Estimation of the appendicular skeletal muscle mass and phase angle cut-off values from a young Turkish reference population using multifrequency bioelectrical impedance analysis

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Abstract. – OBJECTIVE: Population-specific muscle mass cut-off values are recommended for the diagnosis of sarcopenia. In this study, we aimed to determine the appendicular muscle mass index (ASMI) and phase angle (PA) cut-off values for the Turkish population using multi-frequency bioelectrical impedance analysis (mBIA).

PATIENTS AND METHODS: A total of 250 healthy volunteers aged 18-40 years were included in the study between September 2020 and December 2021. PA was measured by mBIA, and appendicular skeletal muscle mass (ASM) was calculated by the Sergi formula using the resistance and reactance measurements from mBIA. ASMI was calculated as ASM (kg)/(height in meters)^2. Two standard deviations (SD) below the mean values were accepted as cut-off points.

RESULTS: 134 women and 116 men were included in the study (26.0±5.6 years). The ASMI cut-offs for men and women were 5.86 and 4.36 kg/m^2, respectively. The PA cut-offs were 5.66° in men and 4.38° in women.

CONCLUSIONS: The present study reported the ASMI and PA cut-off values specific to the Turkish population using the Sergi formula, which was suggested by the European Working Group on Sarcopenia in Older People (EWGSOP).

Key Words:
Sarcopenia, Skeletal muscle mass, Bioelectrical impedance, Phase angle.

Introduction

Sarcopenia is a geriatric syndrome characterized by diffuse progressive loss of muscle mass, strength, and physical capacity, associated with low physical activity, gait disorders, falls, reduced quality of life, and mortality[1]. European Working Group on Sarcopenia in Older People (EWGSOP) published an updated report in 2019 (EWGSOP2), including screening for sarcopenia and identification of high-risk patients, which was recommended as the initial step in the diagnosis of sarcopenia[2]. Low muscle strength indicated probable sarcopenia and, together with low muscle mass, was defined as confirmed sarcopenia. Physical performance was associated with the severity of the problem. Recent studies[3] have recognized that muscle strength is a better predictor of adverse outcomes than muscle mass, leading to an increased emphasis on muscle strength in EWGSOP2. Furthermore, the studies[4] have demonstrated a correlation between muscle strength and both mental and physical quality of life. Sarcopenia is closely related to malnutrition, and low muscle mass is one of the phenotypic criteria of the Global Leadership Initiative on Malnutrition (GLIM) tool for diagnosing malnutrition[5].

To date, different cut-off values for skeletal muscle mass (SMM) have been reported for many populations, including either young, healthy adults or older adults[6]. Some studies[7] have used 2 standard deviations (SD) below the mean value, while others have used the highest sensitivity and specificity values combined with receiver operating characteristic (ROC) curve values. Age- and sex-specific cut-off values have also been proposed, and a minimum SMM of 20% has been used to determine cut-off values in both gender[8,9]. Several parameters have been used to assess muscle mass, including

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fat-free mass (FFM), SMM, appendicular skeletal muscle mass (ASM), total skeletal muscle (TSM), SMM index (SMMI), and ASM index (ASMI)[10]. Accordingly, the prevalence of sarcopenia in different reports varies significantly depending on the populations, definitions, measurement tools, and parameters, making subsequent comparisons impractical[11]. To address this shortcoming, the EWGSOP recommended the use of a cut-off value 2 SD below the mean of reference healthy young adults as the cut-off value[2]. Therefore, a robust evaluation of population-specific cut-off values for muscle mass is of paramount importance for the diagnosis and treatment, and EWGSOP suggests that each population should establish its own cut-off values for muscle mass in healthy young individuals.

The phase angle (PA) is defined as the ratio of resistance (intracellular and extracellular resistance) to reactance (cell membrane-specific resistance) expressed as an angle. It is related to intracellular and extracellular water distribution and body cell mass. Thus, high PA indicates greater cellularity (compared to fat mass), cellular integrity and better cellular functions. PA has been associated with nutritional status and muscle mass[12].

