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ORIGINAL ARTICLE

Accuracy of body mass index in diagnosing obesity in the adult general population

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Background: Body mass index (BMI) is the most widely used measure to diagnose obesity. However, the accuracy of BMI in detecting excess body adiposity in the adult general population is largely unknown.
Methods: A cross-sectional design of 13 601 subjects (age 20–79.9 years; 49% men) from the Third National Health and Nutrition Examination Survey. Bioelectrical impedance analysis was used to estimate body fat percent (BF%). We assessed the diagnostic performance of BMI using the World Health Organization reference standard for obesity of BF% > 25% in men and > 35% in women. We tested the correlation between BMI and both BF% and lean mass by sex and age groups adjusted for race.
Results: BMI-defined obesity ($\geqslant$30 kg m^{-2}) was present in 19.1% of men and 24.7% of women, while BF%-defined obesity was present in 43.9% of men and 52.3% of women. A BMI$\geqslant$30 had a high specificity (men = 95%, 95% confidence interval (CI), 94–96 and women = 99%, 95% CI, 98–100), but a poor sensitivity (men = 36%, 95% CI, 35–37 and women = 49%, 95% CI, 48–50) to detect BF%-defined obesity. The diagnostic performance of BMI diminished as age increased. In men, BMI had a better correlation with lean mass than with BF%, while in women BMI correlated better with BF% than with lean mass. However, in the intermediate range of BMI (25–29.9 kg m^{-2}), BMI failed to discriminate between BF% and lean mass in both sexes.
Conclusions: The accuracy of BMI in diagnosing obesity is limited, particularly for individuals in the intermediate BMI ranges, in men and in the elderly. A BMI cutoff of$\geqslant$30 kg m^{-2} has good specificity but misses more than half of people with excess fat. These results may help to explain the unexpected better survival in overweight/mild obese patients.
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Keywords: diagnosis; body mass index; body fat percent; lean mass

Introduction

Excess adipose tissue (obesity) has been shown to be deleterious for multiple body organ systems through thrombogenic, atherogenic, oncogenic, hemodynamic and neurohumoral mechanisms.[1–5] In fact, obesity recently replaced smoking as the number one killer worldwide.[6]

For the past 30 years obesity has been primarily diagnosed using the body mass index (BMI). This measurement was first described by Adolphus Quetelet in the mid nineteenth century based on the observation that body weight was proportional to the squared height in adults with normal body frames.[7] This simple index of body weight has been consistently used in a myriad of epidemiologic studies, and has been recommended for individual use in clinical practice to guide recommendations for weight loss and weight control.[8–10]

Despite the unquestionable association between BMI-defined obesity and mortality, multiple studies worldwide have shown that overweight subjects have similar or even better outcomes for survival and cardiovascular events when compared to people classified as having normal body weight.[11–16] Results of these studies have challenged the association between adiposity with mortality and cardiovascular disease. However, it is also possible that the surprisingly favorable prognostic implications of higher BMI may in fact reflect intrinsic limitations of BMI in differentiating adipose tissue from lean mass in intermediate BMI ranges.[17–19]

Even though BMI has been used extensively in research and clinical practice, there are very few studies testing its

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diagnostic accuracy and no study has done this in a large, multiethnic adult population representing men and women of many age strata. The aim of this study was to assess the diagnostic performance of BMI and its correlation with body composition measurements in a large representative sample of the US population, with particular emphasis on intermediate BMI ranges. We hypothesized that in persons with normal and mild BMI elevations, BMI will have limited diagnostic performance due to its inability to discriminate between fat and lean mass.

