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Effect of sex and race on body mass index and percent body fat in young adults

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Introduction

Mississippi has the second highest adult obesity rate in the United States. One-third of the adult population (37.3%) in the state of Mississippi falls into the obese category as measured by body mass index (BMI). The condition of being obese or overweight is defined as having abnormal or excessive body fat accumulation that may harm one's health [1]. These high rates of obesity are concerning because of their association with increased risk for chronic diseases such as type 2 diabetes, hypertension, cancer, and cardiovascular diseases [2]. There are numerous methods that can be used to assess adiposity: BMI, skinfold measures, dual-energy x-ray absorptiometry (DXA), waist-to-hip ratio, waist circumference, underwater weighing (hydrostatic weighing), and bioelectrical impedance analysis (BIA) [3]. BMI (kg/m^2) is one of the most commonly used measures for estimating and monitoring body composition within populations, more so than any of the previously listed measurements.

BMI was initially devised by the mathematician Adolphe Quetelet with the assumption that “the transverse growth is less than the vertical,” which led to the derived meaning used today as the ratio of weight (kg) over height (m) squared [4,5]. In 1972, Ancel Keys became the first scientist to use the modern term *body mass index*, and it was not until 1998 that the National Heart, Lung, and Blood Institute released a classification of BMI results that would allow patients to be separated into six categories that were correlated with level of health risk [6,7]. The BMI categories included in the evidenced-based clinical guidelines were labeled *underweight, normal weight, overweight, class I obesity, class II obesity*, and *class III obesity*. The categories released in 1998 are still used today [6].

Researchers and clinicians prefer to use BMI as an indicator of body composition owing to ease of calculation, low cost, and the lack of participant preparation needed [8]; however, BMI has limitations, including the inability to distinguish between lean body mass and fat mass [9] and not being sex-, race-, or age-sensitive. Men and women have different minimum necessary fat percentages, with women having a higher necessary fat requirement owing to hormones and childbearing ability [10]. Nevertheless, BMI categories are the same for both women and men. There are also differences in fat percentage and weight associated with aging because muscle mass often decreases with age and an increasingly limited mobility level [9,11]. Batsis et al. [12] conducted a study reviewing the accuracy of BMI in the elderly population by comparing it with DXA scan results. They concluded that BMI is not the best measure of obesity for this age group because it tends to underestimate the presence of obesity [12]. Another study aimed at reviewing the accuracy of BMI through the use of BIA determined that BMI accuracy decreased as the age of the study group increased [13]. Young athletic individuals have an increased BMI owing to increased muscle mass. An example of this can be seen in American football player Jermaine Mayberry, who weighs approximately 326 lb (148 kg) and measures 6′4" (196 cm) tall with a BMI of 39.6 kg/m^2. If he were to be categorized only by BMI, he would be close to class III obesity. However, he has a body fat percentage (BF%) of ~19%, putting him in a healthy category. Therefore, BMI is not the most effective measure of health because it does not take BF% into consideration and does not give accurate information when compared with other techniques like BIA, DXA, or BOD POD [14–16].

BIA is a recommended method for cross-sectional studies because of its ability to assess a larger number of participants in a short period of time and its excellent correlation with DXA [17]. The BIA method provides a fairly accurate estimation of fat-free mass (FFM) and BF% in participants with different characteristics such as age, sex, and ethnicity. Ramírez-Vélez et al. [18], who studied 1687 Colombian collegiate students, confirmed the validity of BIA for measuring BF% with a comparable method for measuring BF%. Furthermore, Aandstad et al. [19] used several validated methods to predict BF%, such as DXA, skinfold thickness, and BIA in 65 men and women. The results showed that BIA was the most reliable method in both sexes and especially in women, with 95% limits of agreement below ±1% points [19].

