ARTYKUŁ ORYGINALNY / ORIGINAL PAPER
Otrzymano/Submitted: 07.07.2021 • Zaakceptowano/Accepted: 14.10.2021

Is Body Adiposity Index an useful tool among patients with excessive body mass?

Czy Body Adiposity Index jest użytecznym narzędziem wśród pacjentów z nadmierną masą ciała?

Alicja Ewa Ratajczak, Anna Maria Rychter, Agnieszka Zawada, Agnieszka Dobrowolska, Iwona Krela-Kaźmierczak
Department of Gastroenterology, Dietetics and Internal Diseases, Poznan University of Medical Sciences

Abstract

Introduction. BAI (Body Adiposity Index) involves only height and hip circumference and is particularly useful in the absence of other, more specialized devices. In our study, we assessed whether the BAI method is useful in body fat estimation among patients with obesity, and whether it should be generally employed in clinical practice. ***Material and methods.*** The study group consisted of 165 patients. We measured hip circumference and height for BAI calculations. Additionally, body composition analysis was performed, and the correlation between body fat percentage determined by body composition analyzer and that determined by BAI was assessed. ***Results***. All subjects had an excessive body weight (according to the BIA method), based on the BMI value – the mean BMI was 41.70±7.24 kg/m^2. BIA correlated with BAI (r = 0.63), and the correlation was stronger in men than women - (r = 0.77) and (r = 0.43), respectively; however, we found a statistically significant higher percentage of body fat content measured by BIA than by BAI (p = 0.000274). ***Conclusions***. Our results suggest that although BAI correlates with BIA, some significant differences were observed when these two measurements were compared. Therefore, BAI may not be the best formula for assessing fat content in patients with obesity and should be rather used as a process-measuring tool for patients willing to reduce their body weight. *(Farm Współ 2021; 14**:** 169-174). doi**.** 10.53139/FW.20211421*

Keywords: body adiposity index, obesity; body image assessment, BIA, anthropometry

Streszczenie

Wstęp. BAI (ang. *Body Adiposity Index*) wykorzystując wzrost i obwód bioder, używany jest do szacowania zawartości tkanki tłuszczowej w organizmie w sytuacjach kiedy niedostępne są inne, bardziej specjalistyczne metody pomiarowe. Badaliśmy, czy BAI może być metodą użyteczną i wiarygodną do szacowania otłuszczenia organizmu u pacjentów z otyłością i być wykorzystywany w praktyce klinicznej. ***Materiał i metody.*** Grupę badawczą stanowiło 165 pacjentów, którym zmierzyliśmy wzrost oraz obwód bioder, celem obliczenia BAI. Ponadto każdy pacjent został poddany analizie składu ciała metodą bioimpedancji elektrycznej (BIA), której wynik został porównany z rezultatem obliczeń. ***Wyniki***. Wszystkie osoby badane miały nadmierną masę ciała-diagnozowaną na podstawie BMI (średnie BMI wynosiło 41,70±7,24 kg/m^2. Wartości BIA korelowały z BAI (r = 0,63), zwłaszcza u mężczyzn (r = 0,77, u kobiet r = 0,43). Jednakże, znaleźliśmy statystycznie istotne różnice między wynikami określającymi zawartość tkanki tłuszczowej mierzonej metodą BAI i BIA (p = 0,000274). Różnice między BAI i BIA były większe wśród kobiet niż wśród mężczyzn. ***Wnioski***. Nasze wyniki sugerują, że chociaż BAI koreluje z BIA, zaobserwowano pewne istotne różnice podczas porównywania tych dwóch pomiarów. Dlatego BAI może nie być najlepszą formułą do oceny zawartości tłuszczu u pacjentów z otyłością i powinien być raczej stosowany jako narzędzie pomiaru postępów dla pacjentów chcących zmniejszyć masę ciała. *(Farm Współ 2021; 14**:** 169-174). doi**.** 10.53139/FW.20211421*

Słowa kluczowe: otyłość, BAI, antropometria, bioimpedancja elektryczna, ocena składu ciała

[1] These authors contributed equally to this work: Alicja Ewa Ratajczak and Anna Maria Rychter

