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Accuracy of current body mass index obesity classification for white, black and Hispanic reproductive-age women

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Abstract

Objective—To compare the National Institute of Health's (NIH) body mass index (BMI)-based classification to identify obesity in comparison with the World Health Organization (WHO)'s percent body fat (%BF) -based reference standard among white, black and Hispanic reproductive-aged women.

Methods—Body weight, height, BMI and %BF (DXA generated) were determined for 555 healthy adult women 20 to 33 years of age (M ± s.d.; 26.5 ± 4.0 years). Diagnostic accuracy of the NIH based obesity definition (BMI ≥ 30 kg/m^2) was determined using the WHO reference standard (%BF >35%).

Results—Obesity as classified by the NIH (BMI ≥ 30 kg/m^2) and WHO (%BF >35%) identified 205 (36.9%) and 350 (63.1%) of the women as obese, respectively. NIH defined obesity cutoff values had 47.8%, 75.0% and 53.9% sensitivity in white, black and Hispanic women, respectively. White and Hispanic women had 2.9% greater %BF than black women for a given BMI. Receiver operating characteristics curves analyses showed that the respective sensitivities improved to 85.6%, 81.3%, and 83.2%, and that 311 women (56.0%) were classified as obese as a whole when race/ethnic specific BMI cutoff values driven by our data (BMI≥ 25.5, 28.7, and 26.2 kg/m^2 for white, black and Hispanic women, respectively) were used to detect %BF-defined obesity.

Conclusions—Current BMI cutoff values recommended by the NIH failed to identify nearly half of reproductive-aged women who met the criteria for obesity by %BF. Using race/ethnic specific BMI cutoff values would more accurately identify obesity in this population than the existing classification system.

Keywords

Body mass index; percent body fat; race; ethnicity; reproductive-aged women

Introduction

Obesity is fast approaching tobacco as the top preventable cause of death in the U.S. (1,2). It exerts adverse effects on health through multiple organ systems of the body and reduces life expectancy (3,4). In 2000, the World Health Organization (WHO) labeled obesity as the most blatantly visible, but most neglected public-health problem worldwide (4).

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Body mass index (BMI) has been used to identify who is overweight or obese for decades. Further, this method has been used consistently in most clinical and behavioral studies, and is the key measure to assess weight loss programs (5–7). However, arguments against using a single universal cutoff value worldwide to define obesity are widespread (8–19). For example, WHO recommended BMI values of 23 kg/m^2 and 25 kg/m^2 as the cutoff points for overweight and obesity for Asians, respectively (20). Several Asian countries have also recommended using lower cutoff values to identify overweight and obesity (12–19).

The accuracy of the National Institute of Health's (NIH) definition of obesity (21) as those with a BMI ≥ 30 kg/m^2 compared to WHO's reference standard for obesity (percent body fat>25% in men and 35% in women) (6) has been recently challenged as well (9–11). For example, Romero-Corral et al (9) observed that this obesity cutoff value was too high for U.S. adult men and women, and missed more than half of the obese individuals. Evans et al (10) and Blew et al (11) made similar observations in their studies of postmenopausal women. Moreover, white and Hispanic women demonstrated significantly higher percent body fat (% BF) for a given BMI than black women (22). Thus, data on accurate BMI cutoff values based on %BF to define obesity in women of different races/ethnicities are needed to better assess an individual's risk of obesity related morbidity and mortality. This is especially important to determine in reproductive-aged women as they are more likely to be obese than similarly aged men (23), which may make them vulnerable to cardiovascular disease risk factors and other obesity related diseases. To obtain this critical information, we investigated the accuracy of the currently used BMI cutoff value in comparison with WHO's %BF-based criterion standard to identify obesity among reproductive-aged white, black, and Hispanic women.