Methods

Study design and subjects included

The National Health and Nutrition Examination Survey (NHANES) was conducted in a representative sample of the US noninstitutionalized civilian population from 1988 to 1994. It consists of a periodic survey using a stratified multistage probability sampling design to produce a generalizable health estimate of the US population. Details on design and conduction of the survey are available at http://www.cdc.gov/nchs/nhanes.htm. Briefly, of a sample of 39 695 people selected for the NHANES III, 33 994 were interviewed and 30 818 submitted to an examination by a physician at a mobile examination center that included extensive anthropometric, physiological and laboratory testing. For this study, we included only subjects with bioelectrical impedance analysis (15 864) to allow the estimation of body composition. Detailed information on the bioelectrical impedance analysis procedure is presented elsewhere.[20,21] For this study we limited the analyses to adult subjects ($\geqslant$20–79.9 years), yielding an initial sample size of 14 025. We excluded subjects without documented height, weight, waist and hip circumference measurements, and subjects with an estimated total body water > 80% or with total body fat estimates that were negative numbers ($n = 399$). We further excluded subjects with measurements above the 99.9 percentile ($n = 25$), resulting in a final sample of 13 601 participants, including 6580 men and 7021 women.

Anthropometric measurements

All personnel performing NHANES III anthropometric measurements were previously trained and followed a strict protocol. Documentation for the NHANES III measurements is available in written and video presentations.[22,23] Body weight was measured with an electronic load cell scale to the nearest 0.01 kg. Participants wore only undershorts and disposable paper shirts, pants and foam slippers. Stature was measured to the nearest 0.1 cm using a fixed stadiometer. Participants were positioned with heels, buttocks, back and head against the upright surface of the stadiometer with the head positioned in the Frankfort horizontal plane. BMI was calculated as weight in kg divided by squared height in meters (kg m^{-2}).

Body composition calculations

Children younger than 12 years of age, pregnant women and subjects with pacemakers were ineligible for bioelectrical impedance analysis. All subjects were requested to avoid eating or drinking anything except water during the fasting period. There were no restrictions on physical activity or alcohol consumption before the fasting period. The prediction equations for total body water and fat-free mass use resistance measured with data from RJL bioelectrical impedance analyzers (Clinton Twp, MI, USA).[24] The NHANES III resistance data were obtained using a Valhalla impedance analyzer. Therefore, bioimpedance resistance was converted to RJL Res values (Ω) and was used to calculate body fat as previously described by Chumlea *et al*.[25] The prediction equations used to estimate lean mass are the following:

$$\text{Men: Lean mass} = -10.678 + 0.262\text{kg} + 0.652\text{S}^2/\text{Res} + 0.015\text{Res}$$

$$\text{Women: Lean mass} = -9.529 + 0.168\text{kg} + 0.696\text{S}^2/\text{Res} + 0.16\text{Res}$$

Where S^2/Res represent the stature squared divided by resistance (cm^2/Ω). We then calculated body fat percent (BF%) as follows:

$$\text{BF\%} = ((\text{weight} - \text{lean mass})/\text{weight}) \times 100$$

Statistical analyses

Analyses of the NHANES III data were conducted following Analytic and Reporting Guidelines. Continuous variables are presented as mean ± standard errors and number and percentages for categorical variables. The gold standard definition of obesity BF > 25% in men and > 35% in women proposed by the World Health Organization was used to determine the diagnostic performance of BMI to detect obesity using the standardized cutoff points to define overweight as BMI 25–29.9 kg m^{-2} and obesity as a BMI $\geqslant$30 kg m^{-2}.[9] Diagnostic performance was assessed by calculating sensitivity, specificity, predictive values with their respective 95% confidence intervals (CIs) adjusted for continuity and likelihood ratios, and by constructing receiver operating characteristic curves for BMI to detect BF%-defined obesity for all subjects and by sex. Due to the nonlinear relationship of the variables studied, we obtained the Spearman's correlation coefficient (ρ) between BMI and BF% and BMI and lean mass. Finally, we compared correlation coefficients between BMI and BF% vs BMI and lean mass, with the hypothesis that BMI would correlate similarly with BF% as well as with lean mass. All correlations were adjusted for race and are presented by sex and by age groups in decades. All analyses were weighted and were performed using the SAS Windows[26] version and SUDAAN.[27]

Results

The weighted mean age ± standard error of study participants was 42.5 ± 0.19 years for men and 44.4 ± 0.19 years for women. Of subjects, 49% (6580) were men. From the total sample (weighted prevalence) 5411 (76.4%) were non-Hispanic whites, 3840 (10.5%) were non-Hispanic blacks, 3770 (4.9%) were Mexican Americans and 580 (7.9%) were from a different racial/ethnic group.