Introduction

Currently, more and more patients present excessive body mass. According to the statistics, over 2 billion individuals worldwide suffer from overweight or obesity [1]. In most cases, obesity is the result of excessive caloric intake and low physical activity level. The risk factors of obesity among adults are sedentary lifestyle, inappropriate diet, socioeconomic factors, health status, and dysbiosis, as well as genetic factors, as recent studies have demonstrated. In terms of children, the main factors are unhealthy dietary habits, including high consumption of sugar-sweetened beverages and low physical activity with a simultaneous high screening time (activities in front of a screen, e.g. watching TV, or using a computer) [2]. Obesity is not only an aesthetic problem but also a severe health condition associated with an increased risk of cardiovascular disease, certain types of cancer, diabetes, hypertension, stroke, and others [3] type 2 diabetes, and several cancers. The complex pathological processes reflect environmental and genetic interactions, and individuals from disadvantaged communities seem to have greater risks than more affluent individuals partly because of fetal and postnatal imprinting. Obesity, with its array of comorbidities, necessitates careful clinical assessment to identify underlying factors and to allow coherent management. The epidemic reflects progressive secular and age-related decreases in physical activity, together with substantial dietary changes with passive over-consumption of energy despite the neurobiological processes controlling food intake. Effective long-term weight loss depends on permanent changes in dietary quality, energy intake, and activity. Neither the medical management nor the societal preventive challenges are currently being met.","container-title":"Lancet (London, England. However, obesity-related metabolic disorders are more associated with the location than the total amount of adipose tissue [3].

In contrast, SAT (>85% of the total body fat) is only slightly associated with the risk of developing CVD, or related pathologies. In fact, a body mass index (BMI) ≥ 30 kg/m^2 does not inevitably induce insulin resistance and a comorbid metabolic disorder, which develops in 6-40% metabolically healthy individuals with obesity [4]. This hypothesis is strengthened since metabolically healthy subjects with obesity present a lower fat content in VAT than normal individuals with obesity and display fewer cardiovascular events and proper insulin sensitivity [5]. According to the fat distribution, two types of obesity are identified – android (adipose tissue is mostly stored in the abdominal regions) and gynoid (adipose tissue is mostly stored in hip and thigh regions) [6]. Waist-to-hip ratio (WHR) – which involves waist and hip circumference – is one of the several measurements in the diagnosis of obesity type. It should be noted that waist circumference constitutes one of the diagnostic measurements of metabolic syndrome. However, other measurements are also widely used in clinical practice.

Obesity diagnostic

Anthropometric measures, such as waist circumference and body mass index, may be used in the diagnosis of obesity [7]. Additionally, computed tomography, dual-energy x-ray absorptiometry (DXA), or magnetic resonance imaging are the most accurate methods of obesity evaluation [5]. However, due to their high costs, they are not always employed. Bioimpedance analyzers (using bioimpedance analysis, BIA) constitute less expensive, fast and easy-to-use tools to determine body composition. Moreover, BAI technology has been shown to provide satisfactory results among several populations [8]. They can be expressed as a ratio (phase angle. The bioimpedance analysis method involves electrical resistance of various body tissues - impedance (i.e. electrical resistance and reactance). In fact, the phenomenon of resistance is associated with the resistivity of specific tissues, while reactance is mainly associated with the electrical capacitance of cell membranes, which act like capacitors due to their structure [9]. However, in pregnant women, patients with cardiac rhythm management devices or conducting-electricity metal implants, the bioimpedance analysis cannot be performed.

Body Adiposity Index

In 2011, Bergman et al. showed a new index for the estimation of adipose tissue, namely the Body Adiposity Index, which involves only height and hip circumference [10]. Body Adiposity Index is calculated on the basis of the formula:

$$BAI = \frac{hip\ circumference\ (cm)}{height\ (m)^{1,5}} - 18$$

It may be used for both women and men, and it is instrumental in the absence of other, more specialized devices measuring body fat content. BAI is an inexpensive, safe, non-invasive, and simple method aimed at assessing body fat content. It may be used in cases where body composition estimation using other methods is contraindicated. The authors of the Body Adiposity Index reported similarities of body fat content results obtained using BAI and DXA [11].

Aim

Our study aimed to assess whether the BAI method is useful in the estimation of adipose tissue among patients with obesity and overweight, as well as whether BAI results could be compared to the BIA method. The analyses were performed to assess whether BAI should be generally employed in clinical practice, which could be useful, particularly when a bioimpedance analyzer is not available.

Materials and Methods

Study group

The study group consisted of 165 patients (104 women and 61 men) from the Metabolic Diseases Outpatient Clinic at the Heliodor Święcicki Clinical Hospital in Poznan. Patients were previously qualified for a three-week weight-loss program. The inclusion criteria were: age over 18 years and presenting with overweight or obesity, defined as a BMI ≥ 25 kg/m^2. BMI was calculated on the basis of the body mass and height, an increased body fat-mass content (>32% and >25% of total body weight for women and men, respectively, according to the analyser ranges) measured by bioimpedance analysis; written informed consent was also obtained. The exclusion criteria were associated with severe cardiovascular, intestinal, mental, and liver diseases, as well as with renal failure, autoimmune diseases, menopause, and pregnancy.