Methods

We conducted secondary analyses of data gathered to examine the effects of hormonal contraception on bone mineral density (BMD). As a part of larger study, 805 healthy, reproductive-aged non-Hispanic white, non-Hispanic black, and Hispanic women aged between 16 and 33 years were recruited between October 9, 2001, and September 14, 2004. Determination of race was based on self-identification. The methods for the larger study are reported in detail elsewhere (24). Briefly, recruitment was planned to achieve a sample that was balanced by race/ethnicity, age group (16–24 years and 25–33 years), and contraceptive method. We excluded women from participation in the larger study if they weighed >300 pounds (due to safety limitations of the DXA machine), were not eligible to receive hormonal contraceptive containing estrogen, wished to become pregnant in ≤3 years, had received oral contraceptive pills or depot medroxyprogesterone acetate in the last 3 or 6 months, respectively, had used medications or had a medical condition known to affect BMD, or had a dietary intake known or suspected to be high in isoflavones. In addition, to avoid including women with a possible medical condition that could affect their BMD, those with abnormal serum levels of vitamin D, thyroid stimulating hormone, or liver function tests were excluded. We obtained child assent and parental permission for participants under 18 years of age and written informed consent from all others. Of the 805 women who consented to participate, 92 failed additional screening tests and 5 were removed from the study following the baseline bone scan due to results indicative of osteoporosis (T-score ≤ −2.5). Those excluded (n=97) did not differ from women included in the analyses (n=708) on age, but were more likely to be black (22% vs. 10% Hispanic and 2% white, $P < 0.001$) and to have a higher BMI (28.4 kg/m^2 vs. 24.4 kg/m^2, $P < 0.001$). Data reported in this paper were collected at the baseline visit for the longitudinal study. The study received approval from the Institutional Review Board at the University of Texas Medical Branch at Galveston.

Our analysis was limited to adults aged 20 years or older who had %BF data available at baseline. We excluded 146 women who were less than 20 years old, as the obesity definition

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of this age group differs from that of the adult population. In addition, seven adult women did not have %BF data available at baseline. Thus, our final analyses were based on 555 women. In the present analyses, we included data on age, height, weight, BMI, and body composition measures collected at baseline in the clinic for the larger study. We obtained body composition measures using dual-energy X-ray absorptiometry (DXA) (Hologic QDR 4500W densitometer). The coefficient of variation of %BF among adults for repeated measurements ranged from 2.8% to 3.3% (11,25) while the interclass correlation coefficient was 0.994 (25). We calculated %BF by DXA using the following formula: [fat mass (g)/{fat mass (g) + lean mass (g) + total bone mineral content (g)}] × 100. We measured standing height and weight with women wearing light indoor clothing and no shoes. Standing height was measured to the nearest 0.1 centimeters using a stadiometer. Body weight was measured using a digital scale accurate to the nearest 0.1 kg. BMI was calculated as weight (kg) divided by the square of the height (m).

Statistical Analysis

We performed univariable comparisons among three race/ethnic groups using one-way analysis of variance with Bonferroni corrections. We used multiple regression analyses to examine the relationship between %BF and BMI and the effect of age and race/ethnicity on this relationship. We also used nonlinear terms to estimate whether the relationship between %BF and BMI is linear or curvilinear.

The sensitivity and specificity of the currently used BMI cutoff value (≥ 30 kg/m^2) to define obesity were compared to the reference standard definition of obesity in women using percent fat (>35%) (6). Corresponding 95% confidence intervals (CIs) were computed using exact methods (26). We also examined racial differences with regard to BMI accuracy. In addition, we evaluated appropriateness of various BMI values for classifying obesity using receiver operating characteristics (ROC) curves. Analysis using ROC curves generated sensitivity and specificity rates corresponding to various BMI cutoff values. We identified race/ethnicity specific optimum BMI cutoff levels by maximizing the classification accuracy after calculating overall performance (sensitivity + specificity). In addition, we determined the area under the curve (AUC) statistic which is a global measure of the overall diagnostic accuracy of BMI to determine clinical status (obesity) (27,28). We also examined the accuracy of our data driven race/ethnicity specific BMI cutoff values using the same criterion standard of obesity. Improvement of sensitivity with race/ethnic specific BMI cutoff values were compared using McNemar's chi-square tests. All analyses were performed using STATA 10 (Stata Corporation, College Station, TX).

Results

Descriptive characteristics

At baseline, the total sample included 189 white, 159 black and 207 Hispanic women with a mean age of 26.5 (± 4.0) years. Whites were older than blacks, but had lower %BF than Hispanics (Table 1). Black women were more likely to have higher values for body weight and BMI relative to white and Hispanic women, while height was similar among blacks and whites.

