Assessment of body composition by bioelectrical impedance in a population aged > 60 y[1,2]

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ABSTRACT Body composition was measured in a group of 35 healthy men and 37 healthy women aged 60–83 y. Body mass index (BMI) in men was 25.0 ± 2.2 kg/m^2 ($\bar{x} \pm$ SD) and in women, 25.9 ± 3.2 kg/m^2. BMI was low in relation to body fat percentage as determined by skinfold-thickness measurements or densitometry in comparison with the relation found in younger adults. Mean body fat percentage of the male subjects (aged 70.4 ± 5.2 y) as determined by densitometry was 31.0 ± 4.5%, whereas in women (aged 68.0 ± 5.2 y) it was 43.9 ± 4.3%. Body impedance correlated with fat-free mass (FFM). The best prediction formulas for the FFM from body impedance and anthropometric variables were *1*) FFM (kg) = $(0.671 \times 10^4 \times H^2/R) + 3.1S + 3.9$ where H is body height (m), R is resistance (Ω), and S is gender (females, 0; males, 1) ($r = 0.94$; SEE = 3.1 kg) and *2*) FFM (kg) = $(0.360 \times 10^4 \times H^2/R) + 0.359BW + 4.5S - 20T + 7.0$ where BW is body weight (kg) and T is thigh circumference (m) ($r = 0.96$; SEE = 2.5 kg). The prediction equations from the literature, generally determined in younger populations, overestimated FFM in elderly subjects by ~6 kg and are not applicable to elderly subjects. *Am J Clin Nutr* 1990;51:3–6.

KEY WORDS Bioelectrical impedance, body composition, densitometry, skinfold thickness, elderly subjects

Introduction

In the past years the interest in nutrition in elderly people has markedly increased because of the increasing number of elderly people in the general population and its implications for health care (1, 2). An important aspect of health related to nutritional status is body composition. With advancing age, body composition changes such that the fat-free mass (FFM) decreases (3, 4) and the fat mass generally increases (4–6). Also, the amount of minerals in the FFM changes (7), as does the ratio of intercellular to intracellular water (8–12). Many methods are available for assessing body composition (13) but it can be questioned whether some methods can be used in an older population because of practical problems such as the necessary cooperation of the subject. One of the newer techniques for assessing body composition is the bioelectrical impedance technique, a technique that can be easily applied even to bedridden subjects. The principle of the method is that the resistance of an electric current is proportional to the amount of FFM, ie, the amount of water and electrolytes in the body (13). The method is now widely used and validation studies show that the method gives a reliable and valid assessment of body composition (14–16). However, the applicability of the method to subjects in which the water-electrolyte homeostasis is disturbed (17–20) is questionable.

The aim of this study was to compare the bioelectrical impedance method with the densitometric method and with anthropometric measurements in an older population (aged > 60 y).

Methods

The study population consisted of a selected group of 75 elderly individuals aged 60–83 y who participated in a study on nutritional habits. They were recruited by advertisement and by contacting societies for elderly people. The methodology of the study does not require a representative sample of the population. After the aim of the study was explained during a home visit, the subjects were requested to report to the Department of Human Nutrition for the measurement of body composition. The data from two men and one woman were not used in the analysis because of apparent signs of edema. The remaining 35 male and 37 female subjects were apparently healthy and did not show any signs of edema or dehydration and did not use drugs that could affect the water-mineral homeostasis. **Table 1** lists age and body composition data of the subjects. The study protocol was approved by the Ethical Committee of the Department of Human Nutrition.

[1] From the Department of Human Nutrition, Wageningen Agricultural University, Wageningen, The Netherlands.

[2] Reprints not available.

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TABLE 1
Age and body composition data of subjects*

	Men	Women
Age (y)	70.4 ± 5.2	68.0 ± 5.2
Body weight (kg)	75.9 ± 9.3	68.5 ± 8.7
Body height (m)	1.741 ± 0.078	1.627 ± 0.059
Body mass index (kg/m^2)	25.0 ± 2.2	25.9 ± 3.2
Sum of skinfold thicknesses† (mm)	53.9 ± 12.7	73.9 ± 19.5
Waist circumference (m)	0.972 ± 0.074	0.904 ± 0.095
Hip circumference (m)	0.993 ± 0.049	1.039 ± 0.069
Thigh circumference (m)	0.532 ± 0.033	0.583 ± 0.051
Body density (kg/L)	1.0291 ± 0.0100	1.0022 ± 0.0090
Body fat (%)		
From skinfold thicknesses‡	27.9 ± 2.5	38.7 ± 3.2
From body density§	31.0 ± 4.5‖	43.9 ± 4.3‖
Fat-free mass from body density (kg)	52.0 ± 6.6	38.1 ± 4.1
Body impedance (Ω)	460 ± 40	521 ± 45

* $\bar{x}$ ± SD. For men $n = 35$; for women $n = 37$.
† Tricipitalis, bicipitalis, subscapularis, and suprailiacalis.
‡ With Durnin and Womersley's equations (6).
§ With Siri's formula (22), BF (%) = (495/D) − 450.
‖ Significantly different from body fat percentage derived from skinfold thicknesses, $p < 0.001$.

