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ORIGINAL ARTICLE

Prediction of Walking Independence in Older Women with Vertebral Compression Fracture Using Phase Angle: A Preliminary Study Using Propensity Score

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Objectives: This study aimed to clarify whether phase angle can be a predictor of walking independence in older women with vertebral compression fractures (VCFs) and to determine a clinically usable cutoff value. **Methods:** We retrospectively assessed data of older women (n=59; median age, 83.0 years) with VCFs. Propensity score-matching and logistic regression were performed to examine the association between phase angle at admission and walking independence at discharge. The cutoff value for the phase angle at admission for predicting walking independence was calculated based on the receiver operating characteristic curve. **Results:** Thirty-one patients (52.5%) could walk independently at discharge. Thirty patients were extracted from the independent and non-independent groups according to the propensity score. After propensity score matching, there was no significant difference between the groups for age, medical history, knee extension strength, skeletal muscle mass index, mini nutritional assessment-short form score, or revised Hasegawa's dementia scale score. However, the phase angle of the independent group was significantly higher than that of the non-independent group ($P<0.05$). Logistic regression revealed that phase angle at admission was significantly associated with walking independence at discharge (odds ratio, 12.2; 95% confidence interval, 2.1–72.0; $P<0.01$). The area under the receiver operating characteristic curve was 0.868, and the calculated phase angle cutoff value was 3.55°. **Conclusions:** This study revealed that the phase angle can predict walking independence in older women with VCFs. The cutoff values for women calculated in this study can be used as a simple and objective predictive index of walking independence.

Key Words: phase angle; prediction; rehabilitation; vertebral compression fracture; walking

INTRODUCTION

Bioelectrical impedance analysis (BIA) measures body composition by detecting differences in the electrical resistance of various tissues, such as fat and muscles, by applying a weak electric current to the body. The phase angle (PhA) measured using BIA is an alternative indicator of muscle mass that can be used to monitor nutritional status and sarcopenia.[1,2] PhA has become widely used in recent years because it is determined using a direct, objective method that is also non-invasive and rapid.

Apart from nutritional status and sarcopenia, PhA has been reported to indicate outcomes in various diseases. For example, PhA is associated with functionality, quality of life, and mortality in patients with cancer,[3] mobility and balance in patients with hip fractures,[4] and physical function in patients with acute stroke.[5] Moreover, a low PhA is associated with falls, frailty, and mortality in older adults.[6,7] This simple indicator is expected to reflect health status, various functional states, and prognosis in the elderly population.

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Vertebral compression fractures (VCFs) are common among older adult women. A 50-year-old woman has a 40% risk of developing a VCF in her lifetime.[8] Bedrest associated with acute care often causes disuse syndrome (i.e., decline in physical and mental function) in older adults with VCF. About 90% of disuse syndromes in older adults involve malnutrition, and disuse syndromes are caused by both bedrest and malnutrition.[9] In some cases, older adults with VCF have difficulty walking because of declines in physical and mental functions caused by treatment-associated bed rest in the acute phase, which may require long-term rehabilitation.

Prognostication is essential for the development of an appropriate rehabilitation plan. Recently, nutritional status has been reported to be associated with walking independence in older adults with fractures, including VCF.[10] Based on the findings of these previous studies,[4–7,10] we hypothesized that PhA at admission is prognostic for walking ability in older women with VCF; this has not been investigated previously. Using PhA would benefit patients and medical professionals because of its low measurement burden. Although PhA has been used as an indicator for nutritional status and health outcomes in other diseases, no study has explored its application in VCF. This study aimed to clarify whether PhA can predict walking independence in older women with VCF and to calculate a clinically usable cutoff value. The findings of this study can serve as a reference for interpreting PhA as a predictor of walking independence in older adults with VCF.

