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Anthropometric indices of nutritional status in Croatian oldest old: new equations to predict height and weight

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Abstract

Anthropometry is an essential tool in the geriatric nutritional assessment. Measuring height and weight can be quite problematic in the old age so they can be estimated using the WHO equations. The purpose of this study was to: (a) show anthropometric indices of nutritional status of the ambulatory institutionalized oldest old in Zagreb, Croatia; (b) examine the adequacy of WHO equations for predicting height and weight of oldest old persons; (c) develop population-specific equations for estimating height and weight.

The sample of this cross-sectional study comprised 314 examinees (F/M= 234/80, 85-101 years). The classic anthropometric parameters (height, weight, extremities' circumferences, knee height and skinfolds) were measured. The adequacy of WHO equations for predicting height and weight in Croatian oldest old was assessed using the paired t-test. Multiple linear regression analysis was performed to derive population-specific equations for predicting height and weight.

The sexual dimorphism was found in several anthropometric indices; men were taller, had larger weight and knee height, while women had larger triceps skinfold thickness. In women, most indices declined with age and in men the negative relation of knee height with age indicated a secular trend. The WHO equations for elderly acceptably predicted nothing but height in oldest old women. The presently developed equations, using the same WHO's predictor variables, proved to be more adequate for the studied population.

The equations developed for estimating height and weight of non-ambulatory oldest old Croatians proved to be more appropriate than WHO equations and are therefore proposed for use in the everyday practice.

INTRODUCTION

Anthropometry is an essential tool in the geriatric nutritional assessment (*1–3*). It detects changes in body composition and nutritional status in the elderly (65+ years) that involve decrease in body weight and height, a reduction in lean body mass and increase in fat mass accompanied with the redistribution of fat tissue towards the more centralized type of adiposity (*4, 5*). In advanced age (80+ yrs) body fat mass declines in both sexes (*6, 7*).

Amongst numerous anthropometric traits, weight and height are necessary for the calculation of several indices which are the most frequently used indicators in nutritional assessments. However, weight and height cannot be measured in many elderly persons, particularly in those very old who live in the specialized institutions due to serious limitations in their mobility, i.e. are chairbound or bedfast. In addition, as a consequence of diseases like kyphoscoliosis, the spinal shortening may reduce height and thus even introduce an error in indices that include this variable (*8*). For all these persons, the stature and the body mass can be estimated from several other anthropometric traits that are accessible to measurement like knee height (*9*) for estimating height, and extremity circumferences and skinfold thickness for estimating weight (*10*). The estimations of stature have often been used in the disciplines of archeology (*11*) and forensic medicine (*12*), while those applicable to the living were generally developed for adults and elderly, but not specifically for the oldest old (*13*). The WHO equations for the prediction of weight and height in elderly (60+ years) were presented in 1995 (*14*). Although not an ideal solution due to the estimation errors, this is a reasonable approach in non-ambulatory elderly persons. However, the same authors call into question whether the proposed equations are widely applicable in different populations.

The objectives of this study were: (a) to describe the anthropometric indices of nutritional status of the oldest old (85-101 years) ambulatory residents of Homes for the elderly and infirm in Zagreb, the capital of Croatia; (b) to examine the adequacy of WHO equations for predicting the height and weight of oldest old persons; (c) to develop population-specific equations for estimating height and weight that would be more appropriate for the Croatian 85+ years population.

MATERIALS AND METHODS

Subjects

This study is based on the anthropometric data collected in the Survey of complex traits variation and health in Croatian elderly population, which has started in 2007. This survey was designed to study the aging process by searching for the possible genetic and environmental factors and their interaction, as well as for psychological and behavioral traits, which all might influence the successful aging (*15, 16, 17*). A wide spectrum of health-related parameters was collected among the very old persons: an extensive interview included the Mini-Mental State Examination, the Mini Nutritional Assessment, blood pressure measurement, anthropometry, ultrasound measurement of the bone mineral density, and collection of venipuncture specimens for biochemical parameters and genetic analyses. The questionnaire included detailed questions regarding socio-demographic status, health status, medical history, nutritional habits, and examinee's satisfaction with his/her quality of life. Trained examiners filled out a questionnaire during a face-to-face interview. The participation was voluntary and the signed informed consent was obtained from all the participants. The study protocol was approved by the Ethics Committee of the Institute for Anthropological Research in Zagreb.

