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Original Article

BMI and BAI as Markers of Obesity in a Caucasian Population

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Key Words

Body adiposity index · · Body mass index · Obesity · Caucasian population

Abstract

Background: BMI is known to have limited accuracy, which is different for males and females with similar body fat content. That is why Bergman et al. (Obesity 2011;19:1083–1089) introduced an alternative variable of obesity, called the body adiposity index (BAI). Their primary research was conducted in samples of Mexican-American and African-American populations. The objective of our research was to investigate the sex-specific relationship between both BMI and BAI and body fat content in a healthy Caucasian population. The accuracy of both indexes was compared. ***Methods:*** 684 women and 528 men aged 20–22 years with Caucasian origin only participated in the study. Participants were students of universities in southern Poland. They had no indication of cardiometabolic problems, as evaluated by interview. ***Results:*** The study revealed that BAI is a more sensitive method in assessing obesity in Caucasian males rather than BMI. In the population of Caucasian women BAI results indicate a significant underestimation of obesity. ***Conclusion:*** The fact that there is a high statistical correlation between BAI and % fat mass among obese and overweight men and women suggests that BAI could be highly specific provided that the BAI cutoffs will be adapted to the European population.

Introduction

Adiposity per se is the physiological characteristic of obese and overweight individuals, putting these subjects at risk for cardiovascular disease. The relationship between fat content and risk of cardiovascular disease is well documented [1–5].

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The primary means to assess obesity in population studies is the use of BMI with the standards recommended by the WHO [6]. BMI is particularly inaccurate in subjects with elevated lean body mass, such as athletes, and cannot be generalized among different ethnic groups. It is likely that individuals are often misdiagnosed as having inappropriate body fat due to variation in muscle mass and that certain subjects with significant adiposity are overlooked [7, 8]. That is why BMI is known to be of limited accuracy, and its diagnostic value is different for males and females with similar body adiposity. To address this limitation, Bergman et al. [9] introduced an alternative index, the body adiposity index (BAI), in samples of Mexican-American and African-American populations. BAI can be measured without weighing, which may render it useful in settings where measuring accurate body weight is difficult. The BAI allows estimating adiposity and cardiovascular risk what has been confirmed in recent studies [9–12]. In the study of Bergmann et al. [9], the BAI was developed and validated by observations of African-American subjects. The verification process of BAI has just been started in Caucasian populations [13]. That is why we investigated the sex-specific relationships between BMI, BAI and body fat content in young, healthy, Polish, Caucasian men and women. An attempt was made to determine which of the two indexes has a greater sensitivity and specificity for the Caucasian population.

Material and Methods

684 women and 528 men aged 20–22 years with Caucasian origin only participated in the study. Participants were students of universities in southern Poland. They had no indication of cardiometabolic problems as evaluated by interview. Measurements were conducted by qualified academic staff (2 subjects) to minimize inter-observer differences. All subjects were measured for body height (BH), waist and hip circumference (WC and HC) and weight. Body composition was measured using a stand-on Bio Impedance Analyzer (Tanita BC 420SMA, Tokyo, Japan). The measurement was performed in the fasted state, in light clothing, without shoes and socks with clean feet according to a standard protocol of the manufacturer. The device samples periods of 5-second resistance values (Rx) and the reactance of their volume (Xc). These data are the basis for calculating body composition by a computer program including also age, sex and body height [14] and are also used to estimate % body fat.

BMI was calculated by the formula:

$$\text{BMI} = \text{weight (kg)} / \text{height (m}^2\text{)} \qquad (1).$$

BAI was calculated by the formula [14]:

$$\text{BAI} = \frac{\text{hip in cm}}{(\text{height in m})^{1.5}} - 18 \qquad (2).$$

For the measurement of body height a wall-mounted stadiometer with standard scales was used. Body height was measured to the nearest centimeter. WC (cm) and HC (cm) were measured with an anthropometric tape over light clothing. WC was measured at the minimum circumference between the iliac crest and the rib cage and HC at the maximum width over the greater trochanters. Waist-to-hip ratio (WHR) and waist-to-height ratio (WHtR) were then calculated. Determination of WHR is an appropriate method of identifying subjects with abdominal fat accumulation. The WHO recommends the use of WC measurement because it correlates closely with BMI and WHR, and is an approximate index of intra-abdominal fat mass and total body fat [15].

