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The correlation between selected anthropometric indices and BIA-based body fat measures in nursing home women aged 80+ years

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Ryszard Zarzeczny[1ACDE], Agnieszka Nawrat-Szołtysik[2ABC], Anna Polak[2ACD], Jakub Maliszewski[3B], Adam Kiełtyka[4B], Beata Matyja[5B], Magdalena Dudek[2B], Joanna Zborowska[2B], Adam Wajdman[2B]

[1] Institute of Physical Education, Tourism and Physiotherapy, Jan Długosz University in Częstochowa, Poland;
[2] Chair of Physiotherapy Basics, The Jerzy Kukuczka Academy of Physical Education in Katowice, Poland;
[3] TECHNOMEX - Trade and Service Company, Gliwice, Poland;
[4] BetaMed Medical Center, Katowice, Poland
[5] Saint Elisabeth Nursing Home in Ruda Śląska, Poland

Abstract
The aims of the study were to assess whether commonly used anthropometric indices are associated with body fat measures obtained by Bioelectrical Impedance Analysis (BIA) method, and to determine the best anthropometric predictor of BIA-based body fat percentage (%Fat) and visceral fat rating (VFR) in elderly women. The sample consisted of 24 women aged 80 years and older, the residents of long-term care facilities in Upper Silesia (Poland). All women were subjected to standard anthropometric measurements including the following variables: body weight, body height, waist circumference, hip circumference and neck circumference. On the basis of these measures Body Mass Index (BMI) as well as waist-to-hip ratio (WHR) were calculated. The subjects' %Fat and VFR were determined by body composition analyzer TANITA BC 420MA (Japan). Pearson's correlation coefficients were used to quantify the relationships between variables. Stepwise multiple regression analysis with backward elimination was performed to identify possible predictors. The basic characteristics of the investigated subjects were as follows (mean±SD): age - 85.5±3.7 years; body weight - 60.4±11.6 kg; body height - 150.6±7.6 cm; BMI - 26.6±4.6 kg/m^2; %Fat - 31.3±9.6%; VFR - 10.7±2.5. Both of BIA-based measures significantly, positively correlated with body weight, BMI and circumferences of waist, hip and neck (r values from 0.477 to 0.835). The multiple regression analysis for %Fat revealed that the body weight was the only variable statistically significant (r^2=0.414; p<0.001; SEE=7.503%), and for VFR the significant β coefficients were obtained for BMI and neck circumference (0.625±0.133 and 0.341±0.133, respectively) (r^2=0.754; p<0.001; SEE=1.313). Among popular anthropometric indices of body composition in the oldest old group of women, body weight seems to be the best predictor of body fat percentage, and VFR could be predicted by BMI along with a neck circumference.

***Keywords**: Aging, Older Women, Body Composition, Bioelectrical Impedance Analysis, Fat Mass, Anthropometric Indices, BMI*

Address for correspondence:
Ryszard Zarzeczny, Institute of Physical Education, Tourism and Physiotherapy, Jan Długosz University in Częstochowa, 13/15 Armii Krajowej str. 42-200 Częstochowa, Poland
email: r.zarzeczny@ajd.czest.pl

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INTRODUCTION

In most countries populations are ageing. By the year 2035 the percentage of people in EU countries aged 65 years and older will increase from 17.1 in 2008 to 25.4%. In absolute numbers, in 2005 there were about 18.8 million European citizens aged over 80 years and is estimated to rise to 34.7 million by the year 2030. Moreover, from 2015 onwards deaths will outnumber births, and roughly 2 active people (aged 15–65 years) will be caring for one inactive older person [1]. These figures indicate the higher governmental budget costs in upcoming years due to increase in life expectancy. On the other hand, there will be an additional financial burden associated with the health expenditure spent on old people, since the elderly have an increased prevalence of chronic diseases [2]. To reduce the budgetary expenses, there is an obvious need for the health of the elderly to be maintained.

Aging is a continuous process associated with a progressive decline in many physiological systems function, changes in body composition and metabolism [3]. Between the age 20-80 years there is a progressive decrease in fat-free mass (of about 40%) and a rise in fat mass. Despite the fact that after the age of 80 years, fat-free mass and fat mass decrease in parallel, the higher fatness at earlier age [4] along with a decreased energy expenditure in older age (lower metabolic rate and lower level of physical activity) [5] all together may contribute to undesirable obesity state. Indeed, there are epidemiological data suggesting that the prevalence of overweight and obesity increases in the people aged 60-70 years, especially in women [6]. Thus, obesity in the elderly is an issue of serious concern.