MATERIALS AND METHODS

Study Participants

We enrolled 59 female patients (median age, 83.0 years) with VCF admitted to a convalescent rehabilitation ward of Kita-Fukushima Medical Center in Japan from August 2018 to January 2023. The following inclusion criteria were used: 1) women aged 65 years or older and 2) non-independent walking at admission. The following patients were excluded: 1) those with missing data, 2) those who were transferred or who died, and 3) those who could not walk because they required a medical corset and it had not been delivered to them at admission. The Ethics Review Committees of Kita-Fukushima Medical Center and Fukushima Medical University reviewed and approved this study (No. 94–2, general 2020–236). Because this was a retrospective observational study, informed consent was not obtained; study information was publicly available and patients were provided the opportunity to refuse participation. All patients received conservative treatment in an acute care hospital and standard rehabilitation in the convalescent rehabilitation ward.

Study Design and Data Collection

This was a retrospective, observational study. Variables were collected from the medical charts to examine the relationship between PhA at admission and the ability to walk independently at discharge. Walking performance was assessed using the Functional Independence Measure (FIM)[11] at admission and discharge, and a score of 6 or greater was judged to be independent. A body composition analyzer (InBody S10; InBody, Tokyo, Japan) was used to measure PhA at admission. Body composition was evaluated after resting in the supine position for 5 min, avoiding 2 hours after meals. In addition, medical history, the Mini Nutritional Assessment-Short Form (MNA-SF) score at admission, and the Skeletal Muscle Mass Index (SMI) were assessed. To understand the functional status of the participants and use them as covariates, age, sex, knee extension strength, and cognitive function (revised Hasegawa's Dementia Scale [HDS-R]) at admission were collected. Knee extension strength was measured using a handheld dynamometer (μTas F1; Anima, Tokyo, Japan) by isometric contraction in a sitting position with the knee joint at 90°. The extension strength was calculated (in units of Nm/kg) based on the body weight and lower leg length and using the average of the left and right sides.

Data Analysis

Because of the sample size of the study, we performed propensity score matching. The propensity score is good for controlling imbalances between study groups when there are seven or fewer events per confounding variable.[12] First, group comparisons were performed to identify the differences in each variable, including PhA at admission, between those who could walk independently at discharge (independent group) and those who were not (non-independent group) using the Mann–Whitney U test, chi-square test, or Fisher's exact test. Subsequently, propensity scores were created using binary logistic regression methods using variables, other than phase angle, that showed $P<0.10$ for the between-group comparisons. c-Statistics and the Hosmer–Lemeshow test were used to assess the propensity score model. One-to-one pair matching was performed using a caliper width of one quarter of the standard deviation of the estimated propensity score to confirm the difference in PhA between the independent and non-independent walking groups. To confirm the association between PhA and walking independence, logistic regression (forced entry) was performed with walk-

Table 1. Demographics and functional status of study participants

	All subjects (n=59)	Independent group (n=31)	Non-independent group (n=28)	P value
Age, years	83.0 (80.0–87.0)	82.0 (79.0–83.5)	85.5 (82.0–88.5)	<0.01
Medical history, %				
Stroke	6.8	6.5	7.1	0.92
Orthopedic disease	47.5	54.8	39.3	0.18
Hypertension	61.0	64.5	57.1	0.38
Diabetes	11.9	16.1	7.1	0.29
Heart failure or disease	20.3	16.1	25.0	0.30
Respiratory disease	5.1	3.2	7.1	0.49
Chronic kidney disease	13.6	16.1	10.7	0.54
Cancer	20.3	22.6	17.9	0.45
Osteoporosis	78.0	80.6	75.0	0.76
PhA, degrees	3.6 (3.2–4.2)	4.2 (3.6–4.4)	3.3 (2.9–3.6)	<0.01
Knee extension strength, Nm/kg	0.7 (0.6–0.9)	0.8 (0.7–1.1)	0.6 (0.5–0.7)	<0.01
SMI, kg/m^2	4.8 (4.3–5.1)	5.0 (4.7–5.3)	4.5 (4.0–5.0)	<0.01
MNA-SF	8.0 (6.0–10.0)	9.0 (7.0–10.0)	7.0 (6.0–9.0)	<0.05
HDS-R	25.0 (20.0–27.5)	26.0 (21.0–28.0)	24.0 (16.0–26.0)	0.13
Locomotion FIM at admission	1.0 (1.0–1.0)	1.0 (1.0–2.0)	1.0 (1.0–1.0)	0.08
Locomotion FIM at discharge	6.0 (5.0–6.0)	6.0 (6.0–7.0)	5.0 (2.0–5.0)	<0.01

