Is Body Mass Index a Measure of Adiposity in Elderly Women?

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Abstract

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Objective: To evaluate the accuracy of body mass index (BMI) as a predictor of body fat in elderly women.

Research Methods and Procedures: A total of 1423 women aged 67 ± 5 (mean ± SD, range: 60 to 88) years were consecutively enrolled into the study. Fat mass (FM) was measured using DXA.

Results: BMI explained 72.9% of FM variance ($p < 0.0001$), with a root mean square error of estimate (RMSE) of 3.5 kg. After standardization of RMSE on the dependent variable as RMSE%, the prediction error equaled 15%. BMI explained 54.8% of FM% variance ($p < 0.0001$), with an RMSE of 4.1%, corresponding to an RMSE% of 11%.

Discussion: The relatively high RMSE% of the FM and FM%-BMI associations caution against the use of BMI as an adiposity index in individual elderly women. However, an error corresponding to 11% of FM% may be accepted for population studies of body fat in elderly women.

Key words: obesity, elderly, body mass index, DXA

Introduction

Body mass index (BMI), which is the ratio of body weight in kilograms to height in square meters, is the adiposity index most commonly used in adults. BMI is simple to obtain, provides a direct measure of underweight and overweight, and acts as a proxy for fat mass (FM) and mortality risk with a better overall performance than any other weight-stature index (1,2). Standardization of BMI by age provides a better use of this index in adults, although BMI changes during adulthood are small and can be disregarded without substantial loss of performance (3). More recently, BMI has begun to be used as an adiposity index in children and adolescents (4); however, because of unrelated variations in weight and height, changes in BMI are greater during childhood and adolescence than adulthood. Thus, age must be taken into consideration when using BMI in children and adolescents.

Few data are available on the use of BMI as an adiposity index in the elderly (5–7). Elderly females matched by weight and height with young females show higher FM and lower fat-free mass, total body water, total body potassium, and bone mineral content (BMC) (8). Thus, the relationship between weight-stature indexes and body composition may be different in the elderly.

DXA allows rapid and minimally invasive assessment of FM (9). Therefore, DXA is an excellent means of validating BMI as a measure of adiposity at different ages and has been used extensively for this purpose (10–12).

The aim of the present study was to examine the association between BMI and body fat measured by DXA in a large sample of elderly women.

Research Methods and Procedures

Subjects

During a larger research project on nutritional status and osteoporosis at the Geriatric Evaluation and Research Center of Modena University, 1423 white Italian women were consecutively enrolled into the present study (13). The women were recruited through advertisements in local newspapers or had been sent to the center by their primary physicians. To be eligible for the present study, they had to be at least 60 years of age and free of diseases other than (primary) osteoporosis. Presence of disease was excluded by clinical examination and selected blood and urine chem-

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istries. The local ethical committee approved the study protocol and all subjects gave their informed consent.

DXA

By measuring the differential attenuation of X-rays at two different energies, DXA allows the separation of body mass (BM) into FM, lean tissue mass (LTM), and BMC. In this study, FM (in kilograms) was assessed using a Lunar DPX-L densitometer (Lunar Corporation, Madison, WI; software v 3.6) and standardized on BM (in kilograms) to obtain FM%. LTM% was similarly calculated as LTM/BM.

Anthropometry

Weight and height were measured to the nearest 0.1 kg and 0.5 cm, respectively, using a balance with incorporated stadiometer (14). BMI was calculated as weight/height^2 (kg/m^2) (1).

Statistical Analysis

Statistical analysis was performed on a MacOS computer using the Statview 5.1 software package (SAS Institute, Cary, NC). A preliminary analysis showed no difference in FM, FM%, and BMI and their association in women taking estrogen vs. those not taking estrogen (ANOVA and linear regression, p values were not significant, data not shown). Further statistical analyses were thus performed on the pooled sample. The variance of FM and FM% explained by BMI was measured using the adjusted determination coefficient (adj R^2). To assess the accuracy of the prediction further, both absolute values of the root mean squared error of the estimate (RMSE) and percent values (RMSE%) were calculated. RMSE% was obtained by dividing RMSE for the mean value of Y. Values are given as mean ± SD.

