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Original Article

Comparison of obesity classification methods among college students

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A B S T R A C T

The purpose of this study was to compare obesity classification methods (body mass index (BMI), abdominal girth (AG), and body fat percentage (BF%)), among college students. College students (n = 5943) completed an objective fitness assessment, where height and weight (used to calculate BMI), AG, and BF% (using Bioelectrical Impedance Analysis) were assessed. Correlation and chi-square tests for independence analyses examined relationships between variables and obesity classification methods; and, the sensitivity and specify of BMI using AG and BF% were calculated. Significant correlations were found between BMI and BF% for men (r = 0.775, p < 0.001) and women (r = 0.849, p < 0.001); BMI and AG for men (r = 0.868, p < 0.001) and women (r = 0.858, p < 0.001); and, BF% and AG for men (r = 0.749, p < 0.001) and women (r = 0.767, p < 0.001). There were significant associations between BMI, AG, and BF% for both sexes. Obesity categorization differed significantly between methods. In men and women, respectively, 47.6% and 44.1% classified as normal weight based on BF% were classified as overweight or obese based on BMI (Men: $\chi 2 = 1547$, p < 0.001; Women: $\chi 2 = 1127$, p < 0.001). In men and women, respectively, 48.3% and 24.0% classified as normal based on AG were classified as overweight or obese using BMI (Men: $\chi 2 = 1274$, p < 0.001; Women: $\chi 2 = 996$, p < 0.001). Comparing AG and BF%, 25.1% of men and 18.6% of women classified as normal based on AG were classified as overweight or obese using BF% (Men: $\chi 2 = 1412$, p < 0.001; Women: $\chi 2 = 421$, p < 0.001). Obesity classification differed significantly between methods, and BMI demonstrated relatively poor predictive value with respect to obesity classification. Thus, caution should be applied when using BMI to diagnose obesity among college students.

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Introduction

The continuing increase in obesity [1,2], in other words excess adipose tissue [3], should be met with trepidation due to the associated adverse health outcomes that will presumably afflict both individuals and society [4]. With respect to the United States (US) in particular, the prevalence of obesity continues to increase across all age levels, from children [5], to adults [1], and even college students [6,7]. Such trends are concerning for a multitude of reasons including, but not limited to, the negative physical and mental health outcomes associated with obesity [8–10], as well as the resultant societal costs attributable to lost productivity [4,11,12], the increased load placed healthcare systems [13,14], and even premature death [12,15]. Therefore, decreasing the prevalence of obesity is of paramount importance.

Quantification of the prevalence of obesity plays an important role in informing and influencing those with a vested interest in taking steps to decrease prevalence this condition. However, obesity can be classified using a range of methods, such as body mass index (BMI), abdominal girth (AG), and body fat percentage (BF%); each method comes with strengths and weaknesses [16]. National self-report surveys (e.g. BRFSS, NHIS) use BMI to classify weight status, largely due the ease and minimal expense with which it can determine weight status due merely using self-reported height and weight. However, BMI is based on the underlying assumption that at a given height, greater weight is associated greater adiposity, and cannot distinguish between fat and fat-free mass [17]. AG is a relatively simple measure of adiposity that considers central adiposity that can be self-assessed using a tape measure, but is more accurately assessed by a trained technician. By contrast, BF% can be determined using a variety of methods. Some of these methods require expensive equipment of highly trained technicians, such as Dual-Energy X-ray Absorptiometry (DXA), hydrostatic weighing, or air displacement plethysmography (i.e. the Bod Pod®). BF% can also be determined using Bioelectrical Impedance Analysis (BIA), which uses electrical currents to determine the percentage of different

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types of body tissue within the body. While relatively inexpensive and quick, the accuracy of BIA can vary widely and is influenced by food and fluid intake. Skinfolds can also be used to assess adiposity, but calculations vary with number and locations of sites for the measurements and between sexes, and results may vary between testers even when comparing trained technicians.

BMI is widely used to diagnose obesity, yet has been shown to be less accurate than other measures with respect to diagnoses of obesity [18]. BMI has been shown to have strong associations with AG [19,20], and BF% assessed using BIA [21–23]. However, BMI has also been shown to result in misclassification of weight status compared to AG [24]. Moreover, some findings suggest that BIA may offer minimal value over AG [25,26]. Research regarding the accuracy of BMI in comparison to other body composition measures and obesity classification methods of among college students is lacking, though findings indicate that BMI has high sensitivity and low specificity in college men, and low sensitivity and high specificity in college women with BF% used as the criterion variable [27]. Thus, the purpose of this study was to examine the relationship between BMI, AG, and BF%, and the classification of obesity based on these methods among college students.