Relationship between %BF and BMI

Regression analysis between %BF and BMI along with significant BMI-squared terms showed that the relationship is curvilinear (Figure 1). The model building strategy showed that the model with BMI, BMI-squared, and race*BMI interaction had the highest explained variance (R-squared 76.2%) although the model with BMI, BMI-squared and race showed almost the same variance (R-squared 75.8%). No other predictor added additional variance. Age and age*BMI interaction were not predictive of %BF and did not add any extra variance to the model. The following equation represents the final model without the interaction term. Percent body fat can be estimated in black women by putting white=0 and Hispanic=0 in the equation below.

$$\%BF = -22.12925 + 3.0017^{*}BMI - 0.03349^{*}BMI^{2} + 2.94405^{*}white + 2.94593^{*}Hispanic$$

This equation shows that for a given BMI, white and Hispanic women will have 2.9% higher %BF than black women, which implicates that the BMI cutoff value equivalent to 35% BF will differ in black, white and Hispanic women. Although the race*BMI interaction was significant for Hispanic women (regression coefficient=−0.181, standard error=0.059, *P*=.002), the additional contribution was minimal as explained variance improved very little. The interpretation of the significant race*BMI interaction for Hispanic women is as follows: for a given BMI, the difference in %BF between black and Hispanic women narrowed with increased BMI.

Accuracy of NIH-based cutoff value to define obesity

Of the 555 reproductive-aged women we examined, the BMI cutoff value of 30 kg/m^2 suggested by the NIH identified 205 women as obese (%BF >35%). Although the NIH-recommended BMI cutoff point for obesity had high specificity (96.8–100%) in different races/ethnicities, the sensitivity was relatively low (47.8–75.0%) (Table 2). The overall sensitivity and specificity of this cutoff value was 57.7% (95% CI, 52.5–62.8%) and 98.5% (95% CI, 95.8–99.5%), respectively. The sensitivity was significantly higher in black women (75.0%; 95% CI, 65.5–82.6%) compared with white (47.8%; 95% CI, 38.7–57.0%) and Hispanic women (53.9%; 95% CI, 45.7–61.8%; *P*<.001 both for black vs. white and black vs. Hispanic). It did not differ between white and Hispanic women (*P*=.335). Specificities (96.7–100%) were statistically similar in different races/ethnicities.

ROC curve analysis based on our study data showed that the greatest accuracy to identify obesity using 35% BF corresponded to BMI values of 25.5, 28.7 and 26.2 kg/m^2 in white, black and Hispanic women, respectively. The higher BMI cutoff value for black than white and Hispanic women support the finding based on our regression analysis that for a given BMI, black women have a lower %BF than the other two groups of women. The respective AUC was 0.967 (95% CI, 0.946–0.988), 0.946 (95% CI, 0.916–0.977), and 0.927 (95% CI, 0.894–0.960). The sensitivity and overall performance of the race/ethnic specific BMI values generated by the current study were improved over those recommended by the NIH, particularly in white and Hispanic women (Table 2). Of the 555 women, race/ethnic specific BMI cutoff values identified 292 obese women out of 350 actually obese women (90 more than that identified with the NIH-based cutoff value). The sensitivity increased to 85.6% from 47.8% (*P*<.001) in white, 81.3% from 75.0% in black (*P*=.031), and 83.2% from 57.7% (*P*<.001) in Hispanic women. The overall sensitivity was significantly improved from 57.7% to 83.4% (*P*<.001). A greater improvement in sensitivity was observed in white (37.8%) and Hispanic women (29.3%) than among black women (5.3%).

Underestimation of obesity using NIH BMI cutoff value

Table 3 shows the obesity rates and 95% CIs based on %BF, the NIH definition and our data using race/ethnic specific BMI cutoff values. Of the 555 women we examined, 205 (36.9%) were classified as obese based on NIH guidelines (BMI≥ 30 kg/m^2). The obesity rate in black (46.5%) and Hispanic women (37.7%) was significantly higher than that observed in white women (28.0%). However, WHO criterion (%BF >35%) classified 350 women as obese (63.1% of total). When %BF was used: the obesity rate was highest in Hispanic women (69.1%) while the rates were similar in white (58.7%) and black women (60.4%). When race/ethnic specific BMI cutoff values were used, 311 women were labeled as obese (56.0%) with 52.9% of whites, 52.8% of blacks and 61.4% of Hispanics classified as obese.

Discussion

Our study shows that the currently used BMI cutoff value for obesity recommended by the NIH (BMI≥30 kg/m^2) may be too high and does not reflect actual body fatness by race/ethnicity among reproductive-aged women. Use of this definition resulted in the misclassification of many obese women when compared to use of WHO reference despite having very good specificity. Similar to our findings, Romero-Corral et al (9) also observed that the NIH-based BMI cutoff value to define obesity had low sensitivity (49%) in U.S. women aged 20–80 years. Evans et al (10) found similar results in white (47.1%) and black (52.6%) postmenopausal women. Several smaller studies have shown similar results (29,30). Blew et al (11) observed even lower sensitivity (25.6%) when this definition was used in mostly white postmenopausal women. Together, these studies provide evidence that the NIH-based BMI cutoff value is not accurate enough to identify obesity among a large number of adult women residing in the U.S.

