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Accuracy of Body Mass Index to Diagnose Obesity In the US Adult Population

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Abstract

Background

Body mass index (BMI) is the most widely used measure to diagnose obesity. However, the diagnostic accuracy of BMI to detect excess in body adiposity is largely unknown.

Methods

A cross-sectional design of 13,601 subjects (age 20–79.9 years; 48% 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.

Results

BMI-defined obesity (≥ 30 kg/m^2) was present in 21% of men and 31% of women, while BF %-defined obesity was present in 50% and 62%, respectively. A BMI ≥ 30 had a high specificity (95% in men and 99% in women), but a poor sensitivity (36% and 49 %, respectively) to detect BF %-defined obesity. The diagnostic performance of BMI diminished as age increased. BMI had a good correlation with BF % in men (R^2 = 0.44) and women (R^2 = 0.71), but also with lean mass (R^2 = 0.50 and 0.55, respectively).

Conclusions

Despite the good correlation between BMI and BF %, the diagnostic accuracy of BMI to diagnose obesity is limited, particularly for individuals in the intermediate BMI ranges. A BMI cut-off of ≥ 30 kg/m^2 has a good specificity but misses more than half of people with excess fat. These results help to explain the U and J-shape association between BMI and outcomes.

Keywords: Obesity, diagnosis, body mass index, body fat % and 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 and has been linked to multiple medical conditions, such as diabetes, heart disease and several types of cancer [1–5]. In fact, obesity has been recently labeled as the number one killer worldwide replacing smoking in this matter [6].

For the last 30 years obesity has been primarily diagnosed by using the body mass index (BMI). This measurement was first described by Adolphus Quetelet in the mid 19th century based on the observation that body weight was proportional to the square of the 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, when they might just represent intrinsic limitations of BMI to differentiate 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 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 is 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 hypothesize that in persons with normal and mild BMI elevations, BMI would 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) is a representative sample of the US non-institutionalized 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 to the public at http://www.cdc.gov/nchs/nhanes.htm. Briefly, out of a sample of 39,695 people selected for the NHANESIII, 33,994 were interviewed and 30,818 submitted to an examination by a physician at a mobile examination center which 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. 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. Detailed information on the bioelectrical impedance analysis procedure is presented elsewhere [20,21]. For this study we limited the analyses to adult subjects (≥ 20 to 79.9 years), yielding aninitial 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. We further excluded subjects with measurements above the 99.9 percentile, resulting in a final sample of 13,601 participants, including 6,580 men and 7,021 women.

Anthropometric Measurements

All personnel performing NHANES III anthropometric measurements were previously trained and followed a strict protocol. Documentation for the NHANES III measurements are 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 under-shorts 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 kilograms divided by squared height in meters (kg/m^2).

Body Composition Calculations

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, BIA 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 total body water and fat free mass are the following:

Males	Total body water = 1.203 + 0.176 kg + 0.449 S^2/Res
Females	Total body water = 3.747 + 0.113 kg + 0.45 S^2/Res
Males	Fat free mass = −10.678 + 0.262 kg + 0.652 S^2/Res + 0.015 Res
Females	Fat free mass = −9.529 + 0.168 kg + 0.696 S^2/Res + 0.16 Res

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

$$\text{BF}\,\% = [(\text{weight} - \text{FFM})/\text{weight}] \times 100$$
$$\text{Lean mass} = [(100 - \text{BF}\,\%)/100] \times \text{weight}$$

Statistical Analyses

Continuous variables are presented as mean ± standard deviations and number and percentages for categorical variables. Data are presented by sex and age groups in decades. The gold standard definition of obesity of 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 cut-offs points to define overweight as BMI 25–29.9 kg/m^2 and obesity as a BMI ≥ 30 kg/m^2 [9]. Diagnostic performance was assessed by calculating sensitivity, specificity, predictive values, likelihood ratios and by constructing receiver operating characteristic curves for BMI to detect BF %-

defined obesity by sex and age groups (< 60 and ≥ 60 years). We constructed Pearson correlation coefficients between BMI and BF % and between BMI and lean mass to asses if BMI discriminates between BF % and lean mass by sex, age groups and by BMI-defined overweight and obesity. Finally, we used Fisher Z test to assess if R^2 correlations between BMI and BF % and between BMI and lean were similar by sex and age groups (< 60 and ≥ 60 years).

