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WHAT CAN BODY COMPOSITION ANALYSIS REVEAL ABOUT INSPIRATORY AND PERIPHERAL MUSCLE STRENGTH?

ŠTO MOŽE OTKRITI ANALIZA SASTAVA TIJELA O SNAZI INSPIRACIJSKIH I PERIFERNIH MIŠIĆA?

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Abstract

Introduction: Body composition analysis measured with bioelectrical impedance analysis (BIA) is a method which has been frequently used in body composition assessment. The goal of this research is to determine the correlation of the derived measurements with the help of BIA with the strength of peripheral and inspiratory muscles as well as with the diaphragm's function and thickness in healthy population.

Participants and methods: Participants in this research were healthy individuals. They were tested on body composition with the help of bioelectrical impedance on Tanita *MC-780MA* device, maximal inspiratory pressure (MIP) with the POWERbreathe device, dynamometry of forearm muscle flexor and tibia extensor with the help of a dynamometer as well as ultrasound evaluation of diaphragm's function.

Results: The study sample consisted of a total of 50 participants, including 31 females (62%) and 19 males (38%) with a mean age of 41 years. The results have proved that the strength of peripheral and inspiratory muscles together with the diaphragm's thickness and mobility are in strong correlation with muscle mass, sarcopenic index and phase angle measured by BIA.

Conclusion: Bioelectrical impedance analysis is a reliable and practical method for assessing body composition and detecting early signs of muscle dysfunction. The established associations with muscle strength and diaphragmatic function highlight its potential as a simple screening tool for maintaining muscular health in clinical and preventive settings.

Keywords: adult; bioelectric impedance analysis; diaphragm; muscle strength; respiratory muscles

Sažetak

Uvod: Analiza sastava tijela mjerena bioelektričnom impedancijom (engl. *Bioelectric Impedance Analysis*, BIA) metoda je koja se sve učestalije koristi u procjeni sastava tijela. Cilj rada je utvrditi korelaciju dobivenih mjerenja pomoću BIA-e sa snagom perifernih i inspiracijskih mišića te debljine i funkcije ošita u zdravoj populaciji.

Ispitanici i metode: Ispitanici u ovom istraživanju bili su zdravi pojedinci. Na ispitanicima je provedena analiza sastava tijela na Tanita *MC-780MA* uređaju, testiranje maksimalne inspiracijske snage (MIP) pomoću uređaja *POWERbreathe*, dinamometrija mišića fleksora podlaktice i ekstenzora potkoljenice pomoću dinamometra te ultrazvučna procjena funkcije ošita.

Rezultati: Uzorak na kojem je provedeno istraživanje sastojao se od 50 ispitanika od čega je 31 (62%) osoba ženskog spola i 19 (38%) osoba muškog spola, prosječne dobi

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od 41 godine. Rezultati ukazuju na snažnu korelaciju snage perifernih i inspiracijskih mišića i funkcije ošita s mišićnom masom, sarkopenijskim indeksom i faznim kutom mjerenim BIA-om.

Zaključak: Bioelektrična impedancija predstavlja pouzdanu i praktičnu metodu za procjenu sastava tijela i otkrivanje ranih znakova mišićne disfunkcije. Utvrđene povezanosti sa snagom mišića i funkcijom ošita ističu njezin potencijal kao jednostavni alat za rano otkrivanje i očuvanje mišićnog zdravlja u kliničkom i preventivnom kontekstu.

Ključne riječi: bioelektična impedancija; mišićna snaga; odrasli; ošit; respiracijski mišići

Introduction

Preserving muscle mass and functional ability is a cornerstone of healthy aging and maintaining quality of life. Muscle strength, including respiratory muscles is crucial for mobility, autonomy, and resilience against illness (1). Age-related loss of muscle mass and function, known as sarcopenia, and the related phenotype of sarcopenic obesity are increasingly common in today's population, particularly among older adults (2).

Phase angle and sarcopenic index may help in early identification of muscle dysfunction.

