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Original Article

Relationship of Phase Angle to Locomotive Syndrome, Malnutrition, and Sarcopenia Alone and Co-Existence in Community-Dwelling Women Aged 60 Years and Older

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SUMMARY

Background: This study aimed to investigate the relationship between phase angle and existence of locomotive syndrome, malnutrition, and sarcopenia alone or co-existence of locomotive syndrome, malnutrition, and sarcopenia and determine cut-off values of phase angle of these syndromes.
Methods: Overall, 1,063 community-dwelling women aged ≥ 60 years underwent medical checkup. We assessed them for phase angle, locomotive syndrome risk tests, Mini Nutritional Assessment Short Form, grip strength, comfortable gait speed, and skeletal muscle mass index. Participants were classified into eight groups: robust; locomotive syndrome alone; malnutrition alone; sarcopenia alone; malnutrition and sarcopenia; locomotive syndrome and sarcopenia; locomotive syndrome and malnutrition; and co-existence of all syndromes.
Results: The proportions of locomotive syndrome, sarcopenia, and malnutrition were 62.1%, 3.6%, and 36.9%, respectively. Since the prevalence of sarcopenia alone and malnutrition and sarcopenia were 0.0%, these groups were excluded from the analysis. Multinomial logistic regression analysis, adjusted for age and body mass index, showed the relationship between phase angle and locomotive syndrome, malnutrition, locomotive syndrome and sarcopenia, locomotive syndrome and malnutrition, and co-existence of the three syndromes. The phase angles for predicting locomotive syndrome, malnutrition, locomotive syndrome and sarcopenia, locomotive syndrome and malnutrition, and co-existence of the three syndromes were 5.4°, 5.4°, 5.0°, 5.2°, and 4.9°, respectively, all of which showed high predictive accuracy, 0.845, 0.845, 0.917, 0.906, and 0.956, respectively.
Conclusion: The phase angle is a simple assessment of locomotive syndrome, malnutrition, and sarcopenia alone or co-existence, and it may be useful for the early detection of these syndromes in the community.

1. Introduction

Previous studies have shown that locomotive syndrome (LS), sarcopenia, and malnutrition are associated with increased societal burdens, such as future disability, fractures, and mortality.[1–6] LS is a condition in which impairment of one or more parts of the musculoskeletal system, such as muscles, bones, joints, cartilage, and intervertebral discs, interferes with walking and daily life.[1] The LS was defined by the Japanese Orthopaedic Association, as follows: a two-step test score less than 1.3, difficulty standing up on one leg from a 40-cm-high seat in the stand-up test (either leg); 25-question geriatric locomotive function scale score (GLFS) > 7.[1] The LS was adopted by the Japanese government in 2013 as a measure of the second stage of the 21st Century National Health Promotion Strategy, which includes maintaining good nutrition, increasing physical activity, and promoting social participation.[7] Sarcopenia is defined using the Asian Working Group for Sarcopenia (AWGS) criteria, as follows: age greater than 60 years; skeletal muscle mass index (SMI) less than 7.0 kg/m^2 for men and 5.7 kg/m^2 for women evaluated using bioimpedance analysis (BIA); grip strength less than 28 kg for men and 18 kg for women; comfortable gait speed no greater than 1.0 m/s.[8] There are several criteria for malnutrition, but the Mini-Nutrition Assessment Short Form (MNA-SF) has been used in many studies from community to inpatient settings. An MNA-SF score of 11 or less is defined as malnutrition.[9,10] LS, sarcopenia, and malnutrition occur more frequently in women than in men, and these syndromes are more prevalent in the elderly than in the young.[9–13] The prevalence of LS, sarcopenia, and malnutrition in community-dwelling elderly people ranges from 50% to 70%, 32.4% to 43.3%, and 0.1% to 56.7%, respectively.[10–13] These differences are influenced by various factors, including different diagnostic criteria.