The weighted mean ± standard error BMI was 26.5 ± 0.05 kg m^{-2} in men and 26.4 ± 0.07 in women. BF% was 23.9 ± 0.07 in men and 35.0 ± 0.09 in women. Using BMI ($\geqslant$30 kg m^{-2}) as a surrogate for obesity, we found that 19.1% of men and 24.7% of women were classified as obese. When using the World Health Organization gold standard definition of obesity, 43.9% of men and 52.3% of women were classified as obese. Table 1 presents the baseline characteristics of the anthropometric measures by sex and by age groups.

Diagnostic performance of BMI

Table 2 displays details of the diagnostic performance of BMI in detecting obesity using BMI cutoff points of $\geqslant$25 and $\geqslant$30 kg m^{-2} by sex and by age groups. A BMI $\geqslant$30 kg m^{-2} had a poor sensitivity in both men (36, 95% CI, 35–37) and women (49, 95% CI, 48–50) and a good specificity in both men (95, 95% CI, 94–96) and women (99, 95% CI, 98–100) to detect BF%-defined obesity. A BMI cutoff of $\geqslant$25 kg m^{-2} had a moderate-to-good sensitivity in both men (84, 95% CI, 83–85) and women (88%, 95% CI, 87–89) and a poor specificity in men (62, 95% CI, 61–63) but moderate-to-good in women (84, 95% CI, 83–85) to detect BF%-defined obesity. The sensitivity and specificity of BMI in detecting obesity using BMI cutoff points of $\geqslant$25 and $\geqslant$30 kg m^{-2} by sex and race are enclosed in this article as an appendix (Supplementary Information).

Figure 1 displays the receiver operating characteristic curves for BMI to detect an excess in BF% (>25% in men and >35% in women) and the diagnostic performance for the best identified BMI cutoff in all the subjects and by sex. Overall, the area under the curve was 0.88 for BMI to detect an excess in BF%, and the best BMI cutoff identified was 25.5 kg m^{-2}, which resulted in good sensitivity but a moderate-to-good specificity. After stratifying by sex, the area under the curve was lower for men (0.82) than in women (0.94), $P<0.0001$. Furthermore, in men the best BMI cutoff identified was 25.8 kg m^{-2}, which resulted in a moderate sensitivity and specificity, while in women the best BMI cutoff identified was 25.8 kg m^{-2}, and resulted in a good sensitivity and specificity.

Correlations between BMI and both body fat percent and lean mass

The comparisons of correlations between BMI and BF% vs BMI and lean mass by sex and age groups adjusted for race are displayed in Table 3. Overall, in men BMI had a good correlation with BF% ($\rho=0.65$, $P<0.0001$), but also with lean mass ($\rho=0.73$, $P<0.0001$), and for men aged between 20 and 49.9 years, BMI correlated better with lean mass than with BF%, while in men > 50 years, BMI did not differentiate between BF% and lean mass. Overall, in women BMI had an excellent correlation with BF% ($\rho=0.87$, $P<0.0001$) and a good correlation with lean mass ($\rho=0.74$, $P<0.0001$). In women BMI correlated better with BF% than with lean mass across all age groups. Figure 2 presents the age- and