Recent studies have demonstrated variations in body composition between different races [20]. A study conducted with 894 Taiwanese participants and using BMI, regional fat percentage, and BF% determined by BIA, revealed misclassification among BMI and BF% categories [21]. Participants were separated into high and low BF% by a fat percentage specified as 24% in men and 31.4% in

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women. The study found that although 8.3% of the women and 23.2% of the men could be classified as overweight or obese according to BMI, 14.8% of the men and 27.3% of the women were categorized as having an increased BF% according to the preset BF% guideline. The study concluded that multiple screening methods should be used to assess health status rather than BMI alone within this population. It is very clear when reviewing these studies that the general BMI scale used in the United States is inaccurate in Asian populations. This has been recognized in Asian countries and a lower BMI scale is being used. The Asian BMI scale classifies normal weight as BMI between 18.5 and 23 kg/m^2 compared with the scale used for all populations in the United States, which specifies normal BMI as between 18.5 and 24.9 kg/m^2 [22]. Another study conducted in three research locations in the United Kingdom, the United States, and Japan, reviewed BMI and BF% of Asian, white, and black populations using DXA [23]. The study revealed that black women typically had the highest BMI of the groups studied; whereas Asian men had the lowest. The study also showed that compared with the other two ethnic groups studied, the Asian population had a significantly increased BF% regardless of BMI. Blacks also were found to have a lower mean BF% than white participants, which was more pronounced with increased age. Studies show that overall, Asian populations tend to have a higher BF% than whites at the same BMI [24]; whereas black populations have lower BF% than the white population within that BMI range [20].

The Department of Nutrition for Health and Development uses the BMI categories to track obesity nationally and globally [25]. The underweight, normal, overweight, and obese categories were determined so weight of populations could be compared [22]. To date, there is no specific BF% that would be considered obese by the World Health Organization. Studies have defined >25% BF in men and >35% BF in women as obese; however, these are estimations based on BF% in whites, which correlate with BMI categories within the white population [26].

In 2015, about 1.5 million Mississippi adults were categorized as overweight or obese according to BMI [27]. BMI is widely used in various settings as a tool to measure obesity. There are many studies that show inaccuracies when using BMI as a measure of health within different populations. The present study focused on determining the accuracy of BMI as a method of categorizing young adults in weight categories. The effects of ethnicity and sex on BMI and BF% categories in college-age students also were assessed.

Materials and methods

Study population

This was a cross-sectional study consisting of 362 men and women, 18 to 25 y of age. Physical characteristics of participants are presented in Table 2. Self-reported healthy participants were recruited from the university's campus via classroom announcements and e-mail. Participants were invited for one visit to the Nutritional Performance Assessment Composition Testing laboratory located on the university campus.

Data collection

Each participant had his or her height measured by a stadiometer (235 Heightronic Digital), and the total BF% of each participant was measured using a single-frequency (50-kHz) bioelectrical impedance analyzer system (TBF-300 A, Tanita Corp, Tokyo, Japan). The manufacturer's instructions provided for the Tanita were followed. The results from the Tanita were reflected on a printout that included weight, BMI, BF%, basal metabolic rate, BIA, FFM, total body water, desirable range of fat percentage, and fat mass. BMI values were calculated using the standard BMI equation (kg/m^2). Two to three pounds were added for clothing depending on how participants were dressed (e.g., heavy winter or light summer). Participants were asked to avoid eating or drinking for 4 h before the visit. Participants gave consent for their information to be used in the study. Confidentiality was maintained during measurements and archiving of data. The study was approved by the university's Institutional Review Board.

Statistical analysis

Participants were separated into two groups according to sex. Basic descriptive statistics for participants' data were expressed as means ± standard deviation (SD). Differences between means were calculated using one-way analysis of variance. Body adiposity was classified using both BMI and BF% criteria. BMI was classified according to criteria from World Health Organization 2000 (Table 1). BF% categories were classified according to criteria for both age and sex (Table 2) [23,28]. Weighted k (Kw) statistics were calculated to assess agreement. Statistical analysis of data was conducted using the SPSS version 24 (IBM, Armonk, NY, USA). All reported *P*-values were two-tailed and $P < 0.05$ was considered statistically significant.

Results

Baseline group characteristics

In all, 362 students participated in this study: 80.4% (n = 291) were women and 19.6% (n = 71) were men. In the women's category 27% (n = 78) were African American, and 73% (n = 213) were Caucasian. In the men's category 66% (n = 47) were black, and 34% (n = 24) were white. Table 3 presents the physical characteristics of the participants.