Performed measurements

We measured hip circumference (in the widest point of the hip) and height (measured with a stadiometer) in each patient using the tape measure and a stadiometer to calculate Body Adiposity Index. We also performed a body composition analysis using Tanita MC-980 MA (TANITA, Japan). The analysis was performed 2 hours after the last meal, with an empty bladder. Additionally, we subtracted the mass of clothes the patients were wearing (0.5 kg for the summer clothes and 1 kg for winter clothes).

Statistical analysis

We assessed the correlation between the percentage of body fat content determined by the body composition analyzer and established by means of BAI. STATISTICA StatSoft, Inc. Program (2014). Kolmogorov-Smirnov test was used to determine the normality of data distribution. Normal distribution was observed in the percentage of body fat content and BAI. The r-Pearson test and t-student test were used to analyse the data of the dependent tests. The level of statistical significance in all calculations was $p < 0.05$.

The formal approval was obtained from the Bioethics Committee of Poznan Medical University.

Results

Characteristics of study participants

The mean age of patients was 47.81 ± 13.14 years (47.16 ± 12.99 for women, and 48.92 ± 13.42 for men). Based on the BMI value, all subjects presented overweight or obesity - most of the patients suffered from obesity class I (BMI range 30-34.9 kg/m^2), or class II (BMI range 35-39.9 kg/m^2). The difference between the mean BAI value and the percentage of body fat content measured by BIA was 1.89%. The data are presented in table 1.

The percentage of body fat content measured by BIA and BAI

We found a statistically significant difference between the percentage of body fat content measured by BIA and by BAI ($p = 0.000274$). On the other hand, we also observed a moderate correlation between BIA and BAI ($r = 0.63$), and the correlation was stronger among men ($r = 0.77$) than among women ($r = 0.43$). However, BMI correlated with both BIA ($p<0.05$; $r = 0.61$) and BIA ($p<0.05$; $r = 71$) in men and in women. The comparison of the average estimated body fat content measured by the bioimpedance method and using the BAI formula is shown demonstrated in Figure 1.

Discussion

Our study demonstrated that the percentage of adipose tissue measured by BAI correlates with the percentage of adipose tissue measured by the BIA formula in patients with obesity and overweight, and the correlation is stronger among men. However, statistically significant differences were present when we

Table I. BMI, body fat content measured by BIA and BAI, and hip circumference among patients
Tabela I. BMI, zawartość tkanki tłuszczowej w pomiarach BIA i BAI oraz obwód bioder pacjentów

Variable	Women			
	Average± standard deviation	Median	Lower quartile	Upper quartile
BMI (kg/m^2)	41.53 ±7.49	40.45	36.00	45.90
Body fat content measured by BIA (%)	44.24 ±4.32	44.05	41.60	47.10
BAI (%)	42.36 ±8.33	42.25	38.50	47.95
Hip circumference (cm)	127.28 ±17.90	127.75	117.50	139.50
Variable	**Men**			
	Average ± standard deviation	Median	Lower quartile	Upper quartile
BMI (kg/m^2)	41.98 ±6.84	40.70	37.90	45.50
Body fat content measured by BIA (%)	37.67 ±5.35	38.00	34.00	40.60
BAI (%)	35.77 ±6.59	35.40	31.30	38.60
Hip circumference (cm)	129.20 ±15.20	128.00	119.00	138.00
Variable	**Women and men**			
	Average ± standard deviation	Median	Lower quartile	Upper quartile
BMI (kg/m^2)	41.70 ±7.24	40.50	36.50	45.70
Body fat content measured by BIA (%)	41.81 ±5.68	42.00	38.20	45.40
BAI (%)	39.92 ±8.35	39.40	33.40	45.20
Hip circumference (cm)	127.99 ±16.93	128.00	119.00	139.00