Standard BMI norms, i.e. BMI > 25 kg/m^2, and BAI cutoffs (rates for women >35% and for men >22%) were used to identify obese and overweight subjects [15, 16].

The study was approved by the Bioethical Committee of the Academy of Physical Education in Katowice. All tested subjects gave their written consent for participation in the study. They were called to a separate room to take their anthropometric measurements.

Statistical analyses were performed using STATA STATISTICAL SOFTWARE (release 7; StataCorp, College Station, TX, USA). Results are presented as means ± SD for normally distributed data and as geometric

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Table 1. The mean and standard deviations (± SD) of the studied anthropometric variables of men and women and correlations of BMI and BAI

Variables	Women (age 19.64 ± 0.7 years)					Men (age 19.4 ± 0.9 years)				
	mean ± SD	correlation				mean ± SD	correlation			
		for all		obese			for all		obese	
		BMI (n = 684)	BAI (n = 684)	by BMI (n = 70)	by BAI (n = 10)		BMI (n = 528)	BAI (n = 528)	by BMI (n = 112)	by BAI (n = 296)
BH	167.0 ± 6.0	–0.06	–0.5*	0.02	0.06	180.3 ± 6.2	–0.1	–0.4*	0.02	–0.2*
BM	59.4 ± 9.6	0.9*	0.5*	0.8*	0.7*	74.7 ± 12.6	0.9*	0.5*	0.8*	0.5*
BMI	21.3 ± 3.2	1.0	0.8*	1.00	0.8*	22.9 ± 3.5	1.00	0.7*	1.0	0.7*
FAT	23.6 ± 6.7	0.8*	0.5*	0.5*	0.7*	13.9 ± 5.7	0.9*	0.7*	0.7*	0.5*
TBW	53.7 ± 4.3	–0.8*	–0.5*	–0.5*	–0.6*	60.8 ± 4.5	–0.8*	–0.5*	–0.6*	–0.5*
WC	70.9 ± 7.1	0.8*	0.6*	0.7*	0.7*	82.4 ± 9.0	0.9*	0.6*	0.8*	0.6*
HC	95.6 ± 7.0	0.8*	0.8*	0.7*	0.9*	98.5 ± 7.8	0.8*	0.8*	0.7*	0.7*
WHR	0.7 ± 0.05	0.4*	–0.02	0.3*	0.4	0.8 ± 0.06	0.4*	0.02*	0.4*	0.2*
WHtR	1.7 ± 0.1	–0.8*	–0.97*	–0.6*	–1.0*	1.8 ± 0.1	0.7*	–0.97*	–0.7*	–0.9*
BAI	26.4 ± 3.6	0.8*	1.0	0.6*	1.0	22.7 ± 3.4	–0.7*	1.0	0.7*	1.0

*Statistically significant $p < 0.05$.

BH = Body height in cm; BM = body mass in kg; BMI = body mass index in kg/m^2; FAT = % body fat; TBW = total body water in %; WC = waist circumference in cm; HC = hip circumference in cm; WHR = waist-to-hip ratio; WHtR = waist-to-height ratio; BAI = body adiposity index in %.

means with 95% accuracy. Pearson's correlation coefficients were computed between BAI (or BMI) and BMI (or BAI), % body fat, fat mass, WC, HC, WHR or WHtR within each sex group. A linear regression model was used to assess a relationship between % body fat and BAI (or BMI) for both sexes. Interaction terms were entered into the model for sex-specific BAI (or BMI). The level of significance was $p < 0.05$, and statistical tests were two-sided.

Results

Most correlation coefficients were higher for BMI for both sexes. A significant result of the verification rates for the group by sex, included higher correlation coefficients between BMI and % body fat ($r = 0.86$ for women and $r = 0.82$ for men) than between BAI and % body fat ($r = 0.52$ for women and $r = 0.66$ for men, $p < 0.05$). There was a very high inverse correlation of BAI and WHtR for women and men (both –0.97). There was a lack of correlation between BAI and WHR (table 1).