The Kw statistic was used to demonstrate the agreement and degree of disagreement between BMI and BF% for both sexes, black, and white students. $\kappa < 0.20$ was considered poor agreement, between 0.21 and 0.40 was fair, between 0.41 and 0.60 was moderate, between 0.61 and 0.80 was good, and between 0.81 and 1.00 was excellent. $P < 0.05$ was considered statistically significant. Moderate agreement was found for women (Kw = 0.414) and fair agreement for men (Kw = 0.215). Fair agreement was found for black women (Kw = 0.368) and moderate agreement for white women (Kw = 0.410). Poor agreement was found for black men (Kw = 0.144) and fair agreement for white men (Kw = 0.246). See Table 4 for agreement (κ analysis) between BMI and BF% by sex and race.

Comparison between BMI and BF% categories in women and men

This information suggests that in women there is an agreement between the underweight BMI category and underfat BF% category; however, there is a large discrepancy between the other categories, with the largest being normal BMI and healthy BF% categories. There was a 25.1% difference between the number of participants labeled as normal by BMI and the number labeled as healthy by BF% (Table 5). Unlike the women's underweight BMI and underfat BF% populations, which proved to be closely related, the analyzed

Table 1
International classification of weight by BMI in adults

Classification	BMI (kg/m^2)	
	Principal cutoff points	Additional cutoff points
Underweight	<18.50	<18.50
Severe thinness	<16	<16
Moderate thinness	16–16.99	16–16.99
Mild thinness	17–18.49	17–18.49
Normal range	**18.50–24.99**	**18.50–22.99**
		23–24.99
Overweight	**≥25**	**≥25**
Preobese	25–29.99	25–27.49
		27.50–29.99
Obese	**≥30**	**≥30**
Obese class I	30–34.99	30–32.49
		32.50–34.99
Obese class II	35–39.99	35–37.49
		37.50–39.99
Obese class III	≥40	≥40

BMI, body mass index

Table 2
Classification of weight status by BF% in women and men [23,28]

	Women (BF%)				Men (BF%)			
Age (y)	Underfat	Healthy	Overfat	Obese	Underfat	Healthy	Overfat	Obese
20–40	<21	22–33	34–39	>40	<8	9–19	20–25	>26
41–60	<23	24–35	36–40	>41	<11	12–22	23–27	>28
61–79	<24	25–36	37–42	>43	<13	14–25	26–30	>31

Table 3
Physical characteristics of the participants (data expressed as mean ± SD)

	Men(n = 71)	Women(n = 291)	Total(N = 362)	*P*-value*
Age (y)	20.73 ± 2.24	20.51 ± 3.27	20.62 ± 2.75	0.583
Height (cm)	175.87 ± 7.62	166.42 ± 8.23	170.99 ± 7.92	0.001
Weight (kg)	80.66 ± 17.36	65.38 ± 16.14	73.02 ± 16.75	0.001
Body mass index (kg/m^2)	26.14 ± 5.01	24.07 ± 5.40	25.10 ± 5.20	0.003
Body fat (%)	19.30 ± 7.57	28.29 ± 8.95	23.79 ± 8.26	0.000

**P* values are given for comparison between men and women.

Table 4
Interpretation of κ analysis between BMI and BF% for black and white men and women

Participants	κ value	95% CI	Agreements
All women	0.414	0.338 to 0.490	Moderate
All men	0.215	0.085 to 0.345	Fair
Black women	0.368	0.236 to 0.499	Fair
White women	0.410	0.316 to 0.504	Moderate
Black men	0.144	−0.103 to 0.392	Poor
White men	0.246	0.082 to 0.409	Fair

BF%, body fat percentage; BMI, body mass index

Table 5
Comparison of BMI and BF% categories in women and men.