The important matter of body fatness is fat distribution throughout the body. The pattern of adipose tissue distribution is dependent upon many factors including age, sex and physical activity [7]. Traditionally the body fat tissue is distributed into two main compartments: subcutaneous adipose tissue and visceral adipose tissue. While both of these tissue types are important, particular attention has been directed to visceral adiposity since the accumulation of visceral fat is associated with multiple risk factors of metabolic syndrome more closely than the amount of subcutaneous fat [8]. Taking into account that accumulation of visceral fat increases with increasing age and with estrogen deficiency [9] these facts place the elderly women at high risk for abdominal fat gain.

On the contrary, there are studies indicate another serious problem in the elderly which is undernutrition [10]. It has been shown that 16% of community-dwelling elderly consume fewer than 1000 kcal, and the incidents of malnutrition among institutionalized older adults ranges from 23% to 60% [11]. Because of the fact that aging is accompanied by many physiological changes affecting both hunger and satiety such as slower gastric emptying, poorer function of the central feeding control system, impairment the sense of smell and taste, poorer dental health and age-related achlorhydia [12,13] - all of these factors can negatively impact nutritional status.

The methods currently used for body composition assessment are more or less accessible, and not always suitable for field studies in elderly subjects. Imaging technologies including computed tomography (CT), dual-energy X-ray absorptiometry (DXA) and magnetic resonance imaging (MRI), identified as gold standards in body composition analysis [7] are expensive and not generally available techniques. Bioelectrical impedance analysis (BIA) has become a widely used method to assess body composition because of the fact that it is non-invasive and easy to administer method that unlike CT or DXA, avoids exposure to ionizing radiation. BIA is based on the differing of electrical conductivities of various components of the body and can be useful in classifying adipose tissue distribution for the initial diagnosis of general and abdominal obesity for individuals, and for general application in epidemiological studies [7]. Since the resistance to electrical current depends on hydration of body tissues, the hydration status is the main limitation of the BIA method. Other factors that may affect this measurement are eating, intense physical activity and alcohol and fluid intake before the evaluation, states of dehydration or of water retention, use of diuretics, and the menstrual cycle [14].

However, the most commonly used diagnostic tools for characterizing obesity are anthropometric techniques. This kind of measurement is noninvasive and cost-efficient, effective in population-based studies [15].

World Health Organization has assembled international anthropometric data for health assessment, nutrition and well-being emphasizing the significance of phenotypic impact of aging, senility and associated diseases [16]. This urges to gather the anthropometric data for scientific purposes as well as for health self-assessment among the elderly. Thus, our aims in a nursing home residents sample of women aged 80 years and older were to assess whether the commonly used anthropometric obesity indices are associated with BIA-based body fat measures and if so - to determine the best anthropometric predictor of BIA-based body fat percentage and visceral fat rating.

METHODS

Subjects

Women, 80 years of age or older were recruited from the Upper Silesia nursing homes. Subjects were screened through a medical history questionnaire and physical examination. The inclusion criteria were: the age 80 years old and older, ability to perform simple activities of daily living, preserved logical verbal contact, lack of medical contraindications to physical exercise. Subjects were excluded if they had a cancer, uncontrolled high blood pressure or used diuretics, had an atrial fibrillation, implanted cardiac pacemaker, amputations, epilepsy and had demyelinating diseases of nervous system. The purpose and risks of the study were explained to each participant before the examination, and written informed consent was obtained from all participants. The study design conformed to internationally accepted policy statements regarding the use of human subjects and was approved by the Bioethics Committee at the Jan Długosz University in Częstochowa.