A common characteristic of patients with LS, sarcopenia, and malnutrition is a low phase angle.[14–16] The phase angle is the phase difference between the resistance generated when an electric current flows along the body water and the resistance (reactance) generated when it passes through the muscle cells. The higher the density of the muscle, the larger the reactance and the larger the phase angle. Therefore, the phase angle is expected to be an indicator to estimate the quality of muscle. In other words, the phase angle re-

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flects the health and structural stability of the muscle cells, and changes based on proteolysis and chronic inflammatory conditions.[17] Previous studies have reported that phase angle is associated with internal disorders such as diabetes, lung cancer, and cirrhosis, with cut-off values of 4.8°, 5.3°, and 5.4°, respectively, and that mortality is further increased in patients with cirrhosis at values below 4.4°.[18–20] In another study, the cut-off values indicating sarcopenia in younger and older women were 5.02° and 4.2°, respectively, with values varying by age, disease, and country.[21]

The lower the phase angle, the lower the health of the muscle cells, but the difference in phase angle and cut-off values for the existence of LS alone or co-existence LS, sarcopenia, and malnutrition are not clear. In particularly, previous studies have reported an increased risk of mortality in the malnutrition-sarcopenia syndrome, which represents clinical manifestations of both malnutrition and sarcopenia in recent years, and it is necessary to clarify the characteristics of each syndrome alone and in co-existence.[22,23] Additionally, sarcopenia is included in LS, and the association between LS and phase angle reported by previous studies may have been influenced by sarcopenia.[11,15] Clarifying the differences in phase angle and cut-off values due to the existence of LS, malnutrition, and sarcopenia alone or co-existence of LS, sarcopenia, and malnutrition may provide a simple index to determine these three syndromes. The purpose of this study was to clarify the differences in phase angle due to the existence of LS alone or co-existence of LS, sarcopenia, and malnutrition, and cut-off values of the phase angle in these syndromes.

2. Materials and methods

2.1. Study design and inclusion criteria

This was a cross-sectional study. We invited 1,200 local residents of Satte City who were randomly selected to participate in health checkups, all of whom were 60 years of age or older, a rural area, and we obtained information from 1,117 people. Participants were women, living in the community, and had the ability to walk and maintain a standing position. Overall, 1,063 participants completed the required questionnaire and assessments for LS, sarcopenia, and malnutrition and were thus included in the study.

This study was conducted in accordance with the principles of the Declaration of Helsinki. All participants provided written informed consent, and the study was conducted with the approval of the ethics committee of the Japan University of Health Sciences (No. P3001).

2.2. Assessment of participant's characteristics, phase angle, and skeletal muscle mass

All participants were interviewed and asked to report their age, sex, and main diagnoses (i.e., diabetes mellitus and kidney disease).

Body composition parameters such as phase angle, skeletal muscle mass (SMM), and BMI were obtained using a multi-frequency bioelectrical impedance analyzer MC-780 (Tanita Corp., Tokyo, Japan), which is a tool for assessing the body composition of the whole body and various body parts. The BIA instrument used six electrical frequencies (1, 5, 50, 250, 500, and 1000 kHz), with the surface of the hand electrodes in contact with the subject's five fingers and the heel and forefoot in contact with the circular foot electrodes. Phase angle of 50 kHz was used for the analysis in accordance with the recommendations for clinical application of the BIA.[24] We asked the participants to stand on the body composition analyzer MC-780 for approximately 30 s.

2.3. Assessment of LS, malnutrition, and sarcopenia

In this study, the LS risk test was assessed using the two-step value, the stand-up test, and GLFS.

The participants were asked to take two largest possible steps, and the two-step value was measured as the maximum length of two steps from the starting line to the tip of the toe where the participant stopped; the length of two steps (cm) divided by the height (cm) was the two-step score.

For the stand-up test, we evaluated the participant's ability to stand on one leg after rising from a 40-cm-high seat. We instructed the participants to stand up without recoil with their arms crossed and to hold the standing posture for 3 seconds.

The GLFS score is a 25-question instrument consisting of 4 questions on pain, 16 questions on activities of daily living, 3 questions on social functioning, and 2 questions on mental status in the past month. These 25 items are scored on a 5-point scale, and the scores are summed from no disability (0) to severe disability (4).

LS risk tests were used to categorize LS as follows: a two-step test score less than 1.3, difficulty standing up on one leg from a 40-cm-high seat in the stand-up test (either leg); GLFS > 7.[1]

For evaluation of malnutrition, we used the MNA-SF, which has been used in previous studies on hospital patients and community-dwelling people.[10] The screening score ranges from 0 to 14, with scores of 11–14 being considered normal nutritional status and 11 or below considered at risk for malnutrition. In this study, an MNA-SF score of 11 or less was considered to indicate malnutrition.