	Underweight (BMI)	Underfat (BF%)	Normal (BMI)	Healthy (BF%)	Overweight (BMI)	Overfat (BF%)	Obese (BMI)	Obese (BF%)
	n (%)		n (%)		n (%)		n (%)	
Women	49 (16.8)	49 (16.8)	217 (74.1)	141 (49.1)	18 (6.2)	56 (19.2)	8 (2.7)	45 (15.2)
Men	6 (8.4)	0 (0.0)	57 (80.2)	40 (56.3)	6 (8.5)	14 (19.7)	2 (2.8)	17 (23.9)

BF%, body fat percentage; BMI, body mass index

data for the male population reveals that the underweight BMI and underfat BF% categories were very different.

When looking at the male participants, BMI was not accurate for any category. The largest disconnects occurred in the normal/healthy population and the obese populations (Table 5). The Kw value for the entire male population showed minimal (fair) agreement (Table 4).

Comparison of BMI and BF% categories in black students

Among black women, the underfat BF% and underweight BMI categories were fairly close. The normal and healthy groups for the black women showed the greatest disparity. The largest classification discrepancies in the black female population were between the normal/healthy groups and the obese categories (Table 6).

Comparison of normal BMI with BF% categories among men and women of both races

To better understand the misclassification of populations using BMI, we focused on those whose BMI fell within the normal range. A graphical comparison of participants in the normal BMI category with BF% categories is presented in Figure 1.

Discussion

The results from the present study are in agreement with some studies and in disagreement with others. Pasco et al. found that 17.3% of women and 31.6% of men were observed as obese according to BMI but were reclassified according to BF% criteria [29]. The study suggested that BMI underestimates adiposity in young and elderly men [29]. A study of 637 healthy women,18 to 40 y of age,

Table 6
Comparison of BMI and BF% categories in black women and men.

	Underweight (BMI)	Underfat (BF%)	Normal (BMI)	Healthy (BF%)	Overweight (BMI)	Overfat (BF%)	Obese (BMI)	Obese (BF%)
	n (%)		n (%)		n (%)		n (%)	
Women	11 (14.1)	9 (11.5)	50 (64.1)	26 (33.3)	10 (12.8)	19 (24.4)	7 (9)	24 (30.8)
Men	4 (8.5)	0 (0.0)	35 (74.4)	11 (45.9)	6 (12.8)	7 (29.1)	2 (4.2)	6 (25)