Table 1 Baseline anthropometric measures by sex and age groups

Age group (n)	*Height (cm) Mean ± s.e.*	*Weight (kg) Mean ± s.e.*	*BMI (kg m^{-2}) Mean ± s.e.*	*BF (%) Mean ± s.e.*	*Lean mass (kg) Mean ± s.e.*	*BMI obese[a] Number (%)*	*BF % obese[b] Number (%)*
Men (6580)	175.7 ± 0.08	82.0 ± 0.19	26.5 ± 0.05	23.9 ± 0.07	61.8 ± 0.12	1373 (19.1)	6580 (43.9)
20–29.9 (1514)	176.0 ± 0.18	78.0 ± 0.40	25.1 ± 0.11	22.1 ± 0.15	60.1 ± 0.24	213 (12.0)	580 (30.1)
30–39.9 (1353)	176.6 ± 0.19	82.5 ± 0.45	26.3 ± 0.12	23.7 ± 0.16	62.4 ± 0.28	253 (15.8)	626 (42.1)
40–49.9 (1120)	176.3 ± 0.21	84.4 ± 0.48	27.0 ± 0.13	24.3 ± 0.16	63.3 ± 0.31	288 (22.2)	603 (46.6)
50–59.9 (773)	175.7 ± 0.24	85.5 ± 0.53	27.6 ± 0.15	25.1 ± 0.21	63.5 ± 0.32	213 (28.9)	434 (53.0)
60–69.9 (1026)	174.3 ± 0.21	83.6 ± 0.46	27.4 ± 0.13	25.9 ± 0.17	61.5 ± 0.28	261 (24.8)	614 (58.7)
70–79.9 (700)	172.0 ± 0.25	78.8 ± 0.51	26.5 ± 0.15	25.0 ± 0.21	58.6 ± 0.35	130 (19.5)	386 (51.4)
Women (7021)	162.0 ± 0.08	69.3 ± 0.20	26.4 ± 0.07	35.0 ± 0.09	44.0 ± 0.08	2159 (24.7)	4361 (52.3)
20–29.9 (1487)	162.8 ± 0.17	64.1 ± 0.38	24.1 ± 0.13	32.0 ± 0.19	4276 ± 0.15	280 (14.0)	657 (32.3)
30–39.9 (1589)	163.5 ± 0.17	70.1 ± 0.45	26.2 ± 0.16	34.2 ± 0.20	44.9 ± 0.17	512 (25.3)	956 (49.0)
40–49.9 (1204)	162.7 ± 0.18	71.1 ± 0.47	26.8 ± 0.17	35.9 ± 0.20	44.6 ± 0.19	432 (26.5)	837 (55.9)
50–59.9 (884)	161.7 ± 0.21	74.0 ± 0.59	28.3 ± 0.22	37.5 ± 0.23	45.2 ± 0.23	352 (34.5)	638 (67.0)
60–69.9 (995)	160.2 ± 0.19	70.3 ± 0.49	27.3 ± 0.18	37.0 ± 0.21	43.4 ± 0.20	349 (28.8)	730 (65.9)
70–79.9 (779)	158.1 ± 0.23	67.3 ± 0.52	26.8 ± 0.19	36.0 ± 0.24	42.3 ± 0.23	215 (24.4)	487 (58.1)

Abbreviations: BF, body fat; BMI, body mass index. [a]BMI $\geqslant$30. [b]BF % >25 in men and >35% in women.

Table 2 Diagnostic performance of BMI in detecting obesity using BMI cutoff points of ⩾25 and ⩾30 kg m^{-2} by sex and age groups

*Age group (*n*)*	*Sensitivity (%)*		*Specificity (%)*		*PPV (%)*		*NPV (%)*		*+LR*		*−LR*	
	BMI ⩾25	*BMI ⩾30*	*BMI ⩾25*	*BMI ⩾30*	*BMI ⩾25*	*BMI ⩾30*	*BMI ⩾25*	*BMI ⩾30*	*BMI ⩾25*	*BMI ⩾30*	*BMI ⩾25*	*BMI ⩾30*
Men (6580)	84 (83–85)	36 (35–37)	62 (61–63)	95 (94–96)	69 (68–70)	87 (86–88)	80 (79–81)	60 (59–61)	2.2	6.7	0.25	0.67
20–29.9 (1514)	79	32	75	97	66	86	85	70	3.1	10.2	0.28	0.70
30–39.9 (1353)	85	33	62	94	66	82	82	62	2.2	5.4	0.25	0.71
40–49.9 (1120)	89	44	57	96	71	92	81	59	2.1	10.4	0.2	0.58
50–59.9 (773)	85	43	50	92	69	87	72	56	1.7	5.4	0.30	0.62
60–60.9 (1026)	86	38	50	93	72	90	70	50	1.7	5.8	0.29	0.66
70–79.9 (700)	81	27	60	92	71	80	72	51	2.0	3.2	0.32	0.80
Women (7021)	88 (87–89)	49 (48–50)	84 (83–85)	99 (98–100)	90 (89–91)	99 (98–100)	81 (80–82)	54 (53–55)	5.4	43.1	0.14	0.52
20–29.9 (1487)	86	42	90	99	88	100	89	69	8.9	42.0	0.16	0.58
30–39.9 (1589)	87	53	84	99	89	99	81	58	5.4	53.0	0.20	0.47
40–49.9 (1204)	88	51	79	98	90	98	74	46	4.2	23.2	0.16	0.50
50–59.9 (884)	90	54	83	98	93	98	77	45	5.4	22.2	0.12	0.47
60–69.9 (995)	88	47	77	98	91	99	70	40	3.9	24.9	0.15	0.54
70–79.9 (779)	89	43	78	98	87	97	81	51	4.0	15.3	0.14	0.58