Data given as median (interquartile range) or percentage.

ing independence at discharge as the dependent variable and phase angle as an independent variable, with or without a propensity score as a moderator variable (univariate and multivariate models). Finally, a receiver operating characteristic (ROC) curve was used to calculate the cutoff PhA value to indicate walking independence. If the area under the ROC curve was greater than 0.7 (moderate accuracy), the cutoff value of PhA was calculated using the Youden Index. In addition, cutoff values for other nutritional indicators, SMI and MNA-SF, and their accuracies were calculated in the same manner for comparison with PhA. SPSS Statistics version 25 (IBM, Armonk, NY, USA) was used as the statistical software. Significance levels were set at P<0.05.

RESULTS

Demographics, physical and cognitive functions, and walking independence levels of the study participants are shown in **Table 1**. Of the 59 patients, 31 (52.5%) could walk independently at discharge. There was no significant difference in medical history between the groups. Patients in the independent group had higher values for PhA, knee strength, SMI, and MNA-SF and were younger than those in the non-independent group (P<0.05). In addition, because between-group comparison of FIM at admission had P<0.10, the propensity score was calculated using these variables, and 15 pairs were extracted from each group according to the propensity score. The c-statistic was 0.79 and the Hosmer–Lemeshow test showed P=0.67, indicating a good model. After propensity matching, no significant difference in age, medical history, knee extension strength, SMI, MNA-SF, or HDS-R was observed between the groups; however, the PhA of the independent group was significantly higher than that of the non-independent group (P<0.05, **Table 2**). Logistic regression revealed that PhA at admission was significantly associated with walking independence at discharge in the univariate [odds ratio (OR), 18.6; 95% confidence interval (CI), 4.2–82.9; P<0.01) and multivariate models (OR, 12.2; 95% CI, 2.1–72.0; P<0.01) using the propensity score (**Table 3**). ROC analysis of PhA showed that the area under the curve (AUC) was 0.868, and the calculated cutoff value was 3.55° (sensitivity, 83.9%; specificity, 71.4%, **Fig. 1**). The AUC of PhA was higher than those of SMI (0.695) and MNA-SF (0.658) (**Table 4**), indicating a superior model.

Table 2. Comparison of phase angle and confounding factors by group after propensity score matching

	Independent group (n=15)	Non-independent group (n=15)	P value
PhA, degrees	3.9 (3.6–4.6)	3.5 (3.1–3.9)	<0.05
Age, years	82.0 (80.5–84.5)	85.0 (81.0–88.0)	0.46
Medical history, %			
Stroke	6.7	6.7	1.00
Orthopedic disease	73.3	40.0	0.07
Hypertension	60.0	60.0	1.00
Diabetes	20.0	0.0	0.07
Heart failure or disease	20.0	26.7	0.67
Respiratory disease	0.0	0.0	-
Chronic kidney disease	13.3	0.0	0.14
Cancer	33.3	13.3	0.20
Osteoporosis	80.0	80.0	1.00
Knee extension strength, Nm/kg	0.7 (0.6–0.8)	0.7 (0.6–0.8)	0.68
SMI, kg/m^2	4.7 (4.3–5.0)	4.7 (4.4–5.0)	0.84
MNA-SF	8.0 (5.0–10.0)	7.0 (6.0–8.0)	0.41
HDS-R	23.0 (18.0–27.0)	24.0 (18.5–26.0)	0.74
Locomotion FIM at admission	1.0 (1.0–2.0)	1.0 (1.0–1.0)	0.54

Data given as median (interquartile range) or percentage.

Table 3. Logistic regression analysis with walking independence at discharge as dependent variable

	Univariate model		Multivariate model	
	Odds ratio (95% CI)	*p* value	Odds ratio (95% CI)	*p* value
Phase angle, degree	18.6 (4.2, 82.9)	<0.01	12.2 (2.1, 72.0)	<0.01
Propensity score	148.0 (9.3, 2349.1)	<0.01	4.2 (0.1–169.6)	0.45

Propensity score was created by including variables such as age, knee extension strength, SMI, MNA-SF, and locomotion FIM at admission.