Body impedance was measured with a body-composition analyzer (type BIA 101, RJL Systems, Detroit) ≥ 2 h after the last meal, in a supine position, after the bladder was emptied, as described by Lukaski et al (21). Body height was measured to the nearest 1 mm by means of a microtoise and body weight, to the nearest 0.05 kg with a digital scale (ED-60T, Berkel, Rotterdam, The Netherlands). From body height and body weight the body mass index (kg/m^2) was calculated. Four skinfold thicknesses (bicipitalis, tricipitalis, subscapularis, and suprailiacalis) were measured in triplicate as described by Durnin and Womersley (6), by use of a Harpenden skinfold caliper (Holtain Ltd, Bryberian, UK). Waist circumference was measured at the midpoint between the lower rib margin and the iliac crest (normally umbilical level), hip circumference at the trochanter level, and thigh circumference immediately below the gluteal fold. All circumferences were measured to the nearest 1 mm with a plastic tape.

Body density was determined by underwater weighing with simultaneous determination of the lung volume by helium dilution. The underwater weight was measured in duplicate to the nearest 0.05 kg with a digital scale (3826 MP 81, Sartorius, Göttingen, FRG). Siri's formula (22) was used to calculate body fat percentage from body density. The equipment has a precision of 1% (0.002 kg/L).

Regression analysis and stepwise multiple-regression analysis were performed by means of the *SPSS-X* program (23). Regression models were tested for differences in slopes and/or intercepts with *t* statistics by use of the technique described by Kleinbaum and Kupper (24). Student's *t* tests were used to test for significance of differences between several methods of determining body composition. Results are expressed as means ± SD.

Results

In Table 1 age and body composition data of the subjects are given. The body mass index of the male and female subjects is rather low in relation to the body fat percentage. Body fat calculated from skinfold thicknesses was lower than body fat calculated from body density ($p < 0.001$). For further calculations, only the densitometric data are used. In **Table 2** the correlation coefficients of the densitometrically determined FFM with body weight (BW), body height (H), body impedance (R), H^2/R, and age are given for men and women separately and for both sexes combined. FFM in both men and women is significantly correlated with H^2/R. In women, however, the correlation of FFM with body weight was slightly stronger than the correlation with H^2/R. Therefore, in women the term H^2/R was forced in the following regression equations to simplify the comparison between the two sexes.

The regression coefficients in the prediction formulas for FFM from H^2/R for males and females did not differ significantly ($p > 0.5$); thus, a multiple-regression model with gender (S) as a dummy variable (females, 0; males, 1) was developed **(Table 3)**. The most complete model for the prediction of the FFM from body impedance and anthropometric variables included body weight, gender, and thigh circumference [T(m)]:

TABLE 2
Pearson's correlation coefficients between the densitometrically determined fat-free mass and various characteristics of the subjects*

	Age	Weight	Height	Impedance	Height^2/impedance
	y	*kg*	*m*	*Ω*	*m^2/Ω*
Men	−0.17	0.84†	0.76†	−0.48‡	0.85†
Women	−0.01	0.79†	0.33	−0.56†	0.77†
Men and women	0.11	0.76†	0.80†	−0.75†	0.94†

* For men $n = 35$; for women $n = 37$.
† $p < 0.001$.
‡ $p < 0.01$.

TABLE 3
Regression of fat-free mass against body impedance (H^2/R) in men and women aged 60–83 y*

	Men	Women	Men and women
H^2/R (m^2·Ω^{-1}·10^{-4})	0.673 ± 0.007†‡	0.667 ± 0.009‡	0.672 ± 0.005‡
Intercept (kg)	7.0 ± 4.8	4.2 ± 4.8	3.9 ± 2.8
Gender§	—	—	3.1 ± 1.1
Correlation coefficient	0.85	0.77	0.94
SEE (kg)	3.5	2.7	3.1

* For men $n = 35$; for women $n = 37$.
† $\bar{x}$ ± SD.
‡ $p < 0.05$.
§ Females, 0; males, 1.

$$\text{FFM (kg)} = (0.360 \times 10^4 \times \text{H}^2/\text{R}) + 4.5\text{S} + 0.359\text{BW} - 20\text{T} + 7.0 \quad (r = 0.96, \text{SEE} = 2.5 \text{ kg}). \quad (1)$$

In earlier studies with the same techniques (unpublished results) we investigated the correlation of FFM determined by densitometry with body impendance and anthropometric variables in males and females aged 20–40 y. In that young adult population (n = 283) FFM could be predicted by the formula

$$\text{FFM (kg)} = (0.654 \times 10^4 \times \text{H}^2/\text{R}) + 3.9\text{S} + 10.9 \quad (r = 0.94, \text{SEE} = 3.1 \text{ kg}) \quad (2)$$

The regression coefficient (slope) of this prediction formula for younger adults is not significantly different from that of the prediction formula in the elderly population we studied, and the gender factor is not significantly different, either. However, the intercept is significantly lower in the prediction equation for the elderly subjects ($p < 0.05$). As a consequence, the regression equation for the elderly population will always predict a significantly lower FFM.