For evaluation of sarcopenia, we used the AWGS criteria, which have been used in several previous studies among community-dwelling people.[12,25,26] SMI was calculated by the sum of the SMM of the extremities divided by the square of the height. Grip strength was assessed for the dominant hand in a standing position using a T.K.K.5401 grip dynamometer (Takei Corp., Niigata, Japan). To measure comfortable gait speed, participants were asked to walk a straight 6-m course at their normal pace. The time required to complete the course was recorded accordingly.

2.4. Data analysis and statistics

Participants were classified into the following eight groups: no LS, sarcopenia, or malnutrition (robust); presence of LS alone (LS); presence of malnutrition alone (malnutrition); presence of sarcopenia alone (sarcopenia); co-existence of malnutrition and sarcopenia (MS); co-existence of LS and sarcopenia (LSS); co-existence of LS and malnutrition (LSM); and co-existence of all syndromes (co-existence). We planned a study to obtain continuous response variables from eight independent groups. To reject the null hypothesis that the population means of each group are equal with a probability (power) of 0.8, we needed to study 9 participants in each group. The type I error probability associated with testing this null hypothesis was 0.05, and the effect size was 0.5; this sample size calculated using G*power 3.1.9.

The Shapiro-Wilk test was performed to check for the normal variance. Analysis of variance (ANOVA) was used to compare the robust, LS, malnutrition, sarcopenia, MS, LSS, LSM, and co-existence groups. Chi-square and Fisher's exact tests were used to compare the different clinical and demographic characteristics of the participants in the different groups. Multinomial logistic regression analysis adjusted for age and BMI was performed to clarify the relationship between phase angle and the presence or absence of LS, malnutrition, and sarcopenia. Additionally, the cut-off values for phase angle, which were found to be associated with the alone groups and co-existence of these syndromes in multinomial logistic regression analysis, were calculated using receiver operating characteristic (ROC) curve analysis of LS, malnutrition, sarcopenia, and co-existence of syndromes. All statistical analyses were conducted using IBM SPSS Statistics for Windows, version 27.0, (IBM Corp., Tokyo, Japan). Statistical significance was set at $p < 0.05$.

3. Results

3.1. Co-presence of LS, sarcopenia, and malnutrition

At least one syndrome was observed in 88.9% of the participants. The proportions of LS, sarcopenia, and malnutrition were 62.1%, 3.6%, and 36.9%, respectively. The percentage of patients with sarcopenia alone and MS was 0%. Therefore, the sarcopenia and MS groups were excluded from the analysis. Overall, the proportions of LSS, LSM, and co-existence groups were 2.0%, 8.4%, and 1.6%, respectively.

3.2. Difference of characteristics with LS, sarcopenia and malnutrition

The mean value of phase angle was 5.1° overall, with values of 6.0°, 5.0°, 5.1°, 4.8°, 4.9° and 4.6° for robust, LS, malnutrition, LSS, LSM and co-existence, respectively. Weight, BMI, phase angle and SMI in the robust, LS, and malnutrition groups were significantly higher than in the co-existence group (Table 1). Additionally, grip strength and comfortable gait speed in the co-existence group were significantly lower than those in the robust, LS, malnutrition, and LSM groups.

3.3. Relationship with phase angle and the LS, malnutrition, LSS, LSM, and co-existence

Multinomial logistic regression analysis, adjusted for age and BMI, was performed to examine the relationship between phase angle and LS, malnutrition, and sarcopenia. The results showed that LS (odds ratio [OR] = 0.021, 95% confidence interval [CI] 0.011–0.041, $p < 0.001$), malnutrition (OR = 0.031, 95% CI 0.016–0.062, $p < 0.001$), LSS (OR = 0.01, 95% CI 0.003–0.035, $p < 0.001$), LSM (OR = 0.019, 95% CI 0.008–0.048, $p < 0.001$), and co-existence of syndromes (OR = 0.003, 95% CI 0.001–0.013, $p < 0.001$) were significantly associated with phase angle (Table 2). Additionally, the OR of the phase angle was strongly influenced by the co-existence of all syndromes.

Table 2
Relationship with phase angle and LS, malnutrition, LSS, LSM and co-existence.

