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Association of the Bioimpedance Phase Angle and Quality of Life in Postmenopausal Osteoporosis

Yuichi Ono[a] Yuji Kasukawa[b] Kana Sasaki[c] Naohisa Miyakoshi[b]

[a]Department of Orthopedic Surgery, Akita Red Cross Hospital, Kamikitate Saruta, Akita-shi, Akita, Japan;
[b]Department of Orthopedic Surgery, Akita University Graduate School of Medicine, Akita-shi, Akita, Japan;
[c]Department of Orthopedic Surgery, Nakadori General Hospital, Minamidori, Akita-shi, Akita, Japan

Highlights of the Study

- The phase angle is an index calculated directly from bioelectrical impedance analysis measurements.
- The relationship between the bioimpedance phase angle and quality of life in patients with postmenopausal osteoporosis was investigated.
- The phase angle was significantly related to quality of life after adjusting for age, body mass index, muscle mass, and bone density.

Keywords

Osteoporosis · Quality of life · Phase angle · Bioelectrical impedance analysis

Abstract

Objectives: Osteoporosis patients with fragility fractures and vertebral deformities have impaired quality of life (QOL). The phase angle, an index calculated from bioelectrical impedance analysis (BIA) measurements, has been reported to be related to clinical outcomes, mortality, and QOL in various diseases. We aimed to investigate the relationship between the phase angle and QOL in patients with postmenopausal osteoporosis. ***Methods:*** 81 female patients treated for postmenopausal osteoporosis from September 2019 to March 2020 underwent measurement of bone mineral density (BMD) by dual-energy X-ray absorptiometry, body composition by BIA, and QOL by the 36-item Short-Form Health Survey (SF-36). ***Results:*** The phase angle showed significant positive correlations with physical functioning ($r = 0.270$, $p = 0.015$) and physical component summary (PCS) ($r = 0.251$, $p = 0.024$) of the SF-36. The phase angle showed significant positive correlations with appendicular skeletal muscle mass index (ASMI) ($r = 0.456$, $p < 0.001$), lumbar spine BMD ($r = 0.241$, $p = 0.030$), and femoral neck BMD ($r = 0.26$, $p = 0.021$) and a significant negative correlation with age ($r = -0.526$, $p < 0.001$). Multiple regression analysis of the factors potentially associated with SF-36 PCS showed that the phase angle ($r = 7.506$, $p = 0.012$) was a significant contributor to PCS ($R^2 = 0.184$). ***Conclusion:*** The phase angle in postmenopausal osteoporotic patients was significantly related to QOL after adjusting for age, BMI, ASMI, and BMD. As the phase angle is a parameter that can be measured easily and noninvasively, it might be a useful aid for QOL assessment in osteoporotic patients.

Karger@karger.com
www.karger.com/mpp

Karger
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Correspondence to:
Yuichi Ono, yuichi.ono24@gmail.com

Introduction

Osteoporosis, a disease characterized by low bone mass and microarchitectural deterioration of bone tissue, is a global health problem that is associated with aging and is 3 times more common in women than in men [1]. In Japan, the prevalence of osteoporosis is expected to increase as the population ages. Osteoporosis patients with fragility fractures and vertebral deformities have reduced activities of daily living and quality of life (QOL) [2–4]. Therefore, it is important to improve their QOL.

Bioelectrical impedance analysis (BIA) is a method of evaluating body composition by applying a weak alternating current to the body and measuring the impedance of the tissues. Dual-energy X-ray absorptiometry (DXA), which is commonly performed to measure bone mineral density (BMD) of osteoporosis patients, can also measure body composition but has the disadvantages of expensive measurement equipment and radiation exposure. A previous study investigated the relationship between QOL and skeletal muscle mass measured by the DXA method [5]. BIA has the advantages of being easy to install, cost effective, and noninvasive compared to DXA. BIA is therefore more suitable for frequent body composition measurements than DXA. Of the variables measured in BIA, muscle mass and phase angle are considered to be clinically important. The phase angle is defined as the phase difference between current and voltage that occurs when current penetrates a cell membrane and tissue interface. The phase angle is an index calculated directly from the BIA measurements that is estimated based on the ratio of reactance (Xc) to resistance (R) of the whole body as follows: phase angle (°) = arctangent (Xc/R) × (180°/π) [6]. Xc is derived from the capacitance of the cell membranes and tissue interfaces, and R is derived from extracellular and intracellular fluid, such as fat mass in the body. The phase angle is thought to be a sensitive indicator of cellular health, with higher values reflecting cell membrane integrity or vitality of living tissue [7]. It has also been reported that the phase angle is effective for predicting clinical outcomes, mortality, and QOL in hemodialysis patients and elderly cancer patients [8, 9].