In this study, we aimed to determine the cut-off values of ASMI and PA in the Turkish population, based on the EWGSOP2 report[2].

Patients and Methods

Study Population

This study is a cross-sectional observational analysis of 250 healthy adult volunteers aged 18-40 years recruited between September 2020 and December 2021. Individuals with any acute or chronic diseases and/or medical disorders, chronic drug usage, history of surgery within the last three months, those with metal implants (prosthesis, pacemaker), and pregnancy were excluded.

Anthropometric Measurements

Body mass index (BMI; kg/m^2) was calculated by measuring the body height and weight in the morning after an overnight fast.

Multi-Frequency Bioelectrical Impedance Analysis (mBIA)

Anthropometric analysis was performed using a mBIA device (Tanita MC780 MA, Japan). The system used electric current at different frequencies (5, 50, and 250 kHz) to estimate the amount of extracellular and intracellular water in the body. Study participants stood on two metal electrodes and held metal handle electrodes. ASM was calculated using Sergi's formula [ASM (kg) = -3.964 + (0.227 × R) + (0.095 × body weight [kg]) + (1.384 × gender) + (0.064 × Xc)], where "R" is resistance in ohms, "Xc" is the reactance in ohms measured with mBIA, and for the gender, male=1 and the female=0[7]. ASMI was calculated by dividing ASM by the square of body height (m). Phase angle (PA), a linear method of measuring the relationship between electrical resistance (R) and reactance (Rc), was measured with mBIA[13].

Statistical Analysis

Data were analyzed using SPSS 26.0 for Windows (IBM Corp., Armonk, NY, USA). Data were expressed as mean, SD (standard deviation), median, frequency (n), ratio, maximum, and minimum. To calculate the 95% CIs of [mean-2SD], the values of the 95% CI of the mean and the SD at the 95% CI were obtained. For all the statistical analyses, $p<0.05$ was considered significant.

Results

The study included 250 participants: 134 (53.6%) females and 116 (46.4%) males, with a mean age of 26.0±5.6 years and a mean BMI of 23.9±4.1 kg/m^2. Table I shows the anthropometric measurements of the participants.

The mean ASMI values of both genders were 7.09±0.61 kg/m^2 for males and 5.68±0.66 kg/m^2 for females. The mean PA values for men and women were 6.68±0.51° and 5.58±0.60°, respectively (Table II).

Table III shows the ASMI (Sergi formula) and PA cut-off values, which were determined to be 2 SD below the mean values obtained for male and female participants. The ASMI cut-offs for males and females were 5.86 and 4.36 kg/m^2, respectively. The PA cut-offs were 5.66° for males and 4.38° for females.

Discussion

We presented the ASMI and PA cut-off values specific to the Turkish population using mBIA. Appendicular skeletal muscle mass (ASM) is calculated by the Sergi formula using resistance and reactance measurements from mBIA.

Table I. Anthropometric measurements.

		Mean	SD	Min-max
Age (years)	Male	26.8	5.6	18-40
	Female	26.9	5.8	18-40
Height (m)	Male	1.76	0.07	1.61-1.93
	Female	1.63	0.04	1.51-1.76
Weight (kg)	Male	79.0	14.0	54.2-117.8
	Female	61.2	11.3	42.1-110.0
BMI (kg/m²)	Male	25.27	3.79	18.7-35.2
	Female	22.76	4.03	18.9-37.0

SD: Standard deviation, BMI: Body mass index, Min-max: minimum-maximum.

Table II. Mean muscle mass and phase angle values of the participants according to gender.

	Male		Female	
	Mean	SD	Mean	SD
ASM (Sergi's formula) (kg)	22.17	2.66	15.3	2.0
ASMI (ASM/m²) (kg/m²)	7.09	0.61	5.68	0.66
Phase angle (°)	6.68	0.51	5.58	0.60

ASM: Appendicular skeletal muscle mass, ASMI: Appendicular skeletal muscle mass index, SD: Standard deviation.