The survey has had both a cross-sectional and a longitudinal component but only the former is considered here. The data on the institutionalized 85 years old and older persons from Zagreb, Croatia, and its surrounding area, were collected from 2007 to 2009. The subjects were residents of all 11 Homes for elderly and infirm which are the property of the City of Zagreb, and two randomly selected private homes located in Zagreb County. The persons who resided at ward units of these institutions were not examined. Inclusion criteria were the willingness of ambulatory persons to participate and their ability to collaborate during the anthropometry, and the age of 85 years or over. Their mobility (physical status) and independence (mental status) were in the upper categories according to the assessment methodology described by Tomek-Roksandić *et al.* (*18*).

The anthropometric data from altogether 314 examinees (234 women, 80 men, age range 85–101 years) were analyzed here (mean 88.3±3.3 years). They were born between 1906 and 1924. This sample represented 4.04% of the population of City of Zagreb in the age group 85+ years (*19*). The mean time of institutionalization was 5.39±6.06 years for women and 5.69±5.04 years for men.

Anthropometric measures

Anthropometry was undertaken by a single experienced examiner, member of the research team using the standard International Biological Programme methodology (*20*). The subjects were barefooted and lightly dressed. The measurements included weight, height, body circumferences (mid-upper arm-relaxed, maximum calf--relaxed, waist), and skinfolds (triceps, subscapular). Additionally, knee height was measured according to Chumlea et al. (*21*). Longitudinal measures and circumferences were recorded to the nearest 0.1 cm, skinfolds to the nearest 0.1 mm, and weight to the nearest 0.1 kg. Standardized anthropometric instruments were used: anthropometer (Siber Hegner Machinery Ltd.), stadiometer, flexible nonelastic measuring tape, calibrated Harpenden skinfold caliper (John Bull British Indicator Ltd.), and the digital portable scale (Omron).

Body mass index (BMI) was calculated as weight in kilograms divided by squared height in meters (kg/m^2). The prevalence of underweight and obesity was assessed using the cut-off points of BMI<20 kg/m^2 and BMI=30 kg/m^2.

Statistical analysis

Description of the anthropometric measurements included sex-specific means, standard deviations and the prevalence of subjects within the BMI threshold-defined categories. The data were verified for their consistency. Statistical significance of differences in means between sexes was tested using Student's *t*-test ($p<0.05$) and differences in prevalence using the Chi-square (χ^2) test. The Pearson's correlation coefficient of the studied anthropometric indices with age was used.

The adequacy of the WHO (*14*) age-specific equations for predicting height and weight of Croatian elderly persons was assessed using the paired *t*-test ($p<0.05$). The standard error of estimate was calculated as:

$$SEE = SD_{Ka}\sqrt{(1-r_{Ka\,Kp})},$$
where *a* denotes measured and *p* predicted values.

Total error was calculated as:

$$SE = \sqrt{[\Sigma\,(K_a-K_p)^2 / N]}.$$

Multiple linear regression analysis was performed to derive population-specific equations for predicting height and weight in elderly Croatians. Height and weight were regressed against the same independent variables that appear in the WHO equations: 1) knee height (and age in women) for height, and, 2) calf circumference, knee height, mid-upper arm circumference and subscapular skinfold for weight. The analyses were performed separately for each sex. The independent variables were retained if their regression coefficients departed significantly from zero ($p<0.05$). The fraction of explained variance (R^2) and the residual standard deviation (RSD) for each regression were reported. Squared residuals ((measured value minus predicted value)^2) were plotted against independent variables to examine heteroscedascity (fits were required to be non significant). The differences between predicted values based on prediction equations from the present study and from the WHO equations were presented as Bland-Altman plots. The analyses were performed using SPSS/PC+ version 10.0 (SPSS, Chicago, IL, USA).