Results

The mean age ± standard deviation of study participants was 45.5 ± 17 years for men and 45.6 ± 17 years for women. Forty-eight percent (6,580) of the subjects were men. From the total sample 5,411 (39.7%) were Non-Hispanic Whites, 3,840 (28.2%) were Non-Hispanic Blacks, 3,770 (27.7%) were Mexican Americans and 580 (4.2%) were of a different racial/ethnic group.

The mean BMI was 26.6 ± 4.6 kg/m^2 in men and 27.6 ± 6.4 in women. Mean BF % was 24.8 ± 6.0 in men and 36.7 ± 7.4 in women. Using BMI (≥ 30 kg/m^2) as a surrogate for obesity, we found that 20.8% of men and 30.7% of women were classified as obese. When using the World Health Organization gold standard definition of obesity, 50% of men and 62.1% of women were classified as obese. Table 1 presents the baseline characteristics of the anthropometric measures by sex and age groups.

Table 1

Baseline anthropometric measures by sex and age groups

Age years + (n)	Height (cm)	Weight (kg)	BMI (kg/m^2)	BF (%)	Lean mass (kg)	BMI-Obese[*]	BF % Obese[†]
	mean ± SD	mean ± SD	mean ± SD	mean ± SD	mean ± SD	Number (%)	Number (%)
Men (6,580)	173.6 ± 7.4	80.6 ± 15.9	26.6 ± 4.6	24.8 ± 6.0	60.0 ± 9.8	1,373 (20.8)	6,580 (50.0)
20–29.9 (1,514)	173.7 ± 7.7	77.0 ± 16.0	25.4 ± 4.5	23.2 ± 6.3	58.4 ± 9.6	213 (14.0)	580 (38.3)
30–39.9 (1,353)	174.8 ± 7.5	81.4 ± 16.5	26.5 ± 4.8	24.3 ± 6.1	61.0 ± 10.1	253 (18.6)	626 (46.2)
40–49.9 (1,120)	174.3 ± 7.5	83.4 ± 16.2	27.4 ± 4.8	25.3 ± 5.7	61.8 ± 9.9	288 (25.7)	603 (53.8)
50–59.9 (773)	174.4 ± 6.9	84.0 ± 16.0	27.5 ± 4.7	25.6 ± 5.8	61.9 ± 9.7	213 (27.5)	434 (56.1)
60–69.9 (1,026)	172.5 ± 7.1	81.8 ± 14.9	27.4 ± 4.3	26.1 ± 5.7	60.0 ± 9.3	261 (25.4)	614 (59.8)
70–79.9 (700)	171.2 ± 7.0	77.5 ± 14.0	26.3 ± 4.1	25.3 ± 5.7	57.4 ± 9.0	130 (18.5)	386 (55.1)
Women (7,021)	160.6 ± 7.0	71.2 ± 17.3	27.6 ± 6.4	36.7 ± 7.4	44.0 ± 6.9	2,159 (30.7)	4,361 (62.1)
20–29.9 (1,487)	161.5 ± 7.0	66.1 ± 15.8	25.3 ± 5.7	34.0 ± 7.6	42.6 ± 6.3	280 (18.8)	657 (44.1)
30–39.9 (1,589)	161.7 ± 7.1	72.8 ± 18.9	27.8 ± 6.9	36.5 ± 7.9	45.0 ± 7.3	512 (32.2)	956 (60.1)
40–49.9 (1,204)	161.5 ± 6.5	74.5 ± 17.5	28.5 ± 6.4	37.9 ± 6.8	45.3 ± 7.0	432 (35.8)	837 (69.5)
50–59.9 (884)	160.8 ± 6.5	75.3 ± 18.0	29.1 ± 6.6	38.5 ± 7.0	45.3 ± 7.1	352 (39.8)	638 (72.1)
60–69.9	158.9 ±	71.6 ±	28.3 ± 5.9	38.3 ±	43.4 ± 6.4	349 (35.0)	730 (73.3)