These conditions frequently go undetected until marked functional decline, increased fall risk, chronic disease, disability and even elevated mortality have occurred (3). The consequences of sarcopenic obesity have a multifaceted impact on quality of life. Reduced muscle mass and strength, combined with increased adipose tissue, result in decreased mobility, a higher risk of falls, greater incidence of chronic diseases, and reduced independence in performing activities of daily living. In more advanced stages, sarcopenic obesity may lead to disability and significantly increase both morbidity and mortality among older adults (4). In this context, assessment of body composition and muscle function is not only essential for diagnosing sarcopenia or malnutrition, but is also fundamental for early prevention and rehabilitation strategies (6). Techniques such as bioelectrical impedance analysis (BIA) provide a simple, non-invasive and practical method to estimate body composition parameters (e.g., fat-free mass, skeletal muscle mass, appendicular skeletal muscle mass) and cellular health (e.g., phase angle) using measures like impedance and phase angle, together with anthropometric data. Bioelectrical impedance analysis (BIA) assesses the electrical characteristics of the body, specifically impedance (Z) and phase angle (PhA). Using these variables, along with anthropometric measures such as age, height, and body weight, predictive equations can estimate key body composition parameters, including fat-free mass (FFM), skeletal muscle mass (SM), and appendicular skeletal mass (ASM) (5).

Coupling these composition data with functional assessments—such as maximal inspiratory pressure (MIP), handgrip dynamometry, diaphragm thickness and excursion—facilitates a comprehensive evaluation of both peripheral and respiratory muscle function (7,8). Respiratory muscle strength, diaphragm thickness, and respiratory function are known to be reduced in older adults with sarcopenia or frailty. Deniz et al. (9) found that individuals with sarcopenia had reduced diaphragm thickness and lower peak expiratory flow compared with non-sarcopenic individuals.

Diaphragm thickness and mobility associate positively with muscle mass and phase angle.

Additionally, Ohara et al. (10) compared 383 individuals with sarcopenia with healthy participants and reported reduced respiratory muscle strength and handgrip strength in the sarcopenic group. Within the clinical context, the use of straightforward and reliable indicators of nutritional condition and muscular performance can assist in distinguishing various nutritional phenotypes among elderly individuals—whether they live independently or are affected by acute and chronic diseases (4). Evaluating nutritional status and physical fitness is fundamental for performing a comprehensive, multidisciplinary assessment, as well as for preventing conditions such as malnutrition and sarcopenia in older adults. Moreover, these evaluations represent a vital component of both rehabilitation strategies and the overall nutrition care process (11).

By conducting this study in a healthy population, we aim to explore the associations between BIA-derived parameters and functional measures of muscle strength (both peripheral and respiratory) in healthy individuals. Establishing these associations in healthy adults can provide reference data and underscore the utility of BIA as a simple screening tool for early muscle functional impairment. These reference data may serve as a benchmark for comparison with patient populations, in whom preservation of muscle mass and respiratory muscle function is critically linked to outcomes and quality of life.

Methods

The study was conducted at the Special Hospital for Lung Diseases in Zagreb between June 1, 2024, and August 31, 2024. Participants were healthy hospital employees aged 30 to 65. Individuals were considered healthy if they had no self-reported history or clinical signs of respiratory or neuromuscular diseases. A convenience sample of 50 participants was included for the purpose of this pilot study. Exclusion criteria comprised professional athletes and individuals diagnosed with respiratory or neuromuscular disorders.

Before participation, eligible individuals received written and verbal information explaining the purpose of the study. Those who agreed to participate signed an informed consent form in accordance with the Declaration of Helsinki and Good Clinical Practice guidelines. Participation was voluntary. Ethical approval for the study was obtained from the Ethics Committee of the Special Hospital for Lung Diseases in Zagreb.

Body height and weight were measured following a standardized protocol, with participants barefoot and wearing light clothing. Height was measured using a stadiometer, and weight was assessed with a digital medical scale (SECA 799). BMI was calculated as weight divided by height squared (kg/m^2). Body composition was evaluated using a multi-frequency, eight-electrode bioelectrical impedance analyzer (TANITA MC-780MA P, Tanita Corp., Tokyo, Japan), providing segmental analysis of fat-free mass (FFM), muscle mass, bone mass, skeletal muscle mass, fat and muscle percentages, skeletal muscle mass index (SMMI), visceral fat, intracellular and extracellular fluid, total body water, and phase angle. The device has been validated for clinical use (12). All BIA measurements were performed in the morning, in a fasted state after a 12-hour fast to ensure reliability.

