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Phase angle as an indicator of nutritional status: a cross-sectional study on the Iranian population

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Abstract

Background Phase angle (PA), derived from bioelectrical impedance analysis, serves as an indicator of cellular health, membrane integrity, and hydration status. Despite its potential utility, the relationship between PA and nutritional and lifestyle factors has not been extensively studied in Iranian populations. This study aimed to investigate these associations in Iranian adults.

Methods This cross-sectional study included 239 university employees (85 men and 154 women) with a mean age of 43.32 years. Anthropometric indices and blood pressure were measured. PA was measured by the Body Composition Analyzer Mc780 MA device. Dietary intakes were assessed by using a validated 86-item food frequency questionnaire (FFQ). Physical activity was evaluated by the short form of the International Physical Activity Questionnaire (IPAQ). Associations between PA and study variables were analyzed using Pearson's correlation and Linear Regression.

Results Significant positive correlations were observed between PA and several anthropometric and body composition indices, including weight, body mass index (BMI), waist circumference (WC), hip circumference (HC), fat-free mass (FFM), muscle mass, bone mass, and visceral fat. PA showed significant associations with dietary intake variables.

Conclusions This study highlights significant associations between PA and body composition and dietary factors in Iranian adults, with notable sex-based differences. These findings suggest that PA may be a valuable marker for assessing nutritional and cellular health.

Keywords Phase angle, Nutritional status, Anthropometry, Adult, University employees

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Background

Malnutrition is a significant concern contributing to both acute and chronic diseases, which has significant consequences on the survival, quality of life, clinical status, and socio-economic conditions of people in the community, especially patients hospitalized [1, 2]. Accurate assessment of nutritional status across different age groups and genders holds crucial importance. However, in many cases, measuring weight and body mass index are generally used as the criteria for evaluating the nutritional status in adults, which do not have the necessary precision to predict their health status [2, 3].

Bioelectrical impedance analysis (BIA) is an indirect and non-invasive method of assessing body composition (measures body fat and fat-free mass), and is a safe, inexpensive, and easy-to-use approach, compared to other methods. Phase angle (PA), as a BIA parameter, is an indicator of cell membrane health and integrity as well as hydration and nutritional status, reflecting relative contributions of fluid (resistance) and cell membranes (reactance) of the body [4–6]. Bosy-Westphal et al. in 2006 reported that the main determinants of PA in healthy German adults were gender and age. In children and adolescents, the main determinants of PA were age and BMI [7]. The results of a cross-sectional study by Gonzalez et al. on healthy adults showed that the most important determinants of PA in men and women were height, fat-free mass and age, and age had the greatest effect on PA [6].

Overall, PA has been considered a marker of nutritional status and clinical conditions such as inflammation [8], oxidative stress [9], liver cirrhosis [10], heart failure [11], patients with COVID-19 [12], cancer [13], and other diseases [1, 14]. PA is emerging as a global health indicator encompassing the overall well-being of the body. Several studies show that there is a significant correlation between phase angle and overall survival, so patients with low phase angle may have cell membrane deterioration as well as poorer overall survival [1, 13]. A low PA indicates decreased cellular integrity, poor muscle function, catabolism and cell death, while a high PA indicates a state of healthy whole-body condition, better nutritional status and high integrity and health of the cell membrane [1, 9, 12, 13, 15]. People's phase angles vary greatly, and there is currently no standardization for population groups. The standard range of the phase angle depends on various factors such as gender, age, race, body height, measuring position, and, of course, the measuring device [2, 6, 7]. Although phase angle (PA) is widely recognized as a valuable indicator of nutritional and cellular health, normative reference values and their determinants remain underexplored in many populations, particularly among Asians, including Iranians. Given the regional differences in anthropometric characteristics, ethnicity, and lifestyle factors compared to Western populations, it is essential to establish population-specific PA standards. Therefore, the current study aims to determine the PA values in a sample of healthy Iranian adults and to examine their associations with age, sex, BMI, dietary intake, physical activity, and blood pressure.

Methods

Study design and population: The standard formula was used to calculate the sample size, and the type I error (α) was considered to be 0.05, the type II error (β) was considered to be 0.20, and $r = 0.20$ [8]. Considering the probability of sample attrition (10%), 129 people were considered, and to allow for comparison between the two sexes, the final sample size was considered to be 258 people. This study was done cross-sectionally on 258 healthy employees of Isfahan University of Medical Sciences in the age range of 18–60 years who were selected using a non-probability convenience sampling method. The study's protocol was reviewed and approved by the Medical Ethics Committee at Isfahan University of the Medical Sciences, Iran (ethics registration number: IR.MUI.RESEARCH.REC.1399.052).