Our data driven race/ethnic specific BMI cutoff values to define obesity agree with those of several other U.S. studies which included diverse populations (9–11). Evans et al (10) identified obesity as those with BMI values ≥ 26.9 kg/m^2 among white women and ≥28.4 kg/m^2 among black women while our study showed BMI values ≥ 25.5, 28.7, and 26.2 kg/m^2 for white, black and Hispanic women, respectively. However, Blew et al (11) observed even lower BMI cutoff values (24.9 kg/m^2) in mostly white postmenopausal women. Romero-Corral et al (9) found that the cut off value should be 25.5 kg/m^2 among multiethnic women. Moreover, sensitivities of the revised BMI cutoff values generated in our study are also similar to previously published studies (9–11). This suggests that the BMI cutoff value should not only be lower than the value currently used, but also should differ by race/ethnicity.

The difference between actual and observed obesity rates in whites (59% vs. 28%) and Hispanic (69% vs. 38%) women could be a threat to the success of obesity awareness and programs in the U.S. NIH –based obesity rate calculations which show that black women have the highest obesity rate was not supported by %BF data in this study. In contrast, Hispanic women had the highest obesity rates based on %BF classified obesity. Thus, there is a need to organize the obesity prevention programs targeting all three race/ethnic groups equally with a special emphasis on Hispanic women. More than two-thirds of Hispanic reproductive-aged women are obese is a serious public health concern.

Moreover, obesity rates based on NIH guidelines in white and Hispanic women are severely underestimated which needs to be corrected. The current BMI cutoff value results in about half of women with actual obesity (>35% body fat) being labeled as normal or overweight. Thus, the opportunity to reduce body weight by appropriate intervention in this group of people is missed. It is possible that the improvement in sensitivity in white and Hispanic women using race/ethnic specific BMI cutoff values will result in labeling a few women as obese who are not, causing them additional stress. However, considering that fewer women will be misclassified by the revised cutoff values and the myriad public health implications of obesity, any potential harm would be outweighed by the benefit of identifying an increased number of actually obese women.

Our finding that the NIH classified obesity rate was 36.9% among reproductive-aged women is consistent with population based reports of its prevalence in 20–39 years old women (29.1%). According to the National Health and Nutrition Examination Survey (NHANES) 1999–2002 data (23), 24.9% of non-Hispanic whites, 46.6% of non-Hispanic blacks, and 31.2% of Hispanic women between the age of 20 and 39 years were obese (BMI≥ 30 kg/m^2) compared

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to 28.0%, 46.5% and 37.7%, respectively in the current study. The similarity of obesity rates between the current study and the NHANES-based study increases the external validity of our study results.

Published studies show that the influence of race/ethnicity on the relationship between BMI and %BF may not be consistent (10,22,31,32). For example, Fernandez et al (30) did not observe any difference in %BF between white and black postmenopausal women for a given BMI while Evans et al (10) observed that white women had 1% higher %BF than black postmenopausal women. In contrast, our study showed that a difference of almost 3%. Aloia et al (32) also found that at the same %BF black women had significantly higher BMI than white perimenopausal women. Differences in age distribution could be the reason for these discrepancies. However, further studies on age-related changes in %BF based on 10-year increments by race/ethnicity are needed to shed more light on this issue.

This study has several limitations. First, we examined diagnostic performance of BMI in only 20–33 years old women, so we don't know whether similar findings would be observed in other age groups. However, similar findings in studies of postmenopausal white and black women (10) suggest that similar race/ethnic specific cutoff values might work for other age groups of women residing in the U.S. Second, our study is not based on a random sample and, thus, our sample may not be representative of all white, black and Hispanic women. However, similar obesity rates in the current study and NHANES-based study (23) increase the external validity of the study. Third, the Hispanic women in our study were predominantly of Mexican descent, so extension of these data to Hispanic women of other origins should be done with caution. Finally, use of a single site could limit the generalizability of our findings.