Maximal inspiratory pressure (MIP) was assessed using a PowerBreathe device (Powerbreathe International Ltd., Southam, UK) connected to a computer. This non-invasive method measures the highest negative pressure generated during a maximal inspiratory effort and reflects diaphragm and accessory inspiratory muscle strength. Participants were thoroughly instructed and familiarized with the procedure. Measurements were performed in a seated position, with the nose clipped, and the highest value from five attempts was recorded (13). Predicted MIP values were calculated based on age and sex: males, $MIP\_predicted = 120 - (0.41 \times age)$; females, $MIP\_predicted = 108 - (0.61 \times age)$. Measured values were compared to predicted normative data.

Isometric strength of upper and lower limb muscles on the dominant side was assessed using a digital hand dynamometer (Pelican 1150, Lafayette Instrument Company, Lafayette, USA). Maximal voluntary force of elbow flexors (m. biceps brachii) and knee extensors (m. quadriceps femoris) was measured in a seated position. Three attempts were recorded, with a one-minute rest between trials, and the mean value was used for analysis (14, 15)

Diaphragm thickness was measured using ultrasonography (Mindray DC-8, Mindray Medical International, Shenzhen, China) with a 7.5–10 MHz linear probe in the supine position. The probe was positioned at the zone of apposition of the right diaphragm, between the 8th and 9th intercostal space. Thickness was assessed at end-expiration (functional residual capacity) and end-inspiration, with each measurement repeated at least three times and averaged (16, 17,18). All ultrasonography was performed by the same experienced operator to reduce inter-operator variability (19). Measured parameters were compared with literature reference values for age- and sex-matched populations (17).

Categorical variables are presented as counts and percentages. Continuous variables are summarized as mean ± standard deviation for normally distributed data or as median (interquartile range) for non-normal data. Group differences were assessed using the chi-square or Fisher's exact test for categorical variables, and the Mann-Whitney U or Kruskal-Wallis test for continuous variables, as appropriate. Correlations were performed when required. All tests were two-sided, with a significance level of $\alpha = 0.05$. Statistical analyses were conducted using IBM SPSS Statistics for Windows, Version 26.0 (IBM Corp., Armonk, NY, USA; 2019).

Results

The sociodemographic characteristics of the study participants, including sex distribution and age-related variables such as mean, minimum, and maximum age values, are presented in Table 1.

Table 1. Sociodemographic characteristics of participants

Participants	Male	Female	Total
Number	19	31	50
Percentage (%)	38	62	100
Mean age (years)	37,63	43,35	41,18
Youngest age (years)	30	30	30
Oldest age (years)	62	63	63

The median values of the parameters obtained using bioelectrical impedance analysis are shown in Table 2, providing an overview of body composition characteristics relevant to the assessment of muscle health in the study population.

Table 2. Median results of body composition analysis Parameters

Parameter	Median
Height (cm)	170,00
Weight (kg)	72,80
Body mass index (kg/m²)	26,05
Lean mass (kg)	52,25
Muscle mass (kg)	49,60
Skeletal muscle mass (kg)	27,35
Sarcopenic index (kg/m²)	7,68
Phase angle (°)	6,00

Median values of upper and lower limb muscle strength and diaphragm function parameters in the study population are showed in Table 3.

Table 3. Median values of measured parameters

Parameter	Median
Biceps brachii muscle strength (N)	194.64
Quadriceps femoris muscle strength (N)	247.55
Maximal Inspiratory Pressure (MIP – measured value) (cmH_2O)	94.95
Diaphragm excursion during deep breathing (mm)	71.90
Diaphragm excursion during quiet breathing (mm)	25.45
Diaphragm thickness at end-expiration (mm)	1.50
Diaphragm thickness at end-inspiration (mm)	3.05
Diaphragm thickness ratio (Tmax/Tmin)	2.00

To further examine the relationships between the observed variables, Spearman's correlation coefficient was calculated. The correlation coefficients for the analyzed parameters are presented in Table 4, allowing for a clearer interpretation of their interdependence.