Methods

Participants

Students (n = 5986) at a large Northeastern University in the US completed a pre-consultation questionnaire online prior to completing an objective fitness assessment between September 2015 and April 2018. All students were required to complete the ACSM pre-participation health screening process [28]. Students unable to participate in the fitness assessment were excluded from the study. Forty-one participants who were older than 25 years of age were removed to allow analyses of only college-aged students. A further two participants missing data for two of the three body composition were removed from analyses. Analyses were conducted on the remaining 5943 participants. All participants provided informed written consent, and trained technicians administered tests. The Pennsylvania State University Institutional Review Board approved this study.

Protocol

Prior to the fitness assessment participants completed an electronic pre-test questionnaire (BSDI, Califon, NJ), which was linked to the fitness assessment data using an identification number.

Measures

Demographics
Participants self-reported their age and sex in the pre-consultation questionnaire.

Body Mass Index
Height and weight were measured using a stadiometer and scale and then used to calculate BMI. Those with a BMI in excess of 25 kg/m^2 and 30 kg/m^2 were considered overweight or obesity respectively. Those with a BMI between 18.5 and 25 kg/m^2 were characterized as "normal", and those less than 18.5 kg/m^2 were underweight.

Body fat percentage
BF% was calculated via bioelectrical impedance analysis (Bodystat 1500, Bodystat Ltd., Cronkbourne, Douglas, Isle of Man, British Isles). Men and women below 25 and 30% body fat respectively were considered normal weight, and those over as having obesity

Table 1
BMI classification accuracy.

		Using BMI	
		Normal weight	Overweight/obese
Using BF%/AG	Normal fat	True negative	False positive
	Overfat	False negative	True positive

Table 2
Participant Anthropometric Characteristics.

	Men (n = 3596)		Women (n = 2344)	
	M	SD	M	SD
BMI	25.48	3.77	23.70	3.93
BF%	16.19	5.35	26.52	5.78
AG	32.70	3.56	28.78	3.40

[29]. These thresholds were chosen over less conservative alternatives, as there has been debate about which cut off values to use [30].

Abdominal girth
AG was measured by a trained technician on bare skin at the narrowest circumference between the umbilicus and the xiphoid process of the sternum using a tension regulated tape measured (Gullick II). Men and women with an abdominal girth below 40 and 35 in. respectively were classified as having "normal weight", and those over as having obesity [28].

Statistical analyses

Descriptive statistics were computed to characterize the sample. Due to the sex differences in body composition variables, analyses were separated by sex. The relationships between the respective body composition variables were examined using correlation analyses, with scatterplots inlcuding cut-off values for obesity classification for each measure generated. Chi-square tests for independence examined differences between obesity classification methods. Accuracy of BMI as a measure of adiposity using thresholds of both 25 kg/m^2 and 30 kg/m^2 was examined using BF% and AG as criterion measures, with the sensitivity, specificity, and predictive values of BMIcalculated for men and women [31]. Participants were classified into one of four categories (Table 1).

All analyses were run using SPSS 24.0 (IBM, Armonk, NY), with significance levels set at $p < 0.05$.

Results

Participant characteristics

The majority of participants were men (n = 3597, 60.5%), and the remainder were women (n = 2346, 39.5%). The mean age of participants was 21.30 ± 1.05 years. Based on data collected from similar populations at the same university participants were likely predominantly (~80%) non-Hispanic white [32,33].

Participant anthropometric characteristics

The mean BMI, BF%, and AG for men and women are displayed in Table 2.

Body mass index vs. body fat percentage

Men
There was a moderate to strong correlation between BMI and BF% among men (r = 0.775, p < 0.001). However, close to half of those
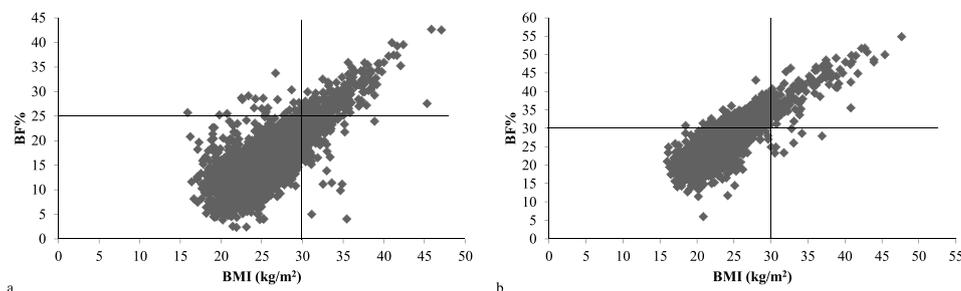
Fig. 1. Correlation between body mass index and body fat percentage among men (a) and women (b).

classified as normal weight based on BF% were classified as overweight (42.2%) or obese (5.4%) using BMI, χ^2 (3, n = 3576) = 1547, p < 0.001, Φ_c = 0.658 (Fig. 1a).