In conclusion, our findings suggest that the currently accepted BMI cutoff value to identify obesity is too high for many reproductive-aged women residing in the US. This suggests that women whose BMI is between 25 and 29.9 kg/m^2 (in addition to ≥30 kg/m^2), may require additional counseling on how to reduce their body weight in order to avoid obesity related morbidity. Furthermore our data suggest that race-specific BMI classifications need to be established to more accurately identify reproductive-aged women who are obese so they can be counseled appropriately. Substantial increases in sensitivity in white (38% increase) and Hispanic women (30% increase) make the BMI cutoff values generated in this study reasonable to consider for reproductive-aged women. As a validation measure, however, these proposed criteria and their relationship to cardiovascular risk factors need to be further examined using an independent nationally representative sample.

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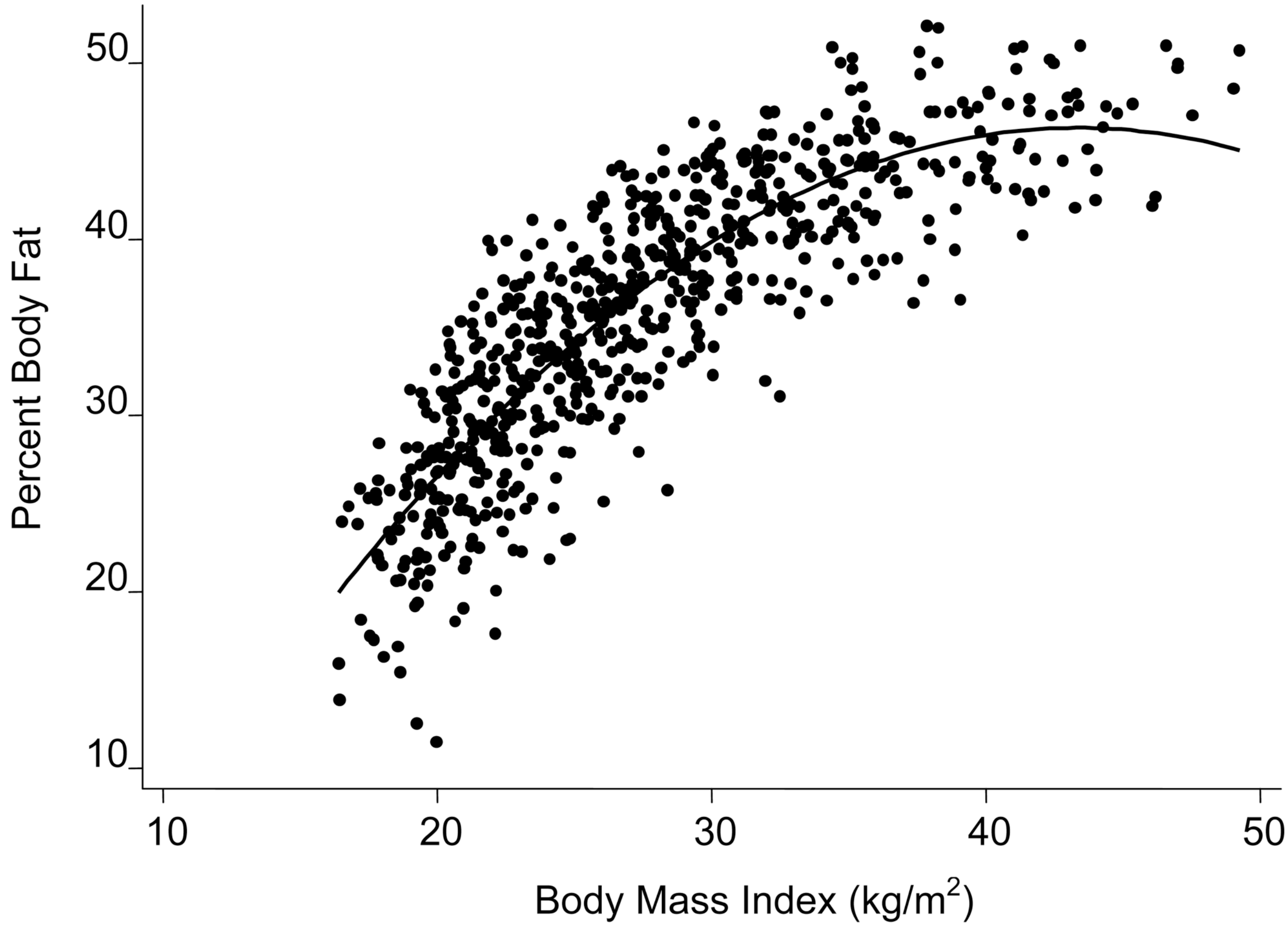