Robust = 0	OR (95% CI, p-value)
LS; presence = 1	
Age, +1 year	1.013 (0.96–1.069, 0.635)
BMI, +1 kg	0.992 (0.918–1.072, 0.835)
Phase angle, +1°	**0.021 (0.011–0.041, < 0.001)**
Malnutrition; presence = 1	
Age, +1 year	1.019 (0.964–1.078, 0.502)
BMI, +1 kg	0.769 (0.703–0.841, < 0.001)
Phase angle, +1°	**0.031 (0.016–0.062, < 0.001)**
LSS; presence = 1	
Age, +1 year	1.11 (1.007–1.224, 0.035)
BMI, +1 kg	0.627 (0.497–0.791, < 0.001)
Phase angle, +1°	**0.01 (0.003–0.035, < 0.001)**
LSM; presence = 1	
Age, +1 year	1.21 (1.119–1.309, < 0.001)
BMI, +1 kg	0.271 (0.215–0.341, < 0.001)
Phase angle, +1°	**0.019 (0.008–0.048, < 0.001)**
Co-existence; presence = 1	
Age, +1 year	1.187 (1.061–1.328, 0.003)
BMI, +1 kg	0.309 (0.217–0.442, < 0.001)
Phase angle, +1°	**0.003 (0.001–0.013, < 0.001)**

Multinomial logistic regression analysis was adjusted by age and BMI.
BMI, body mass index; LS, locomotive syndrome; LSM, LS and malnutrition; LSS, LS and sarcopenia; OR, odds ratio; 95% CI, 95% confidence interval.

Table 1
Difference of characteristics with LS, sarcopenia and malnutrition.

	Total (n = 1,063)	Robust (n = 117)	LS (n = 533)	Malnutrition (n = 286)	LSS (n = 21)	LSM (n = 89)	Co-existence (n = 17)	p-value
Age, years	68.7 (5.1)	67.8 (4.8)	68.6 (4.5)	68.3 (5.7)	70.5 (6.2)	70.9 (5.0)	71.2 (6.2)	< 0.001
Height, cm	152.6 (5.5)	151.2 (5.7)	153.2 (5.5)	151.7 (5.1)	151.4 (7.5)	153.5 (5.3)	153.3 (6.5)	< 0.001
Weight, kg	51.7 (8.3)	53.7 (8.6)*	54.6 (7.3)*	49.2 (7.7)*	46.9 (5.6)	42.7 (3.5)	43.1 (8.8)	< 0.001
BMI, kg/m^2	22.2 (3.3)	23.4 (3.2)*	23.2 (2.8)*	21.4 (3.3)*	20.4 (1.6)	18.1 (1.1)	18.2 (2.6)	< 0.001
Body fat, %	28.4 (7.5)	28.4 (7.8)*	31.3 (5.8)*	26.4 (7.9)	29.1 (4.4)*	19.1 (4.0)	22.1 (8.5)	< 0.001
Phase angle, degree	5.1 (0.6)	6.0 (0.9)*	5.0 (0.4)*	5.1 (0.4)*	4.8 (0.4)	4.9 (0.4)	4.6 (0.5)	< 0.001
MNA-SF, score	11.4 (1.6)	12.7 (1.5)*	11.9 (1.4)*	10.6 (1.2)	10.3 (2.0)	9.8 (1.6)	9.9 (1.9)	< 0.001
Presence of hypertension, %	28.1	40.2	31.3	21.3	38.1	16.9	5.9	< 0.001
Presence of diabetes mellitus, %	6.3	7.7	6.8	4.5	4.8	5.6	17.6	0.341
Presence of hyperlipidemia, %	16.1	17.9	18.0	14.0	14.3	11.2	5.9	0.346
Presence of lumbar and/or knee pain, %	33.5	31.6	36.0	30.4	28.6	31.5	35.3	0.647
Presence of kidney disease, %	2.4	0.9	2.4	3.2	0.0	1.1	5.9	0.553
Presence of heart disease, %	2.9	2.6	3.4	2.4	4.8	2.2	0.0	0.904
Grip strength, kg	23.4 (3.9)	24.3 (4.0)*	23.7 (3.6)*	23.3 (4.2)*	19.9 (3.9)	22.5 (3.0)*	17.6 (2.5)	< 0.001
Comfortable gait speed, m/s	1.39 (0.22)	1.44 (0.22)*	1.38 (0.19)*	1.40 (0.26)*	1.18 (0.24)	1.39 (0.22)*	1.18 (0.28)	< 0.001
SMI, kg/m^2	6.3 (0.7)	6.8 (0.9)*	6.4 (0.6)*	6.2 (0.6)*	5.4 (0.3)	5.6 (0.4)	5.4 (0.6)	< 0.001
Two-step test score, cm/cm	1.33 (0.17)	1.39 (0.12)*	1.33 (0.11)	1.33 (0.25)	1.27 (0.13)	1.32 (0.13)	1.23 (0.14)	< 0.001
Difficulty with one-leg standing from a 40-cm-high seat, %	48.6	0.0	80.7	0.0	66.7	71.8	70.6	< 0.001
25-question geriatric locomotive function scale score	5.0 (6.9)	4.0 (5.4)	4.5 (4.0)	6.3 (10.6)	7.3 (10.3)	4.6 (3.6)	8.2 (11.6)	< 0.001