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BMI = body mass index; BF = body fat;

[*] BMI ≥ 30;

[†] BF % > 25 in men and > 35% in women.

Diagnostic Performance of BMI

A BMI cut-off of ≥ 30 kg/m^2 had an overall poor sensitivity of 43% and a good specificity of 96% to detect BF %-defined obesity. After stratifying by sex, a BMI ≥ 30 kg/m^2 had a poor sensitivity in both men and women (36% and 49%, respectively) and a good specificity (95% and 99%, respectively). A BMI cut-off of ≥ 25 kg/m^2 had an overall good sensitivity of 86% and a poor specificity of 72% to detect BF %-defined obesity. After stratifying by sex, a BMI ≥ 25 kg/m^2 had a good sensitivity in both men and women (84% and 88%, respectively) and a good specificity in women (85%) but not in men (62%). Table 2 displays further details of the diagnostic performance of BMI to detect obesity using BMI cut-off points of ≥ 25 kg/m^2 and ≥ 30 kg/m^2 by sex and age groups.

Table 2

Diagnostic performance of BMI to detect obesity using BMI cut-off points of ≥ 25 and ≥ 30 kg/m^2 by sex and age groups

Age years + (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 (6,580)	84	36	62	95	69	87	80	60	2.2	6.7	0.25	0.67
20–29.9 (1,514)	79	32	75	97	66	86	85	70	3.1	10.2	0.28	0.70
30–39.9 (1,353)	85	33	62	94	66	82	82	62	2.2	5.4	0.25	0.71
40–49.9 (1,120)	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 (1,026)	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 (7,021)	88	49	84	99	90	99	81	54	5.4	43.1	0.14	0.52
20–29.9 (1,487)	86	42	90	99	88	100	89	69	8.9	326	0.16	0.58
30–39.9 (1,589)	87	53	84	99	89	99	81	58	5.4	86.1	0.20	0.47
40–49.9 (1,204)	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	88	47	77	98	91	99	70	40	3.9	24.9	0.15	0.54

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BMI = body mass index; PPV = positive predictive value; NPV = negative predictive value; + LR = positive likelihood ratio; − LR = negative likelihood ratio.

The receiver operating characteristic curves showed an overall area under the curve of 0.88 for BMI to detect an excess in body fat percentage (BF > 25 % in men and > 35% in women). After stratifying by sex, the area under the curve was lower for men (0.82) than for women (0.94). Further stratification by age groups (< 60 and ≥ 60 years) (Figure 1) showed an area under the curve of 0.83 and 0.95 for younger men and women, respectively, while the area under the curve was lower for the older group in both sexes, 0.78 for men and 0.91 for women.