Discussion

Sarcopenia, characterized by the age-related loss of skeletal muscle mass and function, is a major contributor to decreased functional capacity and respiratory performance in both healthy and clinical populations (20, 4). Shin et al. (21) investigated the relationship between skeletal muscle mass assessed by bioelectrical impedance analysis and maximal inspiratory and expiratory pressures in 65 healthy individuals. They demonstrated that both MIP and MEP were positively associated with skeletal muscle mass. Similarly, our findings showed a strong association between skeletal muscle mass and MIP values.

The diaphragm, as the primary muscle of inspiration, plays a critical role in maintaining adequate pulmonary function. Ultrasonographic assessment of diaphragm thickness and excursion provides a non-invasive measure of respiratory muscle function, and has been shown to correlate with both peripheral muscle strength and sarcopenic indices (22,16).

Bioelectrical impedance analysis measurements correlate with peripheral and inspiratory muscle strength.

In addition, our research found that skeletal muscle mass correlated positively with diaphragm thickness measured at end-inspiration and end-expiration. These correlations were also confirmed in the study by Smargiassi et al. (23), conducted in patients with chronic obstructive pulmonary disease, which reported significant correlations between muscle mass and diaphragm thickness. Lee et al. (22) investigated 45 healthy individuals and reported significant positive correlations between diaphragm thickness and handgrip strength ($r = 0.759$, $p < 0.01$), calf circumference ($r = 0.499$, $p < 0.01$), and muscle mass/body mass index ratio ($r = 0.609$, $p < 0.01$). They also demonstrated significant positive associations between MIP and handgrip

Table 4. Spearman's correlation coefficients between examined variables

	Body Mass Index (kg/m²)	Muscle Mass (kg)	Skeletal Muscle Mass (kg)	Sarcopenic Index (kg/m²)	Phase Angle (°)
M. biceps brachii strength	0,173	0,703**	0,704**	0,575**	0,596**
M. quadriceps femoris strength	0,065	0,536**	0,565**	0,414**	0,465**
Maximal inspiratory pressure	0,118	0,663**	0,682**	0,551**	0,469**
Diaphragm thickness at end-inspiration	0,295*	0,424**	0,432**	0,464**	0,309*
Diaphragm thickness at end-expiration	0,571**	0,565**	0,523**	0,665**	0,371**
Diaphragmatic excursion during quiet breathing	0,212	0,337*	0,311*	0,291*	0,024
Diaphragmatic excursion during deep breathing	0,317	0,584**	0,497**	0,450**	0,096

Note: * indicates statistically significant correlation at $p < 0.05$;
** indicates statistically significant correlation at $p < 0.01$.

strength (r = 0.437, p < 0.01), calf circumference (r = 0.408, p < 0.01), and diaphragm thickness (r = 0.652, p < 0.01). Additionally, inspiratory muscle strength, typically assessed via maximal inspiratory pressure (MIP), reflects the functional capacity of the diaphragm and accessory respiratory muscles and serves as an important clinical marker in various populations (11,13). Phase angle, measured by bioelectrical impedance analysis (BIA), has emerged as a reliable indicator of cellular health and nutritional status. Lower phase angle values have been linked to adverse clinical outcomes, including prolonged hospitalization and reduced survival, while higher values indicate better muscle quality and functional reserve (24, 25). This metric, together with direct measures of muscle mass and strength, provides a comprehensive evaluation of sarcopenia and its impact on respiratory function.

Despite growing evidence supporting the importance of skeletal muscle and diaphragm assessment in clinical practice, data integrating these measures in healthy populations remain limited. Therefore, the present study aimed to investigate the relationships between skeletal muscle mass, diaphragm thickness and mobility, inspiratory muscle strength, peripheral muscle strength, and phase angle in a cohort of healthy adults. Understanding these associations may provide insights into early markers of sarcopenia and guide interventions to preserve respiratory and muscular function.

