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How fat is obese?

Abstract The aim of the study was a comparison between body fat measurements and body mass index. We analyzed the data of 890 subjects, 596 females and 294 males, ranging in age from 18 to 83 years, in body mass index (BMI) from 14 to 54 kg/m^2, and in body fat percentage (BF%) from 4% to 57%. A considerable number of subjects, both males and females, could not be classified as obese based on their BMI alone. Such a misclassification is undesirable, especially in general practice, and it calls for diagnostic criteria other than the BMI alone to be used for obesity.

Key words Body mass index • Fat mass • DXA • Obese

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Introduction

The World Health Organization (WHO) defines obesity as a condition in which body fat is increased to the extent that health and well-being are impaired [1]. As body fat measurements are not easy to perform in population studies, the body mass index (BMI) is used as a surrogate measure for body fat. The currently used cut-off points for overweight (i.e., 25 kg/m^2) and obesity (i.e., 30 kg/m^2) are based on morbidity and mortality data in relation to BMI from population studies in Caucasians [1]. Several studies [2–6] have shown that the BMI is highly correlated with body fat percentage BF%. Since the relationship between BF% and BMI is also age dependent in most populations (an older person has generally more body fat at the same BMI than a younger person), it is difficult to 'convert' the BMI cut-off points for overweight and obesity into cut-off points for body fat. Only a few papers in the literature give cut-off values for obesity based on BF% [6–8]. Manuals of some commercially available impedance analyzers also give values that allow assessment of BF%. Generally, these figures are lower compared to values found in scientific papers, causing confusion for physicians and patients. In addition, as a side effect, it may lead to undesirable low target weights during slimming programs.

In clinical practice, the use of BMI as an indicator of overweight and obesity is easy, but its reliability as a tool for measuring body fat on an individual level can be questioned. Direct BF% measurements would be a better tool for diagnosing obesity.

To assess the reliability of the BMI as a diagnostic tool for obesity, a comparison was made between body fat measurements and BMI. For this purpose, obesity as excess body fat was defined if BF% was greater than 25% in male and 35% in female subjects [8].

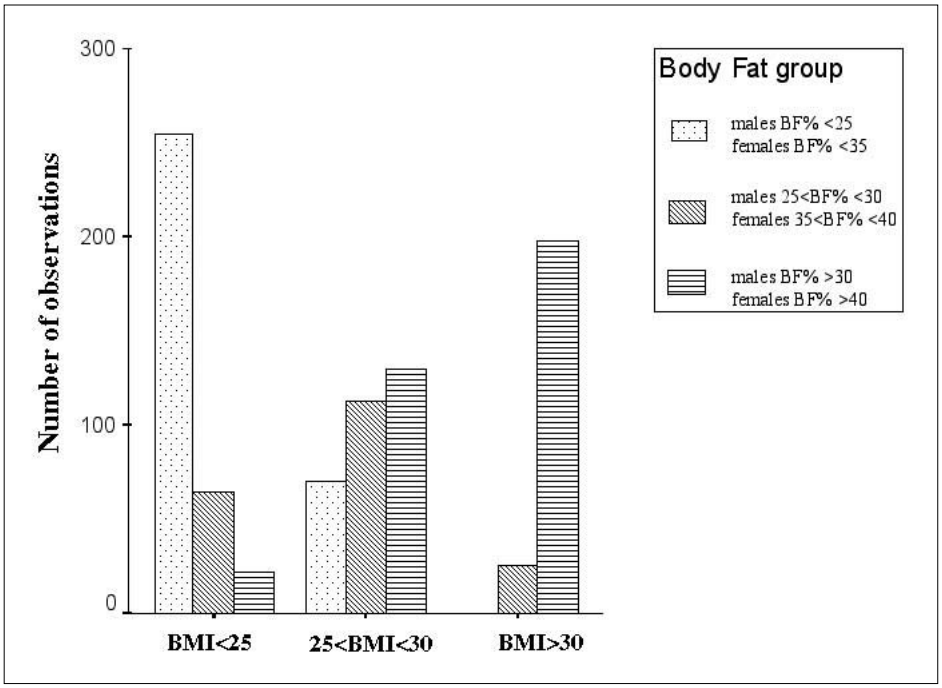

Fig. 1 Classification of subjects in various body mass index (*BMI*) and body fat percentage (*BF%*) categories

Subjects and methods

We analyzed data of 890 subjects, 596 females and 294 males, ranging in age from 18 to 83 years, in BMI from 14 to 54 kg/m^2, and in BF% from 4% to 57%. The subjects participated in ongoing studies on body composition and/or energy metabolism at the Unit of Human Nutrition of the Tor Vergata University (Rome, Italy), from 1995 to mid-2001. The Medical Ethical Committee of the university approved the measurements and all subjects signed informed consent.

Body weight was measured to the nearest 0.1 kg using a beam balance (Invernizzi, Rome, Italy) and body height was measured to the nearest 0.5 cm using a stadiometer (Invernizzi, Rome, Italy). BF% was measured using a Lunar DPX whole-body X-ray densitometer (Lunar Radiation Corp., Madison, WI, USA; software version 1.35) at medium scan mode.