However, it is unclear whether there is a correlation between QOL and the phase angle in patients with osteoporosis. The aim of this study was to examine the relationship between the phase angle and QOL in patients with postmenopausal osteoporosis.

Table 1. Demographics and characteristics of participants

Age, years	75.3±8.6
Height, cm	150.8±5.9
Weight, kg	51.8±10.2
Fat mass, kg	17.4±7.7
BMI, kg/m^2	22.8±4.3
ASMM, kg	14.4±2.2
ASMI, kg/m^2	6.3±0.6
Phase angle, °	4.7±0.6
Lumbar spine BMD, g/cm^2	0.830±0.128
Femoral neck BMD, g/cm^2	0.548±0.095
SF-36	
PF	70.0 (50.0–85.0)
RP	68.8 (50.0–93.8)
BP	52.0 (41.0–72.0)
GH	52.0 (45.0–60.0)
VT	56.3 (50.0–68.8)
SF	87.5 (62.5–100)
RE	75.0 (58.3–100)
MH	70.0 (55.0–85.0)
PCS	38.3 (28.1–45.6)
MCS	54.2 (48.7–61.3)

Values are expressed as mean±SD or median (IQR). BMI, body mass index; ASMM, appendicular skeletal muscle mass; ASMI, appendicular skeletal muscle mass index; BMD, bone mineral index; PF, physical functioning; RP, role physical; BP, bodily pain; GH, general health; VT, vitality; SF, social functioning; RE, role emotional; MH, mental health; PCS, physical component summary; MCS, mental component summary.

Table 2. Correlations between phase angle and SF-36 scales

	r	*p* value
PF	0.270	0.015
RP	0.131	0.243
BP	0.183	0.102
GH	–0.094	0.404
VT	0.034	0.760
SF	–0.065	0.565
RE	0.090	0.424
MH	–0.021	0.856
PCS	0.251	0.024
MCS	–0.150	0.182

Data are Spearman's rank correlation coefficient (*r*) values. PF, physical functioning; RP, role physical; BP, bodily pain; GH, general health; VT, vitality; SF, social functioning; RE, role emotional; MH, mental health; PCS, physical component summary; MCS, mental component summary.

Methods

This observational, cross-sectional study was approved by the Ethics Review Board of Nakadori General Hospital (IRB approval no. 263), and informed consent was obtained from all individual participants included in the study. The work in the present study was conducted in accordance with the Declaration of Helsinki.

Subjects

Patients who visited our hospital for the treatment of postmenopausal osteoporosis from September 2019 to March 2020 were enrolled. The exclusion criteria were as follows: (1) patients who could not answer all questions on the questionnaire for severe dementia, (2) patients who could not stand without support, (3) patients with postoperative pacemaker implantation, and (4) men.

Measurement of BMD

BMD was measured by DXA (Discovery-SL; Hologic, Waltham, MA, USA) of the lumbar spine (L2–L4) and total hip.