BF%, body fat percentage; BMI, body mass index

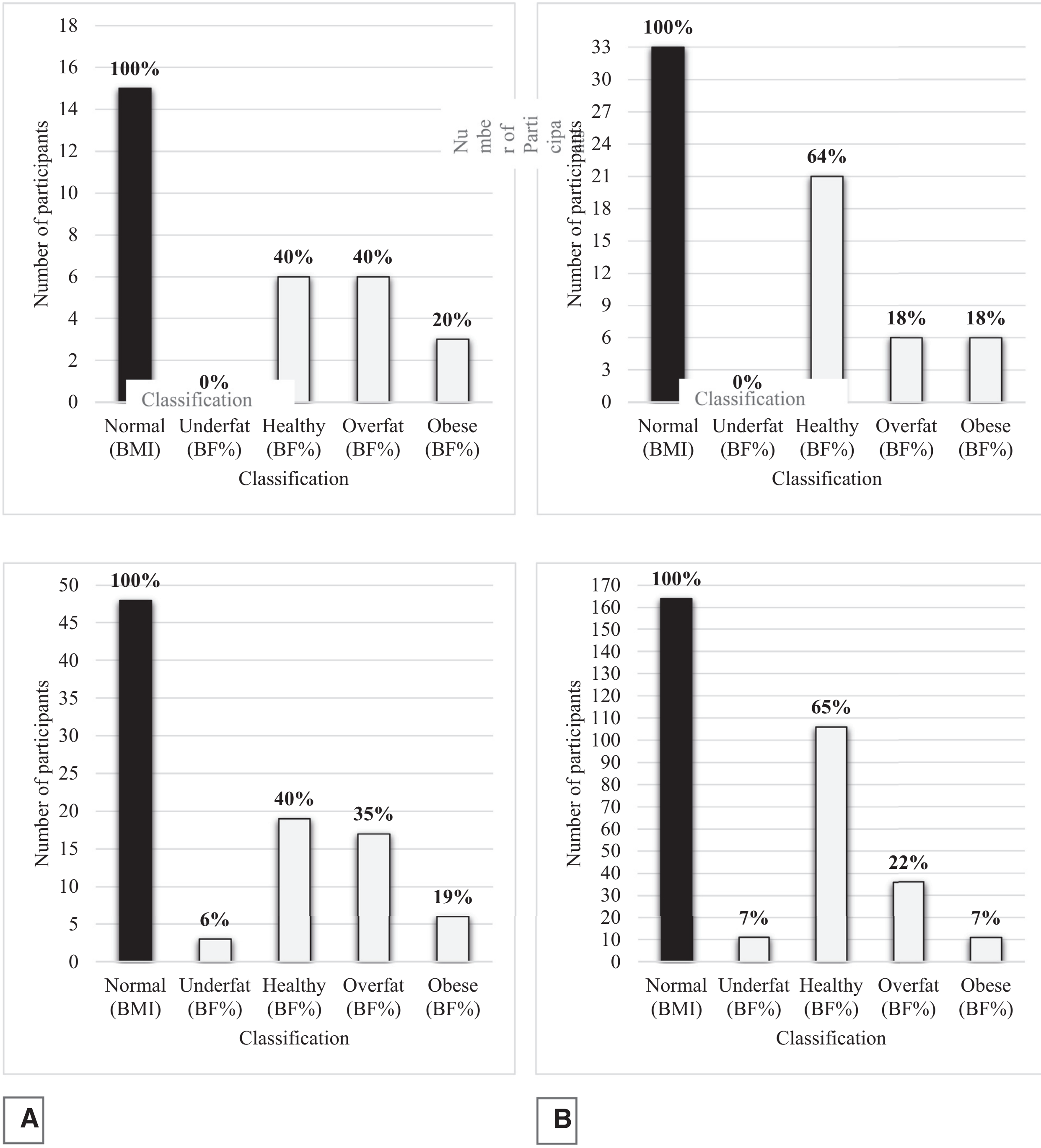

Fig. 1. Comparison of participants with normal body mass index (BMI) against body fat percentage (BF%) categories: (A) black men, (B) white men, (C) black women, and (D) white women.

observed that BIA and BMI methods had similar detection of normal and obese women with 27.67 ± 7.3 kg/m^2 and 25.97 ± 4.7 kg/m^2 [30]. On the other hand, comparing the BIA and DXA in 27 children and adolescents (6–18 y of age), Eisenkölbl et al. [31] found that BIA measurements of BF% of obese participants were 10.6% lower than DXA results and suggested that BIA can be used for measuring but with an SE of 10. Singh Chahar studied 30 men, 26 to 49 y of age, and found that the mean and SD values for BF% measurements by skinfold thickness, BMI, and BIA for his study were 19.95 ± 5.9, 19.67 ± 4.3, and 9.40 ± 4.1, respectively, which means BIA tends to underestimate body fat compared with other methods [32].

Previous studies provided evidence that BMI is less accurate when used in older populations, which is likely due to the natural decrease in muscle mass and increase in fat mass that occurs during aging and is also less accurate in younger populations owing to increased muscle mass [12,16]. In those studies, the BMI error was toward under classifying normal-weight participants as obese. Studies also pointed toward large discrepancies in BF% and BMI categories being attributed to ethnicity. The black population tended to have a lower BF% and white populations a higher BF% at the same BMI category [24].

One study conducted in Mississippi observed the opposite. A greater percentage of black women in the normal BMI category were classified as overfat (35%) or obese (19%) by BF% compared with white women in the normal BMI group, which only reclassified 22% of participants as overfat and 7% of participants as obese by BF%. This suggests that black women are more likely to be misclassified by BMI than white women and that BMI underestimates the number of women who are overweight or obese.

Similarly, as with obese women, obese men, especially black men, were underreported by BMI. This data conflicts with previous studies comparing black populations with white populations [23].