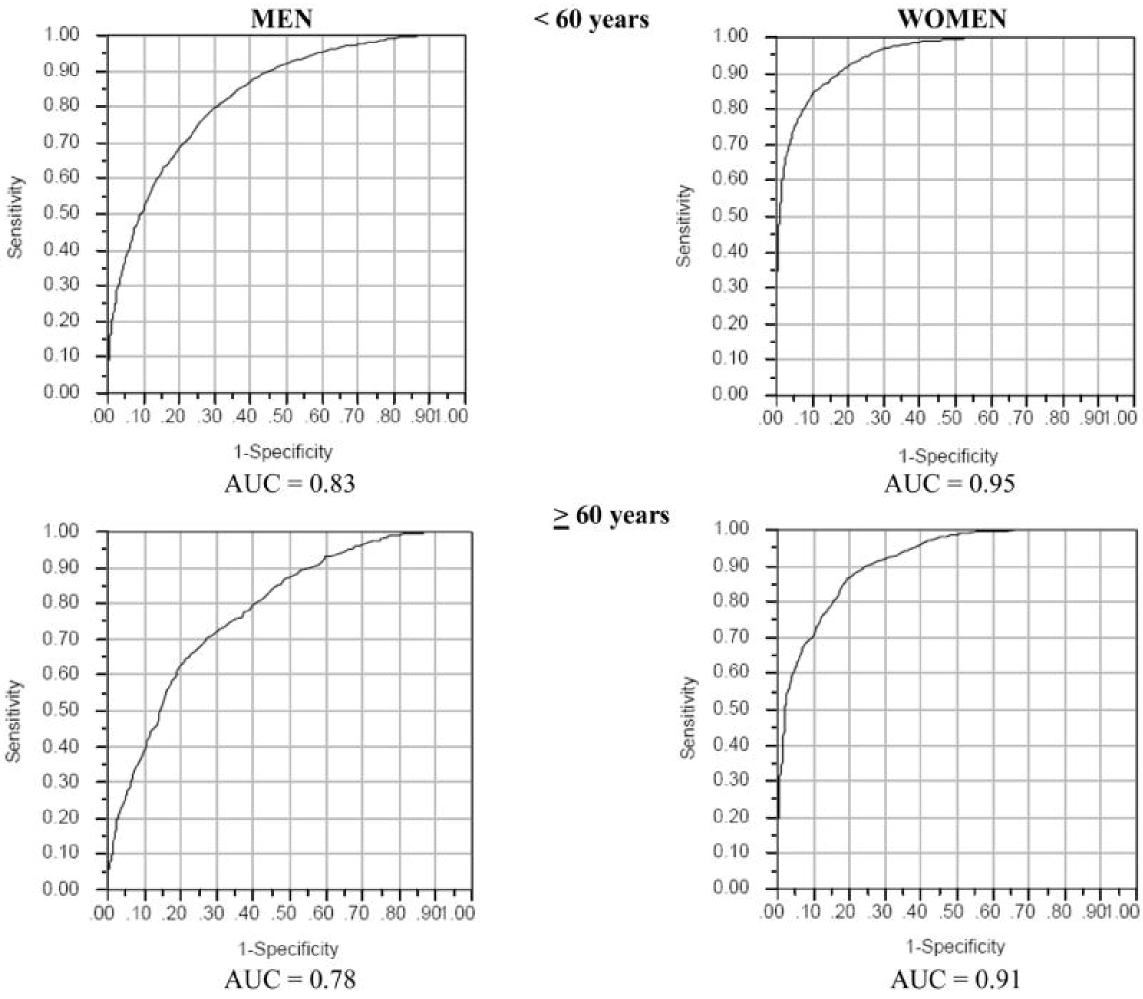


Figure 1

Receiver operating characteristic curves for BMI to detect BF %-defined obesity stratified by sex and age groups (< 60 and > 60 years)