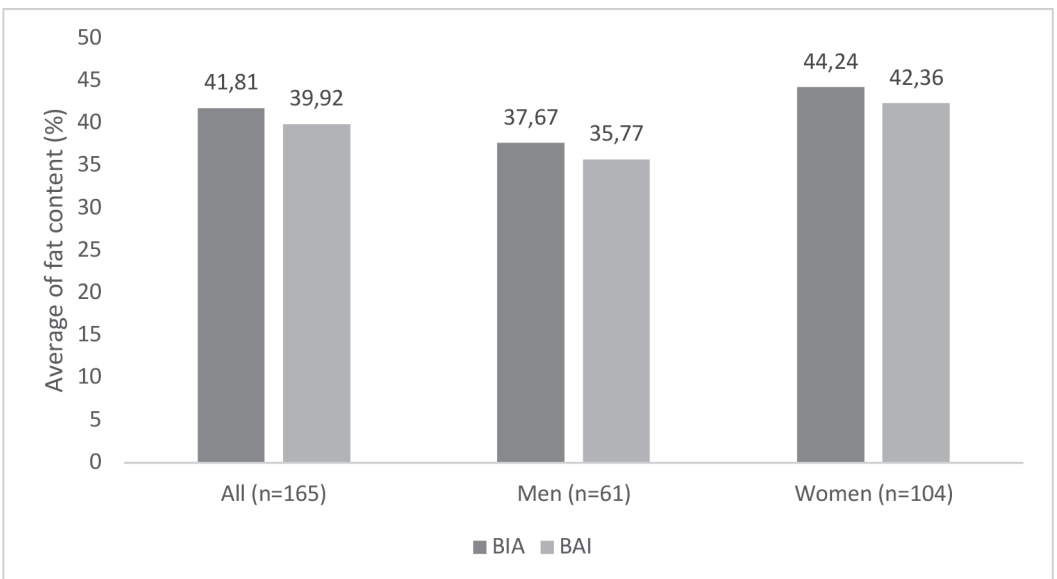

Figure 1. Comparison of the average fat content measured by the bioimpedance method and using the BAI formula
Rycina 1. Porównanie średniej zawartości tkanki tłuszczowej oznaczonych metodą bioimpedancji i z wykorzystaniem wzoru BAI.

compared the percentage of adipose tissue measured by the bioimpedance method and the BAI formula. In fact, the results indicated that although BAI correlates with BIA, it may not be a precise and fully reliable parameter in assessing body fat percentage in patients with excessive body weight. Therefore, it should be mostly used as a progress-measuring tool rather than a method of estimating body fat content. Jabłonowska-Lietz et al. received similar results. The authors confirmed a correlation between BAI and the percentage of body fat as well as of visceral adipose tissue measured by the bioimpedance method [12]. Furthermore, another study conducted on women with obesity demonstrated that BAI and BMI correlate with the percentage of body fat content measured by BIA. BMI also correlates with dual-energy X-ray absorptiometry; however, this correlation was not observed in BAI [13]. Barreira TV et al. reported that the correlation between BMI and percentage of body fat content measured by DXA is stronger than between BAI and DXA [14]. Interestingly, the effectiveness of BAI is different in various populations. In fact, BAI was strongly correlated with BMI and body fat percentage measured by DXA in Caucasian women, but not in African, American, or Filipino female subjects [15]. A correlation between Body Adiposity Index was rather associated with the risk of cardiovascular disease than with WHtR (Waist to Height Ratio), waist circumference, or BMI. Moreover, BAI did not correlate with lipid disorders, impaired fasting glucose, or blood pressure value [16]. However, Dhaliwal et al. found a correlation between BAI and blood pressure values and lipid profile results, although the correlation was stronger in BMI, waist circumference, or WHR [17]. In contrast, Malmer et al. reported that BAI is less correlated with body fat content than with BMI or WHtR. However, the correlation between Body Adiposity Index and serum leptin level – a hormone produced by fat tissue - was stronger than between WHR, WHtR or BMI, and leptin concentration [18]waist-to-hip ratio (WHR. In young adults, the association between the percentage of body fat and BAI was stronger than with BMI (r = 0,668 and 0,192, respectively) [19].

Our results may be attributed to the fact that patients with obesity usually store an excessive amount of fat in the visceral area, whereas BAI - which uses hip circumference - is not a proper formula for patients with this type of excessive body weight. However, in our study, the correlation between BAI and BIA was weaker in women than in men, which usually tend to store more adipose tissue in the hip area. The reliability of the obtained results is limited since only overweight or obese patients were included in the study, and the study group was relatively small. There are numerous studies regarding the assessment of BAI credibility, although presumably their focus should be more on patients metabolically obese yet presenting normal weight (MONW). Future studies should focus on assessing the compatibility of BAI and BIA or DXA in the population with the risk of developing excessive body weight without serious health consequences (metabolically healthy obesity, MHO) [20].

Summary

Many studies indicate that the body adiposity index may be useful in patients where bioimpedance analysis cannot be performed. Although in our study, the percentage of adipose tissue measured by BAI correlated with the percentage of adipose tissue measured by the BIA formula, statistically significant differences were present when we compared the percentage of adipose tissue measured by the bioimpedance method and the BAI formula. Therefore, it should be considered if BAI is a precise and fully reliable parameter or rather it should be used as a process-measuring tool for patients willing to reduce their body weight.