The participants included 18-60-year-old healthy people who are working at the Isfahan University of Medical Sciences campus, Isfahan, Iran, in 2022. Participants under 18 or over 60 years old, pregnant or lactating women, and people with a history of metabolic diseases such as diabetes, malignant diseases, liver or kidney diseases, and hypertension were excluded. Additionally, individuals with a history of adherence to specific dietary patterns (e.g., vegetarian, ketogenic, very low-calorie, or athlete-specific diets) or those undergoing specialized pharmacological treatments were excluded from the study. All eligible participants were informed about the purpose and method of the study and, written informed consent was obtained from them. The study included a visit for anthropometric measures, PA determinations, and a semi-quantitative food frequency questionnaire (FFQ). Demographic data and medical history of participants, including medication use and disease, were obtained through a structured questionnaire. Participant unwillingness to cooperate was anticipated and addressed at various stages of the study. Furthermore, those participants who left more than 40 food items blank on the 86-item food frequency questionnaire (FFQ), as well as those with reported energy intake outside the range of 800–4200 kcal/d. After all these exclusions, 239 participants remained for the current analysis.

Anthropometric measurements and phase angle

The weight with light clothes and body composition of the participants were evaluated by portable TANITA M780 (Tanita, Japan). Height was measured in a standing position, looking straight ahead, arms at sides, and shoulders relaxed with no shoes on, with 0.1 cm precision by Seca 763 scale (Hamburg, Germany). Body mass index was calculated by dividing the weight (kg) by the square of height maist circumference was measured at the narrowest area of the waist and maximum level of the hip, over light clothing, using a flexible tape measure, without any pressure to the body surface and was recorded to the nearest 0.1 cm. Waist-Height Ratio (WHtR) was calculated by dividing the waist in meters by height in meters. Body composition, including fat mass, fat-free mass, muscle mass, bone mass, visceral fat and PA, was measured by the Body Composition Analyzer Mc 780 MA device.).

Blood pressure was measured twice using a standard mercury sphygmomanometer on the left arm in a seated position after a 15-minute rest. Before measuring the blood pressure, they were asked about the consumption of tea, coffee and physical activity. The mean of the two measured systolic and diastolic blood pressures was reported. To minimize measurement error, all measurements were performed by a trained dietitian.

Assessment of dietary intakes and physical activity The usual dietary consumption of the participants over the past year was collected using a validated semi-quantitative 86-item food frequency questionnaire (FFQ) [16, 17]. The participants were asked to specify the frequency of their consumption of each item according to the food servings in the last year. Depending on the type of food consumption, the frequency of consumption, daily, weekly, or monthly, was asked, and it was completed by a trained nutritionist. Then the reported portion size was converted to grams per day using household measures, and the nutrients and energy content were extracted by NUTRITIONIST 4 (First Data Bank, San Bruno, CA). Participants filled in a validated form of the 7-item Physical Activity Questionnaire-Short Form (IPAQ-S) [18]. Data were converted to metabolic equivalent hours/week.

Statistical analysis SPSS software version 23 (IBM, Chicago, IL) was used for analyses. Quantitative data are presented as mean ± standard deviation (SD), while qualitative data are presented as frequency (percentage). The Shapiro-Wilk test was used to assess normality. Independent Sample T-test and Chi-square test were utilized for analyzing variables. P-values < 0.05 (two-sided) were considered statistically significant.

Results

This study included 239 adults (85 male and 154 female). The mean age for men and women was 45.0 ± 7.4 years and 42.4 ± 9.3 years, respectively. Men had significantly higher PA values (6.2 ± 0.6°) than women (5.3 ± 0.6°, $p < 0.001$). The characteristics of the study participants are shown in Table 1. The men had greater weight, height, BMI, FFM, muscle mass, visceral fat, basal metabolic rate (BMR) and PA values compared to women ($p < 0.001$ for all). We used the median PA as the cutoff point for classifying participants (healthy ≥ 5.6). No significant sex-based differences were observed in the physical activity level and diastolic blood pressure, although systolic blood pressure was slightly higher in men (*p = 0.007*). Table 2 shows the energy and macronutrient intake of participants. Compared with women, men had a greater intake of energy, carbohydrate and protein ($p < 0.001$). There was no significant difference in fat intake between men and women (*p = 0.127*). Pearson correlation analysis between the PA and body composition and anthropometric