Sarcopenia is associated with frailty, quality of life, morbidity, and mortality. Low muscle strength and low muscle mass are the hallmarks of sarcopenia. Then, it is necessary to establish population-specific cut-off values for muscle strength and muscle mass cut-off values in different societies[2].

The accuracy of muscle mass cut-off values depends on the population studied and the method of analysis. Magnetic resonance imaging (MRI), computed tomography (CT), and dual-energy X-ray absorptiometry (DXA) are the gold standards for assessing body composition and muscle mass[6]. However, they are difficult to access and perform and are impractical for assessing large populations in diverse settings. BIA is a widely used, rapid, non-invasive, inexpensive, and easy-to-use method of analysis that does not require advanced training. It is related to the electrical permittivity of the tissues. Impedance consists of resistance (R) and reactance (Xc) and also includes the phase angle, which expresses cell permeability through the curve formed by these two values[6]. Although it is the method of choice for measuring muscle mass, it has some challenges, such as its sensitivity to hydration, body temperature, timing, body symmetry, and position[10]. BIA is also recognized by EWGSOP as a favorable alternative to DXA. BIA can be used in both outpatients and inpatients[2]. Another limitation of BIA is that different BIA devices may give different results[10]. Direct BIA measurements and/or calculations using FFM can lead to false positives, overestimation, and unnecessary treatment. Recently, mBIA devices have provided more accurate results regarding body water distribution, lean body mass, fat mass, tissue resistance, reactance, and phase angle measurements. EWGSOP2 recommends the use of calculation-based formulae using resistance and reactance values obtained with BIA[2]. In our study, ASM was calculated with the Sergi formula using resistance and reactance values obtained by mBIA. In previous studies of young reference

Table III. Cut-off values for ASM, ASMI, and phase angle determined with 2-SD below the mean values obtained for male and female participants.

	Male	Female
ASM (kg)	16.9	11.3
ASMI (ASM/m²) (kg/m²)	5.86	4.36
Phase angle (°)	5.66	4.38

ASM: Appendicular skeletal muscle mass, ASMI: Appendicular skeletal muscle mass index.

groups studies[14,15] from two different provinces of Turkey, the cut-off values for skeletal muscle mass index (SMMI, calculated with the formula FFM×0.566 formula) were reported to be 9.2 kg/m² and 8.33 kg/m² for men, and 7.4 kg/m² and 5.70 kg/m² for women.

ASM is the sum of muscle mass of the extremities[16]. The Asian Working Group for Sarcopenia (AWGS) study defined low ASMI as <7.0 kg/m² in males and <5.7 kg/m² in females based on BIA. The mean ASMI in Chinese individuals was 17% lower than in Caucasians[17]. In the USA, Japan, and Korea, ASMI cut-off values of 7.26 kg/m², 7.0 kg/m², 6.75 kg/m² for men and 5.45 kg/m², 5.8 kg/m², 5.07 kg/m² for women have been reported[18-20]. In Mexicans and Caucasians, they were 5.86 and 7.26 kg/m² in men and 4.72 and 5.45 kg/m² in women, respectively[9,21]. A study[22] conducted in Poland investigated gender-specific cut-off values for low muscle mass in different age groups of young, healthy adults and recommended the highest cut-off values of 5.60 kg/m² for females and 7.40 kg/m² for males. Data from the literature are shown in Table IV. In our study, the ASMI cut-offs were 5.86 kg/m² and 4.36 kg/m² for males and females, respectively, according to Sergi's formula, in accordance with the EWGSOP recommendations.

