff phase angle for malnutrition was 3.96° (sensitivity = 0.85, specificity = 0.63) (Fig. 2).

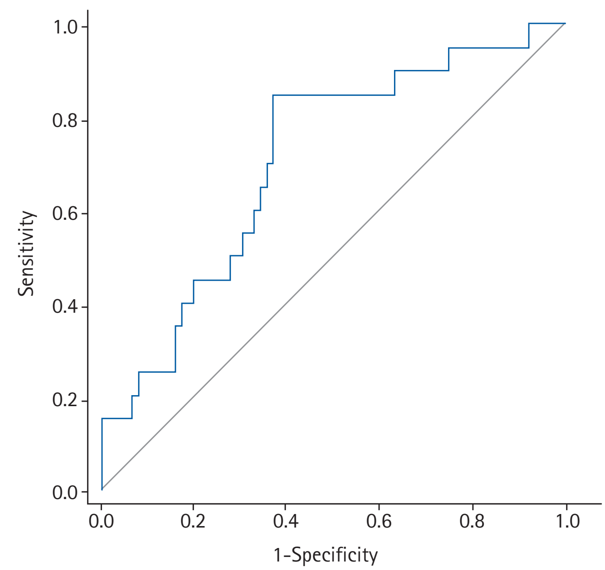

Fig. 2. Receiver operating characteristic curve to estimate the phase angle cutoff for malnutrition. The phase angle cutoff was 3.96° (sensitivity=0.85, specificity=0.63, area under the curve=0.71, 95% confidence interval 0.58–0.83, p=0.001).

DISCUSSION

In this study, the cutoff phase angle for identifying malnutrition in older inpatients with hip fractures was 3.96°. A previous study of inpatients with various diseases reported a mean phase angle on admission of 3.9° ± 0.9°, with cutoff phase angles for malnutrition of 4.03° and 3.65° for men and women, respectively.[27)] This study, which included only patients with hip fractures, yielded similar results. Therefore, the cutoff value in this study showed a certain degree of reliability.

Screening for malnutrition is essential to facilitate prompt nutritional intervention in older inpatients with hip fractures.[9)] Nonetheless, although subjective scales using questionnaires allow for convenient nutritional assessment, their reliability remains questionable.[11)] Although the GNRI is considered a good nutritional assessment index because it incorporates anthropometric factors and serum markers,[28)] blood tests are required to calculate the GNRI and cannot be routinely performed because of the burden they pose on inpatients. Bioelectrical impedance analysis is safe, reproducible, and easy for inpatients, and the results are independent of the examiner's level of experience and skill.[29)] Therefore, our findings overcome the limitations of conventional nutritional assessments and allow for prompt and accurate evaluations.

Nutrition-focused strategies are crucial in the rehabilitation of patients with hip fractures.[7,8)] Moreover, routine nutritional assessments and interventions based on these assessments may be beneficial for the recovery of older adults with hip fractures. However, malnutrition is often not assessed or treated in older adult inpatients.[30)] Therefore, this study, which evaluated a simple method to screen for malnutrition, will help facilitate the development of strategies to promote recovery in older inpatients with hip fractures.

The AUC in this study was 0.71, which was sufficient for diagnostic accuracy, although it was not ideal.[24,25)] Therefore, the ability of the phase angle to identify malnutrition is limited. Considering the relatively high sensitivity for discrimination (0.85), it may be possible to more accurately identify patients with malnutrition by performing a detailed nutritional assessment of those who fall below the phase angle cutoff for screening.

This study has a few limitations. First, we used only the GNRI to assess malnutrition; therefore, nutritional assessments should be performed in conjunction with other assessments. In addition, the GNRI does not demonstrate high accuracy in assessing hypernutrition.[28)] As such, our findings are specific to malnutrition. Nevertheless, the GNRI is a good nutritional indicator[23)] which can be used to assess malnutrition in older patients with hip fractures. Another consideration is that the phase angle is affected by age and sex.[31,32)] Future studies should consider both age and sex to determine more accurate cutoff values. Second, while we performed bioelectrical impedance analysis using the InBody S10 device according to the manufacturer's instructions, we could not confirm whether the procedures described in these instructions were followed. Third, as all subjects in this study were postsurgical inpatients and serum albumin levels were affected by surgery, surgery may have influenced the results of this study.[33] In addition, the times between the date of surgery and the bioelectrical impedance analysis and between the date of surgery and the date of the blood tests were not consistent. Performing blood tests and bioelectrical impedance analyses on the same day is likely to yield more accurate results. Nevertheless, the half-life of serum albumin is 20 days,[34] and the interval between the dates of blood tests and bioelectrical impedance analysis was approximately 8 days in this study. Moreover, the results showed a strong association between the GNRI calculated from serum albumin and the phase angle regarding their ability to determine malnutrition, confirming a certain degree of reliability in the accuracy of the calculated phase angle cutoff; therefore, the results of this study may be applicable to clinical practice. Finally, selection bias may have resulted from the exclusion of individuals with missing GNRI values or an inability to undergo bioelectrical impedance analysis. Nonetheless, this study proposes a simple and objective malnutrition index for older inpatients with hip fractures, which has potential for clinical applications.

In conclusion, this study investigated the utility of the phase angle as an objective nutritional assessment index in older inpatients with hip fractures. The results suggest that phase angle is a potentially useful screening tool for malnutrition, with a cutoff value of 3.96° in older individuals. Our findings will contribute to the development of rehabilitation strategies for older adult patients with hip fractures. In other words, if the phase angle is indicative of malnutrition, monitoring it during rehabilitation may prevent or reduce the occurrence of malnutrition and promote recovery in older patients with fractures.

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CONFLICT OF INTEREST

The researchers claim no conflicts of interest.

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AUTHOR CONTRIBUTIONS

Conceptualization, YK, KN, TN; Data curation, YK, KN; Funding acquisition, YK, TH; Investigation, YK, NK, TN, TH; Methodology, YK, NK, TN, TH; Project administration, YK; Supervision, TH; Writing–original draft, YK; Writing–review and editing, NK, TN, TH.

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