Measures and procedures

In the morning hours (at least 8 hours after the night rest) and in fasting state all participants underwent anthropometric evaluation and body composition analysis. Anthropometric measurements included body weight, body height and circumference of waist, hip and neck. Before the body composition analysis, height was measured to the nearest 0.5 cm using a fixed stadiometer, while the subjects wore light clothing and no shoes. Body weight was measured to 0.1 kg using a body composition analyzer Tanita BC 420MA (Japan). Body mass index (BMI) was calculated as weight (kilogram) divided by the square of height (meter). Waist circumference was measured at the midpoint between the costal margin and the iliac crest in the mid-clavicular line. Hip circumference was measured at the level of the greater trochanter of the femur. The waist–hip ratio (WHR) was computed as waist circumference divided by hip circumference. Neck circumference was measured with head erect and eyes facing forward, in the midway of the neck between mid-cervical spine and mid-anterior neck, just below the laryngeal prominence. All of these measurements were done in orthostatic position, to the nearest 0.5 cm using an inelastic metric tape. Body composition was estimated with a single-frequency bioimpedance analyzer Tanita BC 420MA (Japan). After entering into the BIA machine subjects' height, age and sex, the subject (in bare feet and light clothing) was instructed to stand with her legs straight, feet parallel with the heel and forefoot placed on the metal plates of the leg-to-leg BIA system. A subthreshold electrical constant current (50 kHz, 90μA) was then transmitted through the body. On the basis of bioelectrical impedance, fat free mass (FFM), percentage of body fat (%Fat) as well as visceral fat rating (VFR) were determined using the manufacturer's in-built equations derived from DXA method (for FFM and %Fat) and MRI method (for VFR) [17]. The subjects were instructed not to engage in strenuous activity during the day before the measurement, and for 3 days before the body composition assessment to consume all served in nursing home drinks and liquid meals (c.a. 1500 ml of water).

Data analysis

The distribution of the data was checked for normality using a Shapiro-Wilk test. Due to skewed distribution logarithmic transformed values were used for hip circumference to achieve a normal distribution. Linear regression equations as well as Pearson's product moment correlation coefficients were used to determine the associations between BMI, anthropological variables, %Fat and VFR. The linear relationships were assessed using scatter plots and by the data distribution around a diagonal line in a plot of observed versus predicted values. Stepwise multiple regression analysis with backward elimination was performed separately for %Fat and VFR (dependent variables) to assess the relationship between these features and anthropometric measurements. Only those variables that resulted in a statistically significant correlations with %Fat and VFR were included. The calculations were made using a commercial, statistical software STATISTICA 7.0 (Statsoft, Poland). The level of $P<0.05$ was considered significant. All data are presented as mean ± standard deviation (SD).

RESULTS

Twenty four women with the mean age of 85.5±3.7 years and BMI of 26.8±4.7 kg/m^2 were studied. Descriptive statistics of the subjects are presented in Table 1. The group consisted of 9 subjects with BMI lower than 25 kg/m^2 (37.5% of all investigated women), 8 subjects with BMI ranged between 25-29.9 kg/m^2 (33.3%), and 7 subjects with BMI higher than 30 kg/m^2 (29.2%). Moreover, eighteen women (75%) had healthy level of visceral fat (VFR<13), and 6 women (25%) had excess of visceral fat (VFR≥13) .

To select the most optimal sets of adiposity indicators the correlation coefficients were examined between BIA-measured body fatness indices (%Fat and VFR) and several anthropological as well as easily measured anthropometric variables including: age, body weight, body height, BMI, waist circumference, hip circumference, neck circumference, waist-to-hip ratio (Table 2). Both of BIA-based measures significantly, positively correlated with body weight, BMI and waist, hip and neck circumferences. The slightly higher coefficients were found for VFR (ranges from 0.835 to 0.679) than for %Fat (ranges from 0.643 to 0.477). Interestingly, neither %Fat nor VFR correlated significantly with age, body height, WHR and FFM.

Table 1. Subjects characteristics (n=24; BMI - body mass index; WHR - waist-hip ratio; FFM - fat free mass; % Fat - percentage of body fat; VFR - visceral fat rating)

variable	mean ± SD	range
age [years]	85.5 ± 3.7	80 - 93
body weight [kg]	60.4 ± 11.6	38.5 - 87.7
body height [cm]	150.6 ± 7.6	130.0 - 162.0
BMI [kg/m^2]	26.6 ± 4.6	18.5 - 36.3
waist circumference [cm]	94.1 ± 10.6	75 - 118
hip circumference [cm]	103.6 ± 10.2	89-126
WHR	0.91 ± 0.07	0.72 - 1.08
neck circumference [cm]	34.8 ± 2.7	30 - 41
FFM [kg]	40.8 ± 6.1	32.0 - 54.4
% Fat [%]	31.3 ± 9.6	11.0 - 46.3
VFR	10.7 ± 2.5	6 - 16