Abbreviations: BMI, body mass index; −LR, negative likelihood ratio; +LR, positive likelihood ratio; NPV, negative predictive value; PPV, positive predictive value. Rounded 95% confidence intervals are shown inside the parenthesis.

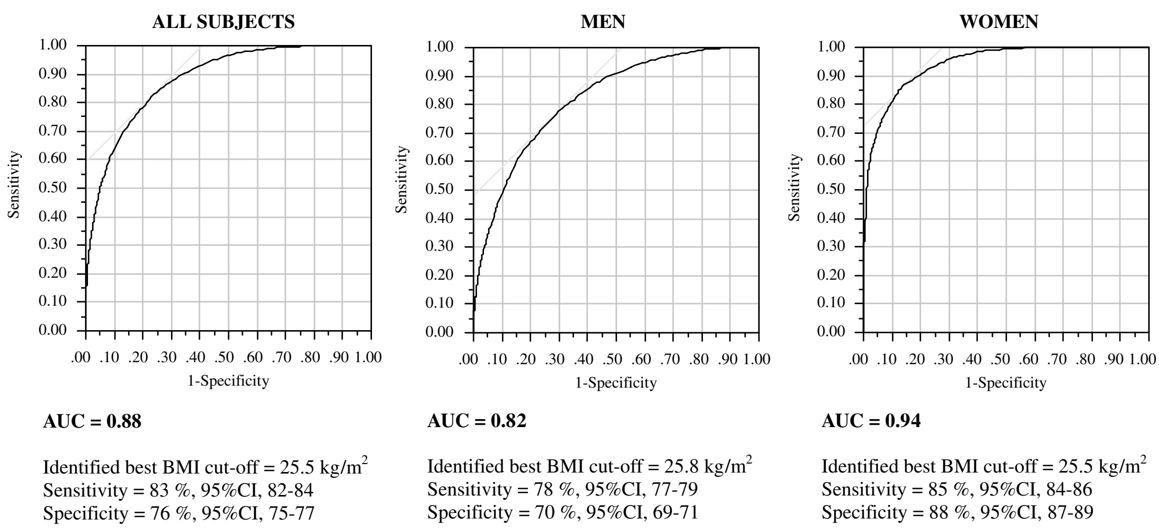

Figure 1 Receiver operating characteristic curves for body mass index (BMI) to detect body fat percent (BF%)-defined obesity for all subjects and by sex.

race-adjusted correlation between BMI and both BF% and lean mass by sex.

We performed subanalyses to assess the correlation between BMI and BF% and BMI and lean mass in the intermediate BMI range of 25–29.9 kg m^{-2} (overweight range). In men ($n=2650$), although not significant, BMI still had a better correlation with lean mass ($\rho=0.32$, $P<0.0001$) than with BF% ($\rho=0.26$, $P<0.0001$), $P=0.33$ for correlation comparison. In women ($n=2101$), BMI was no longer better correlated to BF% ($\rho=0.43$, $P<0.0001$) than with lean mass ($\rho=0.29$, $P<0.0001$), $P=0.28$ for correlation comparison. To further assess the variability of BF% for a given BMI value, we selected all subjects with a BMI of 25 kg m^{-2}, and found that in men ($n=54$), the distribution of BF% ranged widely from 13.8 to 35.3%, while in women ($n=54$), the distribution of BF% ranged from 26.4 to 42.8% (Figure 3).