* Significant difference ($p < 0.05$) from values of the co-existence group.
The presence of hypertension, diabetes, hyperlipidemia, lumbar and/or knee pain, kidney disease, heart disease, and the difficulty with one-leg standing from a 40-cm-high seat are presented as the percentage of participants. Other variables are shown as the mean (standard deviation).
BMI, body mass Index; LS, locomotive syndrome; LSM, LS and malnutrition; LSS, LS and sarcopenia; MNA-SF, mini nutrition assessment short form; SMI, skeletal muscle mass index.

3.4. ROC curve analysis for the LS, malnutrition, LSS, LSM, and co-existence using phase angle

Figure 1 shows the results of ROC curve analysis for LS, malnutrition, LSS, LSM, and co-existence of syndromes. As a result of evaluating the cut-off value at the shortest distance from the upper left corner to the curve, the cut-off values for phase angle to evaluate whether these syndromes occur in women over 60 years old were 5.4° or less for the LS (area under the curve [AUC]: 0.865; $p < 0.001$; sensitivity: 72.0%; specificity: 84.8), and 5.4° or less for malnutrition (AUC: 0.845; $p < 0.001$; sensitivity: 72.0; specificity: 80.1), 5.0° or less for LSS (AUC: 0.917; $p < 0.001$; sensitivity: 95.8; specificity: 71.4), and 5.2° or less for LSM (AUC: 0.906; $p < 0.001$; sensitivity: 85.6; specificity:77.5), and 4.9° or less for co-existence (AUC: 0.956, $p < 0.001$; sensitivity, 95.8; specificity, 82.4). The predictive value of each syndrome using the phase angle trend was high.

4. Discussion

4.1. Characteristics of the LS, malnutrition, LSS, LSM, and co-existence of syndromes

We found that the weight, BMI, phase angle, and SMI of the comorbid group were significantly worse than those of the robust, LS, and malnutrition groups in this study. Furthermore, the grip strength and comfortable walking speed of the comorbid group were significantly lower than those of the robust, LS, malnutrition, and LSM groups. Previous studies have shown that low grip strength, comfortable gait speed, and SMI are associated with disability and mortality among community-dwelling elderly people.[27,28] We thought it necessary to consider the co-existence of LS, sarcopenia, and malnutrition when assessing disease progression, because both SMI and grip strength and walking speed were found to be significantly lower in the co-existence group than in the robust, LS, and malnutrition groups.

4.2. Relationship with phase angle and the LS, malnutrition, LSS, LSM and co-existence syndromes

To examine the relationship between phase angle and LS, malnutrition, LSS, LSM, and co-existence groups, we performed multinomial logistic regression analysis adjusted for age and BMI and found that all syndromes were significantly associated with phase angle. Previous studies have shown that the phase angle is useful in diagnosing early malnutrition and predicting mortality.[29] In adults, phase angle has been shown to be significantly influenced by age and BMI.[30] The present study revealed the relationship between the phase angle and each syndrome alone and in co-existence, after adjusting for age and BMI. We considered that the use of the phase angle would be useful as a simple alternative assessment for each of the syndromes without placing a burden on the body. Even in a busy setting at a local health center or examination room, the use of a device that measures phase angle may provide a quick and simple way to assess the risk of the syndrome and notice whether the participants are at high-risk.