In accordance with the recommended cutoffs, 15% of the participants were classified as overweight and obese when using the BMI values and 25.2% when using the BAI values. In case of BAI a clear discrimination of the distribution of participants classified as overweight and obese has been observed (7 times in women and 3 times in men; table 1).

The coefficients of correlation between BAI or BMI and % body fat in obese participants according to the BAI cutoff were 0.74 ($p < 0.05$) and according to the BMI cutoff 0.36 ($p < 0.05$) for both sexes. In overweight and obese women, the correlation between BAI and % body fat ($r = 0.72$, $p < 0.05$) was stronger than that between BMI and % body fat ($r = 0.49$, $p < 0.05$). Compared with overweight and obese women, the correlation coefficient between BAI and % body fat in overweight and obese men was lower (table 1).

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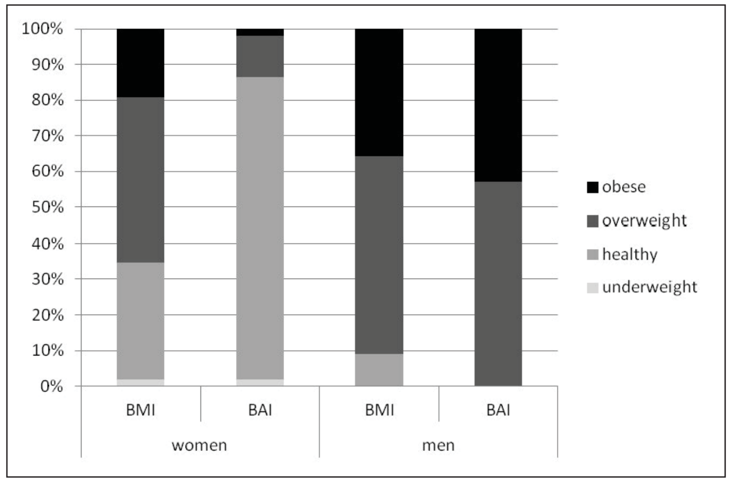

Fig. 1. Classification of women with waist circumference > 80 cm and men with waist circumference > 94 cm according to BMI norms and BAI cutoffs.

A significant finding of this research in selected groups of overweight and obese subjects was the high correlation between BMI and BAI in women (r = 0.81) and men (r = 0.71; both $p < 0.05$).

The classification of subjects according to WC to identify the risk of obesity showed variations depending on the applied index (BAI / BMI). Men with a WC ≥ 94 cm were obese or overweight according to their BAI cutoffs in 100%. However, according to the BMI norms, only 90.4% were classified as obese or overweight while were 9.6% were defined as having normal weight (fig. 1). For women this discrepancy was even more evident. Among women with a WC ≥ 80 cm, according to BAI criteria only 1.3%, were classified as obese while according to BMI criteria obesity was indicated in 19%. More women were identified as overweight by BMI than by BAI in the group with a WC ≥ 80 cm. The classification of men and women with higher fat content measured by bioimpedance analysis (>33% for women and >20% men) revealed the same trend.

Discussion

BAI identified 100% of obese and overweight Caucasian males where obesity was defined as having a WC > 94 cm. When bioimpedance analysis cutoffs were used instead of WC cutoffs, similar results were obtained. Both WC and bioimpedance analysis are methods known for medium to low accuracy but are still used and recommended for population-based screening. BAI is more sensitive than BMI in identifying obese and overweight (defined by a WC cutoff value > 94 cm) Caucasian males; BMI classified 9.6% of these subjects as normal weight.

In contrast, in Caucasian females as many as 86% and 36% of obese or overweight women (as defined by a WC > 80 cm) were identified as having normal weight by using BAI and BMI cutoffs, respectively. However, the fact that a high statistical correlation between BAI and % body fat (r = 0.7) was registered among obese and overweight women suggests that BAI is very specific. This has been confirmed by results of a Spanish Mediterranean population [13].

Different results of BAI in men and women were observed when the ability to discriminate subjects with higher or lower percentage of fat was considered. Considering the cutoff of 35% for women and 25% for men, it was observed that BAI overestimates obesity in men but underestimates it in women.

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The results presented here suggest that BAI cutoffs created for Mexican-American and African-American individuals [9] are not suitable for the Caucasian population, especially for women. Changing the cutoffs in men as well as in women, as indicated previously [11–13], would greatly improve the sensitivity and specificity of the BAI.