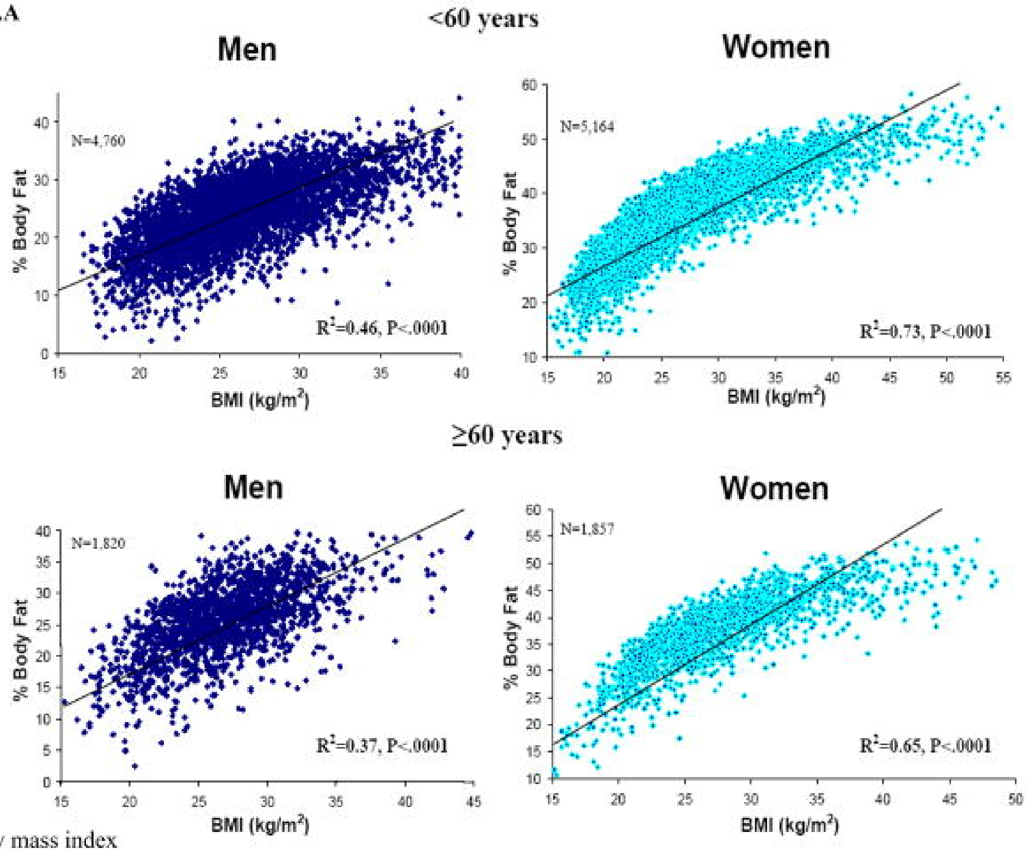
2 upper figures: Receiver operating characteristic curves for BMI to detect BF %-defined obesity in men and women < 60 years

2 bottom figures: Receiver operating characteristic curves for BMI to detect BF %-defined obesity in men and women ≥ 60 years