RESULTS

In the sample of 314 elderly subjects, 74.5% were women and 25.5% were men, with mean age 88.3±3.3 years and 88.5±3.3 years, respectively. The 24.0% (N=75) of subjects were aged 90 years and older. There was no significant difference in age distribution between the female and male sample ($p=0.548$).

In the total sample, 45% of the elderly were in the category of movable persons, and the others belonged to the category of restricted mobility, i.e. occasionally used a stick, crutches, orthopedic walk support. As much as 78% of the total sample reported going out of Homes frequently, while the others walk only within the facility. According to the assessment of their mental status, the majority were independent (82%) and the rest were of restricted independence (occasional mental problems).

Sex-specific values of anthropometric indicators (means and standard deviations) are presented in **Table 1.** Men were taller than women (167.8±7.01 cm vs. 152.7±6.4 cm, $p\leq0.001$) and had 4.6 cm larger mean knee height. They also had higher mean weight than women ($p\leq0.001$) but BMI did not differ between the sexes. Women had higher mean triceps skinfold thickness than men (18.0±7.3 mm vs. 10.6±4.8 mm, $p\leq0.001$). The mean subscapular skinfold thickness as well as the mean values of circumferences on the extremities did not differ between the sexes. The correlation of the investigated anthropometric indices with age is also given in **Table 1**. In men, only height and knee height showed significant negative correlation with age, while in women the significant correlation of the same direction was observed in all the variables but knee height.

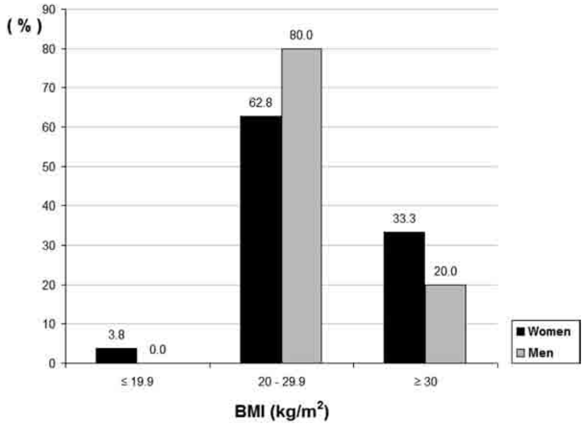

Figure 1. *Prevalence of nutritional status categories according to BMI (31) in Croatian oldest old (85+ yrs).*

While underweight was found only in women (3.8%), obesity existed in both sexes with significantly higher (different) prevalence of obese women than men (33.3% of women vs. 20.0% of men, $p\leq0.01$) (**Figure 1**).

Table 2 gives the results of the analysis of agreement between the actual and the predicted values of height and weight obtained using the WHO (*14*) prediction equations. Although high correlation between actual and predicted values was generally obtained (r between 0.715 and 0.930), good agreement existed only for height in women. In all the other cases the WHO equations gave significantly different predictions. They overestimated height in men for 1.7 cm on the average, and underestimated weight for 7.0 kg in women and for 9.1 kg in men (all $p\leq0.001$) with relatively large total errors.

Table 3 presents regression equations of height and weight on several anthropometric indicators that we developed for our elderly aged 85+ years. The same anthropometric variables that appear in the WHO equations were entered into regressions and all proved to be significant ($p\leq0.001$): knee height (and age in women) was significant for height, and calf circumference, knee height, mid-upper arm circumference and subscapular skinfold were significant for weight. The proportion of explained variance was 86–87% for weight, while it was considerably lower for height (52–60%). For male height, we also tested a model with age added to the regression, but it did not improve the value of R^2. Standard errors of the estimate were similar between the sexes, about 4.4 cm for height and about 4.7 kg for weight. The Bland-Altman plots, given in **Figure 2**, show that prediction agreement between the presently developed equations and the WHO equations existed only for height in women. For male height, marked overpredictions by the WHO equations

TABLE 1

Anthropometric indices and their correlation with age in the oldest old Croatians (85+ yrs) by sex: 234 women and 80 men.