Table 1 Anthropometric measurements and body composition characteristics of the study participants by sex

Characteristics	Men (*n* = 85)	Women (*n* = 154)	*P*-value
Age (year)	45.0 ± 7.4	42.4 ± 9.3	0.034
Biological age (year)	47.5 ± 10.6	43.6 ± 12.7	0.014
Weight (kg)	80.7 ± 11.9	65.4 ± 9.6	<0.0001
Height (cm)	172.1 ± 7.4	159.8 ± 6.3	<0.0001
Bmi (kg/m^2)	27.5 ± 3.9	25.6 ± 4.0	<0.0001
Fat mass (kg)	22.0 ± 6.7	22.4 ± 6.2	<0.0001
Fat free mass (kg)	60.6 ± 6.8	43.0 ± 4.4	<0.0001
Muscle mass (kg)	57.5 ± 6.5	40.8 ± 4.2	<0.0001
Wc (cm)	99.7 ± 9.2	88.6 ± 10.4	<0.0001
Hc (cm)	104.6 ± 5.9	102.9 ± 8.0	0.096
Phase angle (°)	6.2 ± 06	5.3 ± 0.6	<0.0001
Phase angle status < 5.6 ≥ 5.6	12 (14.1) 73 (85.9)	105 (68.6) 48 (31.4)	<0.0001
BMR (kcal)	1754.9 ± 285.6	1300.1 ± 156.1	<0.0001
Bone mass (kg)	3.0 ± 0.3	2.4 ± 0.2	0.029
Visceral fat level	10.0 ± 3.1	5.8 ± 2.6	<0.0001
Physical activity level (met) Low moderate intense	20 (23.5) 64 (75.3) 1 (1.2)	42 (27.3) 111 (72.1) 1 (0.6)	0.736
SBP (mmHg)	118.5 ± 10.2	112.6 ± 11.2	0.007
DBP (mmHg)	77.5 ± 8.2	74.5 ± 7.8	0.052

• Data presented as mean ± sd or number (percent)

• Abbreviations: BMI, body mass index; WC, waist circumference; HC, hip circumference; BMR, basal metabolic rate; MET: metabolic equivalent SBP, systolic blood pressure; DBP, diastolic blood pressure

• Biological age: Estimated functional age of the body

• P-values calculated by independent sample t-test, and chi-square test

Table 2 Dietary intakes of study participants by sex

	Male (*n* = 85)	Female (*n* = 153)	*P*-value
Energy (kcal)	3646.6 ± 1747.7	2538.4 ± 829.4	˂0.0001
Protein (gr)	113.4 ± 53.3	82.9 ± 34.4	˂0.0001
Carbohydrate (gr)	602.0 ± 345.9	372.2 ± 133.7	˂0.0001
Total fat (gr)	97.2 ± 44.8	88.3 ± 41.2	0.127

• Data presented as mean ± sd

variables is presented in Table 3. A positive correlation was observed between PA and weight, BMI, WC, HC, FFM, muscle mass, bone mass, and visceral mass ($p < 0.001$). Conversely, PA correlated negatively with fat mass ($p = 0.624$). The Linear regression model significantly predicted phase angle, $p < 0.001$, explaining 42.9% of variance. Significant predictors included male gender ($B = 0.85$, $p < 0.001$) and higher BMI ($B = 0.05$, $p < 0.001$). Dietary components did not reach statistical significance (Table 4).

Table 3 Correlation between the phase angle and all anthropometric, body-composition and physical activity of study participants

	R	*P*-value
Weight, kg	0.238	<0.0001
Bmi, kg/m2	0.405	<0.0001
Waist circumference (cm)	0.421	<0.0001
Hip circumference (cm)	0.190	0.004
BMR (kcal)	0.566	<0.0001
Fat mass (kg)	−0.032	0.624
Visceral fat (kg)	0.407	<0.0001
Fat free mass (kg)	0.582	<0.0001
Muscle mass (kg)	0.581	<0.0001
Bone mass (kg)	0.563	<0.0001
Physical activity	0.007	0.911

• P-values calculated by Pearson's correlation

• Abbreviations: BMI, body mass index; WC, waist circumference; HC, hip circumference; BMR, basal metabolic rate

Table 4 Linear regression analysis predicting phase angle ($n = 223$)