Correlations between BMI and both BF% and Lean Mass

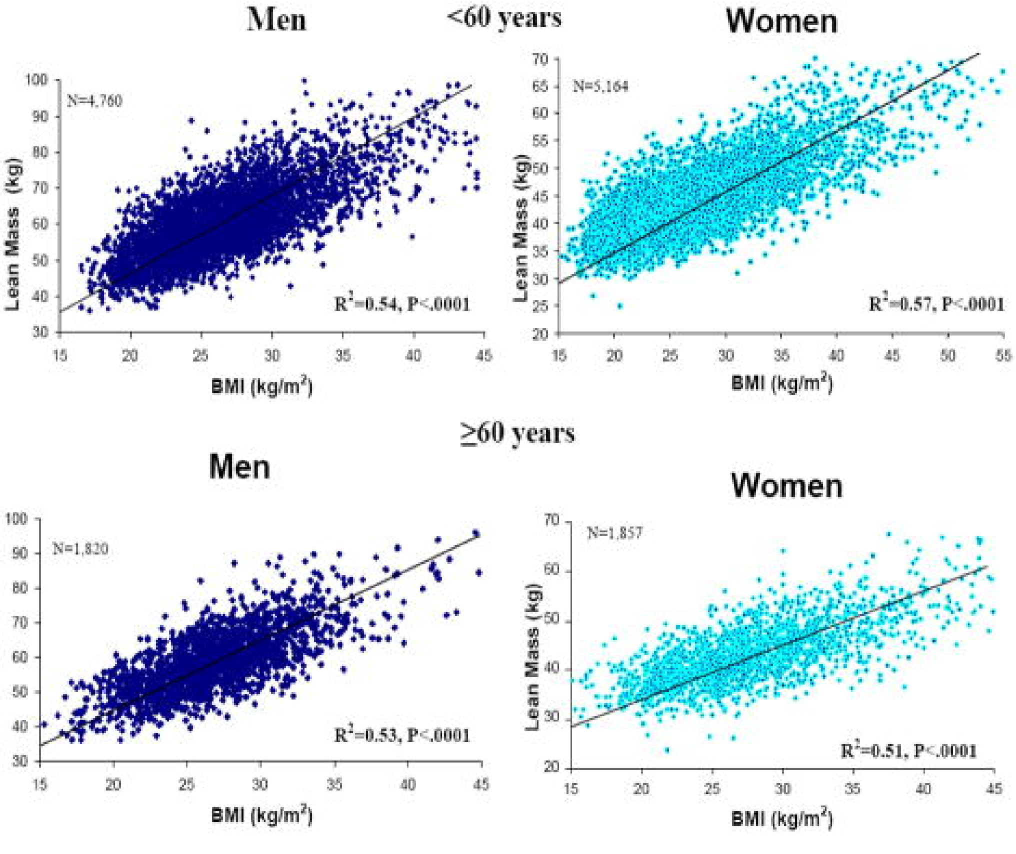
Table 3 shows the correlations between BMI and BF % and also between BMI and lean mass by sex and age groups. Overall, BF % explained 40 % of the variability in BMI ($R^2 = 0.40$, $p<0.0001$) while lean mass explained 20 % of the variation ($R^2 = 0.20$, $p <0.0001$). After stratifying by sex, in men BF % explained 44 % of the variability in BMI ($R^2 = 0.44$, $p<0.0001$) while lean mass explained 53 % of the variation ($R^2 = 0.53$, $p<0.0001$). In fact, BMI correlated better with lean mass that with BF % ($p = 0.008$ for R^2 comparison). In women, BF % explained 71% of the variability in BMI ($R^2 = 0.71$) while lean mass explained 55% of the variation ($R^2 = 0.55$), and in women BMI correlated better with BF % than with lean mass ($p < 0.0001$ for R^2 comparison). When comparing younger and older groups from the study sample (< 60 and ≥ 60 years, see Figure 2), the correlation between BMI and BF % was lower in the older subjects when compared to the older groups ($p = 0.067$). However, the correlation between BMI and lean mass was not significantly different across age groups ($p = 0.38$).

Figure 2.A



BMI = body mass index

Figure 2.B



BMI = body mass index

Figure 2

A. Correlation between BF % and BMI by sex and age groups of < 60 and ≥ 60 years

2 upper figures: Correlation between BF % and BMI in men and women < 60 years old

2 bottom figures: Correlation between BF % and BMI in men and women ≥ 60 years old

B Correlation between BF % and LM by sex and age groups of < 60 and ≥ 60 years

2 upper figures: Correlation between BF % and BMI in men and women < 60 years old

2 bottom figures: Correlation between BF % and BMI in men and women ≥ 60 years old

Table 3

Correlation coefficients between BMI and BF % and between BMI and lean mass by sex and age groups

Age years (n)	BMI - BF%	BMI – Lean mass (kg)
	R^2	R^2
Men (6,580)	0.44*	0.53*
20–29.9 (1,514)	0.49*	0.52*
30–39.9 (1,353)	0.45*	0.52*
40–49.9 (1,120)	0.44*	0.52*
50–59.9 (773)	0.42*	0.57*
60–69.9 (1,026)	0.37*	0.52*
70–79.9 (700)	0.36*	0.54*
Women (7,021)	0.71*	0.55*
20–29.9 (1,487)	0.74*	0.50*
30–39.9 (1,589)	0.74*	0.57*
40–49.9 (1,204)	0.68*	0.59*
50–59.9 (884)	0.70*	0.60*
60–69.9 (995)	0.67*	0.51*
70–79.9 (779)	0.62*	0.54*

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BMI = body mass index; BF = body fat

*P-value < 0.0001.