Variables	Women		Men		Sex differences	Women		Men	
	X	SD	X	SD	p	r	p	r	p
Weight (kg)	65.42	12.17	78.08	12.89	***	–0.323	***	–0.219	ns
Height (cm)	152.72	6.35	167.77	7.08	***	–0.260	***	–0.245	*
BMI (kg/m^2)	28.00	4.73	27.72	4.16	ns	–0.233	***	–0.103	ns
Knee height (cm)	48.53	2.45	53.10	2.63	***	–0.122	ns	–0.228	*
Mid-upper arm circ. (cm)	27.66	3.53	27.41	2.70	ns	–0.329	***	–0.211	ns
Calf circ. (cm)	34.86	3.46	35.43	3.17	ns	–0.186	**	–0.121	ns
Triceps skinfold (mm)	18.02	7.34	10.56	4.78	***	–0.201	**	–0.030	ns
Subscapular skinfold (mm)	17.97	8.03	18.91	7.72	ns	–0.249	***	–0.101	ns

X – mean, SD – standard deviation, r – Pearson's correlation coefficient
* p ≤ 0.05; ** p ≤ 0.01; *** p ≤ 0.001

TABLE 2

Differences between the actual and predicted values of height and weight using the WHO (14) equations for the elderly.

Anthropometric index	X	SD	Difference *a-p* X	t (df)	SEE	SE	Correlation $r_{a\,p}$
Women (N=234)							
Height (cm)							
Actual (*a*)	152.74	6.36					
Predicted (*p*)	152.69	4.78	0.06	0.19 (232)	4.44	4.45	0.715*
Weight (kg)							
Actual (*a*)	65.47	12.21					
Predicted (*p*)	58.45	10.06	7.02	22.21* (232)	4.67	8.48	0.924*
Men (N=80)							
Height (cm)							
Actual (*a*)	167.77	7.08					
Predicted (*p*)	169.46	5.47	–1.69	–3.40 * (79)	4.46	4.74	0.777*
Weight (kg)							
Actual (*a*)	78.08	12.89					
Predicted (*p*)	69.03	10.37	9.05	16.12* (79)	4.74	10.33	0.930*

X – mean, SD – standard deviation, SEE – standard error of estimate, SE – total error
* p ≤ 0.001

vs. the present study can be seen. The plots also illustrate large underpredictions of weight when using the WHO equations in both sexes.

DISCUSSION

This cross-sectional study of the Croatian oldest old (85+ years) gives the sex-specific values of anthropometric indices of nutritional status. Additionally, population--specific equations are developed for estimating the height and weight of non-ambulatory elderly persons, which proved to be more appropriate for the Croatian population than the WHO equations. The study was conducted in a fairly large sample of very oldest old ambulatory users of Homes for elderly and infirm from the City of Zagreb and Zagreb County. The living conditions in these institutions include qualitatively and quantitatively balanced nutrition and enhanced regular access to medical care service, which makes their users a desirable group for the development of referent anthropometric

