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Full Length Research paper

Predictive equations for estimation of stature from knee height, arm span, and sitting height in Indonesian Javanese elderly people

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The purpose of this study was to develop the predictive equations for estimation of stature, using knee height, arm span and sitting height in Indonesian Javanese elderly people. Eight-hundred and twelve healthy elderly people (295 men and 517 women) participated in this cross sectional study. Standing height, weight, knee height, arm span and sitting height were measured. The Chumlea and Eleanor equations were validated in this study. The first equation showed that the mean difference of predicted height compared to actual height in men was 2.78 and 4.90 cm in women. The second equation revealed that the value of difference in men was 2.87 cm and in women was 13.26 cm. Arm span showed the highest correlation with standing height on men (r = 0.815) and women (r = 0.754). Aging was associated with decreased mean of height, weight, arm span and sitting height, but not on knee height in the two sexes. Arm span has the highest validity to predict stature on healthy Javanese elderly people. The correlation coefficient of arm span to actual height was larger on men than women. Stature of Indonesian Javanese elderly people can be estimated by the regression model from the three predictors developed in the study.

Key words: Elderly, knee height, arm span, sitting height, Chumlea, Eleanor.

INTRODUCTION

Height is an important component to assess nutritional status, since accurate measurement of stature is very important in determining Body Mass Index (BMI). Body Mass Index is an indicator for assessing risk of Chronic Energy Deficiency (CED) and obesity. However, measurement of stature in elderly people cannot be conducted perfectly due to kyphosis and scoliosis (Kuchmarski, 1989).

With this population of elderly people, it may be more appropriate to estimate stature from measurement of other skeletal segments such as knee height, arm span and sitting height. Aging process does not influence length of arm, leg (knee) and vertebral bone. Arm span is less influenced by aging. Reduction of arm span on elderly people is slower than reduction of height, so that arm span is recommended as a parameter for stature prediction (Jarzem and Gledhill, 1993; Steele and Chenier, 1990). Sitting height can also be used to predict the stature of elderly people, but tend to decrease along with aging. The prediction of stature in elderly people is considered as quite valid in developing anthropometry index and taking interpretation of the measurement of body composition.

The validation of Chumlea equation has been reported by some studies (Myers, 1994; Chumlea et al., 1998; Fatmah, 2005). These studies proved that the equation was not accurate, when applied on Japanese-American and Indonesian elderly people. The two last studies confirmed that the difference between actual height and predicted height in elderly was quite high. Most studies on knee height measurement were conducted on elderly people of North America and Europe (Pini et al., 2001; Lucia et al., 2002), while studies on Chumlea equation validation on Indonesian elderly people were rarely done. One of the studies was conducted on 150 elderly people in DKI Jakarta (Fatmah, 2005). The study reported that Chumlea regression model showed over-estimation, with women showing significance (p = 0.02). The validation study on Chumlea equation, conducted by Fatmah (2005) on 217 elderly people in DKI Jakarta and Tangerang, showed that the predicted height was lower by 1cm than actual height and it was among women (2 cm). Indonesia

Table 1. Height, weight, knee height, arm span and sitting height in different age groups and sex.

	55 - 59 years					60 - 64 years					65 - 69 years					> 69 years				
	Men		Women		p	Men		Women		P	Male		Female		p	Male		Female		p
Height (cm)	159.5	±6.2	149.2	5.0	0.001	158.5	6.5	148.9	5.6	0.001	158.3	6.4	147.3	5.3	0.001	158.4	5.9	146.3	5.7	0.001
Weight (kg)	57.2	10.5	56.5	11.0	0.626	58.1	11.1	53.9	10.8	0.007	55.0	9.9	51.9	11.1	0.007	54.5	8.9	49.4	9.9	0.008
Knee Height (cm)	48.8	2.7	45.7	2.4	0.001	49.1	3.2	45.7	2.5	0.001	49.1	3.4	45.1	2.4	0.001	49.0	3.7	45.4	3.4	0.001
Arm Span (cm)	164.3	8.3	153.4	6.4	0.001	163.8	7.8	153.2	7.8	0.001	163.4	8.6	152.3	7.3	0.001	163.0	8.9	150.7	8.2	0.001
Sitting Height (cm)	83.8	5.1	78.7	3.4	0.001	84.4	5.2	78.0	3.7	0.001	82.8	4.9	77.0	3.5	0.001	82.4	5.2	76.2	3.4	0.001

Ministry of Health is still using the formula from Eleanor Sthlenker (Ministry of Health, 2006).