Clinical implications

This research suggested several clinical applications. The study found that BMI significantly underreported obesity overall, as well as the severity of obesity in patients within the normal BMI range. Because obesity is one of the most significant risk factors for development of many chronic diseases including diabetes, hypertension, and cancer, such misdiagnosis can result in delayed prevention measures and disease detection. Owing to the misdiagnosis of obese patients, early intervention strategies may not be used. If a patient with a normal BMI is diagnosed as overweight or obese by BIA or other assessment methods, recommendations for lifestyle changes leading to reduction of fat tissue can be made earlier and full development of disease prevented.

This study also suggested that data from the Centers for Disease Control and Prevention regarding obesity in the state of Mississippi are incorrect and the obesity epidemic is even more severe than the data indicate. The Centers for Disease Control and Prevention data are based on BMI categories, which this study proved to be incorrect, specifically within the young adult population [33]. Data also suggest that in states with increased minority populations, such as Mississippi, data may be skewed even more than it is in states with smaller minority populations [34].

Conclusion

The results of this study demonstrated that BMI and BF%, as measured by BIA, are influenced by sex and ethnicity in a college-age population. Therefore, age, sex, and ethnicity should be considered when interpreting BMI and BF% in cross-sectional studies. BMI is not an accurate measurement of body composition in young adults. Other techniques such as BIA should be used to assess weight status of young adults. We suggest that future studies should further investigate differences in body composition among different populations, and BF% and BMI guidelines should be established based on individual age groups and ethnicities.

References

[1] Lavie CJ, Pandey A, Lau DH, Alpert MA, Sanders P, et al. Obesity and atrial fibrillation prevalence, pathogenesis, and prognosis: effects of weight loss and exercise. Journal of the American College of Cardiology 2017;70(16):2022–35.

[2] Lavie CJ, Milani RV, Ventura HO. Obesity and cardiovascular disease: risk factor, paradox, and impact of weight loss. J Am Coll Cardiol 2009;53:1925–32.

[3] Akindele MO, Phillips JS, Igumbor EU. The relationship between body fat percentage and body mass index in overweight and obese individuals in an urban African setting. J Public Health Africa 2016;7:515.

[4] Blackbur H, Jr JacobsD. Commentary: origins and evolution of body mass index (BMI): continuing saga. Int J Epidemiol 2014;43:665–9.

[5] Eknoya G. Adolphe Quetelet (1796–1874)—the average man and indices of obesity. Cambrdige, UK: Oxford University Press; 2007.

[6] National Institutes of Health. Obesity education initiative. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults. https://www.nhlbi.nih.gov/files/docs/guidelines/ob_gdlns.pdf. (Visited on 11/05/2018).

[7] Strawbridge WJ, Wallhagen MI, Shema SJ. New NHLBI clinical guidelines for obesity and overweight: will they promote health? Am J Public Health 2000;90:340.

[8] Chung S. Body mass index and body composition scaling to height in children and adolescent. Ann Pediatr Endocrinol Metab 2015;20:125–9.

[9] Akindele M, Phillips J, Igumbor E. The relationship between body fat percentage and body mass index: overweight and obese individuals in an urban African setting. J Public Health Africa 2016;7.

[10] Norgan N. The beneficial effects of body fat and adipose tissue in humans. Int J Obes 1997;21:738.

[11] Lamberts SW, van den Beld AW, Van Der Lely A-J. The endocrinology of aging. Science 1997;278:419–24.

[12] Batsis JA, Mackenzie TA, Bartels SJ, Sahakyan KR, Somers VK, Lopez-Jimenez F. Diagnostic accuracy of body mass index to identify obesity in older adults: NHANES 1999–2004. Int J Obes 2016;40:761.

[13] Romero-Corral A, Somers VK, Sierra-Johnson J, Thomas RJ, Collazo-Clavell M, Korinek J, et al. Accuracy of body mass index in diagnosing obesity in the adult general population. Int J Obes 2008;32:959.

[14] Dietz WH. Use of the body mass index (BMI) as a measure of overweight in children and adolescents. J Pediatr 1998;132:191–3.

[15] Muralidhar D. Body mass index and its adequacy in capturing body fat. Thai J Physiol Sci 2007;20:97–100.