Body Composition Measurements

For body composition analysis, body mass index (BMI), appendicular skeletal muscle mass, fat, and phase angle were measured using a multifrequency bioelectrical impedance analyzer (MC-780A-N; TANITA, Tokyo, Japan). Height was measured using a wall-mounted stadiometer. The participant stood barefoot on the measurement table, maintaining a standing posture while holding the handgrip. All participants were asked to not consume any food or drink and to avoid strenuous activity within 2 h before the testing. The appendicular skeletal muscle mass index (ASMI) was calculated as follows: appendicular skeletal muscle mass (kg)/height^2 (m^2). The cutoff value for ASMI, defined as low skeletal muscle mass, is <5.7 kg/m^2 for women using BIA [10]. The BIA measures the impedance of the whole body, and the impedance consists of resistance and reactance to the alternating current flowing in the body. According to past reports, the phase angle was determined at a single frequency (50 kHz) for analysis in the right hemibody (the right arm, trunk, and leg) [11, 12].

Evaluation of QOL

QOL was assessed using the Japanese version of the 36-item Short-Form Health Survey (SF-36) [13]. The eight subscales, i.e., physical functioning, role physical, bodily pain, general health, vitality, social functioning, role emotional, and mental health, were directly transformed into a point scale ranging from 0 to 100. The eight scales and two summary measures of the SF-36, the physical component summary (PCS) and mental component summary, were evaluated, and their correlations with other factors were examined.

Statistical Analysis

SF-36 scores are presented as medians with interquartile range, whereas all other values are presented as means with standard deviation (SD). EZR software version 1.27 (Saitama Medical Center, Jichi Medical University, Saitama, Japan) was used for statistical analysis [14]. Spearman's rank correlation coefficient was used for analysis of correlations between the SF-36 scores and phase angle, and Pearson's correlation coefficient was used for analysis of correlations between the phase angle and variables other than SF-36 scores. Age, BMI, ASMI, BMD, and phase angle were included in the multiple regression analysis to determine which variables correlated best with the PCS, and the residuals were normally distributed. For multiple regression analysis, fat mass was excluded because of its high collinearity with other data. Probability values less than 0.05 were considered significant.

Table 3. Correlations between the phase angle and other variables in the study subjects

	Coefficient (*r*)	*p* value
Age, years	−0.526	<0.001
BMI, kg/m^2	0.211	0.059
Fat mass, kg	0.182	0.103
ASMI, kg/m^2	0.456	<0.001
Lumbar spine BMD, g/cm^2	0.241	0.030
Femoral neck BMD, g/cm^2	0.260	0.021

Data are Pearson's correlation coefficient (*r*) values. BMI, body mass index; ASMI, appendicular skeletal muscle mass index; BMD, bone mineral density.

Results

A total of 81 participants were included in the study. The mean age of the participants was 75.3 years (range, 54–93 years; SD, 8.6 years), and the mean BMI was 22.8 kg/m^2 (range, 14.3–35.1 kg/m^2; SD, 4.3 kg/m^2). The prevalence of low skeletal muscle mass was 13.6% (n = 11). General demographic characteristics, body composition, BMD, and SF-36 data are presented in Table 1. Correlations between phase angle and SF-36 scores are shown in Table 2. The phase angle showed significant positive correlations with physical functioning ($r = 0.270$, $p = 0.015$) and PCS ($r = 0.251$, $p = 0.024$) of the SF-36. The correlations between the phase angle and variables are listed in Table 3. Age showed a significant negative correlation with the phase angle ($r = -0.526$, $p < 0.001$). ASMI, lumbar spine BMD, and femoral neck BMD showed significant positive correlations with the phase angle ($r = 0.456$, $p < 0.001$, $r = 0.241$, $p = 0.030$, and $r = 0.26$, $p = 0.021$, respectively). Multiple regression analysis of the factors potentially associated with SF-36 PCS showed that the phase angle ($r = 7.506$, $p = 0.012$) was the significant contributor to PCS ($R^2 = 0.184$) (Table 4).

Table 4. Multiple regression analysis of factors associated with SF-36 PCS in the study subjects

	Regression coefficient (r)	95% confidence interval	p value
PCS adjusted $R^2 = 0.184$ ($p = 0.002$)			
Intercept	40.019	(−12.570 to 92.607)	0.134
Age, years	−0.254	(−0.631 to 0.124)	0.185
BMI, kg/m^2	−0.720	(−1.536 to 0.095)	0.082
ASMI, kg/m^2	1.895	(−4.773 to 8.564)	0.573
Lumbar spine BMD, g/cm^2	−3.101	(−26.430 to 20.227)	0.792
Femoral neck BMD, g/cm^2	−24.311	(−57.852 to 9.229)	0.153
Phase angle, °	7.506	(1.699–13.313)	0.012

PCS, physical component summary; BMI, body mass index; ASMI, appendicular skeletal muscle mass index; BMD, bone mineral density.