The application of Chumlea and Eleanor model is not really appropriate for elderly people in Indonesia. As different studies try to develop a model to predict elderly height in geriatric homes and community health center, as well as lack of standardized model based on the Ministry of Health for predicting elderly height in Indonesia has encouraged the necessity for a study to develop a model to predict elderly height among Javanese elderly people. The reason behind the selection of this ethnic is because Javanese is the most populated among the four biggest populated ethnics in Indonesia, namely Bataknese, Sundanese, Malay and Madurese (Ananta et al., 2005). The objective of this study is to develop equations to estimate stature for use in com-munity settings and also in research related to nutrition and health, using a proxy indicator of standing height namely knee height, arm span and sitting height. The output of this study is a monogram of Body Mass Index on elderly people from height prediction based on the three above named predictors.

MATERIAL AND METHODS

Study population

This was a cross sectional study of 812 elderly people of 55 to 85 years. They were older people living in community representing urban areas: Surabaya, Semarang, and DI Yogyakarta cities; and rural areas: Magetan, Wonogiri and Gunung Kidul Districts. They were 55 - 85 years, living in community; their parents came from original Javanese ethnic. None of the participating subjects had spinal curvature. They were able to stand upright without any support for height measurement and can stretch out their arms. The study was approved by the Ethics Committee of the Research and Development Board, Ministry of Health.

Anthropometric measurements

Height, weight, knee height, arm span and sitting height were measured three times in December 2007 - March 2008. Weight was measured using SECA digital step scale and standing height was measured using microtoise (WHO, 1999). Knee height in lying position was measured using knee height caliper (Gibson, 2005). Arm span was measured using length 2 m ruler (Gibson, 2005) and sitting height was measured using anthropometer, which consists of two chairs with 40 cm length for men and 35 cm length for women (Pheasant, 2000).

Statistical analysis

The mean of three measurements was used in all calculation. Results are expressed as mean and standard deviations. The linear regression analysis was undertaken to derive predictive equations for estimation of stature using knee height, arm span and sitting height according to gender. Differences by sex groups and statistical interactions were assessed by the linear regression techniques. Data analyses were performed with SPSS for Windows. Stature predicted by the regression equations of knee height, arm span and sitting height in different age and sex groups were compared to measured height using independent t-test Associations were considered statistically significant at the $p < 0.05$ and 0.01 level

RESULTS

Table 1 presents the average elderly male height which was reduced from 159.5 cm in 55 - 59 years old to 158.4 cm in 69 years old and afterwards. The elderly female height was reduced from 149.2 cm in 55 - 59 years old to 146.3 cm in 69 years old and afterwards. The biggest discrepancy for reduced height in these two age ranges was found in elderly female (2.9 cm). In general, male height was greater than female height. The weight of the elderly male increased from 57.2 kg at the age of 55 - 59 years old to 58.1 kg in 60 - 64 years old and then gradually reduced to 54.5 kg in 69 years old and afterwards. On the contrary, elderly female weight showed a decrease from 56.5 kg in 55 - 59 years old to 49.5 kg after reaching the age of over 69 years old. The biggest discrepancy of the elderly weight reduction was found in female compare to male (Table 1).

In general, elderly male had bigger average knee height, compared to elderly female in all age groups. A significant difference was found in the average of the three parameters between elderly

Table 2. The Correlation Coefficient of Various Physical Measurements in Different Sex

Physical measurement	The correlation coefficient					
	Men	p-value	Women	p-value	Total	p-value
Arm span and height	0.907	0.001	0.888	0.001	0.939	*0.001
Knee height and height	0.855	0.001	0.796	0.001	0.881	*0.001
Sitting height and height	0.777	0.001	0.774	0.001	0.860	*0.001
Arm span and height	0.790	0.001	0.761	0.001	0.850	*0.001
Arm span and sitting height	0.675	0.001	0.637	0.001	0.782	*0.001
Knee height and sitting height	0.615	0.001	0.527	0.001	0.709	*0.001

*$p < 0.01$.

Table 3. Mean difference of actual height and predicted height using Chumlea and Eleanor in different sex (cm).

	Eleanor	Chumlea	Arm span	Knee height	Sitting height
Men					
Mean	2.87	2.78	2.19	2.61	3.15
Minimum	0.01	0.01	0.00	0.03	0.03
Maximum	11.86	11.06	6.82	10.19	12.40
Standard deviation	2.20	2.12	1.49	1.94	2.38
n	295	295	295	295	295
Women					
Mean	13.26	4.90	1.99	2.56	2.74
Minimum	5.02	0.01	0.00	0.00	0.01
Maximum	22.19	14.61	7.21	9.01	11.33
Standard deviation	3.25	3.00	1.46	1.99	2.01
n	517	517	517	517	517
Total					
Mean	9.48	4.13	2.06	2.58	2.89
Minimum	0.01	0.01	0.00	0.00	0.01
Maximum	22.19	14.61	7.21	10.19	12.40
Standard deviation	5.79	2.90	1.48	1.97	2.16
n	812	812	812	812	812

male and female (Table 1), while (Table 2) shows that arm span had the highest correlation cofficient with actual height, followed by knee height and sitting height.