Table 2. Linear regression equations and Pearson's correlation coefficients between anthropological variables and percentage of body fat (%fat) and visceral fat rating (VFR) (BMI - body mass index; WHR - waist-hip ratio; FFM - fat free mass).

variable	%Fat		VFR	
	equation	r	equation	r
age [years]	%Fat = -0.608*age + 83.262	-0.237 n.s.	VFR = 0.031*age + 7.995	0.046 n.s.
body weight [kg]	%Fat = 0.530*b.w. - 0.750	0.643 P<0.001	VFR = 0.181*b.w. - 0.296	0.835 P<0.001
body height [cm]	%Fat = 0.390*b.h. - 27.562	0.309 n.s.	VFR = 0.057*b.h. + 2.085	0.171 n.s.
BMI	%Fat = 1.120*BMI + 1.472	0.536 P<0.01	VFR = 0.454*BMI - 1.411	0.823 P<0.001
waist circ. [cm]	%Fat = 0.431*w.c. - 9.318	0.477 P<0.05	VFR = 0.162*w.c. - 4.604	0.679 P<0.001
ln (hip circ. [cm])	%Fat = 61.216*h.c. - 252.541	0.605 P<0.01	VFR = 22.027*h.c. - 91.450	0.824 P<0.001
WHR	%Fat = -3.119*WHR + 34.093	-0.024 n.s.	VFR = -0.338*WHR + 10.974	-0.010 n.s.
neck circ. [cm]	%Fat = 2.206*n.c. - 45.404	0.613 P<0.01	VFR = 0.669*n.c. - 12.571	0.703 P<0.001
FFM	%Fat = -0.140*FFM + 36.966	-0.089 n.s.	VFR = 0.098*FFM + 6.649	0.237 n.s.

The stepwise multiple regression analysis for %Fat as dependent variable revealed that the body weight was the only independent variable statistically significant, which explained 41.4% of the variability in percentage of body fat (Tab.3). Using this simplification, %Fat can be estimated as

$$\%Fat = 0.530 * \text{body weight} - 0.750$$

The relationship between measured vs. predicted percentage of body fat is shown in Figure 1.

In the case of VFR as dependent variable, significant and independent variables in a multiple regression model were BMI and neck circumference. Together these predictors explained 75.4% of the change in visceral fat rating. However, the Beta coefficient, which is a measure of the impact of a given independent variable on a dependent variable, was higher for BMI than for neck circumference (0.625 and 0.341, respectively) (Table 3). Accordingly, the following formula can be derived:

$$VFR = 0.345 * BMI + 0.324 * \text{neck circumference} - 9.777$$

The association between measured and predicted visceral fat rating is shown in Figure 2.

Table 3. Results of stepwise multiple regression analysis with backward elimination between dependent variable (percentage of body fat (%Fat) or visceral fat rating (VFR)) and independent variables (body weight, body mass index, waist circumference, ln (hip circumference), neck circumference).

dependent variable	r^2	SEE	independent variable	ß ±SD of ß	B ±SD of B	P
%Fat	0.414 P<0.001	±7.503	intercept	-	-0.750 ±40.480	0.928
			body weight	0.643 ±0.799	0.530 ±0.656	<0.001
VFR	0.754 P<0.001	±1.313	intercept	-	-9.777 ±17.798	<0.05
			BMI	0.625 ±0.651	0.345 ±0.362	<0.001
			neck circumference	0.341 ±0.651	0.324 ±0.617	<0.05