Conflict of interest
None

Correspondence address
Alicja Ewa Ratajczak
Department of Gastroenterology, Dietetics and Internal Diseases, Poznan University of Medical Sciences, Poland,
10 Fredry Street, 61-701 Poznan, Poland
☎ (+48 61) 869 13 43
alicjaewaratajczak@gmail.com

References

1. Ng M, Fleming T, Robinson M, et al. Global, Regional, and National Prevalence of Overweight and Obesity in Children and Adults during 1980-2013: A Systematic Analysis for the Global Burden of Disease Study 2013. Lancet. 2014;384(9945):766-81.
2. Smith KB, Smith MS. Obesity Statistics. Prim Care. 2016;43(1):121-35.
3. Haslam DW, James WP. Obesity. Lancet. 2005;366(9492):1197-209.
4. Phillips CM. Metabolically Healthy Obesity: Definitions, Determinants and Clinical Implications. Rev Endocr Metab Disord. 2013;14(3):219-27.
5. Shepherd JA, Ng BK, Sommer MJ, et al. Body Composition by DXA. Bone 2017;104:101-5.
6. Katsilambros N. New Developments in Obesity. Eur J Intern Med. 2000;11(2):65-74.
7. Adab P, Pallan M, Whincup PH. Is BMI the Best Measure of Obesity? BMJ. 2018;360:k1274.
8. Barbosa-Silva MCG, Barros AJD. Bioelectrical Impedance Analysis in Clinical Practice: A New Perspective on Its Use beyond Body Composition Equations. Curr Opin Clin Nutr Metab Care. 2005;8(3):311-7.
9. Różdżyńska-Świątkowska A, Jurkiewicz E, Tylki-Szymańska A. Bioimpedance Analysis as a Method to Evaluate the Proportion of Fatty and Muscle Tissues in Progressive Myopathy in Pompe Disease. JIMD Rep. 2016;26:45-51.
10. Bergman RN, Stefanovski D, Buchanan TA, et al. A Better Index of Body Adiposity. Obesity. 2011;19(5):1083-9.
11. Lizak D, Budzowski A, Seń M, et al. Przegląd antropometrycznych mierników otłuszczenia ciała stosowanych w diagnozowaniu otyłości. Hygeia Public Health. 2016;51(2):124-33.
12. Jabłonowska-Lietz B, Wrzosek M, Włodarczyk M, et al. New Indexes of Body Fat Distribution, Visceral Adiposity Index, Body Adiposity Index, Waist-to-Height Ratio, and Metabolic Disturbances in the Obese. Kardiol Pol. 2017;75(11):1185-91.
13. Geliebter A, Atalayer D, Flancbaum L, et al. Comparison of Body Adiposity Index (BAI) and BMI with Estimations of % Body Fat in Clinically Severe Obese Women. Obesity. 2013;21(3):493-8.
14. Barreira TV, Harrington DM, Staiano AE, et al. Body Adiposity Index, Body Mass Index and Body Fat in White and Black Adults. JAMA. 2011;306(8):828-30.
15. Djibo DA, Araneta MRG, Kritz-Silverstein D, et al. Body Adiposity Index as a Risk Factor for the Metabolic Syndrome in Postmenopausal Caucasian, African American, and Filipina Women. Diabetes Metab Syndr. 2015;9(2):108-13.
16. Bennasar-Veny M, Lopez-Gonzalez AA, Tauler P, et al. Body Adiposity Index and Cardiovascular Health Risk Factors in Caucasians: A Comparison with the Body Mass Index and Others. PloS One. 2013;8(5):e63999.
17. Dhaliwal SS, Welborn TA, Goh LGH, et al. Obesity as Assessed by Body Adiposity Index and Multivariable Cardiovascular Disease Risk. PloS One. 2014;9(4):e94560.
18. Melmer A, Lamina C, Tschoner A, et al. Body Adiposity Index and Other Indexes of Body Composition in the SAPHIR Study: Association with Cardiovascular Risk Factors. Obesity (Silver Spring). 2013;21(4):775-81.
19. Fedewa MV, Nickerson BS, Esco MR. Associations of Body Adiposity Index, Waist Circumference, and Body Mass Index in Young Adults. Clin Nutr. 2019;38(2):715-20.
20. Conus F, Rabasa-Lhoret R, Péronnet F. Characteristics of Metabolically Obese Normal-Weight (MONW) Subjects. Appl Physiol Nutr Metab. 2007;32(1):4-12.