The lowest gap was found between the predicted height from arm span and the actual height compared to knee height, sitting height based on Chumlea and Eleanor equations. Even the average discrepancy of the predicted height from Eleanor and Chumlea equation towards the actual height in elderly female was higher (13.26 cm) than in elderly male (2.87 cm) compared to Chumlea, as well as predicted height from arm span, knee height and sitting height in this study. A similar description was shown from the average percentage of predicted height difference from the three predictors, using Chumlea and Eleanor compared to the actual height. The lower percentage was found in height, predicted arm span compared to the predicted height from knee height and sitting height as well as the application of Chumlea and Eleanor, both in elderly male and female people. This shows that the arm span was the most accurate predictor in predicting elderly height which is followed by knee height, and the least accurate one was the sitting height (Table 3).

The knee height, arm span and sitting height predictors had significant relationship with actual height based on gender. The correlation coefficient between arm span and actual height is the height in elderly male ($r = 0.815$) and female ($r = 0.754$) of 55 - 65 years old. The arm span showed the highest correlation in elderly male in age group of 55 - 65 year old. Actually, the highest correlation in elderly female was found in the age group of 66 - 85 years old. However, since one of the inclusion criteria was respondents with age of 55 to 65; therefore the correlation measured is for the age group of 55 - 65 years

Table 4. Correlation coefficient between actual height and predicted height in different sex and age groups.

Parameter	Age group					
	Men			Women		
	55 – 65 (n = 203)	66 – 85 (n = 92)	Total (n = 295)	55 – 65 (n = 415)	66 – 85 (n = 102)	Total (n = 517)
Knee height	0.698	0.600*	0.665*	0.679*	0.640*	0.666*
Arm span	0.815*	0.673*	0.765*	0.754*	0.644*	0.729*
Sitting height	0.643*	0.564*	0.618*	0.630*	0.654*	0.642*

*p < 0.01

Table 5. Linier regression model of actual height and predicted height in different age groups and sex .

	Knee height		Arm span		Sitting height	
	Equation	R^2	Equation	R^2	Equation	R^2
Men (years)						
55 - 85	56.343 + 2.102 TL	0.732**	23.247 + 0.826 PD	0.822*	58.047 + 1.210	TD 0.604**
55 - 65	52.853 + 2.175 TL	0.756**	22.575 + 0.830 PD	0.842**	61.245 + 1.172	TD 0.602**
Women (years)						
55 - 85	62.682 + 1.889 TL	0.634**	28.312 + 0.784 PD	0.789**	46.551 + 1.309	TD 0.599**
55 - 65	64.938 + 1.845 TL	0.634**	29.761 + 0.776 PD	0.785**	49.193 + 1.275	TD 0.582**

** p < 0.05.

old (r = 0.785). The arm span was the most accurate predictor in calculating predicted height in male and female because the arm span value only slightly decreased with age (Table 4).

The highest determination coefficient value (R2) of the simple linear regression model or arm span to the actual height was in the 55 - 65 age group. However, when the equation is applied and compared to the predicted height from Chumlea equation and linear regression equation for the age group of 55 - 85 years old, it turned out that the average differences of the three simple linier regression models towards actual height were the lowest, so that three elderly predicted height models were chosen for this study (Table 5).

Sensitivity and specificity of predicted height from the arm span, knee height and sitting height to assess nutrition status was the highest compared to Chumlea and Eleanor equations. Arm span, having the highest validity than knee height and sitting height, was used to assess nutritional status (Table 6).

DISCUSSION

Measurement of height and weight for elderly male and female described the average male height which was taller than female. The situation was similar to the study in Chinese and in Malaysia (Shahar and Pooy, 2003). The anthropometric measurement of elderly people described that male has average weight (55.4 kg) and height (146.2 cm), which was higher than the female (49.5 kg; 146.2 cm). The reduction of height in male was lower than in female. The elderly male experienced 2.7 cm reduction while the female experienced 4.22 cm reduction from 60 years to more than 76 years (Table 1). The males lost their cortical bone slower and it happened naturally when tissue loss was occurring (Suriah et al., 1988). The loss of height in elderly correlated with changes in body posture, osteoporosis, vertebrae damage and kiphosis, and scoliosis (Rossmann, 2006). The functional ability reduction with food intake of only 50%, disorders in mastication process, low appetite and low salivary flow for mastication are also seen. The results of this study was in line with other study: Shahar and Pooy (2003) stated that elderly female weight reduction was bigger than male from the age of 60-69 years old to 80-89 years old (8.43 and 5.2 kg, respectively). A study on elderly in Chili showed a reduction of weight that was slightly higher in elderly male from the age of 60-64 years old to over 85 years old, which was 4.8 kg in male and 4.2 kg in females (Santos, 2004).