4.3. Cut-off values for phase angle to evaluate the LS, malnutrition, LSS, LSM, and co-existence of syndromes

The cut-off values of phase angle for assessing LS, malnutrition, LSS, LSM, and co-existence of three syndromes were 5.4° or less, 5.4° or less, 5.0° or less, 5.2° or less, and 4.9° or less, respectively. Previous studies reported a cut-off value of 4.05 to 5.05 for the phase angle to predict sarcopenia and disability.[24,31] In this study, we showed that phase angle was associated with each syndrome, and that the presence of multiple syndromes led to a gradual decrease in phase angle rather than in the syndrome alone. Theoretically, a low phase angle corresponds to cell death or disruption of the selective permeability of the cell membrane.[32] To identify LS, malnutrition, LSS, LSM, and co-existence of three syndromes among women aged over 60 years, we proposed the optimal cut-off value for phase angle. Sarcopenia and malnutrition have already been reported to have a lower phase angle.[14,16] In particular, it has been shown that the phase is low in high comorbidity patients.[33] Although the phase angle values reported in previous studies cannot be generally compared based on country, sex, or BMI, the cut-off values for the co-existence group in this study were similar to those reported in previous studies for patients with sarcopenia and diabetes mellitus.[19,21] The results of the present study support those of previous studies by showing that the presence of comorbid syndromes also tend to have

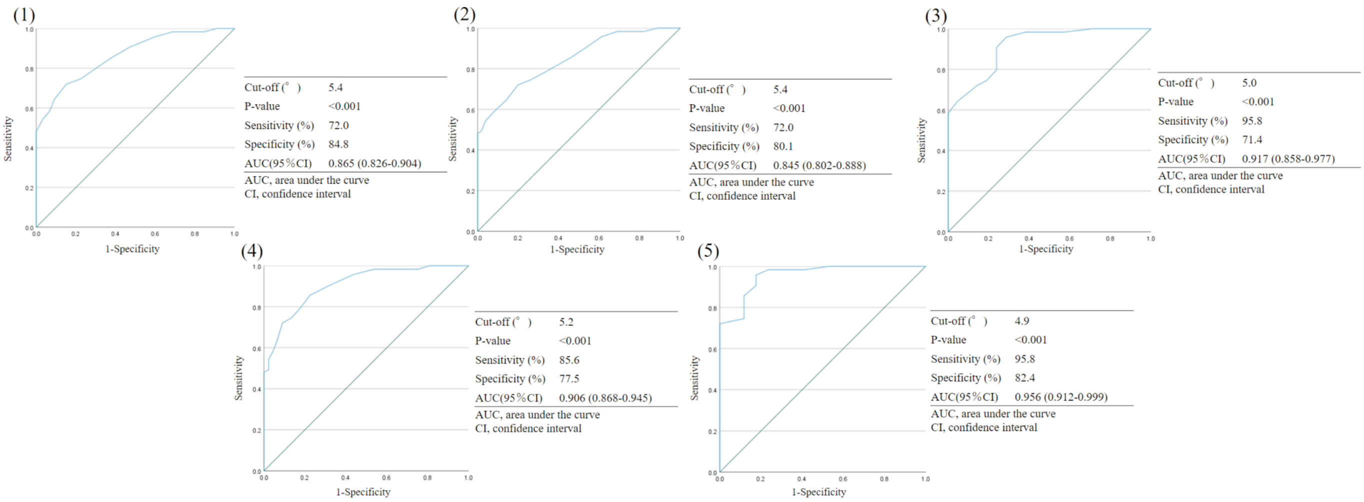

Figure 1. (1) Receiver operating characteristic curve analysis for the locomotive syndrome using the phase angle. This figure shows the cut-off value, sensitivity, specificity, and area under the curve of the phase angle. (2) Receiver operating characteristic curve analysis for the malnutrition using the phase angle. This figure shows the cut-off value, sensitivity, specificity, and area under the curve of the phase angle. (3) Receiver operating characteristic curve analysis for the LSS using the phase angle. This figure shows the cut-off value, sensitivity, specificity, and area under the curve of the phase angle. (4) Receiver operating characteristic curve analysis for the LSM using the phase angle. This figure shows the cut-off value, sensitivity, specificity, and area under the curve of the phase angle. (5) Receiver operating characteristic curve analysis for the co-existence using the phase angle. This figure shows the cut-off value, sensitivity, specificity, and area under the curve of the phase angle.

a lower phase angle. BIA measurement of phase angle was suggested to be a simple and practical assessment to determine the risk of these syndromes and to promote prevention in the community.