Women

There was a strong correlation between BMI and BF% among women (r = 0.849, p < 0.001). A small percentage of those classified as normal weight based on BF% were classified as overweight (11.4%) or obese (0.30%) using BMI, χ^2 (3, n = 2330) = 1126, p < 0.001, Φ_c = 0.695 (Fig. 1b).

Body mass index vs. abdominal girth

Men

There was a strong correlation between BMI and AG among men (r = 0.868, p < 0.001). Of those classified as normal weight based on AG, 41.7% were classified as overweight and 6.6% as obese using BMI, χ^2 (3, n = 3576) = 1274, p < 0.001, Φ_c = 0.597 (Fig. 2a).

Women

There was a strong correlation between BMI and AG among women (r = 0.858, p < 0.001). Of those classified as normal weight based on AG, 21.7% were classified as overweight or and 2.3% as obese using BMI, χ^2 (3, n = 2330) = 996, p < 0.001, Φ_c = 0.654 (Fig. 2b).

Body fat percentage vs. abdominal girth

Men

There was a moderate correlation between BF% and AG among men (r = 0.749, p < 0.001). However, 25.1% of those classified as obese based on AG were classified as normal based on BF%, χ^2 (1, n = 3595) = 1400, p < 0.001, Φ = 0.627 (Fig. 3a).

Women

There was a strong correlation between BF% and AG among women (r = 0.767, p < 0.001). However, 18.6% of those classified as normal based on AG were classified obese based on BF%, χ^2 (1, n = 2344) = 417, p < 0.001, Φ = 0.424 (Fig. 3b).

Body Mass Index accuracy

Analyses revealed that based on the BMI threshold of 30 kg/m^2 for obesity classification, the specificity and negative predictive value of BMI were excellent. However, with the exception of in comparison to BF% among women, BMI demonstrated relatively good sensitivity and poor positive predictive value. Using the BMI threshold of 25 kg/m^2 for overweight/obesity classification, sensitivity and negative predictive values remained good, whereas specificity and predictive values were considerably worse (Table 3).

Among those classified as having overweight using BMI (i.e. between 25 and 30 kg/m^2), the majority of men were classified

as having normal weight using BF% (n = 1411, 98.74%) and AG (n = 1417, 99.09%). Similarly, most women classified as having overweight using BMI were classified as having normal weight using AG (n = 1590, 97.48%). By contrast, far less women classified as having overweight using BMI were classified as having normal weight using BF% (n = 205, 39.88%).

Discussion

While more accurate than body weight alone and a useful as a screening tool, BMI is an indirect and imperfect measure of adiposity and therefore obesity [34,35]. Moreover, there has been a call for evidence-based BMI cut-off values by age, gender, and race for identification of individuals at increased risk for cardiovascular disease [34]. The findings of this study add to those previously reported in the literature [29,36,37], and further reinforce the need for evidence-based BMI cut-off values based on social determinants.

While there were moderate-to-strong correlations between body composition measures among college students, classification of obesity differed significantly between methods, and contributed to meaningful differences in obesity classification. Findings suggest that less expensive alternatives to DXA, such as AG and BIA, provide more accurate classification of weight status compared to BMI. However, this study was limited by the lack of comparison of methods with DXA, which is considered the gold standard for body composition assessment and classification. In future, researchers may want to consider controlling for race/ethnicity given body composition is known to vary based on such variables [38,39], but was not assessed in the current study.

Of the two methods, BIA is relatively quick, requires minimal tester expertise, and can provide relatively accurate measures of adiposity if quality and consistent testing protocols are implemented to control hydration levels, as well as ambient and skin temperatures. Relative fat mass, which takes AG, height, and sex into consideration [40], is also worth consideration, though is still subject to limitations associated with measurement inconsistencies.

Findings are consistent with meta-analyses that concluded that BMI had relatively good sensitivity and specificity when BMI is greater than 30 kg/m^2, but is limited with respect to diagnosing excess adiposity when BMI values between 25 and 30 kg/m^2 [29]. Moreover, subsequent research has found that, relative to BF%, BMI has also been shown to be inaccurate among athletic [37] and ethnically diverse [36] populations. Thus, caution should be taken when using BMI as a measure of obesity when classifying those with a BMI of less than 25 and 30 kg/m^2, particularly among men. Comparison of findings with those reported in the literature are complicated by variation in the use of thresholds to classify individuals as having obesity using BF%.