Results

The measurements of the study subjects are given in Table 1.

Age ranged from 60 to 88 years. There was a wide variability in both FM and FM%, as indicated by a coefficient of variation of 28% and 16%, respectively. Osteoporosis, diagnosed by DXA as described in detail elsewhere (13), was present in 7.5% of the women.

There was a difference of 1.5 ± 0.9 kg between weight measured by scale and BM measured by DXA. Even if this difference was statistically significant ($p < 0.0001$), its practical relevance is minimal because it corresponds on average to only 2.2% of weight.

Regression of FM vs. BMI is shown in Figure 1.

BMI explained 72.9% of FM variance ($p < 0.0001$) with an RMSE of 3.5 kg, corresponding to an RMSE% of 15%. Residuals of the regression (0.0 ± 3.5 kg, mean ± SD) were normally distributed and age and BMC explained only 1.1% and 7.0% ($p < 0.0001$) of their variance.

Table 1. Characteristics of the 1423 enrolled women

	Mean ± SD	Range
Age (years)	67 ± 5	60–88
Weight (kg)	65 ± 9	42–103
Height (m)	1.57 ± 0.06	1.41–1.75
BMI (kg/m^2)	26.2 ± 3.5	18.9–37.5
FM (kg)	23.8 ± 6.7	7.9–47.8
FM% (%)	37.7 ± 6.0	18.0–55.4

Regression of FM% vs. BMI is shown in Figure 2.

BMI explained 54.8% of FM% variance with an RMSE of 4.1%, corresponding to an RMSE% of 11%. Residuals of the regression (0.0 ± 4.1%, mean ± SD) were normally distributed and were not associated with age ($p = 0.144$) or with BMC ($p = 0.966$).

BMI explained 50.7% less variance of LTM than FM (adj $R^2 = 0.22$, $p < 0.0001$) and the same variance of LTM% compared with FM% (adj $R^2 = 0.548$, $p < 0.0001$). However, LTM contributed to only 3% ($p < 0.05$) and 17.7% ($p < 0.0001$) of the unexplained variance of FM and FM%, respectively.

Discussion

Ideally, validation of BMI as an adiposity index should be performed against multicompartment models of body composition or more direct measurements of FM such as those allowed by total body carbon assessment (15). This is especially true for elderly subjects who are expected to show changes in fat-free mass density, which contradicts the assumptions made by two-compartment models, although there is some evidence to the contrary (16).

However, large-scale application of multicompartment models or total body carbon assessment is not possible because of the high cost and degree of technical expertise

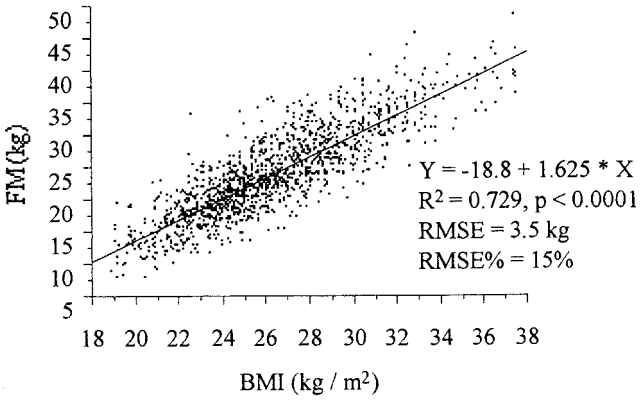

Figure 1. Regression of FM determined by DXA vs. BMI.