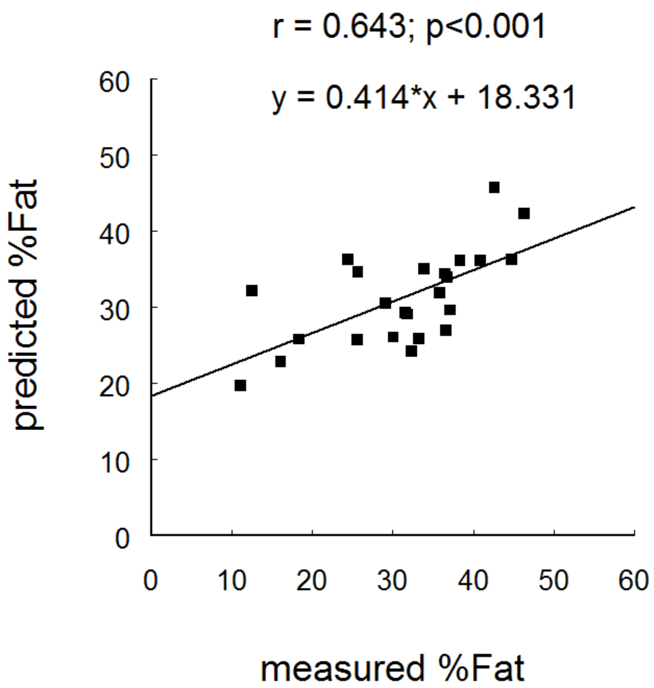

Figure 1. Predicted percentage of body fat (%Fat) based on the proposed model and %Fat measured by BIA method.

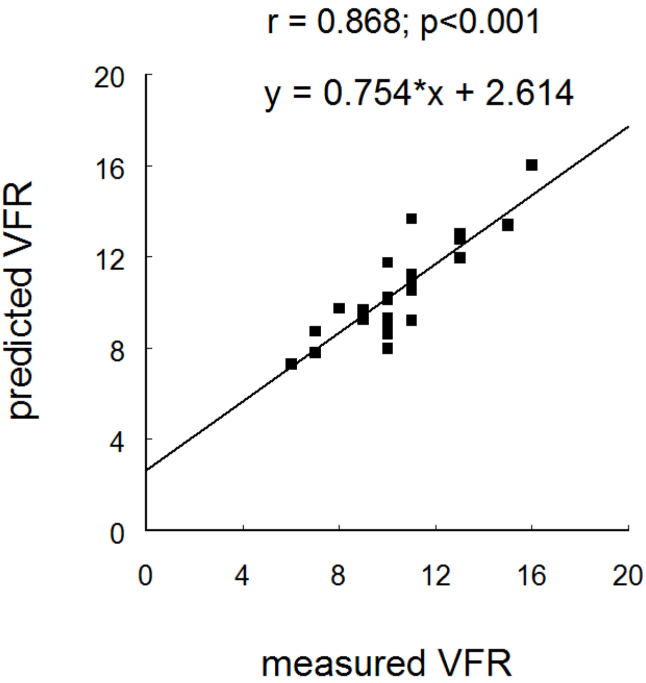

Figure 2. Predicted visceral fat rating (VFR) based on the proposed model and VFR measured by BIA method.

DISCUSSION

Changes in body composition have significant health related effects in the elderly and knowledge of these changes can prevent or at least alleviate many health problems. However, the methods used for body composition measurement are often difficult to apply for financial, technical or conceptual reasons. Therefore, the objective of this study was to assess the relationship between the common anthropometric obesity indices and BIA-based body fat measures to find out the best predictors of fatness in elderly women.

There are two noteworthy points regarding our subjects: 1) the mean age of our recruited individuals (85.5 ± 3.7 years), and 2) residential environment (we investigated women - nursing home residents). In many epidemiologic studies, the authors making the subgroups include into the oldest group people over 60, 65, 70 or 75 years of age. Despite the fact that the age group division is usually arbitrary or based on definition of aging [18], it should be kept in mind that due to increase in life expectancy the biological changes in human body can also be shifted towards the later years. The good example could be the results of The Scottish Health Survey which showed an increase in BMI in women between the age of 60 and 70 although not long ago it was recognized that peak of body fat mass occurs at age of 60 years [6]. On the other hand, into the oldest subgroup are usually included people both free-living as well as institutionalized older adults. This generalization may lead to the false conclusions since the nursing home residents are characterized by a very low physical activity level even compared to non-institutionalized counterparts [19]. Moreover, the growing body of evidence has demonstrated that prevalence of undernutrition and overnutrition may be different in community-dwelling elderly compared to residents of long-term care facilities [10]. Our subjects belonged to the age group known as "the oldest old" [20] and their mean weight, height BMI, %Fat and FFM were similar to these reported by other authors for old women [21, 22, 23]. Additionally, since the mean BMI of our subjects is 26.6 kg/m^2, the obtained results are in agreement with so called "obesity paradox" assuming the lower mortality rate in old people with the BMI ranged 25-30 kg/m^2 [24].