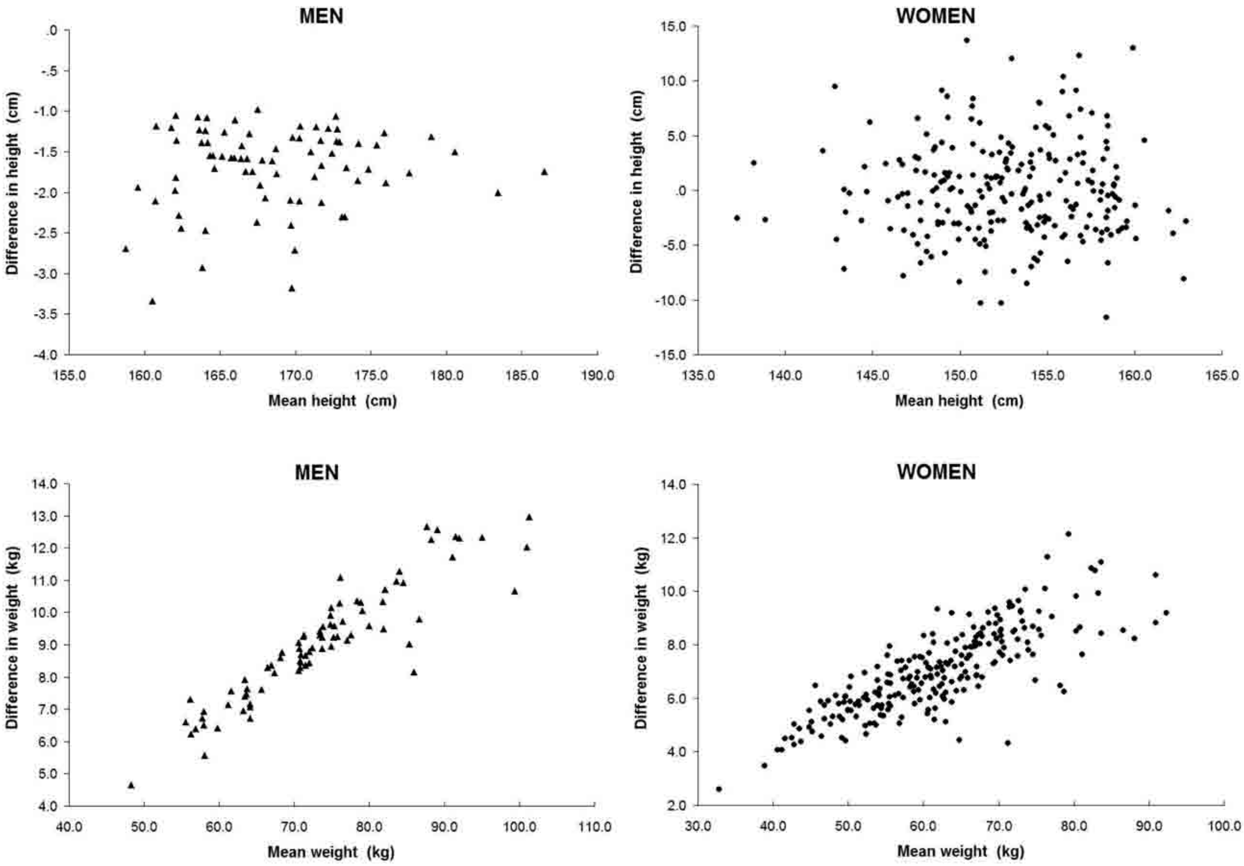

Figure 2. *Bland-Altman plots for the differences in prediction of height (weight) against mean height (weight) predicted by the equations developed in this study and the WHO (14) equations.*

TABLE 3

Prediction equations for the oldest old Croatians (85+ yrs).

	Equation	R	R2%	RSD
Women (N=234)				
Height (cm)	1.755* KH – 0.350* A + 98.502	0.721*	52.0	4.425
Weight (kg)	1.285* CC + 0.972* KH + 1.522* MUAC + 0.288* SSK – 73.815	0.928*	86.1	4.593
Men (N=80)				
Height (cm)	2.091* KH + 56.718	0.777*	60.4	4.485
Weight (kg)	1.050* CC + 1.443* KH + 2.256* MUAC + 0.326* SSK – 103.774	0.932*	86.8	4.813

R – multiple correlation coefficient, RSD – residual standard deviation, * $p \leq 0.001$

KH – knee height in cm, A – age in yrs, CC – calf circumference in cm, MUAC – mid-upper arm circumference in cm, SSK – subscapular skinfold in mm

indicators of nutritional status, superior to the population-based household sample of very old persons.

Anthropometric measures reflect changes in body composition throughout lifetime (*22*). The decline in muscle mass that begins in the mid 30s continues in the elderly, and it is accompanied by a gradual decline in muscle strength and fitness performance. A proportion of body fat increases in middle life (particularly abdominally), but with the increasing anorexia in those over 75 years of age, fat mass tends to decline (*23*). Height and weight are the two most common measures recorded frequently throughout lifespan for the health purposes, including the assessment of nutritional status. However, their changes have rarely been followed in the individuals of advanced age.

The correlation of anthropometric indices with age was sex-specific. In women, we detected significant decline in all the variables with age, with the exception of knee height. This longitudinal trait is known to remain constant in adult phase and does not correlate with age. However, knee height unexpectedly correlated with age in men. The only possible explanation for this result may be the existence of secular trend due to the cross-sectional nature of this study. The lack of other age-related anthropometric changes in men, with the exception of common finding of height reduction, may be a consequence of a selection bias due to the earlier death of overweight and obese individuals or a sampling bias due to refusal or inability of participation of men with health conditions related to obesity.