Predictor	B	SE	β	P	95% CI for B
Intercept	4.073	0.334		< 0.001	3.414–4.732
Age (year)	-0.006	0.005	-0.070	0.202	-0.015–0.003
Gender (male)	0.846	0.093		< 0.001	0.663–1.029
BMI (kg/m²)	0.054	0.010	0.291	< 0.001	0.035–0.074
Protein (gm)	0.007	0.004	0.416	0.103	-0.001–0.015
Fat (gm)	0.013	0.007	0.756	0.077	-0.001–0.028
Carbohydrate (gm)	0.005	0.003	1.885	0.111	-0.001–0.012
Kilocalories (kc)	-0.001	0.0009	-2.607	0.101	-0.003–0.0003
Women					
BMI (kg/m²)	0.067	0.012	1.069	< 0.001	1.045–1.094
Men					
BMI (kg/m²)	0.020	0.178	1.020	0.260	0.985–1.056

B = unstandardized coefficient; SE = standard error; β = standardized coefficient; CI = confidence interval. Model statistics: $R^2 = 0.429$, $p < 0.001$. Gender reference group is female. Standardized coefficients (β) are only interpretable for continuous predictors. Protein, Fat, Carbohydrate, and Kilocalories represent dietary intake variables. BMI = Body Mass Index

Discussion

Our findings demonstrate a statistically significant difference in PA values between men and women, with men exhibiting higher mean PA compared to women. These results align with previous studies indicating that PA is influenced by body composition, particularly the proportion of fat-free mass and muscle mass. Men typically have a higher FFM and lower fat mass than women. While this difference is statistically significant, it's important to recognize that these observed differences reflect known biological patterns in body composition, with higher values in men potentially indicating greater cellular health and metabolic activity, as muscle tissue is more metabolically active than adipose tissue [6, 19]. The strongest correlations were observed between PA and measures of lean body mass, including FFM, muscle mass, and bone mass. These findings are in agreement with studies that have emphasized the role of lean mass in determining PA. FFM and muscle mass are the primary contributors to reactance, which is directly proportional to PA [3, 19, 20]. These robust correlations underscore the fundamental contribution of lean mass to PA, highlighting a clinically relevant association. Conversely, the negative correlation between PA and fat mass observed in other studies was less pronounced in our findings (r = -0.2). This weaker association, while it might reach statistical significance, suggests a less biologically impactful relationship in our study sample and its importance should not be overstated [6, 21, 22]. Compared to our study, Gonzalez et al. [6] conducted a more comprehensive investigation with a larger sample size and separate analyses by sex, enhancing the statistical power and relevance of their findings. Their detailed analysis of the extracellular to intracellular water ratio provided valuable insights into the physiological basis of phase angle variations. Using multivariate regression models adjusted for confounders such as age, race, and height, they identified age, fat-free mass, and hydration status as the strongest independent predictors of phase angle. These well-supported results offer important clinical implications for interpreting phase angle as a marker of cellular health, thereby complementing and extending the findings of our study focused on dietary and lifestyle associations in an Iranian adult population. The study by Jaremków et al. demonstrated that phase angle is significantly influenced by body composition parameters such as FFM, BMI, muscle mass, and ECW/ICW ratio, as well as lifestyle factors including diet quality, physical activity, and screen time. Their findings highlighted the influence of lifestyle behaviors on PA, such as the consumption of energy drinks, alcohol, water, fruits and vegetables, and time intervals between meals. Physical activity and reduced screen time were also positively correlated with higher PA values. These results emphasize the multifactorial nature of PA and its sensitivity not only to physiological parameters but also to modifiable lifestyle factors [22]. Interestingly, physical activity levels, assessed via the short form of the International Physical Activity Questionnaire, did not significantly differ between men and women and showed only a limited association with PA. While Mundstock et al. [23], in a systematic review and meta-analysis found a positive effect of physical activity on phase angle. The cross-sectional study by Yang et al. [24] on Korean adults showed that higher levels of aerobic activity—especially when combined with muscle-strengthening or vigorous exercises—were positively associated with phase angle. These findings underscore the value of PA as a marker of cellular health and highlight the role of structured leisure-time physical activity in improving nutritional, our findings align with Streb et al. [25], who reported no correlation between physical activity and PA. The absence of a strong and clinically relevant correlation in our study, unlike some previous research, warrants further consideration. While physical activity is known to influence body composition, the lack of a statistically significant correlation in our data may stem from the subjective nature of self-reported activity levels, the relatively small variance in physical activity within our study population, other factors such as genetic influences, nutritional status, or specific training adaptations might play a more substantial role [6, 23]. The findings highlight the need for future research utilizing objective activity measurements and more heterogeneous samples to better understand the relationship between physical activity and PA The positive correlation between PA and dietary intake of energy, carbohydrates, and protein in this study underscores the influence of nutrition on cellular and body composition health. Previous studies have shown that protein intake is associated with higher PA values due to improved muscle synthesis and cellular repair mechanisms [26–28]. However, the association between phase angle and dietary intake has been poorly explored, and our results contribute valuable insights to this under-researched area. Unterberger et al. reported no relationship between PA and protein intake in older individuals [29]. Majerr et al. [27]reported that higher protein and phosphorus intakes are associated with improved cellular integrity and muscle mass in dialysis patients. The study also highlighted inadequate nutritional education among patients, emphasizing the need for tailored dietary interventions. These results align with our findings and reinforce the role of adequate dietary intake—particularly protein—in enhancing PA and maintaining cellular health. This discrepancy in findings could be attributed to differences in population characteristics, methodology, or baseline nutritional status of participants, highlighting the need for further investigation to clarify this relationship. Interestingly, in our study, fat intake did not show a significant relationship with PA, suggesting that macronutrients like protein and carbohydrates, which directly support lean mass, have a more pronounced impact on PA than dietary fats.