5. Limitations

This study has several limitations. First, the LSS and co-existence groups tended to have fewer participants than the other groups. However, as the results of the analysis using G*power 3.1.9 showed that the required number of participants was secured, we did not consider this to be a problem in the analysis. Second, although we have shown a relationship between the phase angle and the three syndromes in this study, the causal relationship is still unclear. Future studies are hence needed to evaluate the effect of phase angle on the development of LS, sarcopenia, and malnutrition. Third, this study did not include the cut-off values for phase angle for men; this should be examined in the future.

6. Conclusions

In conclusion, we determined the relationship between phase angle and LS, malnutrition, LSS, LSM, and the co-existence of three syndromes in this study. Additionally, we clarified the cut-off value of the phase angle in women aged over 60 years with these syndromes. The cut-off values of phase angle for evaluating LS, malnutrition, LSS, LSM, and co-existence were 5.4° or less, 5.4° or less, 5.0° or less, 5.2° or less, and 4.9° or less, respectively. The phase angle is a simple assessment of LS, malnutrition, and sarcopenia alone or co-existence, and it may be useful for the early detection of these syndromes in the community.

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References

1. Nakamura K, Ogata T. Locomotive syndrome: Definition and management. *Clin Rev Bone Miner Metab*. 2016;14(2):56–67.
2. Asahi R, Nakamura Y, Kanai M, et al. Stand-up test predicts occurrence of non-traumatic vertebral fracture in outpatient women with osteoporosis. *J Bone Miner Metab*. 2021;39(5):883–892.
3. Di Monaco M, Castiglioni C, De Toma E, et al. Presarcopenia and sarcopenia in hip-fracture women: Prevalence and association with ability to function in activities of daily living. *Aging Clin Exp Res*. 2015;27(4):465–472.
4. Woo J, Leung J, Morley JE. Defining sarcopenia in terms of incident adverse outcomes. *J Am Med Dir Assoc*. 2015;16(3):247–252.
5. Zhang X, Huang P, Dou Q, et al. Falls among older adults with sarcopenia dwelling in nursing home or community: A meta-analysis. *Clin Nutr*. 2020;39(1):33–39.
6. Hegendörfer E, VanAcker V, Vaes B, Degryse JM. Malnutrition risk and its association with adverse outcomes in a Belgian cohort of community-dwelling adults aged 80 years and over. *Acta Clin Belg*. 2021;76(5):351–358.
7. Ministry of Health, Labour and Welfare. A Basic Direction for Comprehensive Implementation of National Health Promotion. Accessed February 17, 2022. https://www.pbhealth.med.tohoku.ac.jp/japan21/pdf/kenkounippon21_01e.pdf
8. Chen LK, Woo J, Assantachai P, et al. Asian Working Group for Sarcopenia: 2019 consensus update on sarcopenia diagnosis and treatment. *J Am Med Dir Assoc*. 2020;21(3):300–307.e2.
9. Htun NC, Ishikawa-Takata K, Kuroda A, et al. Screening for malnutrition in community dwelling older Japanese: Preliminary development and evaluation of the Japanese Nutritional Risk Screening Tool (NRST). *J Nutr Heal Aging*. 2016;20(2):114–120.
10. Leij-Halfwerk S, Verwijs MH, van Houdt S, et al. Prevalence of protein-energy malnutrition risk in European older adults in community, residential and hospital settings, according to 22 malnutrition screening tools validated for use in adults ≥ 65 years: A systematic review and meta-analysis. *Maturitas*. 2019;126:80–89.
11. Yoshimura N, Muraki S, Iidaka T, et al. Prevalence and co-existence of locomotive syndrome, sarcopenia, and frailty: the third survey of Research on Osteoarthritis/Osteoporosis Against Disability (ROAD) study. *J Bone Miner Metab*. 2019;37(6):1058–1066.
12. Chen LK, Liu LK, Woo J, et al. Sarcopenia in Asia: Consensus report of the Asian Working Group for Sarcopenia. *J Am Med Dir Assoc*. 2014;15(2):95–101.