Conclusion

Bioelectrical impedance analysis is a reliable method for assessing body composition, and its measurement outcomes can be utilized as indicators of health, for the early identification of dysfunctions and alterations in body composition that may lead to the development of disease. These results highlight the interdependence of peripheral and respiratory muscle health and support the use of combined assessments, including bioelectrical impedance analysis, ultrasonography, and hand-held dynamometry, for early detection of sarcopenia. Monitoring these parameters in clinical and healthy populations may provide valuable insights for preventive strategies aimed at maintaining muscular and respiratory function. BIA may have significant value in clinical practice; therefore, close attention should be given to specific body composition components that may indicate potential muscular dysfunctions, particularly in patients with chronic diseases.

Future studies with larger and more diverse populations are warranted to validate these findings and to explore potential interventions that preserve both skeletal and respiratory muscle function, thereby improving overall physical performance and quality of life.

References

1. Rodrigues F, Domingos C, Monteiro D, Morouço P. A review on aging, sarcopenia, falls, and resistance training in community-dwelling older adults. Int J Environ Res Public Health. 2022;19(2):874. doi:10.3390/ijerph19020874.
2. Cruz-Jentoft AJ, Bahat G, Bauer J, Boirie Y, Bruyère O, Cederholm T et al. Sarcopenia: revised European consensus on definition and diagnosis. Age Ageing. 2019;48(1):16-31. doi:10.1093/ageing/afy169.
3. Sayer AA, Cruz-Jentoft A. Sarcopenia definition, diagnosis and treatment: consensus is growing. Age Ageing. 2022;51(10):afac220. doi:10.1093/ageing/afac220.
4. Prado CM, Batsis JA, Donini LM, Gonzalez MC, Siervo M. Sarcopenic obesity in older adults: a clinical overview. Nat Rev Endocrinol. 2024;20(5):261-277. doi:10.1038/s41574-023-00943-z.
5. Bosy-Westphal A, Danielzik S, Dörhöfer R-P, 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):309-16. doi:10.1177/0148607106030004309.
6. Ribeiro SM, Kehayias JJ. Sarcopenia and the analysis of body composition. Adv Nutr. 2014;5(3):260-7. doi: 10.3945/an.113.005256.
7. Akınoğlu B, Kocahan T, Özkan T. The relationship between peripheral muscle strength and respiratory function and respiratory muscle strength in athletes. J Exerc Rehabil. 2019;15(1):44-49. doi: 10.12965//jer.1836518.259.
8. Wang S, Yin H, Wang X, Jia Y, Wang L, Wang C et al. Efficacy of different types of exercises on global cognition in adults with mild cognitive impairment: a network metaanalysis. Aging Clin Exp Res. 2019;31(10):13911400. doi:10.1007/s40520019011425.
9. Deniz O, Coteli S, Karatoprak NB, Pence MC, Varan HD, Kizilarslanoglu MC, Oktar SO, Goker B. Diaphragmatic muscle thickness in older people with and without sarcopenia. Aging Clin Exp Res. 2021 Mar;33(3):573-580. doi: 10.1007/s40520-020-01565-5. 4.
10. Ohara DG, Pegorari MS, Oliveira Dos Santos NL, de Fátima Ribeiro Silva C, Monteiro RL, Matos AP et al. Respiratory Muscle Strength as a Discriminator of Sarcopenia in Community-Dwelling Elderly: A Cross-Sectional Study. J Nutr Health Aging. 2018;22(8):952-958. doi: 10.1007/s12603-018-1079-4.
11. Beaudart C, Rolland Y, Cruz-Jentoft AJ, Bauer J, Sieber C, Cooper C et al. Assessment of muscle function and physical performance in daily clinical practice: a position paper endorsed by the European Society for Clinical and Economic Aspects of Osteoporosis, Osteoarthritis and Musculoskeletal Diseases (ESCEO). Calcif Tissue Int. 2019;105(1):114. doi:10.1007/s0022301900545w.
12. Jaafar ZA, Kreidieh D, Itani L, Tannir H, El Masri D, El Ghoch M. Cross-validation of prediction equations for estimating the body fat percentage in adults with obesity. Clin Nutr ESPEN. 2021 Feb;41:346-350. doi: 10.1016/j.clnesp.2020.11.003.
13. Sachs MC, Enright PL, Hinckley Stukovsky KD, Jiang R, Barr RG; Multi-Ethnic Study of Atherosclerosis Lung Study. Performance of maximum inspiratory pressure tests and maximum inspiratory pressure reference equations for 4 race/ethnic groups. Respir Care. 2009 Oct;54(10):1321-8.
14. Aerts F, Sheets H, Anderson C, Bussie N, Hoskins R, Maninga A, Novak E. Reliability and agreement of handheld dynamometry using three standard rater test positions. Int J Sports Phys Ther. 2025;20(2):243252. doi:10.26603/001c.128286.
15. Filipec M, Lončarić Kelečić I, Jurinić A, Pikivača A, Vuković M. Dinamometrija: priručnik za studente fizioterapije. Zagreb: Libertas Međunarodno sveučilište; 2020. ISBN 9789538061141.
16. Carrillo-Esper R, Pérez-Calatayud ÁA, Arch-Tirado E, Díaz-Carrillo MA, Garrido-Aguirre E, Tapia-Velazco R et al. Standardization of Sonographic Diaphragm Thickness Evaluations in Healthy Volunteers. Respir Care. 2016 Jul;61(7):920-4. doi: 10.4187/respcare.03999.
17. Nesek Adam V, Benko Meštrović S. Hitna stanja u fizioterapiji, fizioterapija u hitnim stanjima. Zagreb: HLZ - Hrvatsko društvo za hitnu medicinu: Sveučilište Sjever; 2024.
18. Benko Meštrović S, Poljak A. Propedeutika kardio-respiratorne fizioterapije. From: Jurinić A, Jadanec Đurin M, urednici. Fizioterapijska propedeutika. Zagreb: Hrvatski zbor fizioterapeuta; 2024. p. 97-138.
19. Zhou EF, Fu SN, Huang C, Huang XP, Wong AYL. Reliability and validity of ultrasonography in evaluating the thickness, excursion, stiffness, and strain rate of respiratory muscles in nonhospitalized individuals: a systematic review. BMC Oral Health. 2023;23(1):959. doi:10.1186/s12903-023-03558-y.