As expected, besides being taller, men had larger weight than women, but similar BMI. Sex differences in BMI are not uniform across current population studies in 80+ yrs groups. While no differences between men and women were found in the Mexican study (*24*), higher BMI in men was observed in several U.S. and Brazilian studies (*7, 25, 26*), and higher BMI in women than in men was reported in Italian and Chilean studies (*27, 28*). Multiple factors are probably behind this sex-related variation in BMI including the sex differences in the magnitude of weight and height changes with aging among populations, sex differences in body build and composition among populations, and variable economic and socio-cultural characteristics among populations that may influence living conditions and health of men and women differently.

Anthropometry helps in nutritional status assessment and several body measurements are basic components of nutritional screening tools developed and widely used in the elderly (*29, 30*). BMI is most frequently used to identify subjects at risk for under- and overweight. The BMI thresholds for these conditions in the elderly are being discussed but the cut-off points of BMI<20.00 kg/m^2 and BMI≤30.00 kg/m^2 are currently commonly applied in both clinical practice and epidemiology (*31*). Using the BMI threshold for underweight, 2.9% of our elderly were in this condition, all of whom were women. The applicability of the same value as the indicator of underweight in men should be examined in a larger sample but the present results suggest that a lower cut-off value, that of 18.50 kg/m^2 used by WHO (*14*) for all adults, is inappropriate for screening malnutrition in this age group. The 2/3 of the sample, more men than women, falls within the normal range of nutritional status (20.00 kg/m^2 – 29.99 kg/m^2). Obesity (BMI≤30.00 kg/m^2) existed in both sexes with the overall prevalence of 29.9% but was more pronounced in women.

Weight and height are important variables in defining and calculating values of nutritional status indices that are applicable to elderly persons such as weight divided by square height (BMI), weight for height, creatinine height index and equations for estimating caloric expenditure. However, weight and height are difficult or impossible to measure in the non-ambulatory elderly persons, or the value of height may be spurious if measured in elderly persons with excessive spinal curvature (*32*). It is of high importance to provide effective means for weight and height estimation in such cases. WHO (*14*) recommended the equations that have been developed for the elderly in the U.S. (*32, 33*) but warned that they may not be appropriate for use elsewhere.

Our analysis showed that there is a high correlation of the actual values of weight and height with those predicted by the WHO equations. A high correlation does not automatically imply that there is good agreement between them (*34*). Only the equation for height in women predicted accurately with mean difference of 1 mm and total error of 4.5 cm. The equation for height in men overestimated it for 1.7 cm on the average with total error of 4.7 cm. Both the female and male weight equations gave unacceptably large underestimations (mean difference of 7 kg and 9 kg, respectively) with even larger total errors of 8.5 kg and 10.3 kg, respectively. The lack of agreement between the actual and predicted values in our elderly may be the result of a much larger age range of 60–100 years in the U.S. sample used to develop the prediction equations as well as from the body build differences between the U.S. and Croatian populations. Similar effects were found in surveys conducted in different populations although they studied a wide elderly age range, comparable to that of the U.S. sample (*13, 35, 36, 37, 38*). Therefore, we found it necessary to develop our population- and age-specific equations for the elderly. Such equations have been created and reported for other populations as well (*10, 39, 40, 41*).

We used the regression models that contained the coefficients of common clinical measurements of the knee height, upper and lower extremity measurements, subscapular skinfold thickness and age, as recommended by WHO. The developed equations have a 68% probability of predicting the height of an elderly woman or man to within plus or minus 4.4 cm or 4.5 cm, respectively. The 68 per cent error bounds for the estimated weight are 4.6 kg for women and 4.8 kg men. Thus, each of the two variables can be estimated with similar degree of error in men and women.

The equations recommended by WHO have similarly large error bounds and agree with the presently developed Croatian equations only for female height, they over predict male height, and largely under predict both male and female weight. The observed discrepancies strongly support the use of the presently established age-specific reference equations for height and weight in Croatian oldest old.

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