Discussion

Our study, involving a large multiethnic sample from the US general population demonstrates that BMI has limited diagnostic performance in correctly identifying individuals with excess in body fatness, particularly in those with BMI

$<30\,kg\,m^{-2}$. Although BMI has a good general correlation with BF%, it failed to discriminate between BF% and lean mass, especially in men and in the elderly. Despite the good specificity and positive predictive value of $BMI \geqslant 30\,kg\,m^{-2}$ in identifying obese subjects, BMI has a low sensitivity, missing more than half of people with BF%-defined obesity. Furthermore, for any given BMI value there is significant intersubject variability in BF%.

Table 3 Comparisons of race-adjusted correlation coefficients between BMI and BF % with BMI and lean mass by sex and age groups

*Age group (*n*)*	*BMI—BF% Adjusted* ρ	*BMI—lean mass (kg) Adjusted* ρ	*Correlation comparisons* P*-value*
Men (6580)	0.65*[a]	0.73*[a]	<0.0001
20–29.9 (1514)	0.69*	0.71*	0.038
30–39.9 (1353)	0.66*	0.70*	0.061
40–49.9 (1120)	0.67*	0.72*	0.077
50–59.9 (773)	0.62*	0.76*	0.142
60–69.9 (1026)	0.60*	0.73*	0.111
70–79.9 (700)	0.60*	0.73*	0.188
Women (7021)	0.87*[a]	0.74*[a]	<0.0001
20–29.9 (1487)	0.89*	0.70*	0.006
30–39.9 (1589)	0.90*	0.74*	0.003
40–49.9 (1204)	0.85*	0.77*	0.015
50–59.9 (884)	0.86*	0.77*	0.035
60–69.9 (995)	0.84*	0.72*	0.039
70–79.9 (779)	0.82*	0.69*	0.086

Abbreviations: BF, body fat; BMI, body mass index. **P*-value <0.0001. [a]Additionally adjusted for age.

Previous studies testing the diagnostic performance of BMI[17,28,29] have been performed in small samples of subjects from selected populations and limited in ethnicity and age groups. To our knowledge, the present study is the first to describe the diagnostic performance of BMI, comparing the correlations between BF% and lean mass for men and women across different age groups tested in a large multi-ethnic sample of the US general population.

From our findings it is apparent that the diagnostic performance of BMI in intermediate ranges of body weight is limited mainly because of the inability of BMI to discriminate between BF% and lean mass. This is understandable, since the majority of human body weight (numerator of the BMI) comes from lean mass. Our study clearly shows that a good correlation or a good area under the curve does not necessarily translate into a good diagnostic performance.[30] Indeed, although BMI had a great correlation with BF%, BMI correlated similarly with lean mass (not obvious when looking only at the receiver operating characteristic curves). In fact, in men BMI correlated significantly better with lean mass than with