In sub analyses assessing the correlation between BMI and BF % in the BMI range of 25–29.9 kg/m^2 (overweight range) in men, BMI explained only 5% of the variability in BF % ($R^2 = 0.05$, $p < 0.0001$) while in women BMI explained 18 % of the variation ($R^2 = 0.18$, $p < 0.0001$). To further assess the variability of BF% for a given BMI value, we selected 108 subjects (54 men and 54 women) who had a BMI of 25 kg/m^2, and found that in men, the distribution of BF % widely ranged from 13.8% to 35.3%, while in women the distribution of BF % ranged from 26.4% to 42.8% (Figure 3).

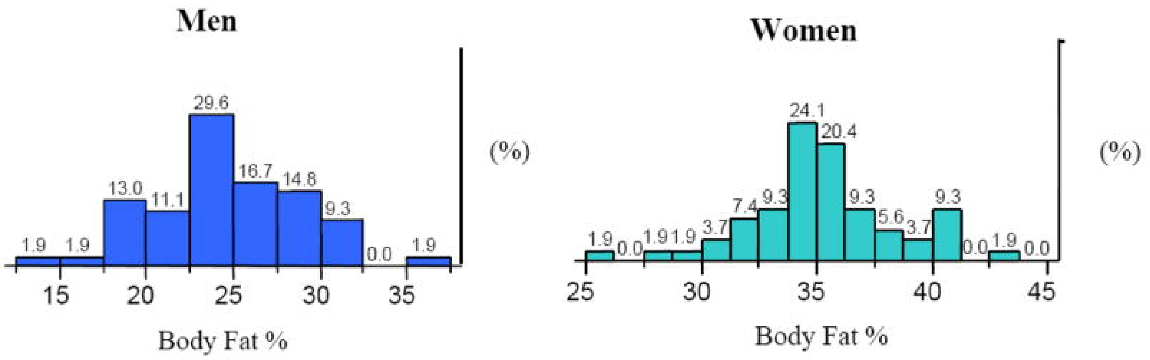

Figure 3

BF % variations among men and women with a BMI of 25 kg/m^2

Discussion

The results of our study, involving a large sample from the US population, demonstrates that BMI has a limited diagnostic performance to correctly identify individuals with excess in body fatness, particularly for those with BMI between 25 to 30 kg/m^2, for men and for the elderly. Body mass index has good general correlation with BF %, but it fails to discriminate between BF % and lean mass. In addition, the sensitivity of BMI ≥ 30 kg/m^2 to diagnose obesity is relatively low, missing more than half of people with BF %defined obesity, while the specificity and positive predictive value are good. Furthermore, for a given BMI value there is significant inter-subject variability in BF %.

Previous studies have also shown a good overall correlation between BMI and BF % and significant variability at individual level. Studies testing the diagnostic performance of BMI [26,27], including our report in a group of patients with coronary artery disease[17], have shown that BMI has a good specificity but a low sensitivity to diagnose obesity. This limitation of BMI has been also reported in pediatric populations. Studies in adolescents have shown that BMI and body fat content have a good correlation only in the highest percentiles of BMI, while in lower percentiles the correlation can be considered limited [28, 29]. Regretfully, these previous studies have been performed in a small sample of subjects from selected populations and are limited to specific age groups. Our present study is the first report to describe the diagnostic performance of BMI and its correlation with BF % and lean mass for men and women and across different age groups tested in a large multiethnic sample of the US 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, understandable since the majority of human body weight (numerator of the BMI) comes from lean mass. Indeed, our analyses found that BMI correlated in similar fashion with lean mass as it did with body fat. In fact, in men BMI correlated significantly better with lean mass than with body fat. In contrast, in women BMI appears to perform better than men, which may explain why BMI-defined overweight in women has been more consistently related to increased mortality than in men in previous studies [30–31].