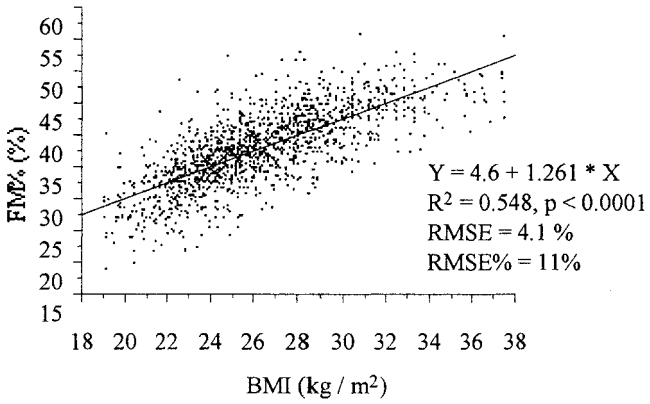

Figure 2. Regression of FM% (FM/BM, both determined by DXA) vs. BMI.

required by these methods. Thus, validation of BMI and other anthropometric indexes has been performed mainly against two-compartment models of body composition, especially body densitometry. On the basis of the results obtained in adults, and to a lesser extent the elderly, BMI is generally assumed to explain from 36% to 64% of the variance of FM% determined by underwater weighing (UWW) (17). In that it is able to explain 54.8% of FM% variance, our validation of BMI is thus in agreement with the findings available in the literature. In this respect, it should be pointed out that the two-compartment UWW model and the three-compartment DXA model generally agree closely for the assessment of body fat (9). (This is true also for the two-compartment models based on total body potassium and total body water measurements.)

To determine the accuracy of an estimate, however, RMSE and RMSE% should be considered along with R^2. Using UWW as the reference method, RMSEs of 3.5% to 5% were reported for FM% determined by BMI in adult and elderly subjects (5–7,17). The RMSE of FM% in this study was 4.1%, which is comparable with previous studies. However, its corresponding RMSE% value was 11%. The RMSE% associated with the prediction of FM from BMI was similarly high (15%), despite the high percentage of explained variance of FM (72.9%). It should be noted, however, that this error is not substantially higher than that associated with other indirect body composition techniques and that BMI has the advantage of being simpler to measure (17).

The relatively high RMSE% associated with the prediction of FM and FM% from BMI cautions against the use of BMI as an adiposity index in individual elderly women. However, an RMSE% of 11% for FM% could be accepted for population studies of body fat in elderly women.

Prediction from BMI left an unexplained variance of 27.1 and 45.2 for FM and FM%, respectively. LTM contributed to only 3.0% and 17.7% of this unexplained variance, respectively, suggesting that factors other than body composition do influence the accuracy of BMI as an adiposity index in the elderly. In this respect, it is of interest that age contributed to only 1.4% of the unexplained variance of FM and did not contribute at all to that of FM%. This may be due in part to the relatively narrow age interval considered by the present study (60 to 88 years). In a previous study, however, we found a similarly low contribution of age to the variability in the relationship between body fat determined by DXA and BMI in children and adolescents (11). It would be of interest to identify the factors responsible for the high intersubject variability in the relationship between BMI and body fat in elderly women because this may provide better knowledge of the aging process and improve our assessment of body composition in the elderly.

Because the data used in this article were obtained from a study aimed primarily at testing the existence of an association between nutritional status and osteoporosis, it was important to establish whether BMC had some relevant effect on the relationship between BMI and body fatness. Because BMC explained only 7% of the residuals of the BMI-FM association and no variance of those of the BMI-FM% association, we conclude that in our study population, BMC did not influence the relationship between BMI and body fatness in a biologically significant way.

On the basis of this study, we conclude that in elderly Italian women, BMI is a reasonably accurate predictor of FM% only at the population level. Even if our subjects had not been selected as being representative of the Italian population of elderly women, the large number and the fact that they were free of diseases other than osteoporosis, which is a common complication of aging, suggests that the results of this study could be extended to other healthy, Italian women.

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