[16] Prentice AM, Jebb SA. Beyond body mass index. Obesity Rev 2001;2:141–7.

[17] Langer RD, Borges JH, Pascoa MA, Cirolini VX, Guerra-Júnior G, Gonçalves EM. Validity of bioelectrical impedance analysis to estimation fat-free mass in the army cadets. Nutrients 2016;8:121.

[18] Ramírez-Vélez R, Correa-Bautista J, Sanders-Tordecilla A, Ojeda-Pardo M, Cobo-Mejía E, Castellanos-Vega R, et al. Percentage of body fat and fat mass index as a screening tool for metabolic syndrome prediction in Colombian University Students. Nutrients 2017;9:1009.

[19] Aandstad A, Holtberget K, Hageberg R, Holme I, Anderssen SA. Validity and reliability of bioelectrical impedance analysis and skinfold thickness in predicting body fat in military personnel. Mil Med 2014;179:208–17.

[20] Deurenberg P, Yap M, Van Staveren WA. Body mass index and percent body fat: a meta analysis among different ethnic groups. Int J Obes 1998;22:1164.

[21] Hung S-P, Chen C-Y, Guo F-R, Chang C-I, Jan C-F. Combine body mass index and body fat percentage measures to improve the accuracy of obesity screening in young adults. Obes Res Clin Pract 2017;11:11–8.

[22] World Health Organization. The Asia-Pacific perspective: redefining obesity and its treatment. Sydney, Australia: Health Communications Australia; 2000.

[23] Gallagher D, Heymsfield SB, Heo M, Jebb SA, Murgatroyd PR, Sakamoto Y. Healthy percentage body fat ranges: an approach for developing guidelines based on body mass index. Am J Clin Nutr 2000;72:694–701.

[24] Chang C-J, Wu C-H, Chang C-S, Yao W-J, Yang Y-C, et al. Low body mass index but high percent body fat in Taiwanese subjects: implications of obesity cutoffs. Int J Obes 2003;27:253.

[25] World Health Organization. Obesity: preventing and managing the global epidemic. http://whqlibdoc.who.int/trs/WHO_TRS_894.pdf. (Visited on 11/05/2018).

[26] Ho-Pham LT, Campbell LV, Nguyen TV. More on body fat cut-off points. In: Mayo Clinic Proceedings, Elsevier; 2011. 2011.

[27] Mendy VL, Vargas R, Cannon-Smith G, Payton M. Peer reviewed: overweight, obesity, and extreme obesity among Mississippi adults, 2001–2010 and 2011–2015. Prev Chronic Dis 2017;14:160554.

[28] Bray GA. Contemporary diagnosis and management of obesity. Longboat Key, FL: Handbooks in Health Care; 2003.

[29] Pasco JA, Holloway KL, Dobbins AG, Kotowicz MA, Williams LJ, Brennan SL. Body mass index and measures of body fat for defining obesity and underweight: a cross-sectional, population-based study. BMC Obes 2014;1:9.

[30] Amani R. Comparison between bioelectrical impedance analysis and body mass index methods in determination of obesity prevalence in Ahvazi women. Eur J Clin Nutr 2007;61:478–82.

[31] Eisenkölbl J, Kartasurya M, Widhalm K. Underestimation of percentage fat mass measured by bioelectrical impedance analysis compared to dual energy x-ray absorptiometry method in obese children. Eur J Clin Nutr 2001;55:423–9.

[32] Singh Chahar P. Assessment of body fat percentage by different methods: a comparative study. Eur J Sports Exer Sci 2014;3:1–6.

[33] Centers for Disease Control and Prevention, Division of Nutrition, Physcial Activity, and Obesity. Mississippi State nutrition, physical activity, and obesity profile. Atlanta, GA: US Department of Health and Human Servises; 2012.

[34] Levi, J, Segal, L, Laurent, RS, & Rayburn, J. (2014). The state of obesity 2014. Trust for America's Health and the Robert Wood Johnson Foundation. Retrieved November 05, 2018. https://www.rwjf.org/content/dam/farm/reports/reports/2014/rwjf414829.