20. Cruz-Jentoft AJ, Bahat G, Bauer J, Boirie Y, Bruyère O, Cederholm T, et al.; Writing Group for the European Working Group on Sarcopenia in Older People 2 (EWGSOP2), and the Extended Group for EWGSOP2. Sarcopenia: revised European consensus on definition and diagnosis. Age Ageing. 2019 Jan 1;48(1):16-31. doi: 10.1093/ageing/afy169. Erratum in: Age Ageing. 2019 Jul 1;48(4):601. doi: 10.1093/ageing/afz046.

21. Shin HI, Kim DK, Seo KM, Kang SH, Lee SY, Son S. Relation between respiratory muscle strength and skeletal muscle mass and hand grip strength in the healthy elderly. Ann Rehabil Med. 2017;41(4):686-692. doi:10.5535/arm.2017.41.4.686.

22. Lee Y, Son S, Kim DK, Park MW. Association of Diaphragm Thickness and Respiratory Muscle Strength With Indices of Sarcopenia. Ann Rehabil Med. 2023 Aug;47(4):307-314. doi: 10.5535/arm.23081. Epub 2023 Aug 28. PMID: 37644714;

23. Smargiassi A, Inchingolo R, Tagliaboschi L, Di Marco Berardino A, Valente S, Corbo GM. Ultrasonographic assessment of the diaphragm in chronic obstructive pulmonary disease patients: relationships with pulmonary function and the influence of body composition - a pilot study. Respiration. 2014;87(5):364-371. doi:10.1159/000358564.

24. Hui D, Bansal S, Morgado M, Dev R, Chisholm G, Bruera E. Phase angle for prognostication of survival in patients with advanced cancer: preliminary findings. Cancer. 2014;120(14):2207-2214. doi:10.1002/cncr.28624.

25. Visser M, van Venrooij LM, Wanders DC, de Vos R, Wisselink W, van Leeuwen PA et al. The bioelectrical impedance phase angle as an indicator of undernutrition and adverse clinical outcome in cardiac surgical patients. Clin Nutr. 2012 Dec;31(6):981-6. doi: 10.1016/j.clnu.2012.05.002.