Figure 1.
Relationship between body mass index and percent body fat measured by DXA in reproductive-age women (20–33 years old) (n=555)

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Table 1

Descriptive characteristics (mean ± SD) of the women in the study population by race/ethnicity

Characteristics	Total sample (n=555)	White (n=189)	Black (n=159)	Hispanic (n=207)	Group Difference
Age, mean, yrs	26.0 (4.0)	26.5 (4.1)	25.3 (3.8)	26.1 (4.0)	W>B
Weight, kg	74.7 (18.7)	72.2 (17.2)	81.7 (21.3)	71.7 (16.3)	B>W, H
Height, cm	161.6 (6.6)	163.7 (5.8)	163.1 (6.8)	158.5 (5.8)	B, W>H
BMI, kg/m^2	28.6 (6.8)	27.0 (6.5)	30.6 (7.6)	28.5 (6.0)	B>W, H
%BF	36.9 (7.6)	36.0 (8.0)	36.5 (8.1)	37.9 (6.5)	H>W

B = black; W = white; H = Hispanic; SD = standard deviation; BMI= Body mass index; %BF=Percent body fat One-way analysis of variance with Bonferroni (P<.017) correction was used to examine between-group differences

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Table 2

Accuracy of BMI cut-off value to define obesity in white, black and Hispanic reproductive-aged women based on NIH guideline and the current study

Race/ethnicity	No of subjects					Sensitivity (95% CI)	Specificity (95% CI)	Overall performance*
	TP	FP	FN	TN	Total			
NIH†								
White	53	0	58	78	189	47.8 (38.7–57.0)	100.0 (95.3 – 100.0)	147.8
Black	72	2	24	61	159	75.0 (65.5 – 82.6)	96.8 (89.1 – 99.1)	171.8
Hispanic	77	1	66	63	207	53.9 (45.7 – 61.8)	98.4 (91.7 – 99.7)	152.3
Overall	202	3	148	202	555	57.7 (52.5 – 62.8)	98.5 (95.8 – 99.5)	156.2
Rahman et al.‡								
Whte	95	5	16	73	189	85.6 (77.9 – 90.1)	93.6 (85.9 – 97.2)	179.2
Black	78	6	18	57	159	81.3 (72.3 – 87.8)	90.5 (80.7 – 95.6)	171.8
Hispanic	119	8	24	56	207	83.2 (76.2 – 88.5)	87.5 (77.2 – 93.5)	170.7
Overall	292	19	58	186	555	83.4 (79.1 – 87.0)	90.7 (86.0 – 94.0)	174.1

*Overall performance equals summation of sensitivity and specificity

BMI = body mass index; TP = true positive; FP = false positive; FN = false negative; TN = true negative;

†BMI cutoff value to define obesity ≥ 30 kg/m^2

Actual obesity is defined as %BF > 35%

‡According to obesity definition derived from the current study: white ≥ 25.5 kg/m^2, black ≥ 28.7 kg/m^2, Hispanic ≥ 26.2 kg/m^2

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Table 3

Obesity rate in our study population – based on WHO, NIH, and race/ethnicity specific BMI cutoff values

Race/ethnicity	Actual obesity rate based on WHO criterion standard (95% CI)[a]	Obesity rate based on NIH's BMI cut off value (95% CI)[b]	Obesity rate based on race/ethnicity specific BMI cut off value (95% CI)[c]
White	58.7 (51.4 – 65.8)	28.0 (21.8 – 35.0)	52.9 (45.5 – 60.2)
Black	60.4 (52.3 – 68.0)	46.5 (38.6 – 54.6)	52.8 (44.8 – 60.8)
Hispanic	69.1 (62.3 – 75.3)	37.7 (31.1 – 44.7)	61.4 (54.4 – 68.0)
Overall	63.1 (58.9 – 67.1)	36.9 (32.9 – 41.1)	56.0 (51.8 – 60.2)

WHO=World Health Organization; NIH=National Institute of Health; BMI = Body mass index

[a]Based on percent body fat>35%

[b]BMI ≥30 kg/m^2

[c]Cutoff value to define obesity according to the current study:

White: BMI≥25.5 kg/m^2

Black: BMI≥28.7 kg/m^2

Hispanic: BMI≥26.2 kg/m^2