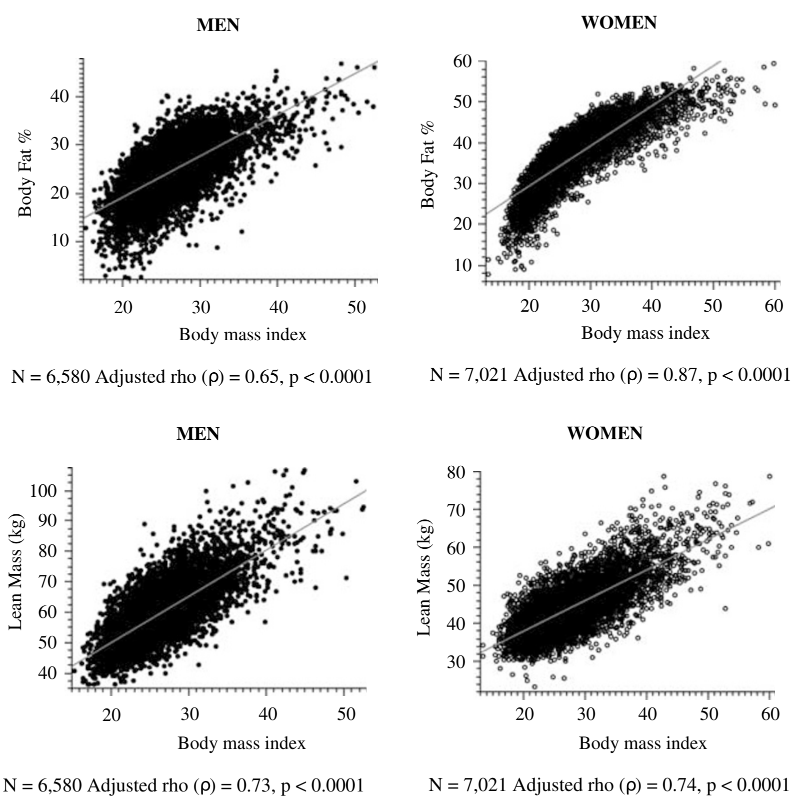

Figure 2 Age- and race-adjusted correlation between body mass index (BMI) and both body fat percent (BF%) and lean mass by sex. (Upper figures) Age- and race-adjusted correlation between BF% and BMI for men and women. (Lower figures) Age- and race-adjusted correlation between BF% and lean mass for men and women.

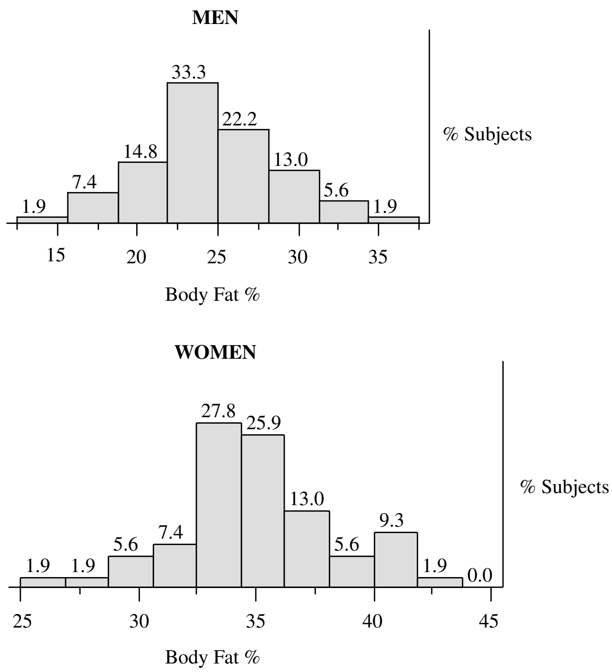

Figure 3 Body fat percent (BF%) variations among men and women with a body mass index (BMI) of $25\,kg\,m^{-2}$.

body fat. In contrast, in women, especially young women, BMI correlated better with BF% than with lean mass, which may explain why BMI-defined overweight in women has been more consistently related to increased mortality than in men in previous studies.[31,32]

Because BMI is calculated using total body mass, it contains two factors that have opposite biological effects, namely adipose tissue and lean mass. While adipose tissue has been associated with deleterious health outcomes, preserved lean mass is positively associated with physical fitness, higher caloric expenditure and exercise capacity, all of which are associated with better survival.[33–35] A scenario to exemplify this would be a person with a BMI of $25\,kg\,m^{-2}$ with normal lean mass and increased fat content, compared to another person with the same BMI of $25\,kg\,m^{-2}$ with decreased lean mass and a high body fat content, both representing completely different levels of exposure to the deleterious effects of adipose tissue, and thus limiting the ability of BMI to predict long-term health outcomes.