Based on the overwhelming evidence of the 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, they have shown a horizontal survival line for BMI values in the overweight BMI ranges (25–27 kg/m^2) followed by an upward trend in risk[11]–[13] at higher levels of BMI. In fact, the U-shape association between BMI and mortality has been previously reported in the NHANES III population [13]. In our results, people with normal and mildly elevated BMI clearly had a mixture of different combinations of adipose tissue and lean mass which are likely to explain the inconsistent relationship between BMI and adverse events. Moreover, in the elderly, where most of the mortality occurs in survival studies, BMI had its worst diagnostic performance. This poor accuracy of BMI in the elderly can also explain the inconsistency in the association between BMI and survival.

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 a better survival[32]–[34]. A scenario to exemplify this would be a person with a BMI of 25 with preserved lean mass and mildly increased fat content, compared to another person with the same BMI of 25 with limited lean mass and a high body fat content, both representing completely different levels of exposure to the deleterious effects of adipose tissue, a fact that limits the BMI ability to predict long-term health outcomes.

Our findings also suggest that the magnitude of the obesity epidemic may be greatly underestimated by the use of BMI as the marker of obesity [35]. In our results, BMI showed an unacceptable low sensitivity for detecting body fatness, with more than half of obese subjects (by body fat measurement) being labeled as normal or overweight by BMI. The true prevalence of obesity might be strikingly higher than that estimated by BMI. Unfortunately, the adjustment of BMI cut-offs for obesity does not overcome the limitations of using BMI as a marker of obesity. Decreasing the BMI cut-off for obesity to ≥ 25 kg/m^2 for instance, will still result in misclassifying as obese 38% of men and 16% of women.

The implications of mislabeling patients are not trivial. By using BMI as a marker of obesity, we misclassify ≥ 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, a fact that could cause unnecessary distress and prompt to unnecessary and costly interventions. In addition, such mislabeling has a deleterious effect on public trust for healthcare providers, particularly from fit patients with evident preserved muscle mass.

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 ≥ 30 kg/m^2 has an excellent specificity and positive predictive value for diagnosing obesity in both sexes. This particular finding could explain why the risk for total and cardiovascular mortality usually peaks up when BMI is ≥ 30 kg/m^2 and suggests that suboptimal diagnostic performance of BMI to detect excess fat could be limited only to intermediate ranges of BMI. Body mass index should continue to be used in clinical practice to identify those at the two extremes of the body weight spectrum, those with a BMI ≥ 30 kg/m^2 who most likely have an excess in body fat, and those with a BMI < 20 kg/m^2. 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 represents fat gain, with the exception of body builders, athletes or patients with conditions that increase the volume of third space such as heart failure, ascitis or renal failure. However, we do challenge the use of BMI to detect excess in body fat for those individuals with intermediate levels of BMI, where it fails to distinguish between excess in body fat or preserved lean mass.

The main limitation of our study is the use of bioelectrical impedance as the method of assessing body fatness. Other more accurate methods to estimated BF %, such as hydrostatic weighting, energy-dual X-ray absorptiometry and air displacement plethysmography would be preferred [36]. Nevertheless, the accuracy of bioelectrical impedance is acceptable, and its ease use, lack of radiation and relatively low cost suggest it is a feasible alternative for measuring body fatness, particularly in large populations.

In conclusion, despite the good correlation between BMI and BF % in a large sample of adults in the US population, the diagnostic accuracy of BMI to diagnose obesity is limited, particularly for individuals in the intermediate BMI ranges. 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 are necessary 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.

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Abbreviations

BMI	body mass index
BF %	body fat percentage
NHANES	National Health and Nutrition Examination Survey

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