Previous researches underscore the significant influence of race on phase angle and suggests that each population requires its reference values for PA, despite similar patterns of variation by sex and age observed globally [6, 13, 30]. The focus of our study on the Iranian population is particularly noteworthy, as it addresses a significant gap in the existing literature. Most PA research has predominantly involved Western and Asian populations, leaving Middle Eastern groups underrepresented. By contributing data from this region, our study not only enriches the global understanding of PA variability but also provides a foundational step for establishing specific reference values for Middle Eastern populations. Such reference standards are crucial for improving the accuracy and clinical relevance of nutritional assessments and for enabling more precise health evaluations and disease risk screening tailored to Middle Eastern individuals.

Strengths and limitations

The present study has several strengths. This was the first study to determine PA in a sample of the Iranian population by comprehensively assessing anthropometric, dietary, and body composition variables with sex-specific analyses, increasing the generalizability of the findings.

The use of a validated food frequency questionnaire (FFQ) and a reliable bioelectrical impedance analysis (BIA) device further strengthens the methodological rigor. Moreover, the findings support the potential utility of PA as a non-invasive biomarker for evaluating nutritional and cellular health in community-dwelling adults. However, some limitations must be acknowledged. The cross-sectional design limits the ability to establish causality, emphasizing the need for prospective studies to validate these findings. Additionally, participants were selected via easy, non-random sampling from university staff; thus, the results may not fully reflect the characteristics and dietary behaviors of the general adult population in Iran. The convenience sampling of university employees limits the representativeness of the study population and may reduce the external validity of the results. Moreover, the reliance on self-reported physical activity data introduces the potential for recall and reporting biases, which may have impacted the results. Finally, the absence of micronutrient intake analysis is a notable limitation, as micronutrient status may influence PA values, warranting further investigation in future research. Prospective studies are recommended to address these issues by incorporating more diverse populations, objective lifestyle measures, and detailed nutrient assessments.

Conclusion

This study demonstrates significant sex-based differences in PA and its association with body composition and dietary intake in an Iranian adult population. These findings underscore the potential of PA as a valuable tool for assessing nutritional and cellular health. Its strong and clinically relevant association with FFM and dietary intake highlights its potential utility in monitoring interventions aimed at improving body composition and overall health. However, further research is needed to validate these associations in diverse populations and to explore the longitudinal implications of PA in health and disease. Additionally, exploring the relationships between PA and other health indicators, such as inflammatory markers and metabolic health, could further elucidate its role in assessing overall well-being.

Abbreviations

PA Phase angle
FFQ Food Frequency Questionnaire
IPAQ International Physical Activity Questionnaire
BMI Body Mass Index
WC Waist Circumference
HC Hip Circumference
FFM Fat-Free Mass. BIA: Bioelectrical Impedance Analysis

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Author contributions

FS, NE, MJT, RA, MA, and FSH contributed to the conception, design, data collection, data interpretation, manuscript drafting and approval of the final version of the manuscript, and agreed on all aspects of the work.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

The study procedure was performed according to the Declaration of Helsinki and the STROBE checklist. All participants provided informed written consent, and the study protocol was approved by the Ethics Committee of Isfahan University of Medical Sciences (IR.ARI.MUI.REC.1399.052).

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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