Discussion

The studied population was a selected population of healthy elderly men and women because at older ages not every subject is able to participate in a study on body composition in which underwater weighing is included. Mean body weight and mean body height were within the normal range compared with values found in a representative elderly population of the same age in The Netherlands (25).

In three subjects apparent signs of edema or dehydration were observed during the examinations. These individuals were excluded from the analysis. The cooperation of the subjects, even of the very old, was good and all measurements could be done without any problems.

Table 1 lists age and body composition data of the subjects. The body mass index in both men and women was rather low in relation to the body fat percentage values found in younger populations (26). This is not surprising because body mass index is a measure of body mass whereas the lean body mass in advanced age is decreased (3, 4) and the fat mass is generally increased (4–6). The results show clearly that the use of the body mass index as a measure of body fatness in older age groups, with the same criterion values as in young adults, eg, > 25 kg/m^2 for overweight and > 30 kg/m^2 for obesity (27), is prohibited.

When body fat percentages determined by densitometry and by the skinfold technique (6) are compared, the densitometric method results in a significantly higher value. This can be explained by the fact that the studied population is older than the reference population of Durnin and Womersley (6) and thus probably has more internal fat (6, 28, 29), which is not reflected in skinfold thicknesses. As a consequence, skinfold measurements will underestimate the total amount of body fat.

However, body fat percentage determined by densitometry in the elderly subjects, by use of Siri's equation (22), might be slightly overestimated (by 1–2%) because the FFM has a lower density (6) due to bone loss (7). Also, the observation of Segal et al (30) that in fatter subjects the water content of the FFM is increased, will cause a lower density of the FFM and a further overestimation of the body fat percentage when Siri's formula (22) is used in these relatively fat subjects. As a consequence of this two factors, the estimation of the FFM from body density, by use of Siri's formula (22), could be an underestimation. The error in FFM made by this underestimation is difficult to predict but it could be as large as 1–2 kg, depending on age and body fat percentage of the subject. For the purpose of this paper no corrections were made for a decreased mineral content and an increased water content of the fat-free body.

When the regression equations of Segal et al (16), Lukaski et al (14), or our own laboratory (Eq 2) for the prediction of FFM from body impedance are applied to the elderly subjects, a large overestimation of the FFM (~6 kg) occurs in males and in females compared with the densitometric method. Hughes and Evans (31) also found a 6–7-kg larger predicted FFM when body-impedance measurements were used compared with the densitometrically determined FFM in elderly (49–74 y) subjects. This greater predicted FFM can hardly be caused by the fact that the densitometrically determined FFM is probably an underestimation, caused by different mineral and water contents in the FFM in elderly subjects. As mentioned in the Results section, the prediction equation of the FFM from body impedance in elderly subjects has the same regression coefficient (slope) but a lower intercept compared with the prediction equation determined in younger subjects. This could be explained by a changed water distribution over the body in elderly subjects. With advancing age the water content of the body decreases. The amount of intracellular water, however, decreases more rapidly than the amount of extracellular water (8–10) although in the studies of Steen et al (11) and Steen (12) a relatively larger decrease in the amount of extracellular water compared with intracellular water was found with advancing age.

In extracellular tissues the concentration of dissolved electrolytes is higher (32) and hence the resistance is lower compared with intracellular tissues. Thus, the total resistance of a given FFM at a given height (R_{tot}), which can be calculated with the formula

$$R_{tot} = R_{ET} + R_{IT} \quad (3)$$

where R_{ET} is the resistance of extracellular tissue and R_{IT} is the resistance of intracellular tissue, will decrease when the proportion of extracellular tissue (with the lowest specific resistance) is higher. As a consequence, the term H^2/R in the prediction formula for FFM will increase; thus, the regression line will shift to the right.

By measuring body reactance during impedance measurements, it is possible to assess the amount of intracellular and extracellular water (33) although the explained variance ($r^2 = 0.42$) found by Segal et al (33) is relatively low. Unfortunately, however, reactance was not measured in our subjects.

The prediction equation for FFM from body impedance as developed for the elderly subjects has a correlation coefficient and an SEE (Table 3) that are comparable with other prediction formulas from the literature (14–16). Thus, the assessment of FFM from body impedance in elderly people seems to be a reliable method as long as population-specific (ie, age-specific) prediction formulas are used. More research on the relation between body impedance and FFM in relation to age is necessary and the prediction formula has to be cross-validated.

In conclusion, FFM and fat mass can be reliably predicted in older subjects from body-impedance measurements from age-specific regression equations. The prediction formulas in the literature that are based on measurements in younger populations grossly overestimate FFM and hence underestimate fat mass and are not applicable to elderly populations.

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