In general, elderly male had higher average knee height, arm span and sitting height compared to elderly female in all age groups. These findings were in line with the results of the study on Philippines elderly male (Tanchoco, 2002), who had higher average knee height and arm span compared to female. The average knee height of the elderly male was 49.1 cm and that of female was 45.7 cm. The average arm span for male was 164.4 cm, and for female was 153.3 cm. A study of elderly people in China (Fang et al., 2004) showed that the arm span of elderly female was lower than elderly male (162.1 and 177.0 cm respectively) and the sitting height of elderly male was higher (89.9 cm) than the elderly female (83.8 cm).

Table 6. Sensitivity and specificity of predicted height with nutritional status in different sex.

Predicted height	Underweight		Overweight	
	Sensitifity	Specificity	Sensitifity	Specificity
Men				
Arm span	89.5	95.8	83.9	94.3
Knee height	76.3	94.7	91.1	94.2
Sitting height	78.9	91.4	85.7	91.9
Women				
Arm span	95.6	97.6	93.4	93.7
Knee height	86.7	97.0	91.0	90.6
Sitting height	71.1	97.0	90.5	88.6

Other study showed that knee height of male elderly was higher than the female elderly but the value was relatively constant in all age group. The different average values of the three height predictors were due to the taller height and more physical activities of males compared to females (Santos, 2004). The correlation between arm span, knee height and sitting height with body height were quite high (0.834, 0.766 and 0.751, respectively). The difference in height in male elderly and female elderly correlated with the average of the three predictors based on gender.

The arm span had the strongest correlation with actual body height (r = 0.939) compared to knee height and sitting height. The arm span has the strongest correlation with actual height (r = 0.939) compared to knee height and sitting height (Table 3). This finding is in line with the study performed in elderly female in South India (Mohanty et al., 2001) that had proven the strongest correlation between the arm span and actual body height (r = 0.82) compared to the sitting height and leg length.

The knee height, arm span and sitting height predictors had significant correlation with actual height based on gender. The correlation coefficient between the arm span and actual height was the highest in elderly male (r = 0.815) and female (r = 0.754) of 55-65 years. The result is in line with previous study performed by Myers and Takiguchi (1994), but it is contradictory to Fatmah's study (2005). The first study reported the higher correlations between the arm length and the body height from the knee height in elderly male and female from American Japanese ethnics. Meanwhile, the second study found that the correlation coefficient between the arm span and the body height was the highest in male group (r = 0.765) and knee height was the highest in female subject (r = 0.761). This difference was caused by the tendency of the reduction rate of the arm span was faster than the knee height with age. This finding was also in line with a study from Tayie (2003) showing that there was a significant relationship between the arm span and actual body height (r = 0.85 in male and r = 0.86 in female) and a study performed on Indonesian elderly showed correlation between the arm span and actual body height (0.83 in female and 0.81 in male) (Rabe et al., 1996).

WHO (1999) recommends knee height and arm span as alternative substitute for measuring height in elderly, and/or disabled individuals who should use wheel chair or lay down because they are unable to walk. The arm span can be used as the substitute for body height in elderly, but the result is not too satisfactory compared to knee height. This is because generally the elderly experiences rigidity in the wrists (joint stiffness), and this can reduce the accuracy of the measurement results. However, WHO (1999) recommends a study in the future to determine whether the arm span as a measurement is valid for knee height as well as body height substitute.

The sensitivity of predicted body height from arm span to assess the poor nutrition status compared to the normal nutrition in elderly male and female is the highest compared to the knee height and sitting height. The same is true for over nutrition status compared to normal in women which show the highest sensitivity in predicted body height from arm span. However, the same is not true for over nutrition status assessment in men because the predicted body height from the knee height is more sensitive than the arm span and sitting height. The arm span can catch poor nutrition cases in men and women among normal elderly in a better way compared to knee height and sitting height because its sensitivity is the highest. Even the sensitivity level among women is slightly higher than in men. Meanwhile, knee height is more sensitive in capturing over nutrition case in women among normal elderly compared to the arm span and sitting height.

In summary, the relationship between stature, arm span, knee height, and sitting height appears to be gender based. Arm span is highly correlated to stature in both sexes. Indonesian Javanese elderly people should use the regression to predict stature.

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