On the basis of evidence of deleterious effects of adipose tissue on body systems and organs, it would be expected that the association between body weight (indexed to height) and outcomes would be linear. To the contrary, most studies testing the effects of body weight on survival have generally shown a U- or J-shape survival curve, or at best, have shown a horizontal survival line for BMI values in the overweight BMI ranges followed by an upward trend in risk at higher levels of BMI.[11,13,14] In fact, the U-shape association between BMI and mortality has been previously reported in the NHANES III population. Latest analyses confirm this and show that patients labeled as overweight by BMI have either the same or better survival than patients with normal BMI regardless of cause of death.[14] Our analyses carried out in the same population confirm that overweight subjects have a mixture of different combinations of adipose tissue and lean mass and in fact, BMI was better correlated with lean mass than BF% in overweight men, which could translate in a lower risk for adverse events, and could explain the unexpected better survival in this BMI group. Furthermore, in the elderly, in whom most of the mortality occurs in survival studies, BMI had its worst diagnostic performance.

The implications of mislabeling patients are not trivial. By using BMI as a marker of obesity, we misclassify $\geqslant$50% of patients with excess body fat as being normal or just overweight and we miss the opportunity to intervene and reduce health risk in such individuals. Conversely, BMI may lead to misclassification of persons with normal levels of fat as being overweight or even obese, a fact that could cause unnecessary distress and prompt unnecessary and costly interventions. In addition, such mislabeling has a deleterious effect on public trust of health care providers, particularly from fit patients with preserved muscle mass, whom we categorize as overweight or obese, based on their BMI.

While our study of BMI illustrates the significant limitations in using BMI for the diagnosis of obesity, it is important to point out that the use of BMI is not without value. A BMI$\geqslant 30\,kg\,m^{-2}$ has an excellent specificity and positive predictive value for diagnosing obesity in both sexes, and for women a BMI$\geqslant 25.5\,kg\,m^{-2}$ appears to be a very good measure to diagnose obesity. Furthermore, BMI or plain body weight might still be the best way to evaluate changes in body fatness over time, because increments on body weight or BMI most likely represent fat gain, with the exception of bodybuilders, athletes or patients with conditions that increase the volume of third space such as heart failure, ascitis or renal failure.

Finally, our findings also suggest that the magnitude of the obesity epidemic may be strikingly greater than that estimated by BMI.[36] Using the gold standard definition of obesity as an excess in BF%, we show that the prevalence of obesity dramatically increases from 21.2% using a BMI$\geqslant 30\,kg\,m^{-2}$ to 48.2% using BF%$>$25% in men and$>$35% in women. Unfortunately, the adjustment of BMI cutoffs for obesity does not overcome the limitations of using BMI as a marker of obesity. Even using the best identified cutoffs for obesity (BMI$\geqslant 25.8\,kg\,m^{-2}$ in men and $25.8\,kg\,m^{-2}$ in women) will still result in misclassifying 30% of men and 12% of women as obese.

Potential limitations of our study include the somehow arbitrary gold standard definition of obesity proposed by the World Health Organization, as the adverse of an excess is a continuum and no proper cutoff has really been established. Second, other methods to measure adiposity, such as sum of the skinfold method, are cheaper and easier to use, despite its limitations. Moreover, the use of bioelectrical impedance tends to underestimate truncal obesity and might not be accurate for athletes and elderly patients.[37] Other more accurate methods to estimated BF%, such as hydrostatic weighting, dual-energy X-ray absorptiometry or air displacement plethysmography would have been preferred.[38] Nevertheless, the good accuracy of bioelectrical impedance, its ease of use, lack of radiation and relatively low cost suggest that it is a feasible alternative for measuring body fatness, particularly in large populations.[39,40]

Conclusions

Despite the good correlation between BMI and BF%, BMI failed to discriminate between BF% and lean mass. The diagnostic accuracy of BMI in detecting obesity is limited, particularly for individuals in the intermediate BMI ranges, in men and in the elderly. Direct but simple measures of body fatness and measures of body fat distribution may be helpful in such individuals to further stratify them according to their level of body fatness. Future studies to determine if body composition measurements predict obesity-related risk better than does BMI, waist circumference, waist-to-hip ratio or other measures of body fat distribution are necessary.

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Disclosure/Conflict of interest

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