Data from Japan and Korea[19,20] show that ASM is lower in Asian populations than in Western countries. Individuals from Northern China have higher skeletal muscle mass (SMM) than those from southern parts of the country[15]. Chinese people have smaller bones and lower SMM compared to Caucasians, and lower body fat compared to Indians and Malaysians[23]. Caucasian Americans had lower fat mass than Caucasian Europeans, and Africans and Caucasians had longer legs and higher SMM than Asians[9,24]. It has been reported that economic development and urbanization may change the physical activities of individuals, which is associated with increased fat mass due to sedentary lifestyles[25]. Muscle mass cut-off values may differ between men and women due to the differences in body composition. Smaller height, weight, and bone length in women result in lower SMM and higher body fat ratio[26]. In a study conducted in Korea[20], it was reported that bone length was associated with SMM, and SMM increased with bone length.

The phase angle is influenced by many variables such as gender, age, nutrition, physical activity, and disease status, and an increased phase angle indicates a strong, healthy cell membrane and healthy cell functions[27]. In addition to being a predictor of cancer survival, phase angle has been shown to be useful in monitoring improvements in nutritional status and biochemical indices[28]. Barbosa-Silva et al[29] found a mean phase angle of 6.93°±1.15° in 1967 healthy adults aged 18-94 years. The study also found that the phase angle was higher in males at all ages and decreased with age in both groups. In males, the mean phase angle was 7.90° in the young adults and 6.19° in the older group (≥70 years), compared to 7.04° and 5.64° in females. Barrea et al[30] found that 29-38 y with normal body weight had

Table IV. Comparison of our cut-off values with those reported in the literature.

	ASMI (kg/m²) Male/Female	Phase angle (o) Male/Female
EWGSOP2†	< 7.0/< 5.5	
AWGS[17]‡	< 7.0/< 5.7	
Sanada et al[19]†	6.87/5.46	
KNHNES-Korea[20]†	6.57/5.07	
Aleman and Ruiz[21]†	5.86/4.72	
Kim et al[23]†	7.40/5.14	
Baumgartner et al[18]†	7.26/5.45	
Krzymińska-Siemaszko et al[22]†	5.60/7.40	
Barbosa-Silva et al[29]		7.90/7.04
Barrea et al[30]		6.72/6.07
Wen et al[31]†	5.85/4.23	
Current study‡	5.86/4.36	5.66/4.38

†DXA, ‡mBIA; AWGS: Asian Working Group for Sarcopenia, DXA: Dual-energy X-ray absorptiometry EWGSOP2: European Working Group on Sarcopenia in Older People Statement 2, KNHNES: Korean National Health and Nutritional Examination Surveys, mBIA: multifrequency bioelectrical impedance analysis.

a higher mean phase angle (male: 6.72°±0.39°, female: 6.07°±0.16°) compared to the 49-58 y group (male: 6.10°±0.34°, female: 5.52°±0.06°). In our study, the mean phase angle of healthy young adults was 6.68°±0.51° for men and 5.58°±0.6° for women. The phase angle cut-off values were 5.66° for men and 4.38° for women.

Limitations

The study had limitations as it was conducted in a single center and there was no comparison with gold standard methods such as DXA or MRI for measuring muscle mass.

Conclusions

Our data reported the ASMI and PA cut-off values for the Turkish population based on a young reference study group. Accordingly, our results obtained with Sergi's formula using resistance and reactance values of mBIA seem to be comparable with those reported in EWGSOP2. Considering that our results were remarkably close to those obtained in the previous DXA studies, it will be a highly reliable reference for the Turkish population.

Conflict of Interest

The authors declare no competing interests.

Availability of Data and Materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Ethics Approval

The study protocol was approved by the Istanbul University Medical School Clinical Research Ethics Committee (Date: 18.09.2020 and file number: 2020/1223).

Informed Consent

The study was conducted according to the guidelines of the Helsinki Declaration, and all the patients or their legal representatives signed an informed consent.

Authors' Contribution

M.A., N.L., and B.S. designed research. Y.G., Y.B.B., T.S.A. and S.N.E. analyzed data. M.A., N.L., and B.S. wrote the paper. All authors critically read and provided feedback on the manuscript. M.A. and B.S. had primary responsibility for the final content.

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