Discussion

This study investigated the relationships between QOL and the phase angle measured by BIA in patients with postmenopausal osteoporosis. Of the body composition variables, the phase angle showed a significant positive correlation with SF-36 PCS. Although there have been reports investigating the relationship between QOL and the phase angle in maintenance hemodialysis patients [8], psoriasis patients [15], and elderly cancer patients [9], to the best of our knowledge, this is the first report involving postmenopausal osteoporosis patients.

The range of the phase angle is between 5° and 7° in healthy adults [6]. A previous study reported that the phase angle is usually lower in women than in men and decreases with age [16]. A low phase angle has been attributed to increased resistance due to increased body fat and decreased water content, as well as decreased reactance due to decreased muscle mass and impaired cellular integrity [6]. The decrease in the phase angle in elderly people is thought to reflect the increase in the volume of extracellular water and the decrease in the volume of intracellular water associated with aging [17]. Several studies have reported that a low phase angle correlated with poor muscle function [17, 18], physical activity level [19], sarcopenia [20, 21], frailty [22], locomotive syndrome [23], and the occurrence of falls [24]. In addition, it has been reported that the phase angle was negatively correlated not only with muscle mass but also with strength (grip strength) in elderly persons [20]. On multiple regression analysis in the present study, skeletal muscle mass was not significantly related to SF-36 PCS, only the phase angle. From these findings, the phase angle might be significantly correlated with SF-36 PCS, reflecting muscle quality and function.

Moreover, a low phase angle was reported to be associated with poor nutritional status [25] and osteoporosis [26]. It is very important to evaluate the physical function and nutritional status of osteoporotic patients because osteoporotic patients often have concomitant sarcopenia [27] and poor nutritional status [28]. It has been reported that age-related changes in muscle mass loss and muscle weakness do not necessarily progress in parallel [29]; thus, assessment of muscle strength and physical function is required to diagnose sarcopenia. However, assessing muscle strength and physical function, such as measuring gait speed or the chair stand test [10], is time-consuming and labor-intensive. The phase angle can be measured easily and noninvasively at the same time as skeletal muscle mass, and it might be useful for early detection of osteoporotic patients whose physical function has declined and who should be treated with exercise therapy or improvement of nutritional status. The results of the present study suggest that postmenopausal osteoporosis patients with low phase angles should be evaluated with more detailed physical function assessments, such as grip strength, knee extension muscle strength, and gait speed.

This study has several limitations. First, the sample size of this study was small. Second, physical function, such as grip strength and gait speed, was not measured. Third, the correlation coefficient between the phase angle and SF-36 PCS was small, indicating a weak correlation. Fourth, although previous reports have reported that dietary habits affect phase angle measurements [30, 31], in the present study, only short-term restrictions were used. Future studies should evaluate the associations of the phase angle with QOL and physical function together to determine the factors that contribute to the decrease in QOL.

Conclusion

The phase angle in postmenopausal osteoporotic patients was significantly related to QOL even after adjusting for age, BMI, ASMI, and BMD. As the phase angle is a parameter that can be measured easily and noninvasively, it might be a useful aid for QOL assessment in osteoporotic patients.

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Statement of Ethics

This study was approved by the Ethics Review Board of Nakadori General Hospital (IRB Approval No. 263). All participants provided written informed consent.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

Yuichi Ono wrote and prepared the manuscript. Yuji Kasukawa and Naohisa Miyakoshi participated in the study design and data analysis. Kana Sasaki participated in data collection. All the authors have reviewed and approved the final manuscript.

Data Availability Statement

The data that support the findings of this study are not publicly available as they contain information that could compromise the privacy of research participants but are available from the corresponding author upon reasonable request.

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