Data were analyzed using SPSS package (SPSS Inc., Chicago, IL, USA). Subjects were categorized in BMI groups according to WHO criteria: normal weight, BMI<24.9 kg/m^2; overweight, 25<BMI<29.9 kg/m^2; and obesity, BMI>30 kg/m^2. In addition, they were classified into categories according to BF%: normal BF%, <25% in males and <35% in females; high BF%, >25% in males and >35% in females; and very high BF%, >30% in males and >40% in females. According to WHO, obesity in young to middle-aged subjects (BMI>30 kg/m^2) corresponds with BF% values of more than 25% in males and more than 35% in females [8].

Cross-tabulation tested for misclassification of overweight and obesity based on BMI (false negative) in relation to actual BF%. Differences in parameters between groups were tested with ANOVA using Bonferroni's 'post hoc' analysis. Data are presented as mean±standard deviation (SD). Significance is set at $p<0.05$.

Results

Table 1 shows the characteristics of the male and female subjects separately. Male subjects were taller and heavier than their female counterparts. The mean age, and BMI, and BF% for men were lower than those for women. According to the WHO criteria, 33.4% of the females and 39.5% of the males were overweight (BMI>25 kg/m^2) and 31.4% of females and 14.6% of males were obese (BMI>30 kg/m^2).

Table 1 Characteristics of male and female participants[a]

	Females (n=596)		Males (n=294)	
	Mean	SD	Mean	SD
Age, years	46	14	41	17
Weight, kg	71.8	15.7	81.0	13.3
Height, cm	160.7	6.9	176.3	7.4
Body mass index, kg/m^2	27.8	5.8	26.1	3.9
Body fat, %	38.0	8.5	23.5	9.1

[a]All parameters are significantly different between female and male subjects ($p<0.05$)

Table 2 Body fat percentages (*BF%*) in female and male subjects with normal weight, overweight, and obesity, based on body mass index (*BMI*)

Female	BMI (kg/m^2)		BF%<35	35<BF%<40	BF%>40	Total
	BMI<25	*n* (row%)	150 (71.4)	50 (23.8)	10 (4.8)	210 (100)
	age	mean (SD)	40 (15)*	49 (13)	58 (13)	
	25<BMI<30	*n* (row%)	27 (13.6)	73 (36.7)	99 (49.7)	199 (100)
	age	mean (SD)	49 (13)	49 (13)	52 (15)	
	BMI>30	*n* (row%)	4 (2.1)	18 (9.6)	165 (88.2)	187 (100)
	age	mean (SD)	46 (8)	46 (10)	44 (13)	
Total		*n*	181	141	274	596
Male	BMI (kg/m^2)		BF%<25	25<BF%<30	BF%>30	
	BMI<25	*n* (row%)	106 (78.5)	15 (11.1)	14 (10.4)	135 (100)
	age	mean (SD)	30 (14)*	59 (16)	62 (12)	
	25<BMI<30	*n* (row%)	44 (37.9)	40 (34.5)	32 (2.6)	116 (100)
	age	mean (SD)	35 (15)*	50 (15)	49 (16)	
	BMI>30	*n* (row%)	1 (2.3)	8 (18.6)	34 (79.1)	43 (100)
	age	mean (SD)	63	42 (14)	41 (12)	
Total		*n*	151	63	80	294

*$p<0.01$ compared to other groups in the same row

Table 2 shows the classification of the subjects according to the WHO BMI classification in relation to their BF%. As can be seen, 60 out of 210 women with a BMI lower than 25 kg/m^2 had a BF% value higher than 35%, and 10 women even at that low BMI had a BF% value of over 40%. Also, the misclassification in the overweight female subjects is considerable, with nearly half of the women with a BMI between 25 and 30 having a BF% higher than 40%. Of the females with a BMI over 30 kg/m^2, 98% had high or very high BF%.

The misclassifications in the male group are also considerable. Detailed analyses show that the false-negative misclassified (based on BMI) females and males are generally older (see Table 2).

Discussion

Body fat can be measured using various methods which are generally expensive, require sophisticated instrumentation and cooperation of the subjects, are not practical for clinical and epidemiological studies [9, 10]. Therefore, the BMI is normally used in population studies in which overweight and obesity are related to morbidity and mortality. However, predictive methods have a relatively large error at an individual level, and thus, if subjects have to be classified into categories, misclassification can occur.

The WHO cut-off points of BMI for overweight and obesity are based on observational studies of the relationship between BMI and morbidity and mortality [1]. There are no studies relating directly body fat measurements to morbidity and mortality, thus no clear cut-off point for obesity, based on body fat measurements, is known. Based on the relationship between BMI and BF%, one can calculate that in young adults a BMI value of 30 kg/m^2 corresponds to about 25% body fat in males and 35% body fat in females [8]. Because body fat generally increases and fat-free mass decreases [11] with increasing age, older subjects will have a higher BF% than young subjects of the same BMI [3–6].

The analyses in this paper show that a considerable number of subjects, both males and females, will not be classified as obese based on their BMI alone. This is true (see Table 2) if obesity corresponds to a BF% of 25% and 35% in males and females, respectively, but it still holds true if obesity corresponds to even higher BF% levels of 30% and 40% in males and females, respectively.

Such a misclassification is undesirable, especially in general practice, and it calls for diagnostic criteria other than the BMI alone to be used for obesity. Unfortunately, most predictive methods, like skinfolds and bioelectrical impedance, also have large prediction errors and might, at least for the moment, not really improve the diagnostics. For this reason, general practitioners as well as researchers should be aware of misclassifications if the BMI is used in diagnostics. This is especially true for older patients.

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