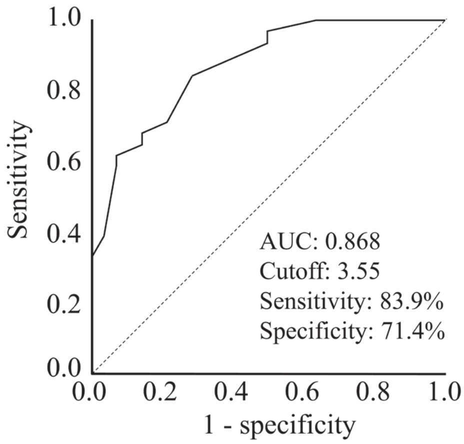

Fig. 1. Receiver-operating characteristic curve for phase angle prediction of walking independence in older women with vertebral compression fracture.

DISCUSSION

The association between PhA and the ability to walk in older adults and patients with various diseases has already been reported in several reports[6,13–17]; however, this association has not been investigated for VCF. This study analyzed the association between PhA and the ability to walk independently in older adults with VCF. Several factors have been reported to be associated with improved activities of daily living in patients with VCF, including early rehabilitation,[18,19] physical activity,[20] and increased SMI[21]; however, no studies have focused on walking independence in these patients.

In this study, PhA was associated with walking independence in older women with VCF even after adjustments for the propensity score created using other indicators of nutritional status (MNA-SF and SMI). This is an important

Table 4. Cutoff values and discrimination performance associated with walking independence at discharge

	Cutoff	AUC	Sensitivity	Specificity	Youden index
Phase angle	3.55°	0.868	83.9%	71.4%	0.55
SMI	4.65	0.695	77.4%	57.1%	0.35
MNA-SF	7.5	0.658	71.0%	60.7%	0.32

finding for rehabilitation, and PhA could be used as a predictor of walking independence in older women with VCF. The association of PhA with walking independence may be related to the sensitivity of PhA to change. PhA is commonly used as a nutritional indicator, and nutritional status is associated with the development of disuse syndrome.[9] Of note, a previous study[22] reported that PhA is more sensitive than muscle mass to resistance training, detraining, and retraining in older women. This suggests that PhA may be an indicator that sensitively reflects not only nutritional status but also changes in muscle, including disuse, which cannot be detected by muscle mass alone. In other words, low levels of PhA may indicate the development of malnutrition and disuse changes in the muscles, which may have been associated with subsequent difficulty in walking. Although these mechanisms are only hypotheses, our results showed that the PhA cutoff values have better predictive ability for walking independence than MNA-SF or SMI in older women with VCF.

The PhA cutoff values for women calculated in this study can be used as a simple and objective predictive index of walking independence. For example, if a patient's PhA is below the cutoff value, the rehabilitation professional can expect that they will experience difficulty in walking independently at discharge, thereby enabling appropriate support to be provided soon after admission. The cutoff value for older women with VCF calculated in this study (3.55°) was lower than those for malnutrition risk in hospitalized geriatric patients (4.7°),[23] sarcopenia in older adults (4.55°),[24] and the incidence of disability in older adults (men 4.95°, women 4.35°).[25] This finding may be associated with the characteristics of patients with VCF: older age, female sex, and high prevalence of osteoporosis. Previous studies reported that lower PhA was associated with aging,[26] sex,[26] and osteoporosis.[27] Notably, the participants of the present study were older women, 78% had osteoporosis, and the study cohort had a low median PhA (3.6°). Therefore, it should be noted that the cutoff value in this study should only be applied to older women with VCF. In addition, because there is a limit to the accuracy of prediction based on this cutoff value alone, it is appropriate to consider it together with other indicators.

A limitation of this study is the small sample size. Increasing the number of samples and conducting a more inclusive analysis will be necessary. Collecting patient data on the pre-fracture activities of daily living and walking ability of patients was also difficult in this retrospective study. Moreover, we were unable to collect detailed assessment data regarding the reasons that participants had difficulty walking on admission (e.g., muscle weakness or pain). These may be important confounding factors and should be re-examined.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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