Our study showed that percentage of body fat was positively associated with body weight, BMI, waist, hip and neck circumferences but only body weight had statistically significant size effect on %Fat. Given that BIA measurement is based on body weight value a such result could be expected. Of note, the body height value is also entered for BIA measurement. Thus, the question arises as to why the body weight and not for example BMI better predicts %Fat. The answer to this question may have two aspects. BMI (Quetelet's index) is most often used in assessing under- and overweight in the elderly [12]. The original principle of the Quetelet's index was to eliminate the height factor by dividing weight by height squared. However, in the elderly height may be reduced substantially due to spinal shortening as a consequence of degenerative bone disease or kyphoscoliosis, and in a result the BMI in old age may be overestimated. This overestimation is most predominant in women who are ≥ 85 years of age, leading to an overestimation by 0.9±0.7 kg/m^2 [25]. On the other hand, although in younger adults BMI is an acceptable index for many purposes, in the elderly the value of BMI can be limited because of so called sarcopenic obesity i.e. increase in body fat mass with concomitant skeletal muscle mass loss [6]. Taking into consideration that 1) after 80 years of age the body fat mass decreases in parallel with fat-free mass [26]; 2) higher body fatness in old age is associated with an accelerated loss of muscle mass [4] and 3) more lean mass is lost during weight loss than is gained during weight gain [27] all of these arguments may explain the higher impact of body weight than BMI on percentage of body fat assessment in investigated women. In fact, our finding is in agreement with the suggested by Visser and Harris [26] the hypothesized role of changes in body weight on body composition changes in old age. However, low value of coefficient of determination in our multiple regression model and a high standard error of estimation indicate that body weight alone rather crudely predicts general obesity in elderly women.

Ageing is associated with body fat distribution changes, i.e. increase in visceral fat and decrease in subcutaneous fat in other regions of the body (abdomen, thigh, calves) [3]. That probably explains the lack of statistical significance of hip circumference in our model assessing the percentage of body fat, even though the hip circumference is recognized as an indicator of general adiposity [28]. The only methods which direct measure the visceral fat depots are CT and MRI. In practice, the common and simple approach to assess general and visceral adiposity is a computation of BMI along with waist circumference measurement [29]. Jansen et al. [30] showed that BMI and waist circumference independently contribute to the prediction of nonabdominal, abdominal subcutaneous, and visceral fat in white men and women; however, combined use of BMI and waist circumference values substantially increases the variance explained in visceral fat. These findings are only partially in agreement with our results. Multiple regression analysis performed in our study showed that BMI along with neck circumference (but not with waist circumference) have a significant impact on VFR. The similar results were obtained by other authors in obese patients. Yang et al. [31] found that neck circumference correlates stronger with visceral fat than waist circumference, and Li et al. [32] showed that BMI is more strongly correlated with visceral fat than neck circumference in both sexes. Taking into account that waist circumference is a well-known measure used in field studies to derive estimates of fat distribution, it is difficult to explain why this measure was not significant in our model of VFR assessment. Considering the fact that waist circumference correlates with both total and intra-abdominal fat, it is possible that observed in older people decreased abdominal muscle tone may underestimate the visceral adiposity [6]. In fact, there are recent indications that the cut points for high-risk waist circumference as endorsed by the

WHO (>102 cm for men and >88 cm for women) should be higher for adults who are ≥ 70 years of age, both men (>100–106 cm) and women (>99 cm) [33].

Despite the potentially important practical implication, the present study has several limitations. The main limitation is the sample size. However, it is partly a result of our strict selection criteria to control all the potential confounding variables regarding BIA method. Another concern is the subjects' age. Our sample consisted of a group of women aged 80 years and older. Although in many studies the oldest investigated group was over 60, 65, 70 or 75 years of age it is possible that subjects over 90 years old had different body composition than women in theirs 80 - especially when we consider the fact of parallel decrease of fat and fat free mass at age over 70. Finally, the low R^2 value in the stepwise multiple regression analysis for general fatness indicates that proposed model may not be the best fit for the data and additional measurements of for example measures of skinfold thickness should be incorporated into this model. Future studies should consider these limitation when prediction formulas for %BF are developed based on BMI method.

In summary, we found that except of body height and WHR all applied in this study anthropometric indices (body weight, BMI, circumferences of waist, hip and neck) are significantly related to %Fat and VFR estimated by BIA method in the oldest old group of investigated women. Among these anthropometric obesity measures only body weight alone has a significant impact on general fatness. On the other hand, the best predictors of visceral fat are BMI and a neck circumference, which can be surrogates of fat distribution in elderly women.

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