Further research is required to determine the optimal BMI cut-off values in comparison with other criterion measures of adiposity
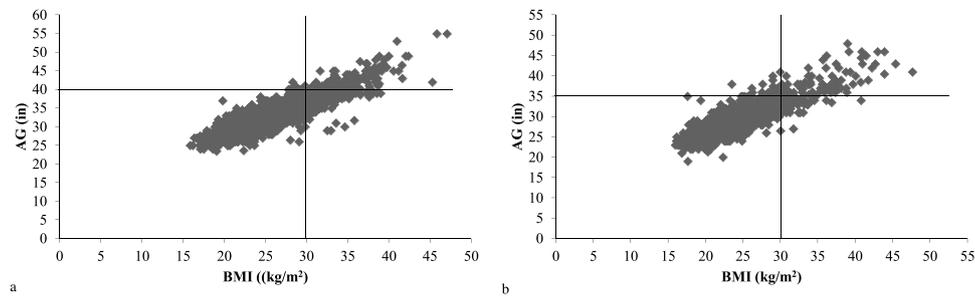
Fig. 2. Correlation between body mass index and abdominal girth among men (a) and women (b).
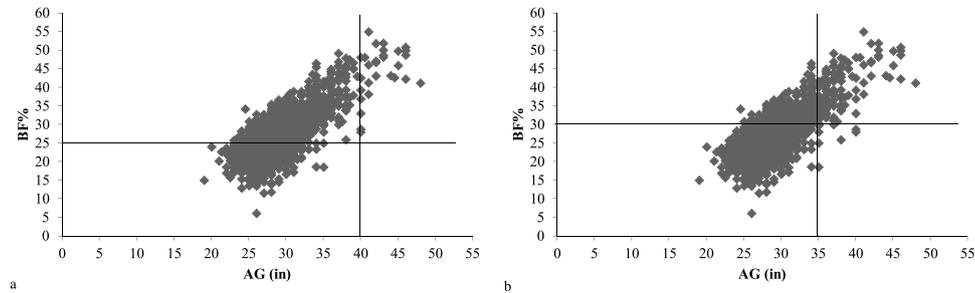

Fig. 3. Correlation between body fat percentage and abdominal girth among men (a) and women (b).

Table 3
Predictive value of body mass index vs. body fat percentage and abdominal girth.

		Sensitivity	Specificity	Positive predictive value	Negative predictive value
		BMI 30 kg/m^2			
Men	BF%	96.23	90.46	52.99	99.54
	AG	100.00	88.50	41.82	100.00
Women	BF%	61.06	99.60	95.83	94.47
	AG	96.88	96.89	64.58	99.81
		BMI 25 kg/m^2			
Men	BF%	96.10	54.02	12.95	99.49
	AG	100.00	51.76	9.59	100.00
Women	BF%	79.59	87.75	61.09	94.68
	AG	96.58	76.01	17.68	99.76

beyond BF%, such as AG, the relatively new variable relative fat mass, as well as adipose, bone, and lean tissue as measured by DXA if possible. Comparison of optimal BMI cut-off values using multiple criterion variables may help to begin to adjust the cut-off values for BMI, which is so commonly used, in order increase the accuracy of obesity diagnoses and benefit the physical and mental health [8–10] of many of the approximately one in three adults in the United States who are currently classified as having overweight using BMI [41]. Aside from adjusting cut-off values from current levels, the findings of this, and previous studies [27], indicate that regardless of the criterion variable the cut-off values for BMI with respect to determining whether individuals have obesity differ between sexes.

In summary, findings highlight the shortcomings of classifying obesity using BMI, regardless of whether height and weight are self-reported or measured by a trained technician. The limitations of BMI identified by this study, combined with errors stemming from using self-reported BMI (i.e. BMI calculated from self-reported height and weight) among college students [42], mean that the true level of the increasing prevalence of obesity among college students self-reported BMI [6,7], and the associated potential physical and mental health problems facing students remains unclear. Moreover, aside from missed opportunities to intervene if those who have obesity are classified as normal weight, misclassification as having obesity has the potential to negatively impact mental health [43,44]. Thus, for BMI to continue to be used as to classify obesity

among college students, and other populations, it is crucial to work towards establishing separate cut-off values for BMI for each sex to avoid disparities in the quality of care provided.

Conflicts of interests statement

The authors declare no conflicts of interest and do not have any financial disclosures.

Ethics statement

The Pennsylvania State University Institutional Review Board approved this study.

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