Disclosure Statement

The authors declared no conflict of interest.

References

1 Leiter LA, Abbott D, Campbell NR, Mendelson R, Ogilvie RI, Chockalingam A: Lifestyle modifications to prevent and control hypertension. 2. Recommendations on obesity and weight loss. Canadian Hypertension Society, Canadian Coalition for High Blood Pressure Prevention and Control, Laboratory Centre for Disease Control at Health Canada, Heart and Stroke Foundation of Canada. CMAJ 1999;160(9 suppl):S7–12.
2 Tunstall-Pedoe H (ed), for the WHO MONICA Project: WHO Monica Project MONICA Monograph and Multimedia Sourcebook: World's Largest Study of Heart Disease Stroke, Risk Factors and Population Trends 1979–2002. Geneva, WHO, 2003.
3 Vazquez G, Duval S, Jacobs DR Jr, Silventoinen K: Comparison of body mass index, waist circumference, and waist/hip ratio in predicting incident diabetes: a meta-analysis. Epidemiol Rev 2007;29:115–128.
4 Welborn TA, Dhaliwal SS: Preferred clinical measures of central obesity for predicting mortality. Eur J Clin Nutr 2007;61:1373–1379.
5 Chan RSM, Woo J: Prevention of overweight and obesity: how effective is the current public health approach? Int J Environ Res Public Health 2010;7:765–783.
6 WHO: Obesity: Preventing and Managing the Global Epidemic. Report of a WHO Consultation. Geneva, WHO Technical Report Series 894, 2000.
7 Bouchard C: BMI, fat mass, abdominal adiposity and visceral fat: where is the 'beef?' Int J Obes (Lond) 2007; 31:1552–1553.
8 Taylor RW, Keil D, Gold EJ, Williams SM, Goulding A: Body mass index, waist girth, and waist-to-hip ratio as indexes of total and regional adiposity in women: evaluation using receiver operating characteristic curves. Am J Clin Nutr 1998;67:44–49.
9 Bergman RN, Stefanovski D, Buchanan TA, Sumner AE, Reynolds JC, Sebring NG, Xiang AH, Watanabe RM: A better index of body adiposity. Obesity 2011;19:1083–1089.
10 Barreira TV, Harrington DM, Staiano AE, Heymsfield SB, Katzmarzyk PT: Body adiposity index, body mass index, and body fat in white and black adults. JAMA 2011;306:828–830.
11 Elisha B, Rabasa-Lhoret R, Messier V, Abdulnour J, Karelis AD: Relationship between the body adiposity index and cardiometabolic risk factors in obese postmenopausal women. Eur J Nutr 2013;52:145–151.
12 Kaushik B, Debsharma B, Das S: Is body adiposity index a good measure of nutritional status? A study among two adult tribal populations of Paschim Medinipur, West Bengal, India. Sci J Sociol Anthropol 2011. *www.sjpub.org/sjsa/Bose-et-al.pdf.*
13 López AA, Cespedes ML, Vicente T, Tomas M, Bennasar-Veny M, Tauler P, Aguilo A: Body adiposity index utilization in a Spanish Mediterranean population: comparison with the body mass index. Plos ONE 2012; 7:e35281.
14 Kyle UG, Bosaeus I, De Lorenzo AD, Deurenberg P, Elia M, Gómez JM, Lilienthal Heitmann B, Kent-Smith L, Melchior J-C, Pirlich M, Scharfetter H, Schols AMWJ, Pichard C: Bioelectrical impedance analysis part II: utilization in clinical practice. Clin Nutr 2004;23:1430–1453.
15 Obesity – the Policy Challenges. Report of the National Taskforce on Obesity, 2005. Department of Health and Children (DOHC). *http://hdl.handle.net/10147/46689*.
16 Body Adiposity Index Calculator Tool – Better than BMI. *www.intmath.com/functions-and-graphs/bmi-bai-comparison.php.*
17 Shuster A, Patlas M, Pinthus JH, Mourtzakis M: The clinical importance of visceral adiposity: a critical review of methods for visceral adipose tissue analysis. Br J Radiol 2012;85:1–10.