13. Ide K, Banno T, Yamato Y, et al. Relationship between locomotive syndrome, frailty and sarcopenia: Locomotive syndrome overlapped in the majority of frailty and sarcopenia patients. *Geriatr Gerontol Int*. 2021;21(6):458–464.
14. Kilic MK, Kizilarslanoglu MC, Arik G, et al. Association of bioelectrical impedance analysis-derived phase angle and sarcopenia in older adults. *Nutr Clin Pract*. 2017;32(1):103–109.
15. Tanaka S, Ando K, Kobayashi K, et al. The decrease in phase angle measured by bioelectrical impedance analysis reflects the increased locomotive syndrome risk in community-dwelling people: The Yakumo study. *Mod Rheumatol*. 2019;29(3):496–502.
16. Rinaldi S, Gilliland J, O'Connor C, Chesworth B, Madill J. Is phase angle an appropriate indicator of malnutrition in different disease states? A systematic review. *Clin Nutr ESPEN*. 2019;29:1–14.
17. Norman K, Stobäus N, Pirlich M, Bosy-Westphal A. Bioelectrical phase angle and impedance vector analysis - Clinical relevance and applicability of impedance parameters. *Clin Nutr*. 2012;31(6):854–861.
18. Selberg O, Selberg D. Norms and correlates of bioimpedance phase angle in healthy human subjects, hospitalized patients, and patients with liver cirrhosis. *Eur J Appl Physiol*. 2002;86(6):509–516.
19. Dittmar M, Reber H, Kahaly GJ. Bioimpedance phase angle indicates catabolism in Type 2 diabetes. *Diabet Med*. 2015;32(9):1177–1185.
20. Gupta D, Lammersfeld CA, Vashi PG, et al. Bioelectrical impedance phase angle in clinical practice: Implications for prognosis in stage IIIB and IV non-small cell lung cancer. *BMC Cancer*. 2009;9:37.
21. Akamatsu Y, Kusakabe T, Arai H, et al. Phase angle from bioelectrical impedance analysis is a useful indicator of muscle quality. *J Cachexia Sarcopenia Muscle*. 2022;13(1):180–189.
22. Hu X, Zhang L, Wang H, Hao Q, Dong B, Yang M. Malnutrition-sarcopenia syndrome predicts mortality in hospitalized older patients. *Sci Rep*. 2017;7(1):3171.
23. Vandewoude MF, Alish CJ, Sauer AC, Hegazi RA. Malnutrition-sarcopenia syndrome: Is this the future of nutrition screening and assessment for older adults? *J Aging Res*. 2012;2012:651570.
24. Uemura K, Doi T, Tsutsumimoto K, et al. Predictivity of bioimpedance phase angle for incident disability in older adults. *J Cachexia Sarcopenia Muscle*. 2020;11(1):46–54.
25. Yoshimura N, Akune T, Fujiwara S, et al. Incidence of disability and its associated factors in Japanese men and women: the Longitudinal Cohorts of Motor System Organ (LOCOMO) study. *J Bone Miner Metab*. 2015;33(2):186–191.
26. Matsumoto H, Tanimura C, Tanishima S, Osaki M, Noma H, Hagino H. Sarcopenia is a risk factor for falling in independently living Japanese older adults: A 2-year prospective cohort study of the GAINA study. *Geriatr Gerontol Int*. 2017; 17(11):2124–2130.
27. Malhotra R, Tareque MI, Tan NC, Ma S. Association of baseline hand grip strength and annual change in hand grip strength with mortality among older people. *Arch Gerontol Geriatr*. 2020;86:103961.
28. Studenski S, Perera S, Patel K, et al. Gait speed and survival in older adults. *JAMA*. 2011;305(1):50–58.
29. Buter H, Veenstra JA, Koopmans M, Boerma CE. Phase angle is related to outcome after ICU admission; an observational study. *Clin Nutr ESPEN*. 2018;23:61–66.
30. Bosy-Westphal A, Danielzik S, Dörhöfer RP, Later W, Wiese S, Müller MJ. Phase angle from bioelectrical impedance analysis: Population reference values by age, sex, and body mass index. *JPEN J Parenter Enteral Nutr*. 2006;30(4):309–316.
31. Di Vincenzo O, Marra M, Di Gregorio A, Pasanisi F, Scalfi L. Bioelectrical impedance analysis (BIA)-derived phase angle in sarcopenia: A systematic review. *Clin Nutr*. 2021;40(5):3052–3061.
32. Foster KR, Lukaski HC. Whole-body impedance - What does it measure? *Am J Clin Nutr*. 1996;64(3 Suppl):388S–396S.
33. Graf CE, Herrmann FR, Genton L. Relation of disease with standardized phase angle among older patients. *J Nutr Health Aging*. 2018;22(5):601–607.